

ECOLOGICAL NOTES ON CACAO-ASSOCIATED MIDGES  
(DIPTERA: CERATOPOGONIDAE) IN THE  
"CATONGO" CACAO PLANTATION AT  
TURRIALBA, COSTA RICA

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*Abstract.*—A comparison of larvae and pupae of cacao-associated midges (Diptera: Ceratopogonidae) in various breeding substrates was made between successive rainy and dry seasons in the "Catongo" cacao plantation at Turrialba, Costa Rica. One collection of adult midges on cacao flowers was also made in the rainy season. One cluster of 25 larvae of *Forcipomyia fuliginosa* (Meigen) was found in one of 22 leaf litter-filled plastic cups in cacao trees in the rainy season, and several pupae of *F. cinctipes* group were collected from rotten slices of banana tree trunk at this time. A total of five adults of *F. genualis* (Loew) emerged from about 25% of the leaf litter collected in the rainy season. During the dry season, a few slices of banana tree trunks yielded pupae belonging to *F. genualis* and *F. cinctipes* group. Adult midges collected from cacao flowers in the rainy season included *Dasyhelea soriai* Wirth and Waugh. Although only small portions of available breeding substrate materials were occupied by midges in both seasons, immature stages appeared to be more concentrated in the rotting slices of banana tree trunks during the dry season, a time when flowering in cacao is quite low at this locality. Midge populations appear to be more evenly dispersed within the plantation during the rainy season, a time of peak flowering in cacao. These data, while limited, may reflect general patterns of response to tropical seasonal conditions by cacao-associated midges, some of which might be effective pollinators of cacao. The midge species studied deserve further attention in terms of their possible roles as effective pollinators of *T. cacao*.

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A complete understanding of the relationship between flowering patterns in *Theobroma cacao* L. (Sterculiaceae), "cocoa," and the abundance of pollinating midges in the family Ceratopogonidae (Diptera), includes a consideration of how prevailing patterns of tropical seasonality influence both abundance of flowers and pollinators. It is generally believed that *T. cacao*, in its cultivated state, is pollinated chiefly by ceratopogonid midges, and most notably those of a few genera such as *Forcipomyia*, *Euprojoannisia*, and *Dasyhelea* (e.g. Soetardi, 1950; Saunders, 1959; Hernandez, 1965; Soria et al., 1980; Soria et al., 1981, and many



other references). Abundance within adult populations of these tiny midges varies considerably throughout the year in plantations, with greatest numbers retrieved from cacao flowers during the rainy season (e.g. De la Cruz and Soria, 1973; Soria and Abreu, 1976; Winder and Silva, 1975). In lowland tropical rain forest with an erratic annual dry season, highest densities of immature stages (larvae and pupae) of some species of ceratopogonids occur in slices of rotting banana tree trunks during the dry season, such substrates or microhabitats acting as ecological "refugia" for these insects (Young, 1982, 1983). The purpose of this paper is to present some limited data on the abundance of primarily ceratopogonid larvae and pupae in various life cycle substrates in a cacao plantation in the highlands of Costa Rica.

#### LOCALITY AND METHODS

The locality is the cacao plantation complex of the Inter-American Institute for Agricultural Sciences (also known as CATIE) at Turrialba (9°55'N, 83°41'W), Turrialba Province, Costa Rica. The area is essentially lower montane rain forest (about 600 m elev.). Because only less than 10% of the days each year have daily temperatures above 28°C and rainfall is high every month, it is not ideal for *T. cacao* plantations, even though harvests of mature pods are fairly constant all year long. I studied ceratopogonid midge species associated with a mature planting of about 70 trees of the "Catongo" self-compatible variety or clone of *T. cacao*. The "Catongo" *T. cacao* originated at Bahia, Brazil and it is readily recognized by its uniformly white flowers and seeds (Dr. G. Enriquez, personal communication). The area of the plantation selected for study has a broken canopy of various legume trees, creating a patchwork of both shaded and sunny places within the *T. cacao*.

