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Movement of the Oriental Fruit Fly, Bactrocera dorsalis (Hendel) (Diptera: Tephritidae), in a Guava Orchard with Special Reference to Its Population Changes 【Research report】

東方果實蠅 ((Bactrocera dorsalis (Hendel)) (雙翅目：果實蠅科) 在番石榴園中之族群變動及遷移【研究報告】

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Abstract

A whole-year census of the oriental fruit fly, Bactrocera dorsalis (Hendel), in a guava orchard was conducted to determine its annual population dynamics and diel activity pattern. Movement of the fly into and out of the orchard is also discussed according to its population changes in the orchard. The peak population of B. dorsalis within the orchard coincided with the fruiting season. Inside the orchard, no flies were present in the evening; however, flies were found in the morning and their population reached a peak in the afternoon. Throughout the year females predominated with a mean ratio of 3.69:1. The ratio was higher in the afternoon than in the morning. Most females in the orchard were mated, and most of them were found on the fruit. Censuses in a plum, peach, and loquat orchard during their fruiting seasons were also carried out to confirm some of the findings. Our study indicates that the oriental fruit fly exhibits a diel pattern of movement into and out of the orchard. Females are more likely than males to visit the orchard, and their movement into the orchard seems to be for the purpose of oviposition.

摘要

本試驗在農業試驗所一處番石榴園內調查東方果實蠅全年及單日之族群變動，並依據東方果實蠅在園內之族群變動推論此果實蠅遷移於果園內外的情形。試驗結果顯示，東方果實蠅在果園內的族群高峰期與果實成熟期一致，且其族群數量每日有一週期性的變化。在果園內之夜間調查中並未發現東方果實蠅，果實蠅在早上才出現於果園中，並於下午數量達到高峰。果園內的東方果實蠅以雌性為主，其雌雄性比為3.69 : 1，而下午果園內雌蟲的比例更較上午為高。大多數在果園內的雌蟲為已交尾者，且多停留於果實上。另外我們也同樣在農業試驗所之李園、桃園、及枇杷園內，於果實成熟期調查東方果實蠅的族群變動情形，以對照番石榴園的試驗結果。本研究顯示東方果實蠅每日以一週期性的固定模式遷移於果園內外。雌蟲較雄蟲喜於遷入果園，而雌蟲進入果園的目的應是為了產卵。

Key words: fruit flies, Bactrocera dorsalis, behavior, ecology, diel pattern
關鍵詞: 果實蠅、Bactrocera dorsalis、行為、生態、日週期模式

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ABSTRACT

A whole-year census of the oriental fruit fly, *Bactrocera dorsalis* (Hendel), in a guava orchard was conducted to determine its annual population dynamics and diel activity pattern. Movement of the fly into and out of the orchard is also discussed according to its population changes in the orchard. The peak population of *B. dorsalis* within the orchard coincided with the fruiting season. Inside the orchard, no flies were present in the evening; however, flies were found in the morning and their population reached a peak in the afternoon. Throughout the year females predominated with a mean ratio of 3.69:1. The ratio was higher in the afternoon than in the morning. Most females in the orchard were mated, and most of them were found on the fruit. Censuses in a plum, peach, and loquat orchard during their fruiting seasons were also carried out to confirm some of the findings. Our study indicates that the oriental fruit fly exhibits a diel pattern of movement into and out of the orchard. Females are more likely than males to visit the orchard, and their movement into the orchard seems to be for the purpose of oviposition.

Key words: fruit flies, *Bactrocera dorsalis*, behavior, ecology, diel pattern

Introduction

The oriental fruit fly, *Bactrocera dorsalis* (Hendel), is a serious pest of many fruit crops in all parts of Taiwan. Eggs are deposited in the pericarp and larvae feed inside the fruits. Infestations not only cause severe damage by reducing both fruit production and quality, but also impede exportation of fresh fruit due to the quarantine restrictions. Male annihilation with poisoned methyl eugenol is the practice adopted by the government for area-wide control of this pest in Taiwan.

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However, the already-existing high population of this fly, the extremely broad host range including many non-economically important plants, and the effects of global warming make this satisfactory form of control very difficult to achieve. Fruit bagging, net-house cultivation, and density-independent insecticide sprays have been the major strategies used by the growers for protection of their crops against *B. dorsalis*. Yet the fruit bagging and net-house cultivation are labor intensive, while heavy insecticide sprays have serious impacts on the environment.

Insects, in many cases, have different habitats for feeding, mating, and oviposition, and this involves movement of the insects among different habitats. Tropical fruit fly species are usually strong fliers, having a considerable capacity for long-distance displacement (Christenson and Foote, 1960; Bateman, 1979; Al-Zaghal and Mustafa, 1986; MacFarlane *et al.*, 1987). The movement of fruit flies can be divided functionally into two categories: between-habitat or migratory movements, and within-habitat or trivial movements (Bateman, 1972; Fletcher, 1989). Migratory movement includes post-teneral movements away from emergence sites, movement between patches of host plants, and movement to and from long-term refuges such as overwintering sites. Trivial movement involves foraging flights in search of food, mates or oviposition sites within a habitat at a specific locality. Most of the movements are related to the availability of resources. Nevertheless, the post-teneral dispersal wherein newly-emerged adults in a number of species emigrate relatively long distances from the orchard (Steiner *et al.* 1962; Iwahashi, 1972; Fletcher, 1973; Qureshi *et al.*, 1975; Drew and Hooper, 1983; MacFarlane *et al.*, 1987) are irrelevant to the host conditions. Furthermore, some fruit fly species have been reported to have a distinct diurnal pattern of movement between their hosts and nearby non-host plants (Nishida and Bess, 1957; Syed, 1969; Matanmi, 1975; Steffens, 1983; Malavasi *et al.*, 1983; Hendrichs and Hendrichs, 1990; Aluja and Birke, 1993; Aluja *et al.*, 1993; Warburg and Yuval, 1997; Aluja *et al.*, 1997). They were observed with a peak population inside the host fields during certain times of the day for oviposition, and then move out into the surrounding vegetation where feeding and resting take place. Information on movement of pest species is crucial for planning effective control programs.

In the oriental fruit fly, studies have indicated that this species can migrate relatively long distances with a maximum record of 65 km (Steiner *et al.*, 1962; Iwahashi, 1972; Yao *et al.*, 1977). Besides, Bess and Haramoto (1961) reported that adult *B. dorsalis* in Hawaii were not found in large numbers on fruiting guava trees except during the daily peak of oviposition activity. They move to other plants nearby for food and shelter. However in West Pakistan, Syed *et al.* (1970) found *B. dorsalis* adults remained in the orchards when there was ripe fruit on the trees. They were neither seen on surrounding vegetation, nor on the trees of adjacent orchards where there were no fruits. This study investigated the annual population dynamics and the diel population changes of *B. dosalis* in a guava orchard. It provides information on the movement of this pest and may help the improvement of the control efficiency.

