Mating Behavior of Wild Melon Flies, *Dacus cucurbitae* COQUILLET
(Diptera: Tephritidae) in a Field Cage:
Distribution and Behavior of Flies

Hiroyuki KUBA,¹ Juro KOYAMA² and R. J. PROKOPY³

Okinawa Prefectural Agricultural Experiment Station,
Naha, Okinawa 903, Japan

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Mating behavior of the melon fly, *Dacus cucurbitae* COQUILLET, was observed in a field cage. As a potential rendezvous site, a coral tree (non-host plant) with 60 leaves and 30 attached host fruits was placed in the cage. Several major characteristics of melon fly mating behavior in the field cage proved essentially the same as those observed in small laboratory cages in previous studies. However, considerable new information was obtained in the field-cage study: (1) Mating behavior was initiated principally on the tree leaves (bottom surface), with a lesser amount on the cage wall; (2) Very few males were located on the fruit and no matings were initiated there; (3) Both sexes concurrently moved from the tree to the wall 20–30 min before dusk, following which males returned to the tree (on leaves), when they emitted sex pheromone attractive to females—receptive females then returned to the tree and copulated with males; and (4) Our observations strongly suggested the existence of lek formation on tree leaves by the males.

INTRODUCTION

Observations on the mating behavior of the melon fly, *Dacus cucurbitae* COQUILLET, have been conducted in small laboratory cages (KOBAYASHI et al., 1978; SUZUKI and KOYAMA, 1980, 1981; KUBA and KOYAMA, 1982). Conditions in small cages are different from those in nature, especially with respect to distance between individuals. Furthermore, small cages are devoid of objects such as trees. SOEMORI et al. (1980) found that the mating competitiveness of mass-reared vs. wild melon flies varied depending on size of cage and fly density. On the other hand, it has proven difficult to observe melon fly mating behavior in nature, because as yet there exists little or no knowledge of the sorts of plants or types of plant structures (leaves, fruit or branches) on which the sexes assemble and copulation is initiated.

Mating behavior of several sub-tropical or tropical fruit fly species has been studied through release of flies onto trees confined in field cages: *Dacus tryoni* (FROGGATT) (TYCHSEN, 1977); *Ceratitis capitata* (WIEDEMANN) (PROKOPY and HENDRICHs, 1979);

¹ Present address: Fruit-fly Eradication Project Office, Okinawa Prefectural Government, Māji, Naha, Okinawa 902, Japan

² Present address: Kyushu National Agricultural Experiment Station, Chikugo, Fukuoka 833, Japan

³ Present address: Department of Entomology, University of Massachusetts, Amherst, Massachusetts, 01002, USA

Anastrepha suspensa (LOEW) (DODSON, 1982); *Toxotrypana curvicauda* GERSTAECKER (LANDOLT and HENDRICH, 1983); and *Anastrepha fraterculus* (WIEDEMANN) (MORGANTE et al., 1983). Such observation of mating behavior under field cage conditions may be profitable as a step to direct observation under completely natural conditions.

In this paper, we describe results of observations on the mating behavior of the melon fly in a field cage containing a tree.

MATERIALS AND METHODS

Insects. The adults used for the experiments emerged from pupae obtained from naturally infested bitter melon, *Momordica charantia* var. *pavel* CRANTZ, on Okinawa Island. Soon after eclosion, the sexes were segregated and maintained under natural photoperiod conditions at $25 \pm 1^\circ\text{C}$ in small screen cages ($30 \times 30 \times 45$ cm) provided with water, sugar and protein hydrolysate (Amber BYF series-100®). Sexually mature flies (26–41 days old) were gently transferred individually from the small screen cages to the bottom surface of leaves of the field-caged tree at least 3 hr prior to dusk (when copulation occurred).

Field cage. The field cage was 3 m long $\times$ 2 m wide $\times$ 1.8 m high. It contained a broad leaved, non-host coral tree, *Erythrina variegata* var. *orientalis* MERR., ca. 1.7 m tall $\times$ 1.0 m in diameter (canopy). For convenience of observation, all but 60 of the ca. 12 cm long $\times$ 10 cm wide leaves were removed. Thirty uninfested fresh fruits (ca. 2 cm in diameter) of a cucurbit, *Diplocyclos palmatus* C. JEFFREY, were distributed on the tree branches. This fruit is the most important and common host of the melon fly in Okinawa. Each fruit was punctured once with a pin to provide a ready oviposition site for a female.

Experiments. The following 5 experiments were conducted. Experiments I, II, and III: 30 males, 30 females, or 15 males and 15 females, respectively, were transferred to the tree leaves. Experiment IV: 30 males were so transferred, and a small screen cage ($15 \times 15 \times 15$ cm) containing 60 males was placed at the center of the tree. This small cage was covered with a double thickness of fine mesh gauze to eliminate visibility of the flies within. Experiment V: 30 females were transferred to the three leaves; otherwise, same as Exp. IV. Experiments I–III were replicated 4 times each, and Experiments IV and V were replicated 2 times each. The experiments were conducted during August and September, 1980.