Beginning in late June 1980, I tagged 52 randomly selected *T. cacao* trees within this plantation, and obtained monthly data on abundance of flowers and new fruits, information to be interpreted in terms of monthly rainfall and temperature patterns. At the time these studies were initiated, I established an experiment designed to examine the breeding or life-cycle substrate associations of ceratopogonid midges within this plantation. To accomplish this, I distributed in random fashion 22 large, debris-filled plastic cups (Fig. 1), suspended individually from different *T. cacao* trees, with approximately half in shaded places and the others in sunny places. I also set up ten ground plots, each about 2 × 2 meters, of freshly sliced cross-sections of recently-felled banana (plantain) trees (*Musa* sp.) available in the area. Each of these plots was positioned beneath a *T. cacao* tree and contained about 30 slices of the trunks (Fig. 1). The trunk slices are allowed to decompose naturally, making them attractive as breeding micro-habitats for the midges. I also established a set of eight 2 × 2 meter wooden frames piled generously with rotting leaves from *T. cacao* trees, and distributed these randomly in the same plantation (Fig. 2). All of the substrates were left undisturbed until the following November (late rainy season) at which time the debris was collected from them and examined for larvae and pupae of midges. The substrates were replenished at this time and a second census taken the following February (1981), or mid-dry season. During June 1980 I also made a limited collection of adult midges from *T. cacao* flowers in the plantation. Records were kept on the condition



