A Trap Survey of Flying Insects in "Finca Experimental La Lola" in Costa Rica[1]

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ABSTRACT

Within an approximately one-year period, we assessed the effectiveness of three kinds of commercially-produced entomological sticky traps and water-filled McPhail traps in the sampling of flying insects in "Finca Experimental La Lola" in the Limon Province of Costa Rica. In some of the treatments using sticky traps, we scented traps with steam-distilled floral oils of *Theobroma cacao* Linnaeus ("UF-613"), *T. mammosum* Cuatr. & Leon. and *Herrania cuatrecasana* Garcia-Barriga. We also deployed these floral oils in McPhail traps, and also floral oil of *T. simiarum* Donn. Smith. Our intention was to determine if non-colored but scented sticky traps (Pherocon I.C. and "Pherocon Tent" traps) were more effective in attracting flying insects than brightly colored (yellow) rectangular sticky traps ("Pherocon A.M." traps) having no scent in one experiment conducted late in the wet season (1985). Furthermore, we compared the effectiveness of floral oil-scented non-sticky (McPhail) traps in both dry and wet seasons in two other experiments (1986) with the results from the sticky traps. "Pherocon I.C." and "Pherocon Tent" traps were least effective in trapping insects in both open and shaded cacao habitats, compared to the high numbers and species of insects trapped in the colored "Pherocon A.M." traps at the same time. We attributed the effective attraction of flying insects to the colored sticky traps to be due to the bright yellow color and possibly the rectangular shape of these traps. Even when non-colored (white) sticky traps are scented with floral oils and major volatile constituents (pentadecene and pentadecane) or mixtures, there is no increased attraction of insects. Water-filled McPhail traps scented with serially-diluted floral oils of *Theobroma* species attracted low but regular numbers of insects during both dry and wet seasons, but with more species and greater numbers attracted during the dry season in both cacao habitats studied ("cacao proper" and "Barker cacao forest"). McPhail trap samples may be more accurate indicators of true population densities and spatial distribution of insect species in cacao plantations as compared to colored sticky traps (without scent), which

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COMPENDIO

En el lapso de aproximadamente un año, se probó en la Finca Experimental La Lola, en la provincia de Limón, Costa Rica, la eficacia de tres clases de trampas entomológicas comerciales, unas con sustancias pegajosas y otras del tipo McPhail con agua, para contar insectos voladores. En algunas trampas con sustancias pegajosas se colocaron esencias destiladas de las flores de *Theobroma cacao* Linnaeus ("UF-613"), *T. mammosum* Cuatr. & Leon. y *Herrania cuatrecasana* (García-Barriga). También, se colocaron estas esencias en las trampas McPhail y además, la esencia de la flor de *T. simiarum* Donn. Smith. Se trató de determinar si las trampas "incoloras" o sea blancas con sustancias pegajosas, las trampas "Pherocon I.C." y "Pherocon Tent", son más eficientes para atraer a los insectos voladores que las trampas rectangulares de color amarillo brillante, "Pherocon A.M.", con sustancias pegajosas pero sin esencias florales. Este experimento se hizo a fines de la época lluviosa en 1985. Además, durante el tiempo seco y la temporada de lluvias de 1986, se comparó la eficiencia de las esencias florales en las trampas McPhail sin sustancias pegajosas con los resultados de las pruebas hechas con las trampas y con las sustancias pegajosas. Las trampas "Pherocon I.C." y "Pherocon Tent" resultaron ser menos eficientes para atraer insectos —tanto en el área asoleada como en el área sombreada de la plantación de cacao— que las trampas amarillas "Pherocon A.M." con las cuales se hicieron pruebas simultáneas. Se llegó a la conclusión que la gran atracción de los insectos voladores se debía al color amarillo brillante y a la configuración rectangular de estas trampas. Aún cuando se emplean las trampas blancas con sustancias pegajosas y esencias florales o sus ingredientes volátiles principales (pentadecene y pentadecane o combinaciones de éstos), no hay incremento de los insectos que caen en las trampas. Las trampas McPhail a base de agua con concentraciones progresivas de las esencias de las flores de las especies de *Theobroma*, atrajeron pocos insectos pero en números constantes, durante el tiempo seco y en la temporada de lluvias, pero con más especies y más individuos durante el tiempo seco en los cacaotales bajo cultivo abandonados. Las muestras de las trampas McPhail podrían ser más fieles para indicar las densidades numéricas correctas y las distribuciones de las especies de insectos en cacaotales que las trampas amarillas, con sustancias pegajosas y sin esencias florales las cuales, probablemente, atrajeron insectos provenientes de grandes distancias. Los grupos de insectos que predominaron en las muestras en las trampas fueron: Diptera, Hymenoptera, Coleoptera y Homoptera. Estos y otros grupos que se encontraron en las trampas indican que se podría organizar un programa para censar las poblaciones insectiles con las trampas "Pherocon A.M." con sustancias pegajosas y con las trampas McPhail con esencias florales. Este programa podría ser una forma útil para observar los ciclos de poblaciones de varias especies de insectos de los diversos grupos tróficos (basureros, herbívoros, parásitos, etc.). Puesto que las muestras estudiadas fueron muy limitadas, no se pudo determinar si había diferencias o no entre la intensidad de atracción para los probably draw insects from a considerable distance. Insect groups that dominated the trap samples, in terms of both numbers and individuals and species, were: Diptera, Hymenoptera, Coleoptera, and Homoptera. These and other groups trapped indicate that a regular censusing program deploying "Pherocon A.M." colored sticky traps and floral oil-scented McPhail traps can provide a useful means of monitoring the population cycles of various species of insects belonging to different trophic groups (scavengers, herbivores, parasites, etc.). Because our insect samples were very small, we were unable to determine if there exist habitat-related differences in the assemblages of flying insects associated with this cacao plantation. The chemical composition of *Theobroma* floral oils differs greatly among different species, but whether or not these differences in volatile constituents have a biological role in determining possible differences in the species of insects attracted to them remains to be studied. We could not, however, find any particularly effective role of the two major volatile constituents of *T. cacao* floral oil, namely, the "oily" hydrocarbons pentadecene and pentadecane, in attracting insects.

insectos, según las especies de esencias de *Theobroma*. También, por los números tan limitados de muestras, no se pudo determinar si hay diferencias entre los grupos de insectos voladores que existen en cacaotales bajo cultivo y abandonados. La composición química de las esencias de *Theobroma* varía mucho, según las especies, pero queda por estudiar si las diferencias de los ingredientes volátiles tienen un papel biológico en la determinación de las posibles diferencias entre las especies que atraen. No se pudo determinar, si los dos principales ingredientes de la esencia de *T. cacao* —es decir— los hidrocarburos "aceitosos" pentadecene y pentadecane desempeñan un rol determinante en la atracción de los insectos.

INTRODUCTION

A thorough understanding of the multi-facted roles of insects on the overall long-term agronomic success of commercial and experimental cacao plantations throughout the humid tropics necessitates the analysis of the numbers of insects, both in terms of taxonomic affiliations and abundance, found in these habitats. Based largely upon studies done in Africa (2), frequently different sampling techniques at various times of the year are required to obtain an accurate description of insect activity in cacao plantations. As a first attempt to define both adequate sampling methods and a preliminary assessment of insect activity in one Costa Rican experimental cacao plantation, we compared several different trap methods for flying insects at different times of the year. Our data, while preliminary, define the broad range of insect species active in the plantation, and illustrate, in a comparative context, the effectiveness of water-filled McPhail traps scented with floral oils of *Theobroma* and *Herrania*, including cacao, and scentless, commercially produced sticky traps. These data sets complement previous studies on the ground- and leaf-litter inhabiting insects of this particular cacao plantation (9, 10, 11, 12, 13, 14, 15, 16, 17).

MATERIALS AND METHODS

Our studies were conducted at "Finca Experimental La Lola," an experimental cacao plantation near Siquirres (10 06'N, 83 30'W), Limon Province, Costa Rica. Given the considerable monthly variation in rainfall typical of this locality (Fig. 1), our three experiments encompassed both wet and dry seasons.

