Hopper (Homoptera: Auchenorrhyncha) diversity in shaded coffee systems of Turrialba, Costa Rica

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Abstract

Diversity of hopper species (suborder Auchenorryncha) in coffee (*Coffea arabica*) plantations with no shade (C) was compared with the diversity in plantations with shade of either poró (*Erythrina poeppigiana*) (CP) or poró plus laurel (*Cordia alliodora*) (CPL) in Turrialba, Costa Rica. Species-abundance and rarefaction curves were plotted for each system, and indices of diversity (Shannon-Wiener), dominance (Simpson), species evenness, and similarity (Jaccard) were calculated. The majority of hopper species and individuals belonged to the Cicadellidae family. A particular species dominated in each system: *Graphocephala* sp. (C), *Fusigonalia lativittata* (CP) and *Hebralebra nicaraguensis* (CPL). The richness and diversity of hopper species were highest in the CP system, followed by the CPL and C systems. Species similarity was closest between the CP and CPL systems, but varied considerably according to plant component and geographic location of each plot. Even though hoppers have not been reported as coffee pests in Mesoamerica, some of them cause serious problems elsewhere.

Introduction

Coffee (*Coffea* spp.) plantations are one of the most common agroforestry systems in Mesoamerica and the Caribbean (OTS-CATIE, 1986). The shade trees, which are a part of these systems, play important roles, not only from agronomic and economic standpoints (Beer et al., 1998), but also as a refuge for biodiversity, including birds and insects (Perfecto et al., 1996). Several insect groups, such as some Hymenoptera and Coleoptera, have been shown to reach high levels of diversity in traditional shaded coffee plantations (Nestel et al., 1993; Perfecto and Snelling, 1995; Perfecto and Vandermeer, 1994; Perfecto et al., 1996, 1997).

However, it is important to know if such a pattern holds also for other insect groups in order to make recommendations concerning either insect species conservation or pest management approaches. Therefore, the taxonomically well known insect group of leafhoppers, treehoppers, froghoppers, etc. (Homoptera: Auchenorryncha) was chosen to appraise the effect of coffee plantations with no shade or with shade from poró (*Erythrina poeppigiana*, Leguminosae) and/or laurel (*Cordia alliodora*, Boraginaceae).

Even though hoppers have not been reported as coffee pests in Costa Rica (ICAFE-MAG, 1989), some Cicadellidae are important virus vectors on annual crops in Mesoamerica (Saunders et al., 1998). In Indonesia and Asia, *Lawana candida* (Flatidae) has been reported to cause serious damage of young coffee plants, *Erythrina* spp. and other tree species (Le Pelley, 1968). The objective of this research was to gain insight into the key

interactions between coffee and shade tree species that could be manipulated, from a pest management standpoint, in order to preclude hopper outbreaks.

Materials and methods

This research was carried out in 1998 in Turrialba, on the Caribbean watershed of Costa Rica. The coffee farms studied were located between 600–800 m.a.s.l., at 9°55′ N and 83°39′ O, within the premontane wet forest and tropical moist forest life zones (Tosi, 1969). Average annual values of climatic variables were 2,616 mm, 22 °C, and 88% RH.

Homopteran diversity and similarity patterns were studied in three contrasting systems: unshaded coffee (C), coffee-poró (CP), and coffee-poró-laurel (CPL). Three commercial plantations were sampled for each type of system on three dates between March and October 1998. Five plantations were located at CATIE (Cabiria and La Montaña), two in Pavones, one in La Suiza and one in Verbena. Experimental plots differed in coffee variety (Caturra, Catimors, or Catuaí, of various ages), planting densities (4,000–6,000 plants ha^{-1}, and size (5,000–8,000 m^2), as well as in the type of surrounding vegetation.

Each plantation was divided into four quadrants. Sampling included 100 coffee plants per quadrant (25 consecutive plants in each of four rows, two to three rows apart to prevent insect disturbance while sampling), as well as five poró or laurel trees in the CP and/or CPL plots. In shaded plots, poró and laurel trees were selected so that they did not exceed 3 m in height to allow sampling with an sweepnet made out of a resistant fabric. Each coffee plant was swept three times with the net at different heights in order to catch insects present in the upper, medium and lower strata. The poró and laurel trees were swept 15 times along the lower edge of their crown. The apical portion of the net was formed by a piece of fine cloth to allow light penetration to easily concentrate captured insects there.