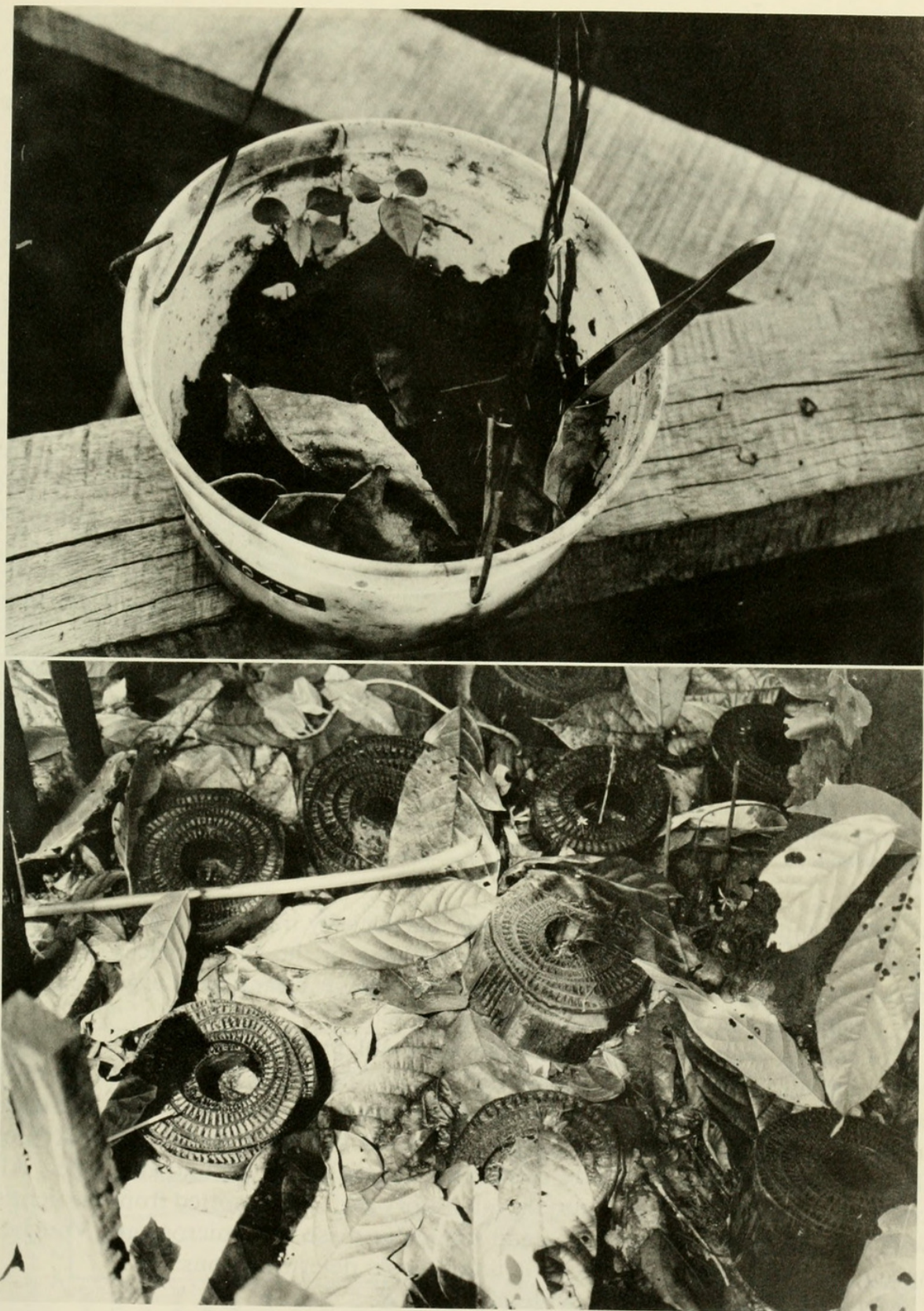


Fig. 1. Experimental breeding microhabitats for ceratopogonid midges studied in the "Catongo" cacao plantation at Turrialba, Costa Rica. Above: litter-filled plastic cup; note standard laboratory forceps for scale; each cup outfitted with drainage holes in bottom and suspended by sturdy wires from branches of *T. cacao* trees. Cups courtesy of the Sweetheart Corporation, Chicago, Illinois. Below: slices of banana tree trunks rotting on the ground beneath *T. cacao* trees. Slices are prepared by cutting a freshly fallen banana tree trunk with a machete.