Weather conditions. For each experiment, air temperature, relative humidity and light intensity were measured at 10-min intervals. Light intensity was measured at 5 points in the cage, but we report here (Table 1) only the greatest intensity of the 5.

Table 1. Mean light intensity (lux) in each experiment

Exp.	No. of repli- cations	Time (min) before dusk (0 lux time)									
		–90	–80	–70	–60	–50	–40	–30	–20	–10	0
I	4	2,450	2,360	2,130	1,770	1,240	640	360	110	20	0
II	4	2,100	1,860	1,800	1,260	830	520	240	100	10	0
III	4	2,500	2,380	2,030	1,630	1,190	740	300	80	10	0
IV	2	2,700	2,400	2,050	1,150	830	650	230	70	10	0
V	2	2,900	2,450	2,200	1,650	1,250	800	400	110	20	0

Table 2. Census of males, females and mated pairs on field cage wall, tree leaves, fruits, branches, and small cage containing males (combined data over all census periods)

Exp.	Sex	Total no. observed	Percentage of total no. on				
			Field cage wall	Tree			
				Leaves	Fruit	Branches	Small cage ^a
I	Male	1,137	69.0	30.2	0.3	0.5	—
II	Female	1,073	78.2	16.4	4.7	0.7	—
III	Male	447	66.9	32.0	0.4	0.7	—
III	Female	459	73.0	18.3	7.2	1.5	—
III	Mated pair	88	36.4	56.8	6.8	0.0	—
IV	Male	556	85.8	13.8	0.0	0.2	0.0
V	Female	561	72.5	12.3	7.7	2.0	5.5

^a Sixty males were confined in this small screen cage (15×15×15 cm).

Census data on the location and behavior of flies in each experiment (Figs. 1–4) were graphically arranged according to intervals of time (min) before dusk (0 lux time), based on the format in Table 1. As we found no relationship between fly behavior and relative humidity or air temperature within the range of values under which the experiments took place, these weather data are not presented or discussed in this paper. When wind velocity was strong enough to influence fly behavior (greater than ca. 20 km/hr), the experiment was interrupted.

Observation of flies. Observations were conducted by a pair of observers from 90 min prior to dusk until dusk. One observer counted the number of males, females and copulating pairs located on the tree leaves, branches, or fruits and on the cage wall (=ceiling and sides) at 10-min intervals. The other observer selected a fly at random on either the tree or cage wall and followed the actions of the fly for 30 sec from a distance of ca. 50 cm. The data obtained are characterized as follows: movement more than 1 cm (MOVE), encounter with another fly (ENC), wing vibration of a male (WV), copulation attempt (CA), copulation success (C), and oviposition by a female (OV). Such observations were made repeatedly, on different flies, at 1-min intervals.

RESULTS

Table 2 summarizes, over all observation periods, the census data on the location of flies. Even though the flies were initially released onto tree leaves, the majority of each sex observed during census periods (which began 90 min after fly release) were located on the cage wall, except for mated pairs in Exp. III. Among flies found on the tree, males were located almost exclusively on leaves, with very few on fruits or branches. The same was true for females, except there were comparatively more on fruit.

Figure 1 depicts temporal changes in the location of flies on the cage wall versus the tree over the 10 census periods in each experiment. Both males and females gathered in greatest numbers at the cage wall 20–30 min before dusk (dusk=0 lux time). After that, many males returned to the tree, regardless of the presence of females (Exps. I and III). Many females also returned to the tree from the cage wall before dusk when males were present (Exp. III), but did not when males were absent (Exp. II). Copulations were initiated principally on the tree and exclusively from ca. 30 min before

Fig. 1. Temporal changes in fly location on cage wall versus tree under various conditions. Shaded areas show percentage located on tree (combined data over all census periods).

Fig. 2. Temporal changes in fly behavior under various conditions. Solid lines show the frequency of movement (MOVE) per individual per 30-sec observation period, and broken lines show the frequency of encounter (ENC). The data represent combined numbers on the cage wall and tree.

dusk until dusk, with most mated pairs remaining on the tree. Under presence in the tree of a small cage containing 60 males (Exp. IV), the temporal distribution pattern of males was similar to that in Exps. I and III except that a larger proportion of males was on the field cage wall from 90 to 30 min before dusk. In Exp. V, females moved to the tree ca. 20 min before dusk and aggregated near the small cage containing males even though females could not catch sight of the males inside the small cage because of the netting (Table 2 and Fig. 1). This result in Exp. V suggests that females responded to pheromone released and/or sound produced by males in the small cage. Many females located on fruit attempted boring or oviposition despite being virgin. No copulation attempts were observed on fruit. The 6.8% of mating pairs observed on fruit (Table 2) were originally on leaves where copulation was initiated, later moving from the leaves to fruit.