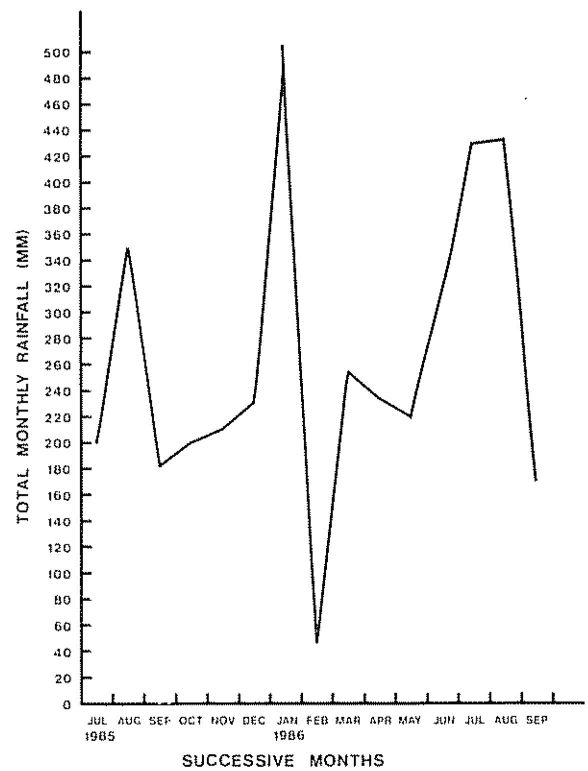

Fig. 1. Total monthly rainfall, encompassing the 1985 and 1986 trap experiments, at "Finca Experimental La "Lola" in Costa Rica. Data courtesy of CATIE.

The first, between 21-26 September and 2 October, 1985, consisted of a comparison of insects trapped in entomological sticky traps (non-scented and others scented by us with floral oils and other volatiles:

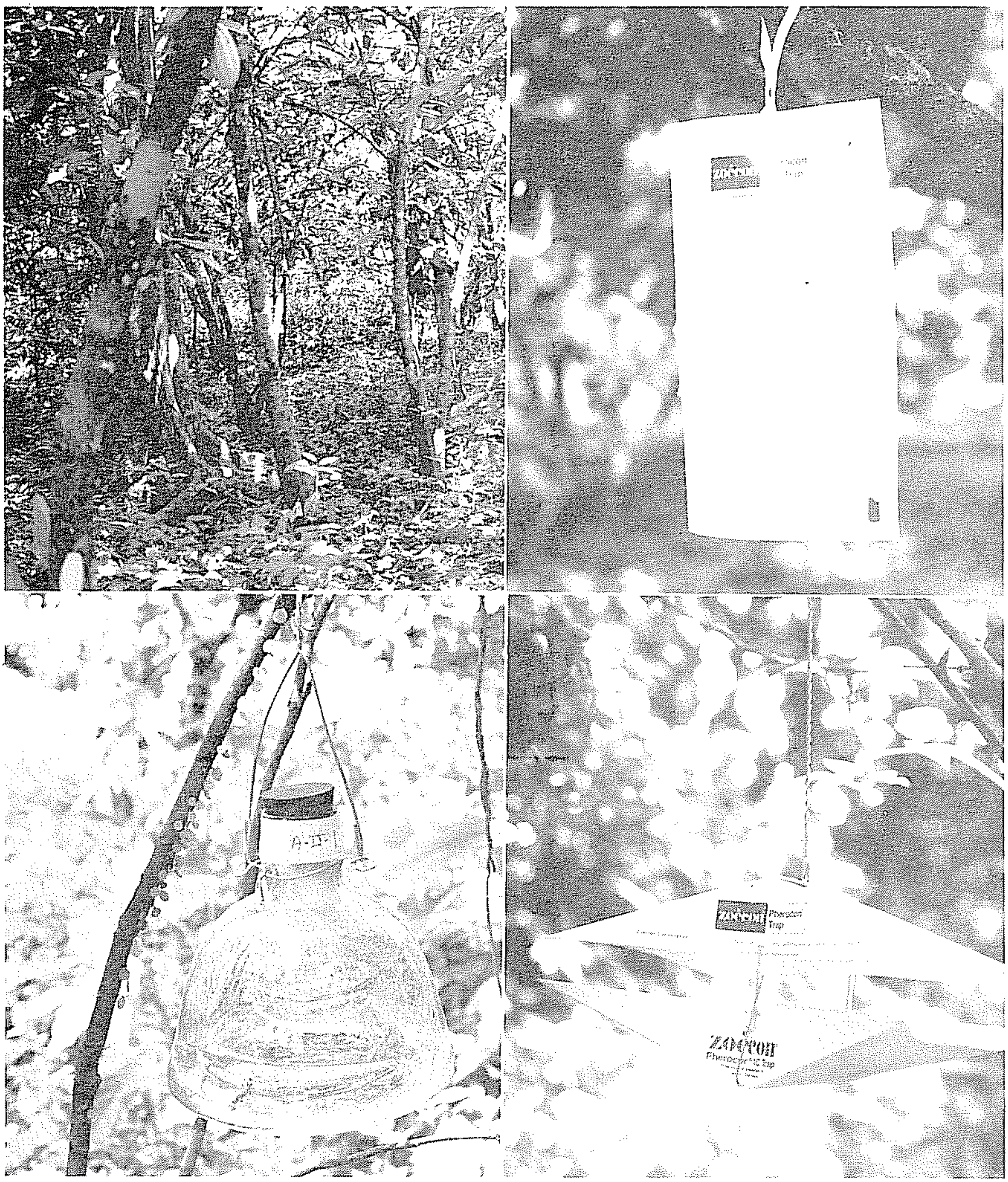

Fig. 2. Experimental trapping of flying insects in cacao. Clockwise, beginning in upper left: "Barker cacao forest;" "Pherocon A.M." Trap; "Pherocon I.C." Trap; McPhail Trap

"Pherocon A.M. Trap(R);" Pherocon Tent Trap(R);" "Pherocon I.C. Trap(R)," courtesy of Zoecon Corp., Palo Alto, California) with McPhail (non-sticky but scented by us with floral oils and related volatiles) water-filled traps (courtesy of the California Dept. of Agriculture) distributed in equal numbers between an open (largely non-shaded), well-maintained section of the La Lola cacao ("cacao proper") and a nearby (approximately 500 m distance) border area of well-shaded abandoned cacao ("Barker cacao forest") (Fig. 2).

The 1985 experiment consisted of the following field treatments: (1) four McPhail traps in each of the two habitats, with one trap each inoculated with 10 microliters of 99% pure pentadecane, pentadecene, 9:1 mixture of pentadecene to pentadecane, and control (blank) of 10% solution of chloroform solvent in distilled water; (2) three Pherocon I.C. traps in each of the two habitats, with one trap each inoculated with pentadecene, pentadecane, and blank (as above); (3) four Pherocon A.M. traps in each habitat, non-scented; (4) five Pherocon Tent traps in each habitat, two inoculated with 100% *Theobroma cacao* L. floral oil (10 microliters, "UF-613"), one trap each with *T. mammosum* Cuatr. & Leon, *Herrania cuatrecasana* Garcia-Barriga floral oils (100%), and control (blank) as described above; (6) eight McPhail traps in the "Barker cacao forest" habitat only, scented with aqueous solutions of floral oils, at varying serial dilutions, as follows: *T. cacao* floral oil, one trap each, of one-part, ten-parts, 100-parts per million (in ppm) and pure (100%) oil; one trap each inoculated with pure (100%) floral oil of *T. simiarum* Donn Smith, *T. mammosum*, and *H. cuatrecasana*; one control (blank) as in the other treatments outlined above. Most of these treatments lasted two or three days, with the exception of (6) above, which lasted for one week. All traps were suspended within one or two meters of the ground from the branches of cacao trees, in both habitats.

There were two identical experiments conducted in 1986, one in the dry season (February) and the other in the following wet season (July). Only McPhail traps were used in these experiments. In each experiment, which lasted six successive days, there were eighteen "experimental" traps, consisting of three treatments (serial dilutions) for each of two floral oils (*T. cacao*, "UF-613" and *T. simiarum*), with three replicate traps for each treatment. The serial dilutions were the same as in the 1985 experiment. Traps were recharged with fresh floral oil every three days, or halfway through each of the two experiments. Additionally, there were six control or blank traps, prepared as before, for each of the two 1986 experiments, giving a total of twenty-four traps used each time. Both experiments were conducted in the "Barker cacao forest." No sticky traps were used. As in the previous trap studies, we censused the McPhail traps at 24-hour intervals, allowing for day-night cycle changes in the chemical composition of floral oils (Fig. 3), which may influence the diurnal activity cycle of flying insects attracted to cacao flowers.

The floral oils used in all three experiments were obtained by steam-distilling specific quantities of freshly-collected flowers. The method of steam distillation, analyses of floral oils, and the techniques used to inoculate the McPhail traps are described in detail elsewhere (1, 5, 19). The use of pentadecane and pentadecene (Sigma Corp., St. Louis, Missouri) in some of the 1985 experimental treatments was prompted by our prior discovery of these hydrocarbons being major constituents of the floral oil of *T. cacao* (1). Insects collected from the traps in the three experiments were sorted in the laboratory and stored in vials filled with 70% ethanol for further determinations by specialists.