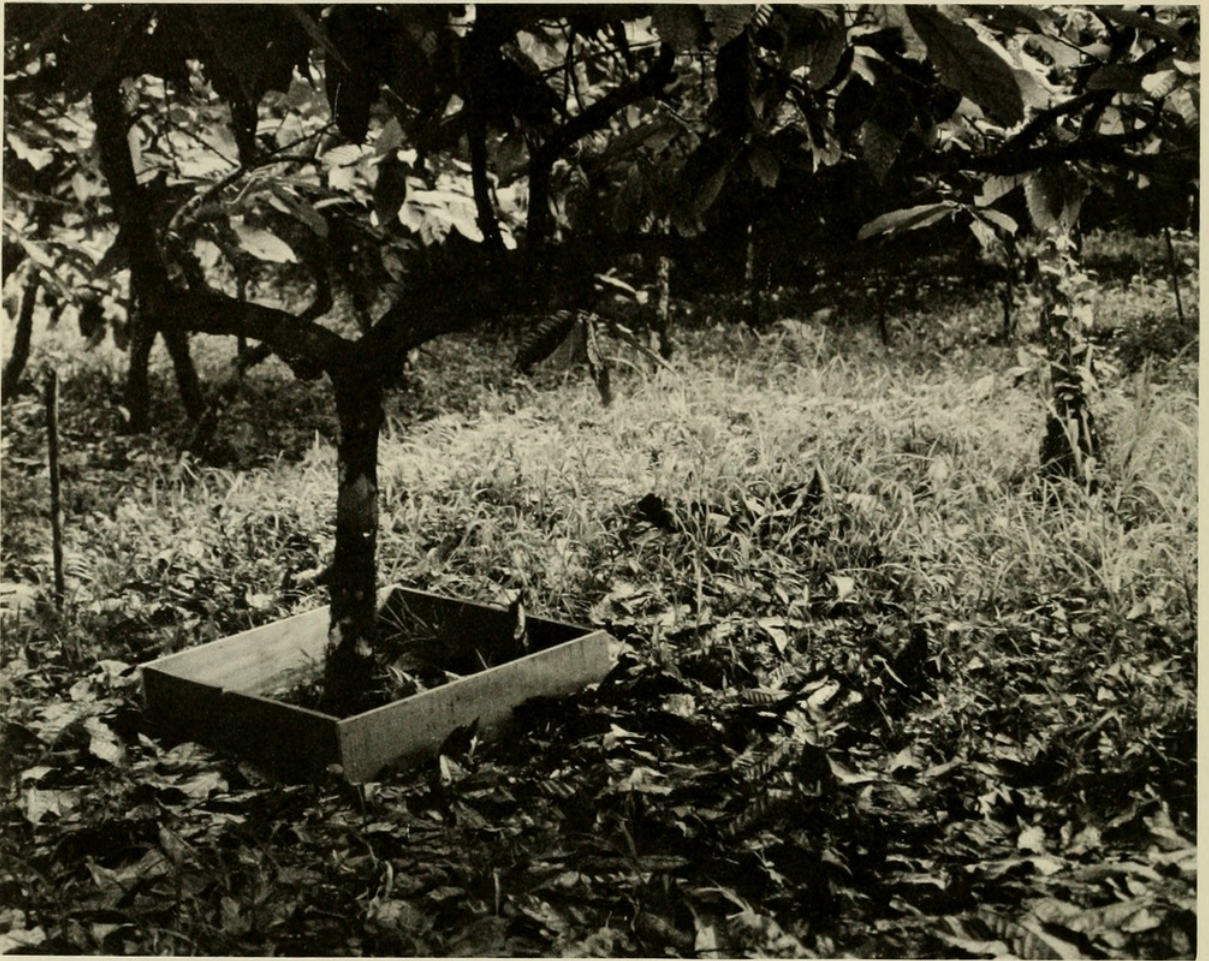


Fig. 2. Experimental ground box of cacao leaf litter. The box is actually a wooden square frame set on the ground and filled with rotting *T. cacao* leaves. Note shaded place in foreground and sunny place behind.

of the ground leaf litter in the plantation, particularly in terms of general depth, dryness, and the height of weedy plants growing in the sunny places. In a few instances I confined portions of test substrates in large, clear plastic bags to capture any freshly-eclosed midges coming from them.

Collections from the cups, designed to simulate bromeliads, were done by collecting all of the litter in them. For the rotting banana trunk slices, I only collected those individual pieces sufficiently decomposed and moist to have midges in them; otherwise, the remaining ones were left behind. I collected about  $\frac{1}{4}$  of the total leaf litter in each box to make a census of the ground box litter. All collected samples were taken into the laboratory and insects sorted from the debris with use of a powerful hand lens and binocular dissecting microscope. Voucher specimens were retained for generic and specific determinations.

Meteorological data was provided by CATIE.

## RESULTS

A marked decline in monthly rainfall in January through March each year at Turrialba coincides with very pronounced declines in the amount of flowering in *T. cacao* (Fig. 3). Peak flowering in *T. cacao* at this locality is largely confined to the early-to-middle rainy season (Fig. 3). During the late rainy season census of potential ceratopogonid midge breeding sites, I collected a total of three species,





Fig. 3. Phenological patterns of the "Catongo" *T. cacao* at CATIE, Turrialba. Data for flowering recorded from 52 tagged trees. Meteorological data courtesy of CATIE.



*Forcipomyia fuliginosa* (Meigen), *F. (F.) genualis* (Loew), and *F. (F.) cinctipes* group. One aggregated group of 25 larvae of *F. fuliginosa* were collected from a dry leaf (Fig. 4) in one of the arboreal litter-filled cups, and all other cups were completely devoid of midges. All but four slices of the banana trunks were completely decomposed and thus not censused, and the four collected and censused yielded seven pupae of *F. (F.) cinctipes* (all from one piece). One composite bag of box leaf litter yielded a total of five adults of *F. genualis* in about 24 hours (13–14 November 1980).