Figure 2 shows temporal changes in fly behavior over numerous 30-sec observation periods (data from the cage wall and tree were combined, as no difference was found between them). MOVE frequency of males increased about 40 min before dusk regardless of the presence of females (Exps. I and III). Females likewise began to move concurrently with males when males were present (Exp. III), but when males were absent, females began to move later (Exp. II).

Fig. 3. Temporal changes in frequency of wing vibrations (WV) of males on the cage wall or tree. Solid and broken lines show the frequency of WV/individual/30-sec observation period on the tree and cage wall, respectively.

Fig. 4. Temporal changes in frequency of copulation attempts (CA) and copulation successes (C). Solid, broken, and dotted lines show the frequencies of CA on the tree and cage wall, and C on the tree, respectively.

ENC frequency of males increased correspondingly with movement activity, regardless of the presence of females (Exps. I, III, and IV). ENC frequency of females when confined with males increased like that of males (Exp. III), but when only females were present in the cage, it did not increase and showed a rather constant value (Exp. II). Because ENC frequencies of mated pairs were excluded from the data in Exp. III, values of ENC frequencies of males in Exp. III were lower than in Exp. I. When a small cage containing males was placed in the field cage, females aggregated at the small cage, and ENC frequencies among females increased to a high level around dusk.

From these results, it appears that when light intensity near dusk decreases to some critical value, males aggregate at locations such as tree leaves and emit a sex pheromone that is attractive to females. Thus, sexual contact between females and acceptable males occurs on the leaves.

One of the most characteristic sexual behaviors of male melon flies is wing vibration. Figure 3 shows the temporal change in wing vibration activity of males on the cage wall and tree. Wing vibration activity began earlier and reached a higher level among males on the tree than on the cage wall. When males were confined with females (Exp. III), wing vibrations of males on the tree occurred earlier than when only males were present (Exps. I and IV).

Temporal changes in the frequency of copulation attempts and copulation successes are shown in Fig. 4. Copulation attempts ($N=24$) occurred predominantly on the tree, and copulation success ($N=2$) was observed only on the tree. When only males were confined in the field cage (Exps. I and IV), copulation attempts occurred among males but initiation of such was later than that between males and females (Exp. III).

DISCUSSION

From these field cage observations, the pattern of mating behavior of the melon fly may be described as follows. When light intensity decreases to some critical value,

males aggregate on a plant (not necessarily a host tree), engage in wing vibration on the surface of leaves, and emit a sex pheromone. Such males attract receptive females, jump at approaching females, and then attempt to copulate.

Females are less active in the absence of males than in their presence. Males are active irrespective of female presence. Males move about the tree, frequently encounter other individuals, and attempt copulation regardless of the sex of the prospective partner. If females are present nearby, males become active earlier than when only males are present.

As shown in Fig. 1, males and females shifted position from the tree (darker) to the cage wall (brighter) 20–30 min before dusk. This phenomenon implies that both sexes move to areas receiving greatest light at that time. In the field, such movement might bring the flies from the interior of a plant to its periphery or top, or even to a taller neighboring plant receiving greater light. Males then release sex pheromone attractive to nearly receptive females. Thus, in nature, copulation is likely to occur on foliage located near the periphery or top of a plant.

Our observations also strongly suggest the existence of lek formation in melon flies, similar to that observed in *D. tryoni* (TYCHSEN, 1977) and several other tephritids. A lek is a communal display area where males congregate for the sole purpose of attracting and courting females and to which females come for mating (EMLEN and ORING, 1977). Unlike the situation in *C. capitata* (PROKOPY and HENDRICHs, 1979) and *A. suspensa* (BURK, 1983), but like the situation in *A. fraterculus* (MORGANTE et al., 1983) and apparently also *D. tryoni* (TYCHSEN, 1977), copulation in melon flies is initiated on foliage but not on fruit. Indeed, the entire array of movements of both sexes of melon flies in our study appeared to correspond very closely with those of field-caged *D. tryoni* in studies by TYCHSEN (1977).

To confirm our suggestion that mating in the melon fly is initiated just before dusk near the periphery or top of plants (possibly tall non-host trees growing in the vicinity of hosts—see NISHIDA and BESS, 1957), direct observation in nature is required. Furthermore, more detailed observation of mating is needed to clarify fine details of the courtship behavior. With respect to the sterile insect technique, a time lag in sexual activity between wild and mass-reared strains of the melon fly has been observed in laboratory cages (SUZUKI and KOYAMA, 1979). Whether males of the mass-reared strain form leks, and whether such leks are similar to those of wild melon flies, should be investigated in the future.

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