RESULTS

For both habitats combined, pentadecene and pentadecane-scented sticky traps attracted many more insects than the scentless controls (Table 1). When the two treatments of cacao floral oil major hydrocarbons are combined, close to four times the number of insects were found in these traps, as compared to the control. Diptera were far more numerous, albeit in small sample sizes, than other insects (Table 1). The total numbers of insects found in the sticky traps in the 1985 experiment, for both treatments, were very similar between the two habitats (Table 1). The larger, bright yellow, but non-scented "Pherocon A.M." sticky traps yielded a ten-fold increase in insects over the "Pherocon I.C." sticky traps scented with floral hydrocarbons (Tables 2 and 3 combined, and compared with Table 1, respectively). Yet strikingly similar numbers of insects (total of 105 individuals in the "cacao proper" and 99 individuals in the "cacao forest," Tables 2 and 3, respectively) were found between the two cacao habitats. Although the total number of Diptera trapped between these habitats was very similar (39 and 37), almost twice as many Coleoptera were trapped in the "cacao forest" habitat than in the "cacao proper" habitat (Tables 2 and 3). With the exception of ants, which were similar in abundance between the two habitats in the scentless sticky traps, almost twice as many flying Hymenoptera (parasitoids) were trapped in the "cacao proper" than in the abandoned cacao (Tables 2 and 3). In

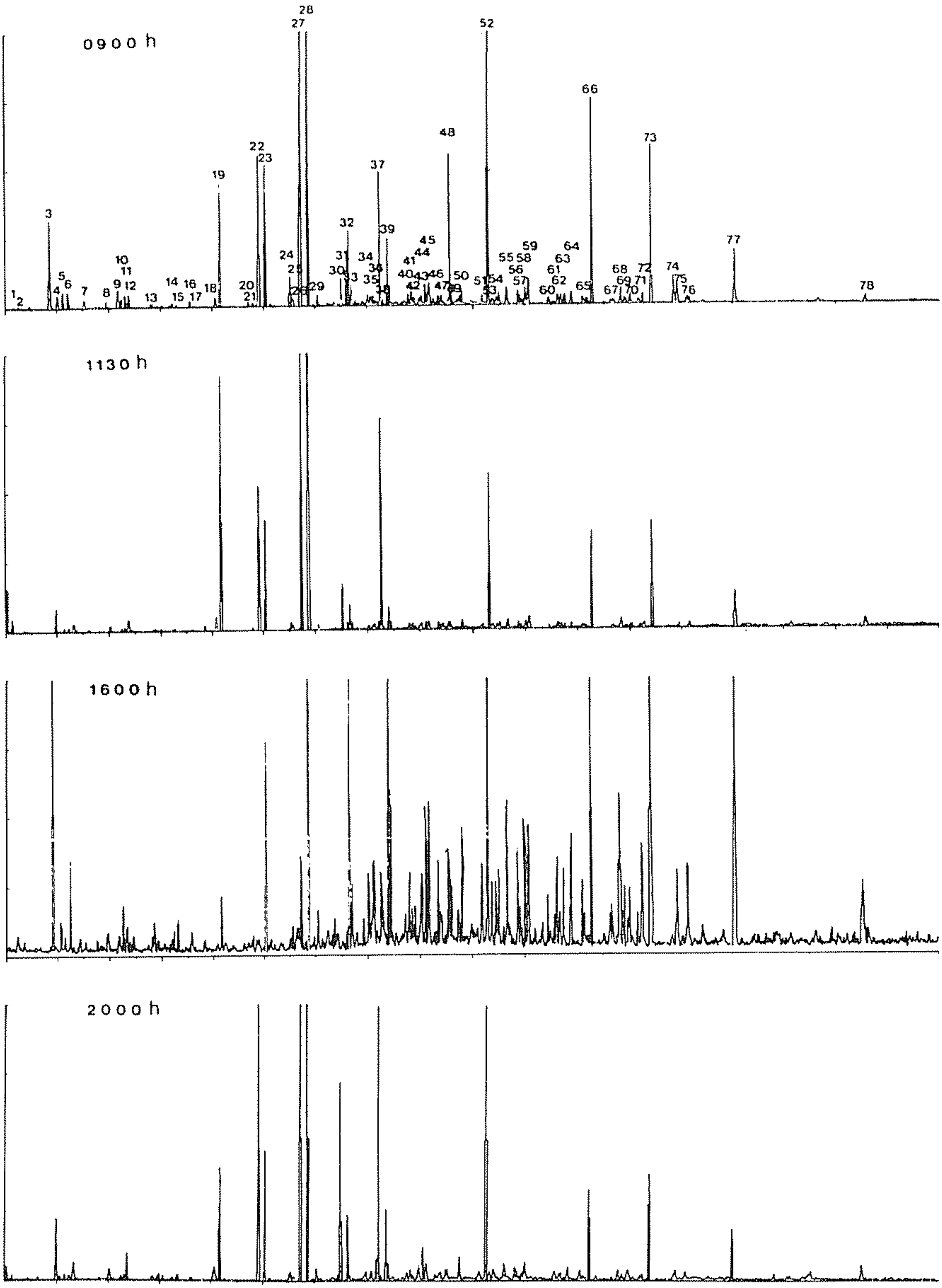

Fig. 3. Ion chromatograms for the steam-distilled floral oil of *Theobroma cacao* Linnaeus taken at four different times of the day and evening (based on collections of flowers taken at these times)

Table 1. The distribution of insects in "Pherocon IC Traps"* (sticky traps) inoculated with pentadecene and pentadecane, and in blanks (controls), in two cacao forests at La Lola during the late wet season (September 1985).

	Numbers of insects in traps:**								
	Pentadecene			Pentadecane			Controls		
Taxa	cacao proper	cacao forest	total	cacao proper	cacao forest	total	cacao proper	cacao forest	total
Diptera									
Phoridae									
Megaselia sp. 1	0	1	1	1	2	3	0	0	0
Dohrniphora sp. 1	0	0	0	0	1	1	0	0	0
Sciaridae									
Bradysia sp. 1	0	0	0	0	0	0	1(f.)	1	2
Bradysia sp. 2	3(f.)	0	3	0	4(m.)	4	0	0	0
Bradysia sp. 3	0	0	0	0	1(m.)	1	0	0	0
Dolichopodidae	1	0	1	0	1	1	0	1	1
Total Diptera:	4	1	5	1	9	10	1	2	3
Hymenoptera									
Formicidae									
Ponerinae, *Odontomachus*	0	1	1	1	2	3	1	1	2
Myrmicinae	0	0	0	1	0	1	0	0	0
Evaniidae	1	0	1	0	0	0	0	0	0
Braconidae, *Phaneratoma*	0	0	0	0	0	0	0	1	1
Total Hymenoptera:	1	1	2	2	2	4	1	2	3
Excluding Formicidae:	1	0	1	0	0	0	0	1	1
Coleoptera									
Chrysomelidae, Alticinae									
Monomacra sp. 1	3	0	3	0	0	0	0	0	0
Curculionidae, *Zygops* sp.	0	0	0	0	1	1	0	0	0
Total Coleoptera:	3	0	3	0	1	1	0	0	0
Lepidoptera									
Oecophoridae	0	0	0	1	0	1	0	0	0
Homoptera									
Derbidae, *Anota* sp.	0	0	0	1	0	1	0	0	0

* Zeocon Corporation (Palo Alto, California). 10 ul each of 98% pure pentadecene and 99% pure pentadecane (Sigma Chemical Co., St. Louis, Missouri) were used.

** Only one replicate for each of the three kinds of trap treatments used. Total of 6 traps used.

both habitats, the numbers of insects trapped among different replicate traps greatly for the most abundant groups (Diptera, Hymenoptera, and Coleoptera), and much less so for the other groups of insects trapped (Tables 2 and 3). Within each of the three most abundant orders of insects trapped, there was a similar number of species between the two habitats, although, overall, fourteen more species were found in the "cacao proper" traps than in the "cacao forest" traps (total of 37 species in the "cacao proper" and 23 species in the "cacao forest").

Other sticky traps ("Pherocon Tent Traps") inoculated with steam-distilled floral oils of *Theobroma* and *Herrania* attracted relatively few flying insects, as seen even when the data for both habitats are combined (Table 4). As in the other treatments tested in the 1985 experiment, Diptera were the most abundant insects in these traps, even though the sample was very small (Table 4). McPhail traps inoculated with cacao floral oil major hydrocarbons (pentadecene and pentadecane) and a mix of both, yielded very few insects, although slightly more

Table 2. The distribution of insects in replicated "Pherocon A.M. Traps"* (sticky traps) in the La Lola cacao plantation during the late wet season (September 1985)**.