The dry season census (16–18 February 1981) gave somewhat different results. No midges were collected from the arboreal simulated bromeliads, even though most of these containers had a considerably thick (range 20–90 mm) layer of rotting leaf litter. But most of the litter in the cups at this time, unlike in the late rainy season census, was extremely dry and brittle. The ground leaf litter was much drier now than in the late rainy season, and most of the thick weed cover found previously, gone. The box litter samples yielded no midges at this time. Only two plots of the rotting banana trunk slices had pieces moist enough to have midges. The slices in the other plots were very hard and mummified as a result of the intense dryness of this period. Such pieces generally do not have midge larvae and pupae. The two *T. cacao* trees with trunk slices still moist enough for midges were located in shaded parts of the plantation. One plot of 18 moist slices yielded two pupae of *F. genualis*, and a second set of 19 slices from the other tree produced 13 pupae of *F. cinctipes* group. An additional set of six banana trunk slices collected from several different plots at this time produced a total of 10 *F. genualis* adults in 24 hours.

Thus the census program produced a total of 22 individuals (larvae and pupae) of three species of ceratopogonid midges in the late rainy season, and a total of 25 individuals belonging to two species in the following dry season. These samples are very small and most likely represent less than 20% of the total midge fauna of the plantation. An initial survey of midges in open *T. cacao* flowers during June 1980 (early rainy season) yielded three *F. genualis* (one female, two males), *Forcipomyia (F.)* sp. (one male), *F. (Euprojoannisia)* sp. (one male), and *Dasyhelea soraii* Wirth & Waugh (one female). Thus several additional ceratopogonid species associated with *T. cacao* were not accounted for by the limited census program for immature stages in rotting organic debris.

The dry season data suggest possible contraction of midge populations: a total of 43 banana tree trunk slices produced 25 larvae and pupae during the dry season, while only four pieces produced seven individuals during the late rainy season.

During the rainy season, the ground leaf litter, as well as that in the simulated bromeliads, contained several species of ants, as well as spiders and roaches. Other typical litter inhabitants in this cacao plantation include at least one unidentified species of carabid beetle, a millipede, and a centipede. The late rainy season cup litter, for example, yielded one individual of the salticid spider *Chapoda festiva* Peckhams, a form which I have observed successfully capturing adult *Forcipomyia* midges in *T. cacao* trees at "Finca La Lola," near Siquirres, Limon Province, Costa Rica (Young, 1983). At least one other salticid, *Metacyrba* sp., also occurs in the cup litter at Turrialba. During the dry season, however, such arthropods are generally absent from the same litter substrates. During the rainy season, both leaf litter and banana tree trunk slices decompose in *T. cacao* plantations more quickly than they do in the dry season.