Insect samples were placed in plastic bags and taken to the laboratory where they were killed. Specimens were separated according to morphospecies and the number of individuals per species was recorded. Representative specimens of each morphospecies were mounted on entomological pins for identification at the National Institute of Biodiversity (INBio). Species-abundance curves were plotted for each system and indices of diversity (Shannon-Wiener), dominance (Simpson), species evenness and similarity (Jaccard) were calculated for each system, plant component and plot (Krebs, 1989). In addition, similarity indices were complemented with a cluster analysis (Krebs, 1989), for which index values were subtracted from 1 (total similarity), and thus considered as a measure of distance.

Results and discussion

Species composition

In Turrialba seasonality is not well defined (Herrera, 1985). Nonetheless, the eight-month sampling period allowed the collection of a high number of hoppers during both dry and rainy periods (a total of 10,612 specimens of 131 species from 10 families). Previous records for hoppers in coffee plantations in Costa Rica were quite poor. Overall, 58% of the species and 71% of the individuals belonged to the family Cicadellidae, followed by Membracidae and Cercopidae. At least three are undescribed species. A complete list of the sampled species is given in Rojas et al. (2001). Rarefaction curves, which allow predictions of the expected number of species for a given sample size (Krebs, 1989), had the common form of growth saturation curves (Figure 1). This means that the likelihood of finding new species rose at an increasingly slower rate as sample size increased. However, there were differences between systems. When taking a sample of equivalent size for each system, the number of species was higher in the coffee-poró (CP), followed by the coffee-poró-laurel (CPL) system. For example, in a sample of 500 individuals there were 44, 38 and 33 hopper species in CP, CPL and C, respectively, whereas in a sample of 2,500 individuals there were 75, 64 and 60 species, respectively.

The species-abundance curves, with an inverted J shape, had the same pattern in the three systems (Figure 2) and were best fitted by a logarithmic series. This is the typical curve of natural com-
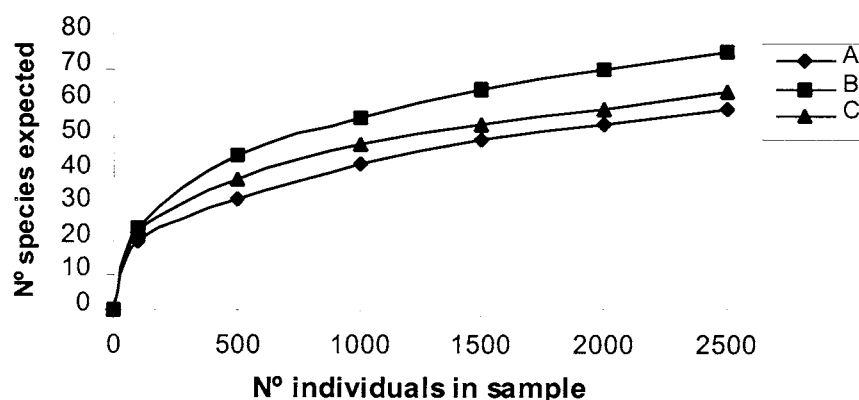
Figure 1. Rarefaction curves for hopper species in: A) unshaded coffee (*Coffea arabica*); B) coffee-poró (*Erythrina poeppigiana*); and C) coffee-poró-laurel (*Cordia alliodora*) systems in Turrialba, Costa Rica.

munities (Krebs, 1978), which shows that species are not equally abundant; a few of them are very abundant, many are of intermediate abundance, and the bulk of them are represented by a few individuals. The former can be considered as dominant species for each community of hoppers, because of their higher density (Krebs, 1978). A particular species dominated in each system: *Graphocephala* sp. in C, *Fusigonalia lativittata* in CP and *Hebralebra nicaraguensis* in CPL (Table 1). However, species dominance varied notoriously between systems, components and plots. The three dominant species were barely or not represented at all in the other systems, com-

ponents or plots. Likewise, the relative importance of the ten most common species varied considerably between systems; only four of them (*F. lativittata*, *Clastoptera* sp., *Empoasca* sp. and *Neocoelidia* sp.) ranked among the most common in two of the systems.