	Numbers of insects in trap replicates:						
Taxa	total	$\bar{X}$	S.E.	Taxa	total	$\bar{X}$	S.E.
Diptera				Coleoptera			
Cecidomyiidae				Chrysomelidae (Alticinae)			
Ledomyia sp.	1	0.25	0.25	*Monomacra* sp. 1	5	1.25	0.48
Ceratopogonidae				*Monomacra* sp. 2	4	1.00	0.71
Atrichopogon sp	1	0.25	0.25	*Colapsis* sp.	2	0.25	0.25
Phoridae	3	0.75	0.75	*Synbrotica* sp.	1	0.25	0.25
Sciaridae				*Monolepta* nr. *bipartita*	2	0.50	0.50
Bradysia sp. 1	3	0.75	0.75	Jacoby			
Bradysia sp. 2	2	0.50	0.50	*Acalymma* nr. *blomorum*	1	0.25	0.25
Dolichopodidae	8	2.00	1.22	Monroe & Smith			
Richardidae				Coccinellidae	10	2.50	1.50
Richardia sp.	12	3.00	2.35	Curculionidae			
Odontomera sp	3	0.75	0.75	*Apion* sp.	1	0.25	0.25
Chloropidae							
Oscinellinae, *Coryphistron*	5	1.25	0.75	Total Coleoptera:	26	6.50	1.66
Xylomyidae	1	0.25	0.25				
				Homoptera			
Total Diptera:	39	9.75	4.09	Cicadellidae			
Hymenoptera				*Gypona trita* DeLong & Freytag	1	0.25	0.25
Formicidae				*Scaphytopius* sp.	4	1.00	0.71
Ponerinae, *Odontomachus*	10	2.50	2.18	*Ladoffa elauta* Young	1	0.25	0.25
Formicinae	1	0.25	0.25	Membracidae			
Chalcidae				*Spongophorus biclavatus*	1	0.25	0.25
Spilochalcis	2	0.50	0.50	(Westwood)			
Haltricellinae	1	0.25	0.25	*Amastrus obtegens* (Fabr.)	4	1.00	0.71
Ceratosmicra sp	3	0.75	0.75	Cercopidae			
Scelionidae				*Clastopera globosa*	3	0.75	0.75
Ceratobaeus sp.	1	0.25	0.25	Fowler			
Encyrtidae				Tropiduchidae			
Metaphycus sp.	2	0.50	0.50	*Neorudia* nr. *minor*	1	0.25	0.25
Braconidae				(Fowler)			
Heterospilus sp	1	0.25	0.25	Issidae			
Bethylidae				*Colpoptera sinuata*	1	0.25	0.25
Dissomphalus sp	1	0.25	0.25	Burmeist.			
Eurytomidae							
Eurytoma sp	1	0.25	0.25	Total Homoptera:	16	4.00	2.35
Sphecidae (Cabronini)	1	0.25	0.25				
Total Hymenoptera:	24	6.00	3.44				
(excluding Formicidae)	13	3.25	1.31				

* Zoecon Corporation (Palo Alto, California). Total of 4 traps used.

** Data summed for 4 successive days (22-25 September 1986) of checking traps.

than in the control (Table 5). By contrast, floral oils of *Theobroma* at varying concentrations in McPhail traps yielded a considerably greater number of flying insects, especially Diptera, than McPhail traps scented with pure hydrocarbons or a mixture (Table 6 compared with Table 5). Serially-diluted cacao floral oil attracted more insects than the pure (100%) cacao floral oil of *T. mammosum* treatment (Table 6). Because our sample sizes of insects trapped were so small, it was not possible to discern a definite preference of insects for one or more of the floral oil concentrations tested. Clearly, however, the absence of insects in the control treatment indicate an attraction of flying insects, especially Diptera, to *Theobroma* floral oils (Table 6). Bees, while far less numerous in our samples, were represented by one stingless bee species and the European honey bee, *Apis mellifera* Linnaeus (Table 6). The bees did not appear in the

Table 3. The distribution of insects in replicated "Pherocon A.M. Traps"* (sticky traps) in the Barker cacao forest adjacent to La Lola during the late wet season (September 1985)**.

Taxa	Total numbers of insects in traps: total	$\bar{X}$	S.E.
Diptera			
Phoridae			
Megaselia sp. 2	4	1.00	0.41
Dohrniphora sp. 1	2	0.50	0.50
Sciaridae			
Bradysia sp. 1 nr *coprophila*	7	1.75	0.75
Bradysia sp. 2	18	4.50	2.90
Bradysia sp. 3	1	0.25	0.25
Bradysia sp. 4	1	0.25	0.25
Dolichopodae	1	0.25	0.25
Chironomidae	2	0.50	0.50
Lauxaniidae	1	0.25	0.25
Total Diptera:	37	8.75	2.56
Hymenoptera			
Formicidae			
Solenopsis picea Emery	2	0.75	0.48
Ponerinae, *Odontomachus*	1	0.25	0.25
Myrmicinae	1	0.25	0.25
Encyrtidae, *Sympiesis* sp.	1	0.25	0.25
Braconidae	1	0.25	0.25
Scelionidae, *Ceratobaeus* sp.	2	0.50	0.50
Evaniidae, *Hyptia* sp	3	0.75	0.75
Ichneumonidae, *Cryptanura* sp.	1	0.25	0.25
Total Hymenoptera:	13	3.25	0.85
(excluding Formicidae)	9	2.25	0.95
Coleoptera			
Chrysomelidae, Alticinae			
Monomacra sp. 1	2	0.50	0.50
Hermaeophaga sp.	6	1.50	0.65
Eumolpinae	1	0.25	0.25
Coccinellidae	36	9.00	4.42
Brentidae, *Hyperephanus* sp.	1	0.25	0.25
Total Coleoptera:	46	11.50	3.97
Homoptera			
Cicadellidae			
Ladoffa elauta Young	1	0.25	0.25
Membracidae			
Boethoos reticulata (Fabr.)	1	0.25	0.25
Total Homoptera:	3	0.75	0.75

* Zoecon Corporation (Palo Alto, California). Total of 4 traps used.

** Data summed for 4 successive days (22-25 September 1985) of checking traps

traps until the final day (the seventh day) of census. The Dipteran family Phoridae was represented in the 1985 trap experiment by *Megaselia* and *Dorhniphora*, two genera known to be pollinators of *Herrania* in Costa Rica (13).

In spite of a four-fold increase in the number of McPhail traps used in the 1986 dry and wet season experiment, we found very little increase in the numbers of flying insects lured to traps scented with the serially-diluted floral oils of *T. cacao* and

Table 4. The distribution of insects in "Pherocon Traps"* inoculated with concentrated *Theobroma* and *Herrania* floral oil ("old"**) in cacao habitats*** at La Lola during the late wet season (September 1985)****.

Taxa	Total number of insects in traps:***** *T. cacao*	*T. mammosum*	*Herrania*	*Total*	$\bar{X}$	S.E.
Diptera						
Cecidomyiidae						
Karshomyia sp	1	0	0	1	0.33	0.33
Phoridae	1	1	0	2	0.66	0.33
Sciaridae						
Bradysia sp. 1	2(m.)	1(m.)	0	3	1.00	0.58
Dolichopodidae	0	1	0	1	0.33	0.33
Total Diptera:	4	3	0	7	2.33	1.20
Hymenoptera						
Formicidae						
Ponerinae, *Odontomachus*	1	0	0	1	0.33	0.33
Solenopsis picea Emery	0	0	1	1	0.33	0.33
Myrmicinae	0	1	0	1	0.33	0.33
Total Hymenoptera:	1	1	1	3	1.00	0.58
Excluding Formicidae:	0	0	0	0	–	–
Coleoptera						
Chrysomelidae						
Megascelis sp.	0	1	0	1	0.33	0.33
Total Coleoptera:	0	1	0	1	0.33	0.33
Homoptera						
Cicadellidae						
Agallia sp.	0	1	0	1	0.33	0.33
Membracidae						
Vanduzae segmentata (Fowler)	2	0	0	1	0.33	0.33
Amastrus obtegens (Fabricius)	0	0	1	1	0.33	0.33
Total Homoptera:	2	1	1	4	1.33	0.33

* Zoecon Corporation (Palo Alto, California). Total of 10 traps used

** Floral oils, collected by steam distillation, and kept frozen for about six months prior to use, rather than freshly-collected at the time of this bioassay

*** Data combined for two habitats, cacao plantation proper, and cacao forest (abandoned cacao) nearby, since numbers of insects trapped in each habitat for any given group ranged 1-2 individuals only. Only two insects (ants) were found in the controls

**** Data summed for four successive days of checking the traps.

***** Data presented for total of replicates for each kind of trap used: *T. cacao*, total of 4 replicates (2 per habitat); *T. mammosum*, total of 2 replicates (one per habitat); *Herrania* (*H. nitida*), total of 2 replicates (one per habitat), and total of 2 replicate blanks (controls)

T. simiarum. For groups such as Coleoptera, Lepidoptera, Hymenoptera (excluding ants), Homoptera, and Orthoptera, the numbers of any one species represented in the traps in either the dry or wet season census seldom ranged above two or three individuals (Tables 7, 8, 9, 10 and 11). The data for the Diptera from this experiment are summarized elsewhere (19).