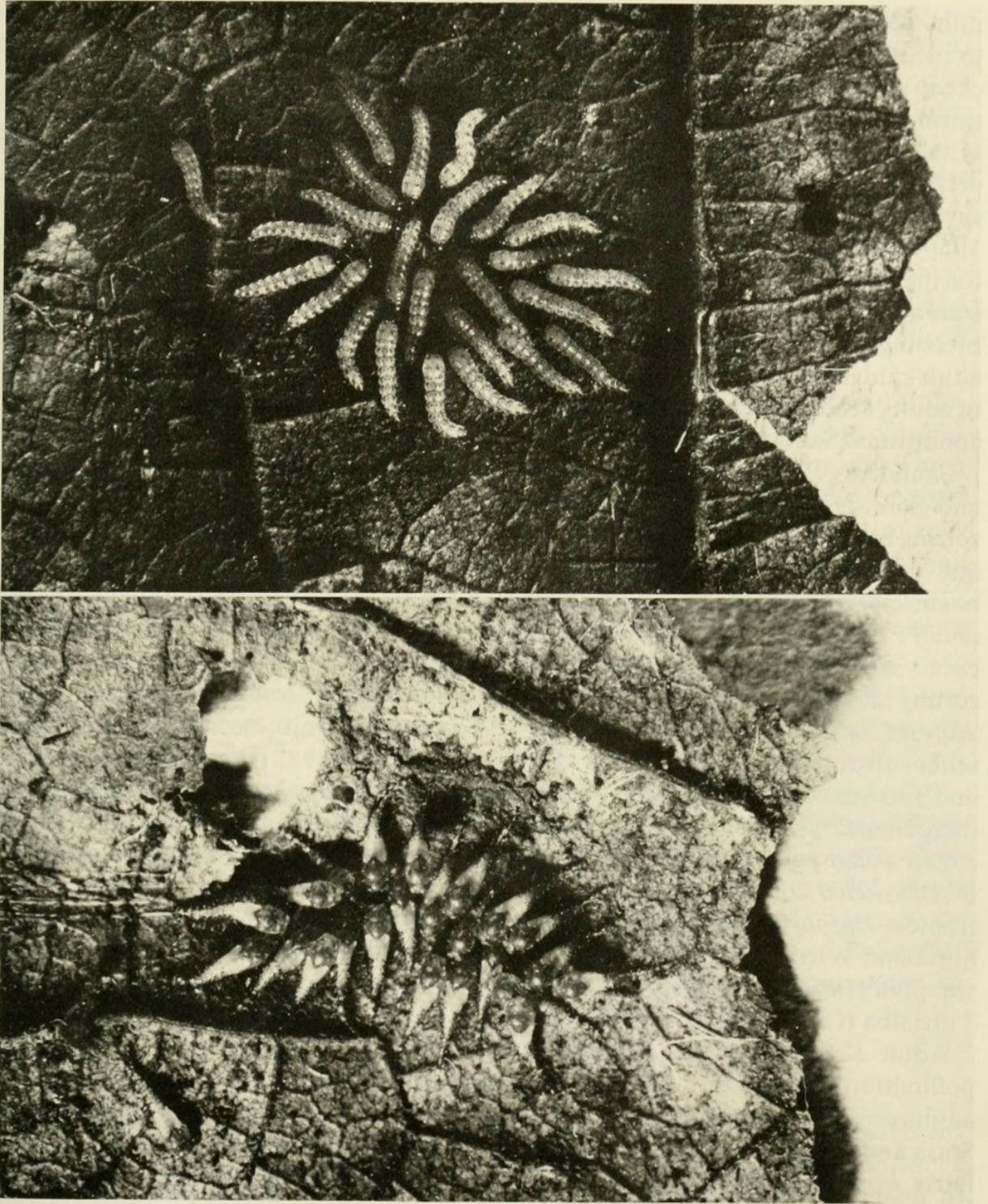


Fig. 4. Immature stages of *Forcipomyia fuliginosa*. Above: aggregate of larvae; below: pupae. Larvae and pupae attached to rotting *T. cacao* leaf in arboreal plastic cup (simulated bromeliad).

#### DISCUSSION

Although ceratopogonid midges are active in *T. cacao* plantations throughout the year, the spatial distribution of breeding populations may change considerably between rainy and dry seasons, as suggested by the limited data gathered in the present study. Young (1982, 1983) noted considerable increases in the densities of larvae and pupae in rotting banana tree trunk slices during the dry season in the lowlands of Costa Rica's Caribbean coastal floodplain. During the lengthy



rainy season, densities in such a substrate are lowered considerably, a response to increased availability of other suitable breeding sites during this season. In *T. cacao* plantations, various groups of insects associated with this tree species cycle through the year in terms of abundance which is an adaptive response to changes in the availability of food supplies (Leston, 1969; Gibbs and Leston, 1970). For ceratopogonid midges, the life cycle requires very moist conditions, places where suspected larval food supplies such as bacteria, fungi, and mold thrive (Saunders, 1959). The high abundance of adult midges in *T. cacao* flowers commonly seen for the rainy season (e.g. Soria and Abreu, 1976) reflects the increased size of the immature populations during this period. During the dry season, many preferred breeding sites may dry up in cacao plantations, generating very low numbers of adult midges at this time (e.g. Winder and Silva, 1975). Even the daily activity of adult cacao-pollinating ceratopogonids is governed largely by prevailing weather conditions (Soetardi, 1950).