Species numbers in the coffee component itself were 60 (C), 71 (CP) and 53 (CPL), but only 8, 6 and 3, respectively, were represented by at least 100 individuals. Some species, like *Graphocephala* sp., were very abundant in unshaded coffee, but their numbers dropped sharply when coffee was associated with either poró or laurel. On the contrary, numbers of *F.*
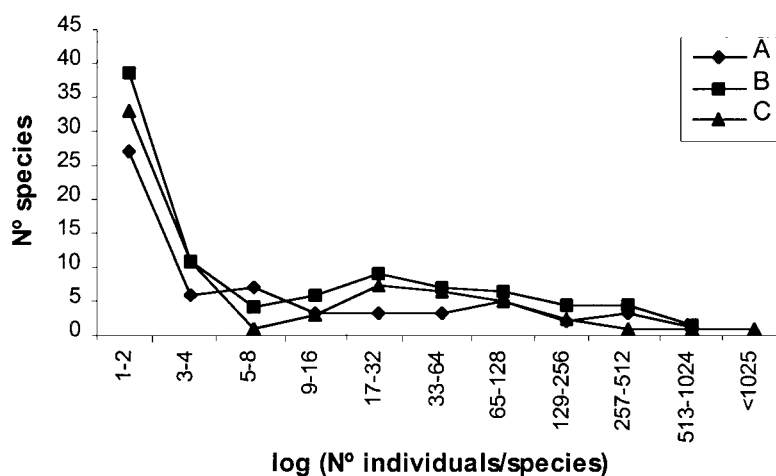

Figure 2. Species-abundance curves for hopper species in: A) unshaded coffee (*Coffea arabica*); B) coffee-poró (*Erythrina poeppigiana*); and C) coffee-poró-laurel (*Cordia alliodora*) systems in Turrialba, Costa Rica.

Table 1. The five most common hopper species in shaded and non-shaded coffee (*Coffea arabica*) systems in Turrialba, Costa Rica.

Coffee		Coffee-poró[a]		Coffee-poró-laurel[a]	
Graphocephala sp.	640	*Fusigonalia lativittata*	1108	*Hebralebra nicaraguensis*	1346
Fusigonalia lativittata	411	*Neocoelidia* sp.	490	*Omegalebra* n.sp.	538
Clastoptera sp.	294	*Clastoptera* sp.	335	*Empoasca* sp.	360
Graphocephala permagna	272	*Cicadellidae* n.sp.	278	*Neocoelidia* sp.	235
Neocoelidia sp.	199	*Empoasca* sp.	217	*Scaphytopius* ca. *latidens*	181

[a] Poró (*Erythrina poeppigiana*), laurel (*Cordia alliodora*).

lativittata were high in unshaded coffee and highest in coffee within the CP system. The number of individuals of other species, such as *Neocoelidia* sp. and *Scaphytopius* ca. *latidens*, tended to be similar in coffee, regardless of the system; however, the former reached high numbers in poró, but the latter did not. This suggests that the addition of one or more tree components, directly or indirectly favors some species, while limiting others, and may have no effect on the majority of them. Only two species, *Empoasca* sp. and *Bothriocera* sp. (Cixiidae) were closely associated with poró. Even though *Neocoelidia* sp. attained high numbers in poró in one plot (Verbena), it preferred coffee in the other plots. The following four species were common and almost restricted to laurel: *H. nicaraguensis*, *Omegalebra* n. sp., *Micrutalis* sp. (Membracidae) and *H. panamensis*.

Variation in species composition and dominance probably resulted from a combination of factors pertaining to both the coffee systems and hopper biology. Plots differed in coffee variety and age, planting densities, amount of shade, size, and surrounding vegetation, whereas species of Auchenorrhyncha vary in their food preferences and have specific morphological and physiological adaptations to feed upon leaf phloem, mesophyll or xylem (Backus, 1986). For example, *F. lativittata*, *Graphocephala* sp. and *G. permagna* (subfamily Cicadellinae) feed on xylem, whereas *H. nicaraguensis* and *Empoasca* sp. (subfamily Typhlocybinae) probably feed on the leaf mesophyll (Nault and Rodriguez, 1985).

Species diversity

Hopper species richness was highest for the CP system, followed by CPL and C (Table 2). Species diversity was also highest for the CP system, except in one plot (Verbena), with the values for the other two systems were similar. Evenness was similar among systems, but dominance for CPL was barely higher than for the other two systems, perhaps because of the unusually high numbers of *H. nicaraguensis* in laurel.

Since the Shannon-Wiener index accounts for both species richness and evenness (Krebs, 1989), it clearly reflected that the CP system was the most diverse in hopper species as a result of high richness and a relatively even species representation. However, although two of the CP plots showed values as high as 2.99 and 2.89, the value for the Verbena plot (2.34) was lower than those attained for all the CPL plots and even one of the C plots. This is explained by the high numbers of two particular species, *F. lativittata* and *Neocoelidia* sp. in Verbena, the former in coffee and the latter in poró. In addition, when the index was disaggregated by plant component within each

Table 2. Community indices for hopper species in coffee systems in Turrialba, Costa Rica.