Our exceedingly small samples from the expanded use of McPhail traps in the 1986 experiments precluded the detection of a possible differential

Table 5. The distribution of insects in McPhail Traps* inoculated with pentadecene, pentadecane, and a mixture of both volatiles, and blanks (controls) in the Barker "cacao forest" adjacent to the La Lola cacao plantation during the late wet season (September 1985).

Taxa	Numbers of insects in traps**						
	pentadecene	pentadecane	mixture	total	$\bar{X}$	S.E.	blanks
Diptera							
Cecidomyiidae							
Aphidodiplosis triangularis (Felt)	0	0	1(m.)	1	0.33	0.33	0
Culicidae							
Culex sp.	0	0	0	0	-	-	1
Total Diptera:	0	0	1	1	0.33	0.33	1
Hymenoptera							
Formicidae							
Solenopsis picea Emery	0	0	1	1	0.33	0.33	0
Paratrechina caeciliae (Forel)	0	2	0	2	0.66	0.33	0
Scelionidae							
Baryconus sp.	1	0	0	1	0.33	0.33	0
Platygastridae							
Leptaris sp	0	1	0	1	0.33	0.33	0
Total Hymenoptera:	1	3	1	5	2.50	0.96	0
Excluding Formicidae:	1	1	0	2	0.66	0.33	0
Coleoptera							
Chrysomelidae, Alticinae							
Hermaeophaga sp.	0	0	0	0	–	–	1

* Water-filled, inverted bell-shaped pendant traps (Fig. 2); "experimentals" inoculated with 99 pure pentadecene and 98% pure pentadecane (10 ul each) or mixture of both (9:1 pentadecene to pentadecane). "Blanks" consisting of traps alone without volatiles added. Commercial volatiles from Sigma Chemical Co. (St. Louis, Missouri). Total of 8 traps used.

** Experiment consisted of placing one replicate of each trap-treatment, or total of four, in each of two distinct cacao habitats: "cacao plantation" (proper) of La Lola, and "cacao forest" of A. Barker. But only insect was captured in "cacao proper" traps (Hymenoptera: Scelionidae), so data are combined for both areas and presented as "cacao forest."

attraction of flying insects to the floral oils of *T. cacao* and *T. simiarum*. Yet, in a comparative context, experimental traps, those inoculated with floral oil, contained more insects than the blanks in all instances (Tables 7-11). Three major groups of insects, Lepidoptera, Orthoptera, and Homoptera, were greatly reduced in numbers in the wet season (Tables 8, 10, and 11). For all insects combined, seven times the number of insects were trapped in the dry season experiment than in the wet season experiment several months later (total of 36 insects in all traps in the dry season experiment and nine insects in the wet season). A total of nineteen insects were collected from *T. cacao*-scented traps, and sixteen insects from *T. simiarum*-scented traps, for both experiments combined. Ants were the most abundant insects in floral oil-scented traps, and they were especially abundant in the dry season experiment (Table 12).

Almost four times the total number of species of insects were found in the traps during the dry season experiment than in the wet season experiment (total of 26 species and seven species, respectively) (Tables 7-12).

DISCUSSION

Costa Rican commercial and experimental cacao plantations support high-diversity assemblages of insects and other arthropods, as shown by surveys of ground, leaf-litter, and limited arboreal microhabitats (9, 10, 11, 12, 14, 15, 16, 17). Additionally, New World cacao plantations also support many species of cacao-pollinating Diptera and allied Diptera (7). What our data indicate is that cacao plantations such as La Lola support diverse assemblages of principally scavenging and herbivorous species. To what extent

Table 6. The distribution of insects in McPhail Traps in a preliminary bioassay of *Theobroma* and *Herrania* floral oil concentrated and serially-diluted (using "fresh" and "old" oils) in the Barker cacao forest adjacent to La Lola during the late wet season (September 1985).

Taxa	*T. cacao*								
	Numbers of insects in traps:**								
	100 ppm (fresh)	10 ppm (fresh)	1 ppm (fresh)	pure (old)	total	$\bar{X}$	S.E.	*T. mammosum*	blank
Diptera									
Cecidomyiidae									
Mycodiplosis ligulata Gagné	0	1 (f.)	0	0	1	–	–	0	0
Feltiella sp.	0	0	0	0	0	–	–	1	0
Aphidodiplosis triangularis	0	4(3 f.)	0	0	4	1.00	1.00	0	0
Phoridae	0		3	0	3	0.75	0.75	0	0
Sciaridae									
Bradysia sp. 1 nr. *coprophia*	0	0	0	2	2	0.50	0.50	0	0
Total Diptera:	0	5	3	2	10	2.50	1.04	1	0
Hymenoptera									
Apidae									
Trigona perilampoides	0	0	2	0	2	0.50	0.50	0	0
Apis mellifera Gresson	0	0	1	0	1	0.25	0.25	0	0
Formicidae									
Solenopsis picea Emery	0	0	0	1	1	0.25	0.25	0	0
Total Hymenoptera:	0	0	3	1	4	1.00	1.00	0	0
Excluding Formicidae	0	0	2	0	3	0.75	0.75	0	0
Lepidoptera									
Noctuidae									
Anticarsia anisopila (Walker)	0	0	1	0	1	–	–	1	0
Pyralidae	1	10	0	0	2	0.50	0.50	0	0
Total Lepidoptera:	1	1	1	0	3	0.75	0.75	1	0
Homoptera									
Cicadellidae									
Planicephalus sp	0	0	0	0	0	–	–	1	0
Agallia sp	0	0	0	0	0	–	–	1	0
Total Homoptera	0	0	0	0	0	–	–	2	0

* Water filled, inverted bell-shaped glass traps, inoculated with 10 ul quantities of floral oils, pure (100% concentration) or serially-diluted (pts/million in chloroform), either "fresh" (oil distilled within a day of use), or "old", (distilled several months earlier and kept frozen until use).

** One replicate trap for each treatment indicated; additionally, one trap of *T. simiarum* "old" floral oil, used at 100% concentrated, but yielding no insects. All traps checked for each of four successive days of study. Blank (control) trap inoculated with chloroform alone. Total of 8 traps used.

these species are associated with cacao trees or simply transient species exploiting other resources cannot be ascertained from our study. But our study does provide, however, an approximate measure of the taxonomic range of insects active in the air space among cacao trees in open, non-shaded areas and within densely shaded abandoned cacao

The observed high diversity and abundance of flying insects collected from the bright yellow "Pherocon A.M." traps in the September (late wet season) experiment, relative to the very low numbers of insects collected from the other traps, including those scented with *Theobroma* floral oils and major floral oil (cacao) hydrocarbons, is very likely due to

Table 7. The distribution of beetles (Coleoptera) in McPhail Traps* containing serial dilutions of *Theobroma* floral oils and blanks (controls) during the dry season (February 1986) and wet season (July 1986) in the Barker cacao forest adjacent to La Lola.

Taxa	Total numbers of insects in traps: 100 ppm	10 ppm	1 ppm	total	$\bar{X}$	S.E.
			Dry Season			
			Theobroma cacao			
Coccinellidae (*Diomus* sp.)	0	2	0	2	0.66	0.33
Total:	0	2	0	2	0.66	0.33
			nos. replicates with beetles: 2/9 (11.11%)			
			Theobroma simiarum			
Coccinellidae (*Diomus* sp.)	2	1	0	3	1.00	0.58
Nitidulidae	1	0	0	1	0.33	0.33
Total:	3	1	0	4	1.33	0.33
			nos. replicates with beetles: 3/9 (33.33%)			
			blanks (controls)			
no insects	0	0	0	0	–	-
			Wet Season			
			Theobroma cacao			
Chrysomelidae						
Aphthona sp.	1	0	0	1	0.33	0.33
Colaspis sp.	1	0	0	1	0.33	0.33
Total:	2	0	0	2	0.66	0.33
			Theobroma simiarum			
Curculionidae	1	0	0	1	0.33	0.33
			blanks (controls)			
no insects	–	–	–	–	–	–

* Data combined (summed) for six successive days of checking traps in each season; floral oil-inoculated traps replenished with fresh oil on the third day. Chloroform blanks also re-inoculated. Total of N-24 traps (18 "experimentals" and 6 "controls") in each season.

an attraction of many insects, especially Diptera, to yellow colors in nature. Yellow-colored rectangles and spheres suspended in trees are very attractive to some Diptera, including the walnut husk fly, *Rhagoletis* spp. (Tephritidae) in North America (4). In our late wet season experiment, the yellow color of the non-scented "Pherocon A.M." traps was a far more effective attractant to flying insects than steam-distilled floral oils and other attractants.