Saunders (1959) reared *F. genualis* from rotting cacao pod husks, and Wirth and Soria (1975) reared the closely related *F. harpegonata* Wirth & Soria from rotting banana trunks and other substrates. Young (1982, 1983) reared *F. genualis* and *D. soriai* from rotting banana tree trunk slices in Costa Rica. This species has also been reared from the debris in an epiphytic bromeliad, and both *Dasyhelea* and *F. cinctipes* group have been reared from this substrate as well as rotting cacao pod husks (Winder, 1977). *Forcipomyia fuliginosa* has been reared from rotting jackfruit and epiphytic bromeliads, but not from rotting banana tree trunk sections, although at least one species of *Dasyhelea* has also been reared from the latter substrate at Bahia (Winder, 1977). Young (1982, 1983) reared several genera and species of ceratopogonids from rotting banana trunk slices in Costa Rica, including *F. genualis* and *D. soriai*. Soria et al. (1978) reared *F. fuliginosa* from rotten cacao pods at Bahia. Wirth and Waugh (1976) noted that several species of *Dasyhelea* completed their life cycles in rotten cacao pods in the American tropics. *Dasyhelea* species, considered to be major pollinators of *T. cacao* (e.g. Soria and Wirth, 1979; Wirth and Waugh, 1976), appear to have broad breeding site preferences, having been reared from a variety of rotten organic materials in Turrialba (CATIE) cacao plantations (Soria et al., 1981).

Adult *Forcipomyia* are limited in terms of activity related to breeding and pollination by moisture conditions. Oviposition requires moist substrates and adults generally require liquid food for survival (Saunders, 1959; Kaufmann, 1975; Soria and Wirth, 1975). During the rainy season, adults of individual species are fairly evenly distributed in cacao plantations, with actual densities over small parcels of the habitat determined largely by sunlight and moisture conditions (e.g. Soria and Abreu, 1976). During the same period, populations of larvae and pupae are generally more diffuse than in the dry season (Young, 1982, 1983). Rotting banana tree trunk slices provide a major breeding microhabitat for ceratopogonids in both seasons (Young, 1982, 1983; and the present study), but during the dry season, they become the major breeding site exclusive of most others. During the dry season, leaf litter becomes very dry in the cacao plantation, a condition that concentrates breeding in those substrates that remain moist. While densities of larvae and pupae are higher in banana tree trunk slices in the dry season as a result of such effects, a bias is introduced by the very high rate of decomposition of these substrates in the rainy season. The highly scattered census program used



in the present study undoubtedly misses many ceratopogonids that thrived in banana tree trunks, and ones never recorded because the substrates disappeared.

Soria et al. (1980) consider *F. fuliginosa* not to be an important pollinator of *T. cacao* relative to other species, even though it is usually one of the more abundant species encountered. These authors list eight genera and species of ceratopogonids from *T. cacao* flowers in Turrialba (CATIE) cacao plantations. Clearly many species were missed by the census program in the present study. Soria and Wirth (1979) suggest that ceratopogonids such as *F. genualis* and *F. cinctipes* group require further study to determine their effectiveness as *T. cacao* pollinators. *Forcipomyia genualis* might be a pollinator of *T. cacao* in lowland cacao plantations in Costa Rica (Young, 1982, 1983), although direct descriptions of pollinating behavior are lacking.

Behavioral patterns associated with immature stages may have marked influence on the distribution of ceratopogonid species in cacao plantations, and requires further study. The aggregative behavior of forms such as *F. fuliginosa*, in which both the larvae and pupae occur in organized clusters or groupings in litter, suggests a very different spatial arrangement of breeding populations from others such as *D. soriai*, in which larvae and pupae generally occur singly. Such behavior may also be related to the ability of species to occupy different kinds of moist microhabitats. *Dasyhelea* species, for example, exhibit different strategies of colonizing various kinds of aquatic microhabitats (McLachlan and Cantrell, 1980).

Although limited, I propose that the data presented here are fairly representative of the general patterns of adaptive response of cacao-associated ceratopogonids to tropical seasonality in cacao plantations. The tropical dry season is a period of environmental stress to small, relatively soft-bodied insects (Janzen and Schoener, 1968), resulting in a decline of their populations in the dry season (same reference). The apparent "synchronization" of peak flowering in *T. cacao* within the rainy season at Turrialba allows for maximal pollinating activity by small-bodied insects, including ceratopogonid midges. What is needed, however, is further delineation of those ecological factors limiting abundance of pollinator populations throughout the year, and such patterns of limitation are related to levels of pollination in *T. cacao*.

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