	C[a]	CP	CPL
Richness	60	88	74
Diversity	2.61	2.84	2.56
Evenness	0.63	0.62	0.59
Dominance	0.11	0.11	0.15

[a] C: unshaded coffee, CP: coffee-poró, CPL: coffee-poró-laurel.
Coffee (*Coffea arabica*), poró (*Erythrina poeppigiana*), laurel (*Cordia alliodora*).

plot, coffee in the CP and the CPL systems generally had higher values than unshaded coffee. The highest value for coffee (2.94) was attained in Cabiria 1, a CPL plot, and the lowest (2.18) in a CP plot in Verbena. This finding suggests that, even though the coffee component strongly contributed to increased hopper diversity in the three systems, there were important plot effects on the global index values, probably due to variations in local factors, such as microclimate, agronomic practices, use of external inputs and surrounding vegetation.

Higher diversity values for coffee can be attributed not only to a higher sampling intensity in this crop (1,200 net beats, as compared to 300 in both poró and laurel for each date), but also to species recruitment in response to planted area. The concept of species-area (MacArthur and Wilson, 1967) has been useful in explaining insect species recruitment in cacao and sugarcane worldwide (Strong, 1974; Strong et al., 1977). In Turrialba, typical planting densities for coffee are 5,000–6,000 plants ha^{-1}, and for poró and laurel are 155 and 70–150 trees ha^{-1}, respectively. In effect, the isolated poró and laurel trees resemble small islands among coffee shrubs, which decreases the probability of recruiting further hopper species (MacArthur and Wilson, 1967). In addition, there were some operational shortcomings when sampling poró and laurel: for poró, spines made it difficult to sweep foliage with the net; whereas for laurel, sampling was restricted to the lower portion of the tree crown.

The contribution of poró to the total diversity index was generally not high and poró index values were always lower than those for associated coffee in CP and CPL, except in Verbena where poró density (270 trees ha^{-1}) was almost twice the density in the other plots (155 trees ha^{-1}). However, in the CPL system, values for poró were always higher than those for laurel. A factor that did not affect this study, but that could influence hopper diversity patterns, is that poró is routinely pruned once or twice a year, so that hoppers have to recolonize it after it resprouts. In contrast, laurel trees are barely disturbed, since only the lower branches are pruned on an occasional basis. The five most abundant hopper species in poró were also present in coffee, and a few of them appeared in laurel. This suggests that these species move

to coffee shrubs when poró has no foliage, but when they recolonize poró their reproductive rate is probably increased due to the high nitrogen content of poró leaves, as has been documented for many insect species (Strong et al., 1984).

On theoretical grounds, the CPL system should have shown higher diversity values than CP. However, results did not support this expectation, not only because of the specific effect of some plots, but maybe because this type of system generally receives less external inputs, such as fertilizers (J. Beer, pers. comm. 1998). Higher fertilizer levels in the other two systems could increase the nutritional value of coffee and poró foliage, thus favoring certain hopper species.

Species similarity

Hopper species similarity was closer between the CP and CPL systems (Table 3) than in the other two possible pairings (C-CP and C-CPL) which had very similar values. The CP and CPL systems shared 55 (51%) of the 107 species present in one and/or the other, with *Empoasca* sp., *Neocoelidia* n. sp. and *S. latidens* being the most abundant. This suggests that the mixed systems (CP and CPL) favored certain hopper species. For example, *Empoasca* sp. was barely present in coffee, *Neocoelidia* n. sp. reached rather high numbers in all three components and *S. latidens* was especially abundant on coffee, but with only intermediate numbers in poró and laurel.

Even though, in all the CPL plots, hopper species similarity was highest between poró-laurel, followed by coffee-poró and coffee-laurel, there were important differences between plots. In addition, the effect of specific plot characteristics on similarity values was obvious at the two higher

Table 3. Jaccard's similarity index for hopper species in coffee systems in Turrialba, Costa Rica.