To what extent some insects were accidentally caught by the sticky traps cannot be ascertained from our study. But the range of the insect taxa represented in our "Pherocon A.M." trap samples, including Diptera, Hymenoptera, Coleoptera, Homoptera, etc., suggests that these traps provide and effective means for entomologists to assess the general activity of flying insects in cacao plantations. The studies of Gibbs and Leston (2) in African cacao plantations indicate that the diversity and population structure of insect assemblages associated with cacao change dramatically throughout the year at a particular locality. A regular implementation of non-scented sticky traps consisting of yellow rectangles (Fig. 2) may provide one means to monitor changes in insect populations in cacao plantations over time. To our knowlege, our experiment is the first attempt at deploying such a technique in Central America. Brightly colored sticky traps have been successfully used to monitor populations of parasitic Hymenopte-

Table 8. The distribution of Lepidoptera (various groups) in McPhail Traps* containing serial dilutions of *Theobroma* floral oil and blanks (controls) during the dry season (February 1986) in the Barker cacao forest adjacent to La Lola.**

Taxa	100 ppm	10 ppm	1 ppm	total	$\bar{X}$	S.E.
			Total number of insects in traps:			
			Theobroma cacao			
no insects	0	0	0	0	–	–
			Theobroma simiarum			
Pyralidae (Pyraustinae)	0	0	1	1	0.33	0.33
Pyralidae (Chryauginae)	0	0	1	1	0.33	0.33
Tortricidae (*Platynota* sp.)	0	0	1	1	0.33	0.33
Total:	0	0	3	3	1.00	0.58
			nos. replicated with moths: 2/9 (22.22%)			
			blanks (controls)			
	0	0	0	0	–	–

* Data combined (summed) for six successive days of checking traps; floral oil-inoculated traps replenished with fresh oil on the third day. Chloroform blanks also re-inoculated. Total of 24 traps (18 "experimentals" and 6 "controls").

** No Lepidoptera were found in the traps during the wet season experiment.

ra and their habitat associations in North America (6).

It is not unusual to find that many species of insects are attracted to scented traps designed to attract specific species (3). Young *et al.* (19) used McPhail traps scented with steam-distilled floral oils of *Theobroma* to determine whether or not cacao-pollinating midges (Diptera: Ceratopogonidae and Cecidomyiidae) were attracted to these volatile substances in the La Lola cacao plantation. Similar to what we have found for floral oil-scented McPhail traps in the present study for various groups of insects, Young *et al.* (19) discovered very low numbers and densities of midges in their trap samples. As with Young *et al.* (19), we interpret such very low abundances of virtually all groups for flying insects in both well-maintained and abandoned cacao groves to be the result of insect population structure: floral oil-scented McPhail traps clearly attract many more insects than control traps indicating that insects are attracted to the floral oils, and that insects most likely to be trapped under such conditions are those in the immediate vicinity of traps. Since the control traps contained a mixture of 90% distilled water and only 10% chloroform, it is very possible that insects observed in these traps were attracted to moisture, expecially during the dry season. In a very real sense, the low abundance of insects in our 1986 dry and wet season experiments, and in the findings of Young *et al.* (19) and Young (10.) for La Lola midge populations, provide a more accurate picture of insect densities in cacao plantations. We make this conclusion since McPhail traps inoculated with serially-diluted *Theobroma* floral oils very likely do not attract insects from a distance. On the other hand, we strongly suspect that colored, non-scented, sticky traps (such as the "Pherocon A.M." traps) attract insects from greater distances than the McPhail traps, and distort the actual spatial abundance of insect species. Non-colored sticky traps, with or without floral oil scents, do not provide a reliable means of monitoring insect activity, as indicated by the very low abundance of insects in them in our study. Taken together, "Pherocon A.M." traps and floral oil-scented McPhail traps provide one means of assessing the abundance of cacao-pollinating midge abundance in relation to the general activity of flying insects in cacao plantations. To accomplish this, one would have to devise a regular census program throughout

Table 9. The distribution of parasitic Hymenoptera (various genera) in McPhail Traps* containing serial dilutions of *Theobroma* floral oils and blanks (controls) during the dry season (February 1986) and wet season (July 1986) in the Barker cacao forest adjacent to La Lola.

	Total number of insects in traps:					
	100 ppm	10 ppm	1 ppm	total	X̄	S.E.
			Dry Season			
			Theobroma cacao			
Diapriidae	0	1	0	1	0.33	0.33
Total:	0	1	0	1	0.33	0.33
			nos. replicates with wasps: 1/9 (11.11%)			
			Theobroma simiarum			
Encrytidae	1	0	0	1	0.33	0.33
Scelionidae	0	2	0	2	0.66	0.33
Aphidiidae	0	1	0	1	0.33	0.33
Total:	0	3	0	3	1.00	0.58
			nos. replicates with wasps: 3/9 (33.33%)			
			blanks (controls)			
Diapriidae: 1			nos. replicates with wasps: 1/6 (16.67%)			
			Wet Season			
			Theobroma cacao			
Eulophidae, nr *Horismenus*	0	0	1	1	0.33	0.33
			Theobroma simiarum			
Cynipidae, *Trissodontapsis* sp.	0	1	0	1	0.33	0.33
			blank (controls)			
no insects	–	–	–	–	–	–

* Data combined (summed) for six successive days of checking traps in each season; floral oil-inoculated traps replenished with fresh oil on the third day. Chloroform blanks also re-inoculated. Total of N = 24 traps (18 "experimentals" and 6 "controls") in each season.

the year. Our study provides only a preliminary description of insect activity using these methods. Our study is, therefore, an important first step toward insect monitoring programs in cacao plantations.

The observed differences in the taxonomic diversity and abundance of some insect groups such as the Homoptera and Coleoptera between the two cacao habitats studied may be related to differences in the structural and taxonomic diversity of the vegetation in the two areas at La Lola. For example, the greater abundance and taxonomic diversity of Homoptera in the "cacao proper" may be due to the likely greater abundance of soft meristem tissues there. Homopterans are more frequently associated with non-woody food plants. Yet the greater range of Coleoptera in the "cacao forest" may be due to the greater diversity of foliage types present in this habitat, since the majority of beetles collected in the 1986 McPhail trap experiments were herbivorous species. The observed high diversity of parasitic Hymenoptera in both the 1985 and 1986 experiments suggests a high availability of soft-bodied herbivorous host insect species in the La Lola cacao plantation.

Table 10. The distribution of Orthoptera (various groups) in McPhail Traps* containing serial dilutions of *Theobroma* floral oils and blanks (controls) the dry season (February 1986) and wet season (July 1986) in the Barker cacao forest adjacent to La Lola.**

Taxa	Total number of insects in traps: 100 ppm	10 ppm	1 ppm	total	$\bar{X}$	S.E.
			Dry Season			
			Theobroma cacao			
Tettigoniidae (*Phlugis* sp.)	1	0	0	1	0.33	0.33
Tettigoniidae (*Caulopsis* sp.)	0	1	0	1	0.33	0.33
Tettigoniidae (*Neoconcephalus* sp.)	0	0	1	1	0.33	0.33
Blattellidae (*Cheruisneura* sp.)	1	0	0	1	0.33	0.33
Blattellidae (undetermined nymph)	1	0	0	1	0.33	0.33
Total:	3	1	1	5	2.50	0.96
			nos. replicates with orthopterans: 4/9 (44.44%)			
			Theobroma simiarum			
no insects	0	0	0	0	–	–
			blank (controls)			
Blattellidae (*Neoblattella* sp.) 1						
			nos. replicates with orthopterans: 1/6 (16.67%)			
			Wet Season			
			Theobroma cacao			
Tettigoniidae (*Ancistrocerus circumdatus* Walker)	1	0	0	1	0.33	0.33
Tettigoniidae (*Cocconotus* sp.)	1	1	0	2	0.66	0.33
Blattellidae (*Euphyllodroma angustata* Latreille)	1	0	0	1	0.33	0.33
Total:	3	1	0	4	1.33	0.33
			nos. replicates with orthopterans: 4/9 (44.44%)			
			Theobroma simiarum			
no insects	0	0	0	0	–	–

* Data combined (summed) for six successive days of checking the traps; floral oil-inoculated traps replenished with fresh oil on the third day. Chloroform blanks also re-inoculatad. Total of N = 24 traps (18 "experimentals" and 6 "controls").