Materials and Methods

Annual population dynamics and diurnal population changes of *B. dorsalis* in the fruit orchard

A guava orchard situated at the fruit crop conservation farm in Taiwan Agricultural Research Institute (TARI), Wufeng, Taichung was used for carrying out the investigations (Fig. 1). The orchard sized 0.3-ha with 144 3-year-old guava trees. The guava trees reached an estimated height of 1.5

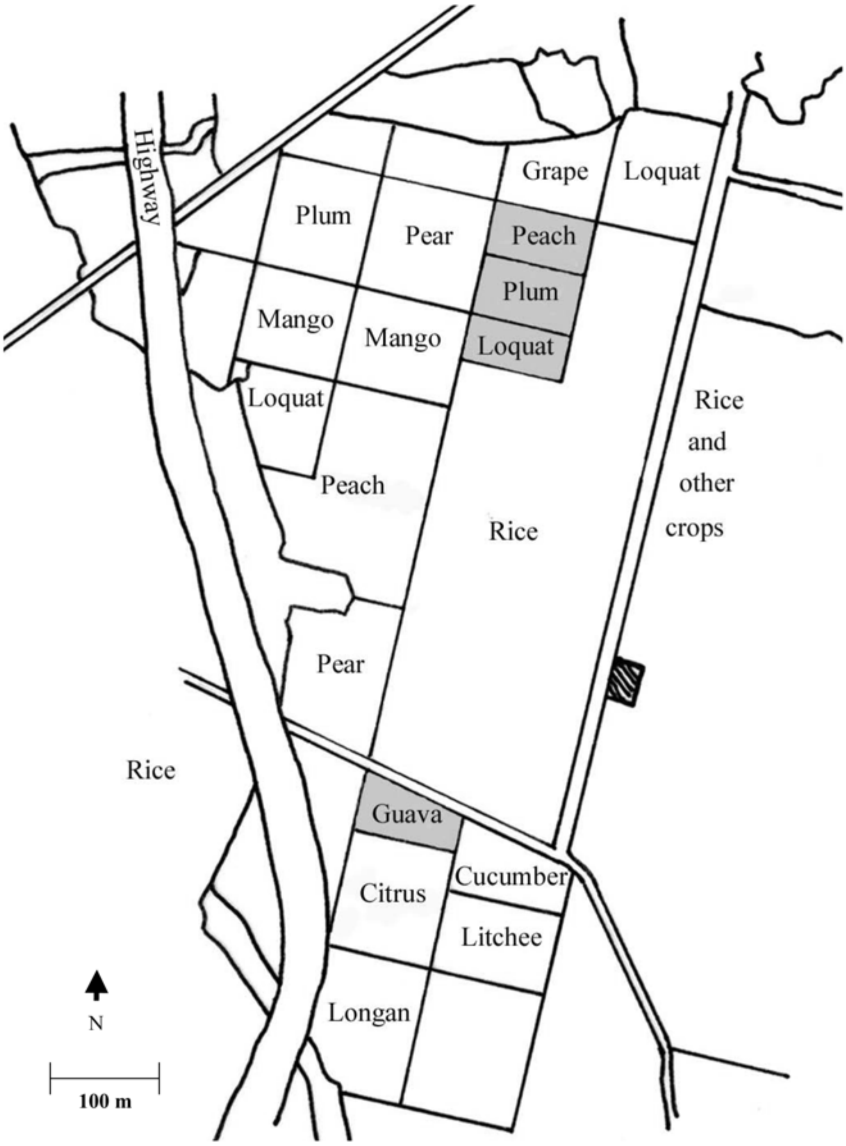

Fig. 1. Relative locations of the investigated orchards (areas shaded in gray) at the fruit crop conservation farm at Taiwan Agricultural Research Institute, Wufeng, Taichung, Taiwan.

m, and a canopy of ca. 2.5 m in diameter, and fruited all year round with peak fruiting seasons in April through May and September through October. The guava orchard neighbored with citrus, litchi, pear, paddy rice, and cucumber. No insecticides were applied to the experimental trees during the investigations except two sprays of acetamiprid for controlling the spiraling whitefly.

The investigations in the guava orchard were conducted twice a day (9:00 am and 3:00 pm) and twice a week. A total of 99 censuses were carried out from March 2001 to March 2002. The fruit flies on the whole tree were examined systematically by sight, and the numbers of male and female flies found on the fruits and leaves (both the upperside and the underside surfaces) of each tree in the orchard were recorded, respectively. During the evening censuses, a flash light was used. Additionally, two 3-day consecutive investigations in the guava orchard were carried out on April 16-18 and October 14-16, 2002. Censuses were conducted 3 times a day at 9:00 am, 3:00 pm, and 8:00 pm, respectively. During the census, numbers of male and female flies on the trees were recorded respectively.

Similar investigations were also carried out in a plum, a peach, and a loquat orchard situated at the same fruit crop conservation farm in TARI (Fig. 1). The sizes of these three orchards were 0.25 ha with 47 plum trees, 0.5 ha with 91 peach trees, and 0.5 ha with 424 loquat trees. The same method as that described above was used to census the oriental fruit flies in these orchards, except that only 33 censuses were carried out from April to July 2001. The investigation period covered the main fruiting season of these three orchards. The censuses in the loquat orchard were carried out only to the height that could be inspected.

Determination of mating status of female *B. dorsalis* in the orchard

On August 5-29, 2002, a period of time during the main fruiting season of the guava, female flies were sampled from the guava orchard twice a day and twice a week, and a total of 16 samplings were carried out. During each sampling, 20 female flies were collected and brought to the laboratory. They were then dissected under a stereomicroscope and the ovaries examined for maturity of ovaries (presence of mature eggs) and mating status (availability of sperm in the spermatheca).

Mark and release experiment

On May 6, 2002, one hundred pairs of mated (18- to 20-day-old) and 100 pairs of unmated (3- to 5-day-old) *B. dorsalis* were immobilized at 4ºC in a walk-in refrigerator and marked with different colors of paint on the dorsum of mesothorax. Preliminary laboratory studies had indicated that marks applied in this manner were not detrimental to the flies. The marked flies were released at the center of the guava orchard at 9:00 am, and searches of the marked flies in the orchard were started at 3:00 pm on the same day, and continued to June 3 twice a day at 9:00 am and 3:00 pm, respectively. The marked flies of different mating status present in the orchard were recorded respectively during the search. The same study was repeated again on May 21 and lasted to June 3, 2002 with the release of 500 pairs of mated and unmated marked flies, respectively. The color of the markers used on the two replication dates was different so that the flies released on the different dates could be distinguished. The fruit flies used in this study were taken from a laboratory maintained colony. The larvae of the colony were fed on an artificial diet described by Chiu (1978) in a growth chamber at 25 ± 1ºC and 70% RH. The adults were reared on a diet containing protein hydrolysates and sucrose (3:1) in a cage (30 x 30 x 30 cm) with a water soaked sponge on the top. The rearing units were kept in a rearing room at 25 ± 1ºC with a photoperiod of 12 : 12 (L:D) h.

Data analysis

Student's t tests were used to analyze the differences between all pair-wise data. All comparisons were based on the mean number of fruit flies during the investigation periods.