	C[a]	CP	CPL
C	–	0.37	0.38
CP	0.37	–	0.51
CPL	0.38	0.51	–

[a] C: unshaded coffee, CP: coffee-poró, CPL: coffee-poró-laurel.
Coffee (*Coffea arabica*), poró (*Erythrina poeppigiana*), laurel (*Cordia alliodora*).

hierarchical levels (systems and plant components). These trends were confirmed by a cluster analysis (Figure 3), which allowed the examination of the degree of species affinity between and within components for all plots in each system. In general, it revealed that species composition varied considerably by plant component and the geographic location of each plot. For instance, for the CP system, the highest affinity was found between poró in La Montaña 2 and 3, which were closer to coffee in La Montaña 2, than to poró in Verbena (Figure 3A); in fact, hopper species composition in poró in Verbena differed most from other CP components/sites. However, for the CPL system, the highest affinity was detected between coffee in La Montaña 1 and laurel in La Suiza, followed by poró in the same locations (Figure 3B); laurel in Cabiria 1 differed most from the other plots. Aside from differences associated with local factors, such as microclimatic conditions, variations in the structure of each coffee plantation and management practices, differences in sampling dates could also have contributed to variations between plots. Originally, it was intended to use three evenly spaced sampling periods, involving all plots. However, distorted rainfall patterns due to the 'La Niña' atmospheric phenomenon in 1998 forced sampling at irregular intervals for some plots, which could have affected comparability.
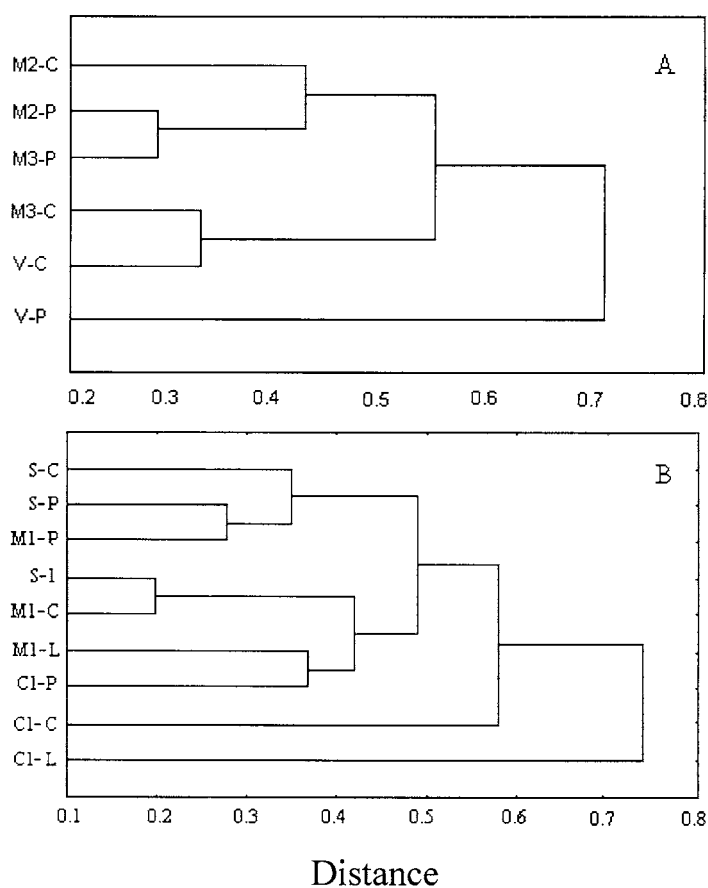

Figure 3. Dendrogram for hopper species similarity by plots and plant components in: A) unshaded coffee (*Coffea arabica*); B) coffee-poró (*Erythrina poeppigiana*); and C) coffee-poró-laurel (*Cordia alliodora*) systems in Turrialba, Costa Rica. Symbols represent plots (M: La Montaña, V: Verbena, S: La Suiza, C: Cabiria) and components (C: coffee, P: poró, L: laurel).

Conclusions

Hopper diversity was higher in coffee than in the shade trees, and it increased in the mixed systems, especially in the coffee-poró system. These findings are in general agreement with data for several Hymenoptera and Coleoptera in Costa Rica and Mexico, which revealed that insect species diversity in traditional, well-shaded coffee plantations is higher than in unshaded plantations (Nestel et al., 1993; Perfecto and Snelling, 1995; Perfecto and Vandermeer, 1994; Perfecto et al., 1996, 1997). The specific mechanisms by which poró contributes to increased hopper diversity remain unknown. To address this issue, it would be necessary to conduct large-scale experiments in non-commercial plots, where key variables, related to both coffee and shade trees, could be manipulated. It would then be possible to gain insight into both detrimental and beneficial inter-actions between coffee and shade tree species, as well as to learn how to manipulate shade trees to maximize their beneficial aspects towards pest management. One such beneficial aspect would be the role of shade tree species in maintaining high populations of parasitoids and predators to preclude potential hopper outbreaks.

Acknowledgements

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