** No Orthoptera were found in the traps during the wet season experiment.

Young (10) found that breeding populations of cacao-pollinating and other Ceratopogonidae aggregate in moist microhabitats during the dry season at La Lola, and become far less densely aggregated in the wet season. We believe that the overall greater number of insect species, and the greater number of insects in the 1986 dry season experiment with floral oil-scented McPhail traps, is also a response on the part of insects to dryness: McPhail traps filled with water provide sources of moisture to attract insects, expecially in the shaded conditions of the "Barker cacao forest" where many small-bodied insects are already present, having moved in from the surrounding, open cacao nearby. When moisture stress is alleviated during the wet season (see also a discussion of dry season-wet season shifts in population structure in Young (8)), insect populations become more dispersed and individuals are less likely to be attracted to McPhail traps in one particular are of the

Table 11. The distribution of true bugs (Homoptera) in McPhail Traps* containing serial dilutions of *Theobroma* floral oils and blanks (controls) during the dry season (February 1986) in the Barker cacao forest adjacent to La Lola.**

Taxa	Total number of insects in traps: 100 ppm	10 ppm	1 ppm	total	$\bar{X}$	S.E.
			Theobroma cacao			
Cicadellidae (*Ladoffa* sp.)	0	1	0	1	0.33	0.33
Derbidae (undetermined)	0	0	1	1	0.33	0.33
Total:	0	1	1	2	0.66	0.33
			nos. replicates with bugs: 2/9 (22.22%)			
			Theobroma simiarum			
Cicadellidae (*Osbornellus anonae*) Linnavuori	1	0	0	1	0.33	0.33
Derbidae (undetermined)	1	0	0	1	0.33	0.33
Delphacidae (undtermined)	0	0	1	1	0.33	0.3
Total:	2	0	1	3	1.00	0.58
			nos. replicates with bugs: 2/9 (22.22%)			
			blanks (controls)			
no insects	0	0	0	0	–	–

* Data combined (summed) for six successive day of checking traps; floral oil-inoculated traps replenished with fresh oil on the third day. Chloroform blanks also re-inoculated. Total of N = 24 traps (18 "experimentals" and 6 "controls")

** No Homoptera were found in the traps during the wet season experiment.

habitat. Our 1986 experimental data support this contention.

Although Erickson *et al* (1) discovered considerable differences in the chemical composition of *Theobroma* and *Herrania* floral oils within the molecular weight range for volatile constituents (Fig. 4), as did Strand (5) in a similar study (Fig. 5), our bioassays of floral oils for attractiveness to flying insects using McPhail failed to discern a similar difference among the floral oils for the species of insects attracted to them. Young *et al* (19) reported a similar absence of floral oil-specific differences in Ceratopogonidae and Cecidomyiidae attracted to scented McPhail traps at La Lola. Yet there is no *a priori* reason to suspect that floral fragances alone provide a species-specific environmental cue for pollinating insects and other insects. Young *et al.* (18) describe differences in the floral biology of *Theobroma* species which may influence the expression of specialized pollinator relationships.

Our attempt to report in this paper the range of flying insects with various trapping methods provides an initial data base for further entomological research studies in the La Lola cacao plantation. Given the fact that scavenging, herbivorous, and parasitic insects were collected in our trapping program, we believe that such information can be useful in identifying various kinds of future entomological research with cacao.

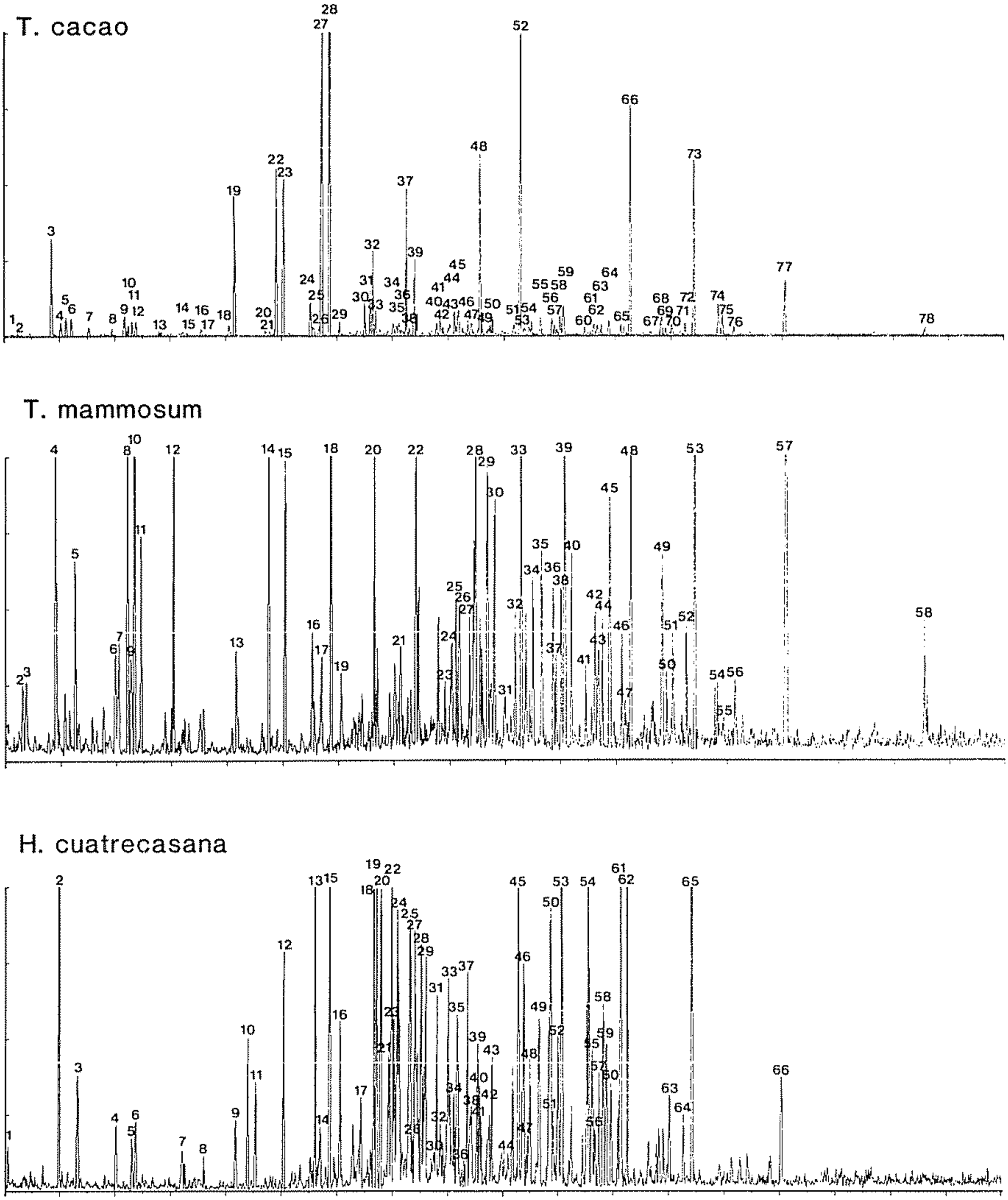

Fig. 4. Ion chromatograms for steam-distilled floral oils for *Theobroma cacao* Linnaeus, *T. mammosum* Cuatr. & Leon, and *Herrania cuatrecasana* Garcia-Barriga

Table 12. The distribution of ants (Hymenoptera: Formicidae) in McPhail Traps* containing serial dilutions of *Theobroma* floral oils and blanks (controls) during the dry season (February 1986) and wet season (July 1986) in the Barker cacao forest adjacent to La Lola.

Taxa	Total numbers of insects in traps: 100 ppm	10 ppm	1 ppm	total	X̄	S.E.
			Dry Season			
			Theobroma cacao			
Camponotus auricomus Roger	0	1	0	1	0.33	0.33
Solenopsis picea Emery	0	3	1	4	1.33	0.33
Total:	0	4	1	5	2.50	0.96
			nos. replicates with ants: 3/9 (33.33%)			
			Theobroma simiarum			
Solenopsis picea Emery	0	2	0	2	0.66	0.33
Total:	0	2	0	2	0.66	0.33
			nos. replicates with ants: 1/9 (11.11%)			
			blanks (controls)			
Solenopsis picea Emery: 3						
			nos. replicates with ants: 1/6 (16.67%)			
			Wet Season			
			Theobroma cacao			
Solenopsis picea Emry	1	0	0	1	0.33	0.33
			Theobroma simiarum			
no insects	–	–	–	–	–	–
			blank (controls)			
Solenopsis picea Emery: 1						
Camponotus auricomus Roger: 1						

* Data combined for six successive days of checking traps in each season; floral oil-inoculated traps replenished with fresh oil on the third day. Chloroform blanks also re-inoculated. Total of N = 24 traps (18 "experimentals" and 6 "controls") in each season.