Results

Our results from the whole year

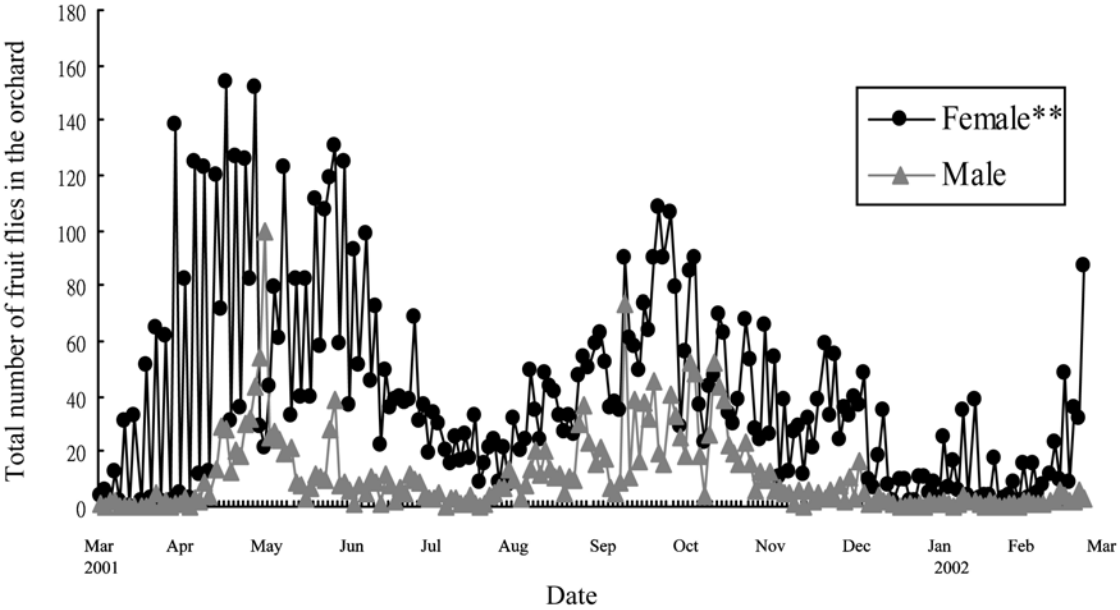

Fig. 2. Population dynamics of different sexes of *Bactrocera dorsalis* in a guava orchard at Taiwan Agricultural Research Institute, Wufeng, Taichung, Taiwan. Censuses were conducted twice a day at 9:00 am and 3:00 pm, and twice a week. Data represent total number of fruit flies sighted at each census date. Double asterisks indicate a significant difference between number of flies of different sexes at $p < 0.01$ (Student t test; SPSS 10.0 for windows 1999).

censuses showed that the populations of *B. dorsalis* in the guava orchard peaked in April through May and August through October in 2001 (Fig. 2), which coincided with the main fruiting seasons of guava. The populations of both sexes in the orchard were always higher in the afternoon than in the morning (t = 6.66; df = 98; $p < 0.001$) (Fig. 2 & 3). The diel pattern of *B. dorsalis* was further confirmed with two consecutive 3-day investigations conducted three times a day at 9:00 am, 3:00 pm and 8:00 pm in April and October of 2002 (Fig. 4 & 5). In these investigations, no flies were found in the orchard during the evening censuses, however, the flies were sighted again in the orchard at the morning censuses and the fly populations reached the peak in the afternoon. These results implied that *B. dorsalis* exhibited diurnal movements into and out of orchard. We also found that the female was significantly the major sex (t = 12.64; df = 98; $p < 0.001$) in the orchard throughout the year with the mean ratio of 3.69 : 1, and the ratio was even higher in the afternoon (Fig. 2 & Table 1). Most females in the guava orchard were mated (Fig. 6) (t = 12.86; df = 15; $p < 0.001$), and more females than males stayed on the fruit (Fig. 7) (t = 12.89; df = 197; $p < 0.001$). But for those stayed on the leaf, there was no difference between sexes (Fig. 8) (t = 7.90; df = 197; $p < 0.001$). Besides, Table 2 showed that there was no significant difference in the numbers of female flies found on fruit versus on leaves in the morning (t = 1.21; df = 98; $p > 0.05$); but in the afternoon, there were more females found on fruit than on leaves (t = 10.32; df = 98; $p < 0.01$). In addition, the number of females on leaves decreased from morning to afternoon, but on fruit they increased

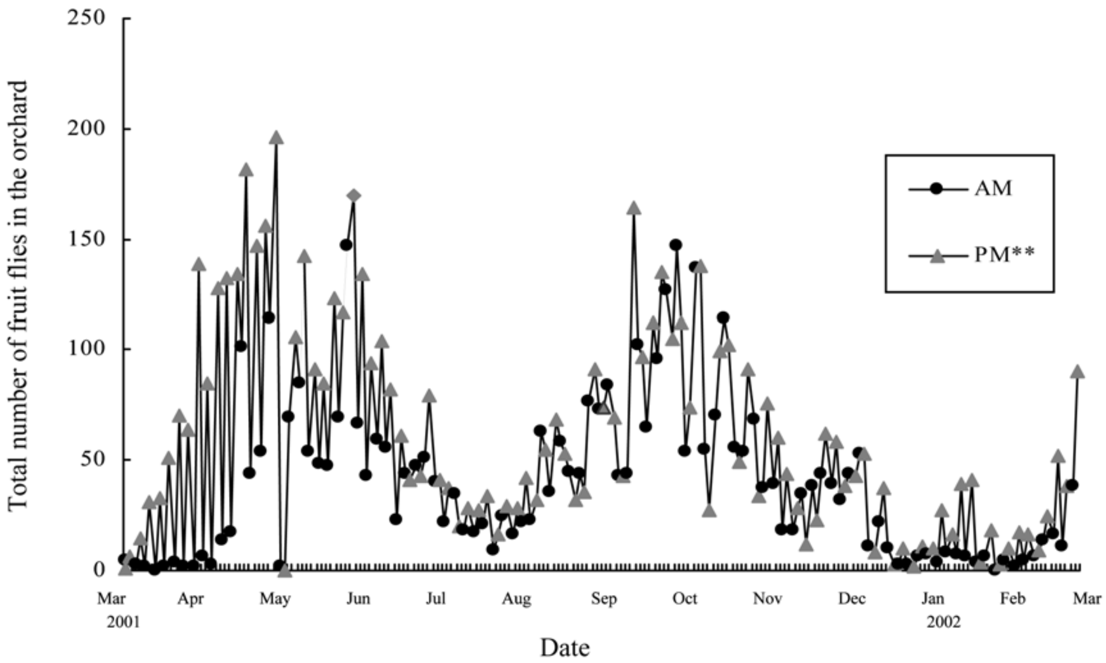

Fig. 3. Daily population changes of *Bactrocera dorsalis* in a guava orchard at Taiwan Agricultural Research Institute, Wufeng, Taichung, Taiwan. Censuses were conducted twice a day at 9:00 am and 3:00 pm, and twice a week. Double asterisks indicate a significant difference between number of flies at different times at $p < 0.01$ (Student *t* test; SPSS 10.0 for windows 1999).

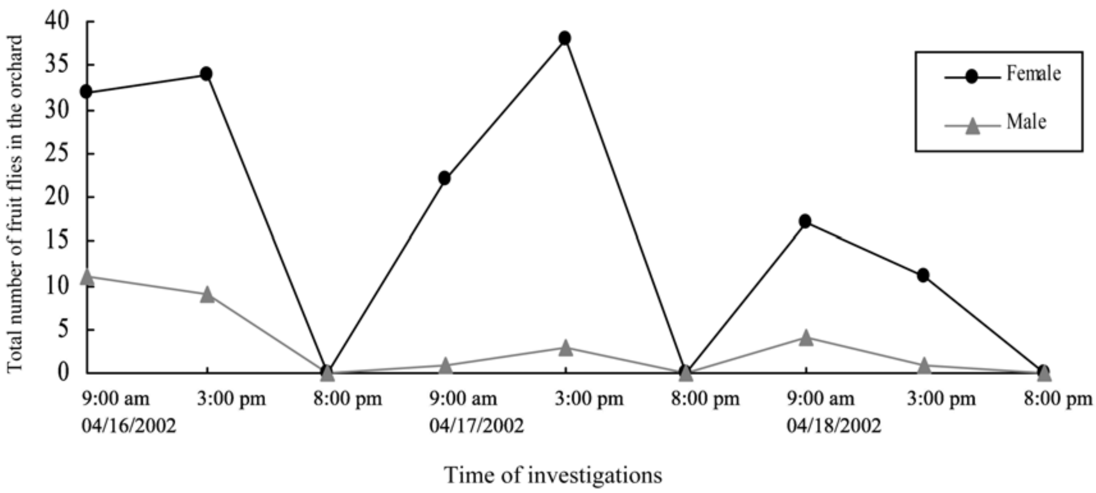

Fig. 4. Daily population changes of *Bactrocera dorsalis* in a guava orchard at Taiwan Agricultural Research Institute, Wufeng, Taichung, Taiwan.

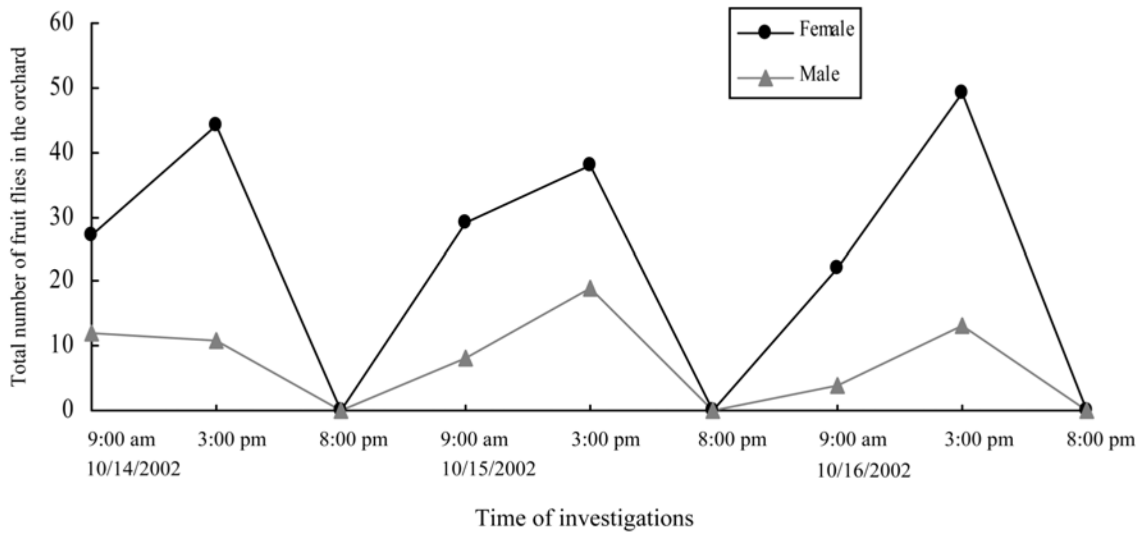

Fig. 5. Daily population changes of *Bactrocera dorsalis* in a guava orchard at Taiwan Agricultural Research Institute, Wufeng, Taichung, Taiwan.

Table 1. The mean number of *Bactrocera dorsalis* female and male found in the morning and the afternoon in a guava orchard at Taiwan Agricultural Research Institute, Wufeng, Taichung, Taiwan

Insect	Total no. of fruit flies (mean ± SE) [1)] Morning	Afternoon
♀	29.0 ± 25.3	52.5 ± 38.3
♂	10.6 ± 11.9	11.5 ± 16.8
p (*t*-test)	< 0.001	< 0.001
♀ : ♂	2.74 : 1	4.57 : 1

[1)] Data represent total number of fruit flies sighted on all the guava trees in the orchard on each census date. Censuses were carried out twice a day at 9:00 am and 3:00 pm, and twice a week from March 2001 to March 2002.

(fruit: $t = 8.37$; df = 98; $p < 0.01$, leaf: $t = 7.80$; df = 98; $p < 0.01$). On the other hand, there were always more males staying on leaves than on fruit both in the morning and afternoon censuses (morning: $t = 2.14$; df = 98; $p < 0.05$, afternoon: $t = 2.40$; df = 98; $p < 0.05$), and the number of males staying on fruit or leaf did not change through the day (fruit: $t = 0.38$; df = 98; $p > 0.05$, leaf: $t = 0.61$; df = 98; $p > 0.05$).

The censuses in the plum, peach, and loquat orchards also showed that the peaks of fly population in the orchards coincided with the fruiting seasons (Fig. 9, 10 & 11). In addition, the female populations in the plum and peach orchards were significantly higher than the male ones (plum: $t = 4.43$; df = 65; $p < 0.001$, peach: $t = 9.61$; df = 65; $p < 0.001$) although there was not an obvious diurnal pattern between the fly populations of the morning and of the afternoon (Fig. 9 & 10). However, there was no significant

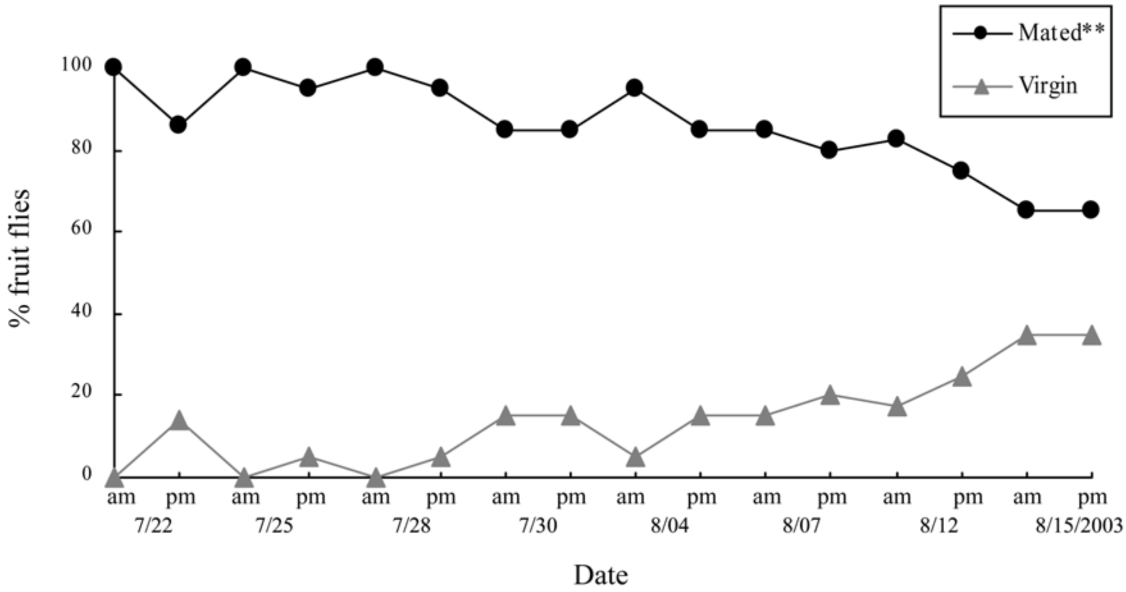

Fig. 6. Occurrence of different mating status of female *Bactrocera dorsalis* in a guava orchard at Taiwan Agricultural Research Institute, Wufeng, Taichung, Taiwan. Censuses were conducted twice a day at 9:00 am and 3:00 pm, and twice a week. Double asterisks indicate a significant differences between number of flies of different mating status at $p < 0.01$ (Student *t* test; SPSS 10.0 for windows 1999).

difference in fly populations between female and male in the loquat orchard ($t = 1.86$; df = 65; $p > 0.05$) (Fig. 11).