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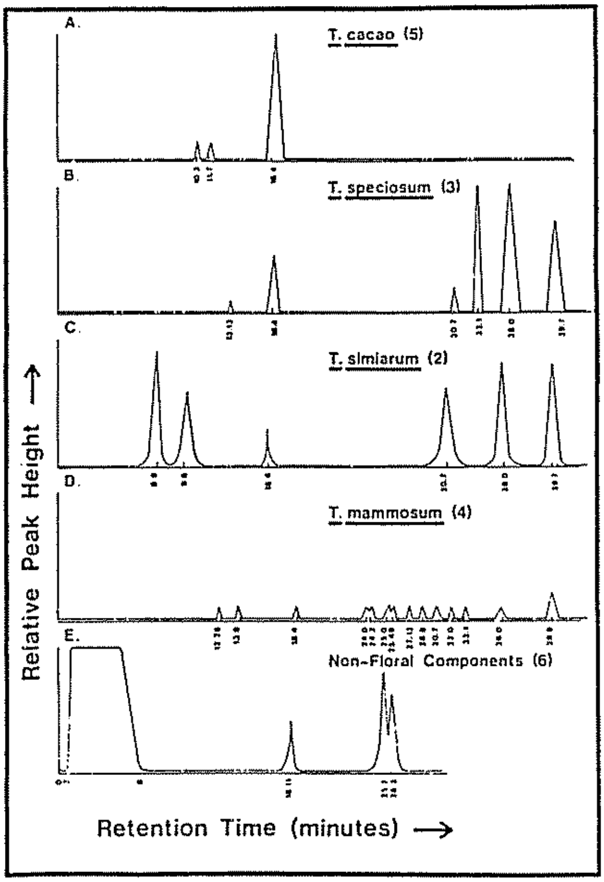

Fig. 5. Gas chromatograms of several *Theobroma* species (Sterculiaceae) highlighting some major differences in the distribution of peak constituents. Taken directly from Strand (1984).

LITERATURE CITED

1. ERICKSON, B.J.; YOUNG, A.M.; STRAND, M.E.; ERICKSON, JUNIOR, E.H. 1987. Pollination biology of *Theobroma* and *Herrania* (Sterculiaceae). II. Analyses of floral oils Insect Science and its Application 8: in press

2. GIBBS, D.G.; LESTON, D. 1970. Insect phenology in a forest cocoa-farm locality in West Africa. Journal of Applied Ecology 7:519-548.

3. HAMILTON, D.W.; SCHWARTZ, P.H.; TOWNSEND, B.G. 1970. Capture of male bumble bees and honey bees in traps baited with lures to attract Japanese beetles. Journal of Economic Entomology 63:1 442-1 445.

4. REIDL, H.; HISLOP, R. 1985. Visual attraction of the walnut husk fly (Diptera: Tephritidae) to color rectangles and spheres. Environmental Entomology 14:810-814.

5. STRAND, M.E. 1984. Comparative floral morphology of four *Theobroma* (Sterculiaceae) species in relation to pollination biology. Master's Dissertation Univ. of Wisconsin, Milwaukee. 78 p.

6. WESELOH, R.M. 1986. Host and microhabitat preferences of forest parasitic Hymenoptera: inferences from captures on colored sticky panels. Environmental Entomology 15:64-70.

7. WINDER, J.A. 1978. Cocoa flower Diptera: their identity, pollinating activity and breeding sites. PANS 24:5-18.

8. YOUNG, A.M. 1982. The population biology of tropical insects. New York, Plenum. 511 p.

9. YOUNG, A.M. 1983. Patterns of distribution and abundance of ants (Hymenoptera: Formicidae) in three Costa Rican cocoa farm localities. Sociobiology 8:51-76

10. YOUNG, A.M. 1983. Seasonal differences in abundance and distribution of cocoa-pollinating midges in relation to flowering and fruit-set between shaded and sunny habitats of the La Lola cocoa farm in Costa Rica. Journal of Applied Ecology 20:801-831.

11. YOUNG, A.M. 1983. Patterns of distribution and abundance in small samples of litter-inhabiting Orthoptera in some Costa Rican cacao plantations Journal of the New York Entomological Society 91:312-327.

12. YOUNG, A.M. 1984. Change in the distribution and abundance of some Dermaptera between tropical seasons in cocoa plantations at three localities in Costa Rica. Journal of the New York Entomological Society 92:184-187.

13. YOUNG, A.M. 1984. Mechanism of pollination by Phoridae (Diptera) in some *Herrania* species (Sterculiaceae) in Costa Rica. Proceedings of the Entomological Society of Washington 86:503-518.

14. YOUNG, A.M. 1985. Notes on the distribution and abundance of midges (Diptera: Ceratopogonidae and Cecidomyiidae) in some Central American cacao plantations. Brenesia 24:273-285.

15. YOUNG, A.M. 1985. Studies of cecidomyiid midges (Diptera: Cecidomyiidae) as cocoa pollinators (*Theobroma cacao* L.) in Central America. Proceedings of the Entomological Society of Washington 87:49-79.

16. YOUNG, A.M. 1986. Notes on the distribution and abundance of Dermaptera and Staphylinidae (Coleoptera) in some Costa Rican cacao plantations. Proceedings of the Entomological Society of Washington 88:328-343.

17. YOUNG, A.M. 1986. Notes on the distribution and abundance of ground and arboreal-nesting ants (Hymenoptera: Formicidae) in some Costa Rican cacao habitats. Proceedings of the Entomological Society of Washington 88:550-571.

18. YOUNG, A.M.; ERICKSON, JUNIOR, E.H.; STRAND, M.E.; ERICKSON, B.J. 1987. Pollination biology of *Theobroma* and *Herrania* (Sterculiaceae). I. Floral biology. Insect Science and its Applications 8: in press.

19. YOUNG, A.M.; ERICKSON, B.J.; ERICKSON JUNIOR, E.H. 1987. Steam-distilled floral oils of *Theobroma* species (Sterculiaceae) as attractants to flying insects during dry and wet seasons in a Costa Rican cocoa plantation. Tenth International Cocoa Research Conference. Proceedings. (Santo Domingo, R.D.). 1987

Notas y Comentarios

Novedades sobre las moscas de las heridas de soldados

No fueron las balas las que mataban más soldados antes de la Segunda Guerra Mundial. Fueron las bacterias que entraban en sus heridas, causando gangrena y envenenando su sangre. Algunos heridos tenían que sufrir el horror adicional de ver moscas que se posaban en sus heridas, poniendo huevos de los que emergían larvas. Estas se alimentaban de la carne muerta y en descomposición de las heridas, antes de desprenderse para empupar en el suelo. Pero estos soldados eran los afortunados. Sorprendentemente, como lo notaron los cirujanos de los ejércitos de Napoleón, los hombres heridos que eran infestados por la mosca de carroña (*Calliphora* y otras especies), eran los que más sobrevivían. No desarrollaban envenenamiento de su sangre y sus heridas sanaban más rápido.

Esta observación fue puesta en uso. En la guerra civil de Estados Unidos, los cirujanos militares ponían deliberadamente gusanos en las heridas para eliminar los tejidos en descomposición. Ahora, con el surgimiento del interés por antibióticos novedosos, los investigadores han estado examinando en detalle la manera cómo exactamente los gusanos mantienen en raya a la gangrena. Gary Erdmann, de la Universidad de Minnesota, describe lo que han descubierto en ese centro de estudios, en la última edición de **Parasitology Today**, (vol 3, p. 215).

Estudios preliminares revelaron que una bacteria, *Proteus mirabilis*, que se halla en las glándulas salivales de los gusanos, secretaba sustancias que mataban a otras bacterias. Estos estudios preliminares no identificaron los compuestos antibióticos, sino simplemente los llamaron "mirabilicidas". Erdmann prosiguió con sus estudios y aisló dos compuestos, ácido fenilacético (PAA) y fenilacetaldehido (PAL), que mataban bacterias.

El PAL es inestable y se transforma en PAA, pero ambos compuestos probablemente funcionan infiltrándose en la grososa membrana celular para interferir en la capacidad de las bacterias de movilizar los aminoácidos. También pueden bloquear la elaboración de compuestos ricos en energía necesaria para llevar a cabo diversas reacciones químicas dentro de la bacteria. El PAA y el PAL se mueven en la membrana de la célula con mejor eficacia en ambientes ácidos. En un pH de 2,5, Erdmann descubrió que "el PAA matará la mayoría de los organismos patógenos en unos pocos segundos".

El problema es que la mayoría de las heridas parecen ser neutrales o ligeramente alcalinas. *Proteus mirabilis* secreta amoníaco y otras aminas básicas que tienden a hacer las heridas ligeramente alcalinas. Erdmann señala algunos trabajos de B. Greenberg, quien descubrió que algunas bacterias dañinas no sobreviven un viaje a través del intestino de una larva de mosca de carroña deliberadamente infectada con *P. mirabilis*. Greenberg estudió más la mosca de carroña y descubrió que el pH dentro del intestino era de 2,9, ideal para que el PAA actuara como antibiótico.

Erdmann dice que los gusanos pueden ayudar con las heridas al actuar como filtro esterilizante. Conforme los gusanos comen la carne purulenta, las bacterias presentes en ella son eliminadas por los antibióticos que secretan las bacterias en sus glándulas salivales.

A.G.