In the mark and release experiment, the results showed that the released 18- to 20-day-old (sexually mature) and 3- to 5-day-old (sexually immature female/ mature male) flies of both sexes rapidly moved out of the guava orchard within one day (Fig. 12 & 13). Less than 5% of the marked flies were found in the guava orchard in the following 5 days, and after 5 days we never found any marked flies in the guava orchard during our 11- and 25-day-period censuses.

Discussion

A number of fruit fly species have been shown to have a distinct diurnal pattern of movements between their hosts and nearby non-host plants (Nishida and Bess, 1957; Syed, 1969; Matanmi, 1975; Steffens, 1983; Malavasi *et al.*, 1983; Hendrichs and Hendrichs, 1990; Aluja and Birke, 1993; Aluja *et al.*, 1993; Warburg and Yuval, 1997; Aluja *et al.*, 1997). They were observed at peak population levels inside host fields during certain times of the day for oviposition, followed by movement out into the surrounding vegetation where feeding and resting take place. Nishida and Bess (1957) reported that adults of *B. cucurbitae* associated with melon fields in Hawaii have a distinct pattern of movement which is repeated daily. No flies were present in the fields in the early morning. They move into the fields from nearby wild vegetation throughout the day, reach a peak in the fields at around 5 pm, and move back to the surrounding vegetation before nightfall. The movements into the fields appear to be solely for the purpose of oviposition since the flies are predominately gravid females. The males and juveniles remain outside the fields where the wild vegetation provides food

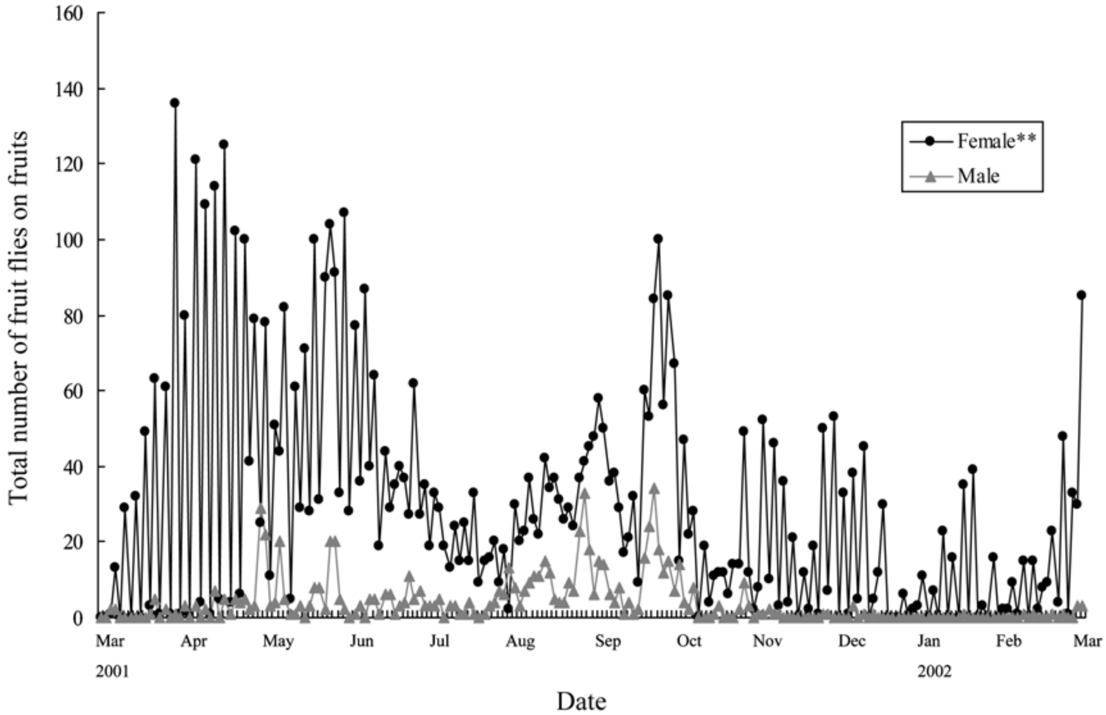

Fig. 7. Occurrence of *Bactrocera dorsalis* on the fruits in a guava orchard at Taiwan Agricultural Research Institute, Wufeng, Taichung, Taiwan. Censuses were conducted twice a day at 9:00 am and 3:00 pm, and twice a week. Data represent total number of fruit flies sighted at each census date. Double asterisks indicate a significant difference between number of flies of different sexes at $p < 0.01$ (Student *t* test; SPSS 10.0 for windows 1999).

and shelter. A similar phenomenon for this melon fly was observed in India (Kazi, 1976). Females of *Dacus frontalis* Becker in the Cape Verde Islands (Steffens, 1983) and *Dacus vertebrates* Bezzi, *Dacus bivittatus* Bigot and *Dacus ciliatus* Loew in Nigeria (Matanmi, 1975) were observed to move from surrounding vegetation into plots of cultivated cucurbits to oviposit in the late afternoon. Syed *et al.* (1970) reported that adults of *B. zonatus* remained in the vicinity of orchards but visited them for oviposition only. They fed and rested on surrounding trees and crops. Aluja *et al.* (1997) found that the papaya fruit fly, *Toxotrypana curvicauda* Gerstaecker, exhibited a clear pattern of movement back and forth between papaya plantations and native vegetation. They entered plantations in the morning and left them in the afternoon. Aluja and Birke (1993), working with *Anastrepha obliqua* (Macquart), documented a daily pattern of displacements between mango and adjacent plum trees. The movements are associated with various life activities, e.g., feeding, mating, oviposition, and resting. Bess and Haramoto (1961) indicated that *B. dorsalis* were not on fruiting guava trees in large numbers except during the daily peak of oviposition activity based on their 3-day 6:00 am - 6:00 pm investigations, and the flies were observed “resting” on panax (*Nothopanax guilfoylei* (Cogniaux and Marchal) Merrill) hedges, which is not a host. Our current study

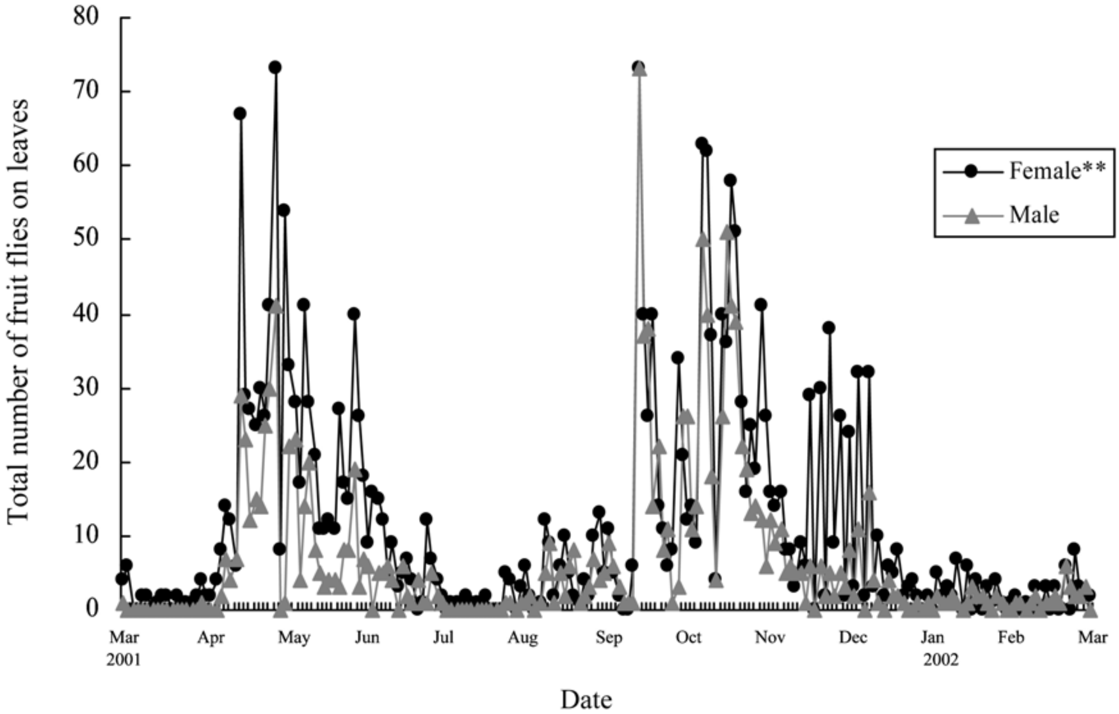

Fig. 8. Occurrence of *Bactrocera dorsalis* on the leaves in a guava orchard at Taiwan Agricultural Research Institute, Wufeng, Taichung, Taiwan. Censuses were conducted twice a day at 9:00 am and 3:00 pm, and twice a week. Data represent total number of fruit flies sighted at each census date. Double asterisks indicate a significant difference between number of flies of different sexes at $p < 0.01$ (Student *t* test; SPSS 10.0 for windows 1999).

Table 2. Summaries of the comparisons on the number of *Bactrocera dorsalis* found in a guava orchard at Taiwan Agricultural Research Institute, Wufeng, Taichung, Taiwan during March 2001 to March 2002

1. AM-F-♀ < PM-F-♀	(t = 8.37, df = 98, $P < 0.01$)
2. AM-L-♀ < PM-L-♀	(t = 7.80, df = 98, $P < 0.01$)
3. AM-F-♂ = PM-F-♂	(t = 0.38, df = 98, $P > 0.05$)
4. AM-L-♂ = PM-L-♂	(t = 0.61, df = 98, $P > 0.05$)
5. AM-F-♀ = AM-L-♀	(t = 1.21, df = 98, $P > 0.05$)
6. PM-F-♀ > PM-L-♀	(t = 10.32, df = 98, $P < 0.01$)
7. AM-F-♂ < AM-L-♂	(t = 2.14, df = 98, $P < 0.05$)
8. PM-F-♂ < PM-L-♂	(t = 2.40, df = 98, $P < 0.05$)

AM: morning; PM: afternoon; F: fruit; L: leaf.

showed a distinct diurnal population change in *B. dorsalis* in the guava orchard. It indicates that *B. dorsalis* exhibits a diel pattern of movement. They started to move into orchard in the morning, then gradually increased their number in orchard and reached the peak in the afternoon, but all inhabited outside the orchard in the evening. We also found that the female was significantly the major

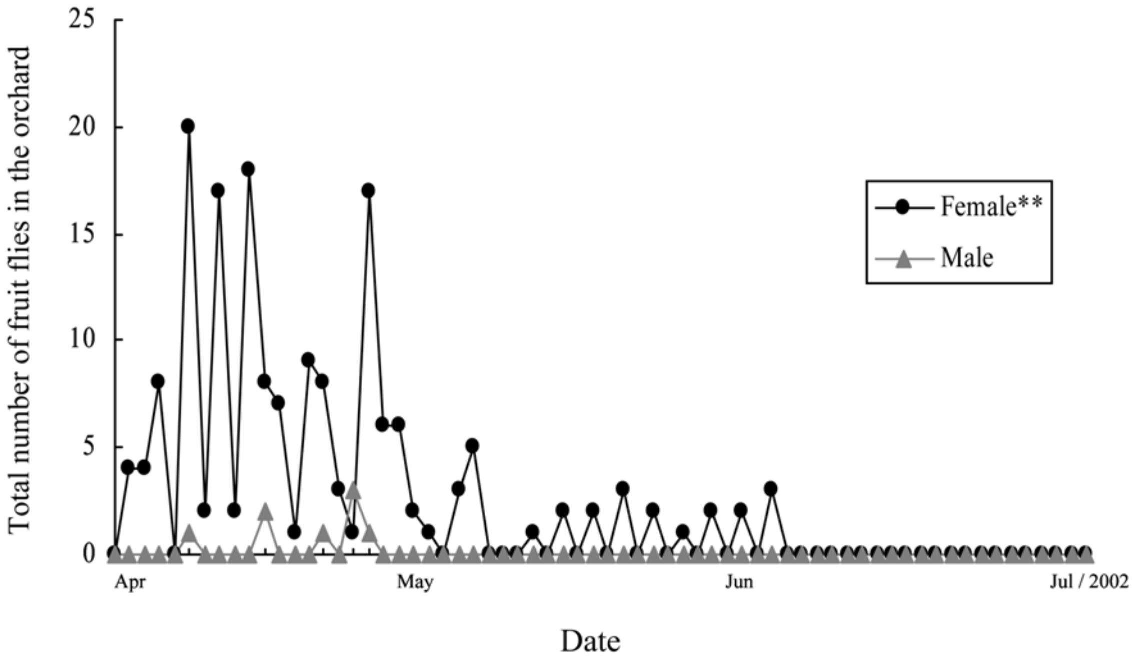

Fig. 9. Population dynamics of different sexes of *Bactrocera dorsalis* in a plum orchard at Taiwan Agricultural Research Institute, Wufeng, Taichung, Taiwan. Censuses were conducted twice a day at 9:00 am and 3:00 pm, and twice a week during the main fruiting season. Data represent total number of fruit flies sighted at each census date. Double asterisks indicate a significant difference between number of flies of different sexes at $p < 0.01$ (Student *t* test; SPSS 10.0 for windows 1999).

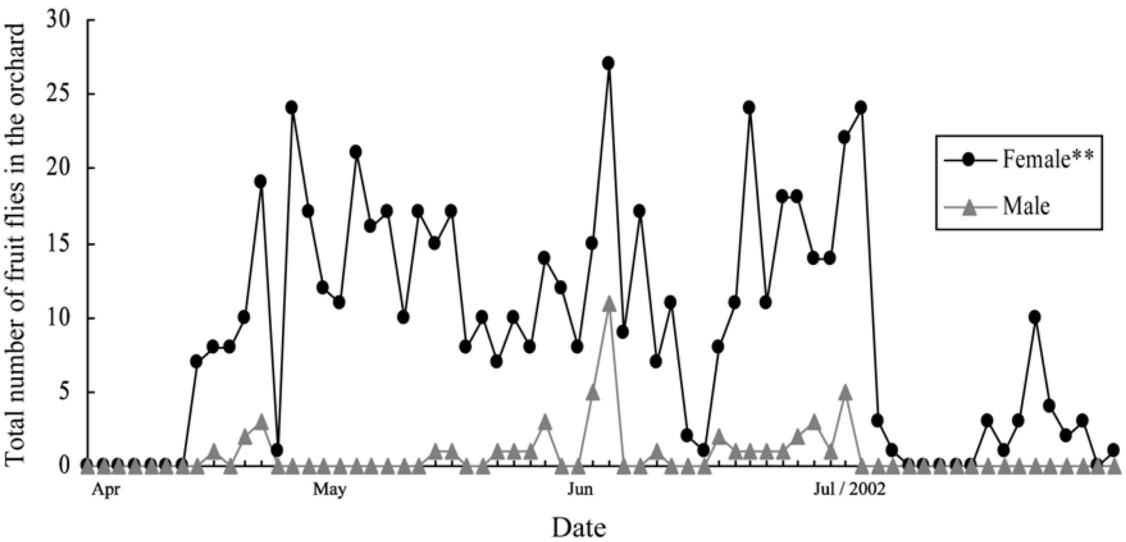

Fig. 10. Population dynamics of different sexes of *Bactrocera dorsalis* in a peach orchard at Taiwan Agricultural Research Institute, Wufeng, Taichung, Taiwan. Censuses were conducted twice a day at 9:00 am and 3:00 pm, and twice a week during the main fruiting season. Data represent total number of fruit flies sighted at each census date. Double asterisks indicate a significant difference between number of flies of different sexes at $p < 0.01$ (Student *t* test; SPSS 10.0 for windows 1999).

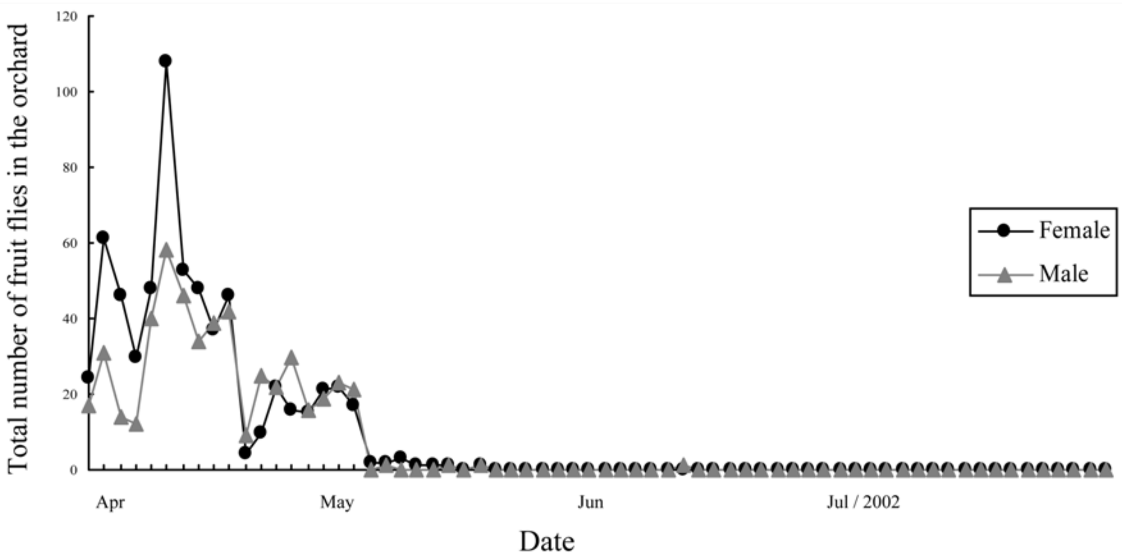

Fig. 11. Population dynamics of different sexes of *Bactrocera dorsalis* in a loquat orchard at Taiwan Agricultural Research Institute, Wufeng, Taichung, Taiwan. Censuses were conducted twice a day at 9:00 am and 3:00 pm, and twice a week during the main fruiting season. Data represent total number of fruit flies sighted at each census date. Number of flies between different sexes are not significantly different at p = 0.05 level (Student t test; SPSS 10.0 for windows 1999).

sex in the orchard throughout the year, and the ratio of female to male was even higher in the afternoon than that in the morning. These revealed that females are more likely than males to visit the guava orchard, and most of them enter the orchard after mid-morning through the afternoon. From the censuses we also found that most females in the guava orchard were mated, and most of them stayed on the fruit. In addition, our results implied that some of the females that enter the orchard in the morning and stay on leaves might move to fruits in the afternoon. Since the peak oviposition activity of the oriental fruit fly occurs in the late afternoon and early evening hours just before sundown, the results indicate that the purpose of the female flies moving into the guava orchard seems to be for ovipostion. It can also be supported by the fact that the peaks of the oriental fruit fly in the guava, plum, peach, and loquat orchard coincided with the fruiting seasons of each orchard, but not with the local fly population peaks which usually coincide with high temperatures (Cheng *et al.*, 2003).

Not all resources required for fruit flies of different stage or different sex are localized on host plants; therefore, fruit flies forage for resources in a variety of host and nonhost plants in sex- and age-specific patterns of movement (Aluja and Birke, 1993). Fruit flies often show a post-teneral dispersive phase during which the juvenile adults move away from the emergence sites, and the post-teneral dispersive movements are largely independent of host trees (Bateman, 1972). In *B. dorsalis*, the newly emerged males have been observed to move considerably between the Ogasawara islands despite the fact that conditions at the release point were often better than where the flies were trapped (Iwahashi, 1972). Our personal communications indicate the existence of a large number of oriental

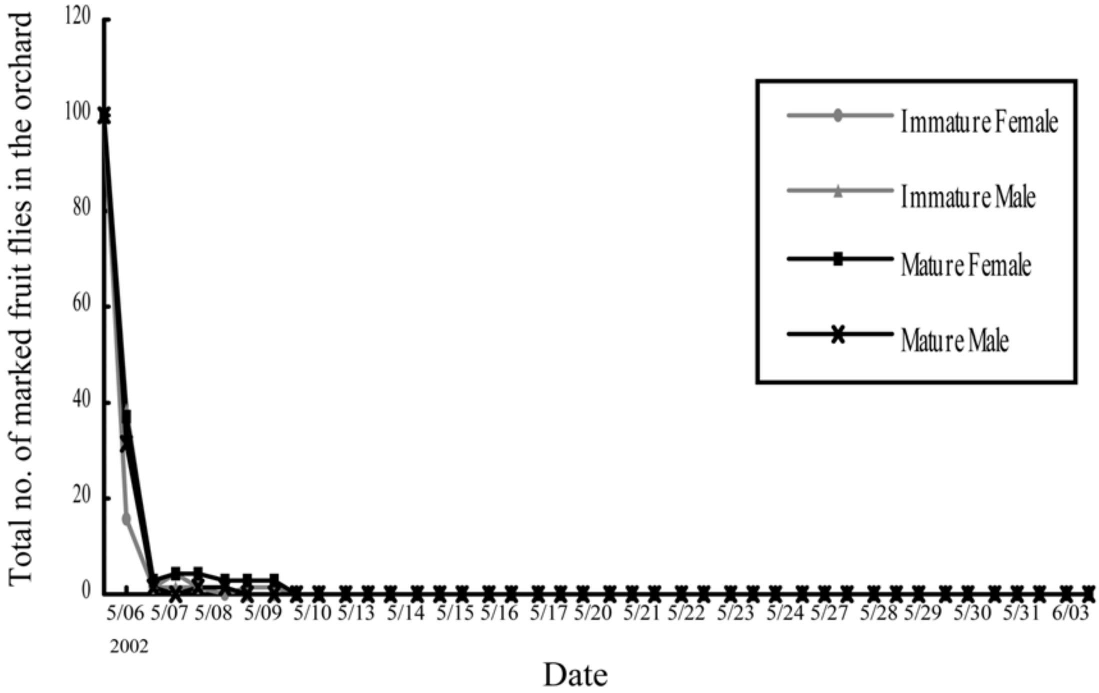

Fig. 12. Occurrence of marked and released *Bactrocera dorsalis* in a guava orchard at Taiwan Agricultural Research Institute, Wufeng, Taichung, Taiwan. One hundred pairs of mature (18- to 20-day-old, mated) and 100 pairs of immature (3- to 5-day-old, unmated) flies were released at 9:00 am on May 4, 2002. Searches of the marked flies were started at 3:00 pm on May 4, and continued to June 3, 2002 twice a day at 9:00 am and 3:00 pm. Data represent total number of marked flies sighted at each census date.

fruit flies in bamboo fields and on hedge plants such as the Hibiscus. The results in this study showed that most oriental fruit flies that moved into the orchard were female and had been mated. The information above implies that there may be other habitats rather than host plants more suitable for oriental fruit flies to feed, mate, and rest. The flies after emergence may move to those habitats and stay there most of time for various life activities, but fly to orchards only for oviposition. Besides, during our investigation in the loquat orchard, we found a special phenomenon that there were aggregation of birds in the orchard during its fruiting season to feed on the loquat fruits, and aggregation of *B. dorsalis* in the orchard to feed on the bird droppings. The same phenomenon was not found in the guava, the plum, and the peach orchard during their fruiting seasons. The fruit fly census showed that there were no significant differences between the numbers of the female and the male in the loquat orchard. This was different from the results obtained from the guava, plum, and peach orchards that showed more females than males in the orchard. It seems to further demonstrate that the movements in *B. dorsalis* are related to the resources. This needs further investigations.

In our mark and release experiment, both sexually mature and immature flies moved away from the release site in the

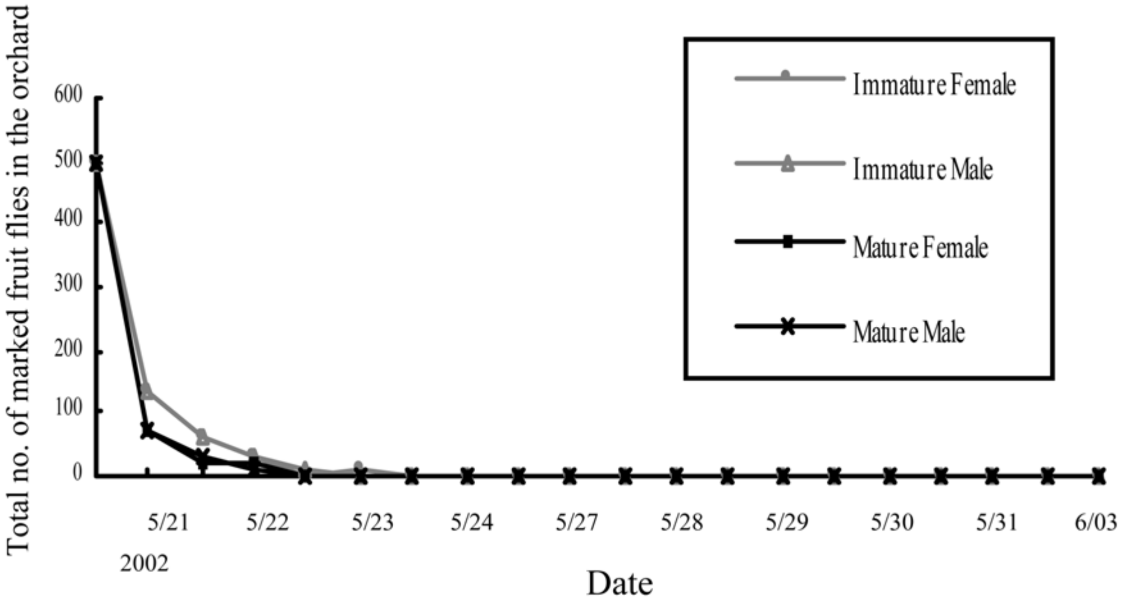

Fig. 13. Occurrence of marked and released *Bactrocera dorsalis* in a guava orchard at Taiwan Agricultural Research Institute, Wufeng, Taichung, Taiwan. Five hundred pairs of mature (18- to 20-day-old, mated) and 500 pairs of immature (3- to 5-day-old, unmated) flies were released at 9:00 am on May 21, 2002. Searches of the marked flies were started at 3:00 pm on May 21, and continued to June 3, 2002 twice a day at 9:00 am and 3:00 pm. Data represent total number of marked flies sighted at each census date.

orchard, and most of them did not return to the same orchard later during our survey. The movement of the immature flies may be associated with the post-teneral dispersal, nevertheless, the movement in mature flies may be related to the vigorous flying ability of fruit flies. Oriental fruit flies are strong flyers. They have been found to travel 4 to 15 miles from the point of their release and to cross 9 miles of open sea between islands (Christenson and Foote, 1960). They were also found to fly several miles within a few days. The laboratory reared flies after release may immediately fly away from the release point. Due to the small size of our study orchard (which is common in Taiwan) and the plenty of nearby fruit orchards, the released flies after moving out might have chosen other orchards for their oviposition sites so that they did not return to the original orchard again.

Taiwan is an island with most of its flat land highly developed. Its agriculture is characterized by densely distributed small farms of various crops throughout the island. The island is continuously in time and space filled with oriental fruit fly hosts of both economically important and unimportant plants. Besides, there are also many non-host plants in which the fly can inhabit during the non-ovipositional period. These in addition to the warm temperature make the control of the oriental fruit fly in Taiwan especially difficult. Study of a pest's behavior is crucial for the efficient control of the target pest. From our studies at the guava, plum, peach, and loquat orchards, we obtained the information that the oriental fruit fly do not always stay inside orchards; instead, they exhibit diel patterns of movement into and out of orchards. The mated females are more likely to enter the orchard, and their visit to the orchard seems to be mainly for the purpose of oviposition. With the agricultural environments of Taiwan in addition to the fly's strong flight ability, the oriental fruit fly here may move among different orchards instead of staying at certain ones for oviposition. Therefore, the control applied by unitary farms is somewhat difficult to be achieved satisfactorily. Since the orchard is not the main habitat of the oriental fruit fly, current control practice with focus on in-field applications should be re-evaluated. However, more studies on this fly's behavior as well as ecology should be carried out such as determination of its behaviors both inside and outside the orchard, the habitats for various life activities, i.e., feeding, mating, oviposition, and rest, and the habitats for certain life stages (e.g., sexually immature adults) and different sexes (male vs. female). Then, the current control strategies and practices such as male annihilation, poisoned bait, and insecticide application can be reviewed more comprehensively to increase the control efficacy through application at the most effective time and place. Besides, certain applications such as trap crop and ovipositional deterrent might also be considered and included into the management programs.

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東方果實蠅 ((*Bactrocera dorsalis* (Hendel)) (雙翅目：果實蠅科) 在番石榴園中之族群變動及遷移

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摘　要

本試驗在農業試驗所一處番石榴園內調查東方果實蠅全年及單日之族群變動，並依據東方果實蠅在園內之族群變動推論此果實蠅遷移於果園內外的情形。試驗結果顯示，東方果實蠅在果園內的族群高峰期與果實成熟期一致，且其族群數量每日有一週期性的變化。在果園內之夜間調查中並未發現東方果實蠅，果實蠅在早上才出現於果園中，並於下午數量達到高峰。果園內的東方果實蠅以雌性爲主，其雌雄性比爲 3.69：1，而下午果園內雌蟲的比例更較上午爲高。大多數在果園內的雌蟲爲已交尾者，且多停留於果實上。另外我們也同樣在農業試驗所之李園、桃園、及枇杷園內，於果實成熟期調查東方果實蠅的族群變動情形，以對照番石榴園的試驗結果。本研究顯示東方果實蠅每日以一週期性的固定模式遷移於果園內外。雌蟲較雄蟲喜於遷入果園，而雌蟲進入果園的目的應是爲了產卵。

關鍵詞：果實蠅、*Bactrocera dorsalis*、行爲、生態、日週期模式。