

Species Diversity and Seasonal Fluctuation of Fruit Flies (Diptera: Tephritidae) in Bamboo Stands in Taipei

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ABSTRACT

Fruit flies were regularly trapped by using four different-colored sticky traps in four bamboo cultivation areas in the vicinity of Taipei from January 1996 to May 1999. In total, 136,160 fruit flies of 62 species were captured. Among them, five species belonged to the Ceratitidinae, eight to the Phyalmiinae, 33 to the Trypetinae, 11 to the Dacinae, and five to the Tephritinae. *Carpophthoracidia matsumotoi* Shiraki was new to Taiwan. Seasonal population fluctuations of 27 fruit fly species were observed. Their composition among the bamboo stands varied from six predominant species and represented 89.97% to 96.87% of the individuals captured. Five preponderant species, i.e. *Acrotaeniostola sexvittata* Hendel, *Acroceratitis plumosa* Hendel, *Gastrozona fasciventris* (Macquart), *Euphranta chrysopila* Hendel, and *Ptilona persimilis* Hendel, were always associated with bamboo. Fly populations varied greatly among and within the study areas; however, their peak population densities coincided with the bamboo shoot production season, and the availability of bamboo shoots could be considered the most important environmental factor affecting population fluctuations of bamboo shoot fruit flies. The survey showed that yellow was the most attractive color to most of the fruit flies, followed in order by green, blue, and white. However, blue and white sticky traps captured most of the *Euphranta* species. Results of this study support colored traps can be used as a tool for monitoring non-frugivorous fruit flies, and their effectiveness can be enhanced if they are used in combinations of yellow or green traps with white or blue traps.

Key words: Tephritidae, bamboo, species diversity, seasonal fluctuation, colored trap.

Introduction

The family Tephritidae includes 4,257 species in 471 genera (Thompson, 1998). Approximately 1,500 species are probably

fruit associated, and an estimate of 600 species in which larvae probably mine the leaves, stems, or roots of their host plants (White and Elson-Harris, 1992). Many fruit flies in the subfamily Ceratitidinae are

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important pests of fruit crops, particularly in Africa. However, in most of the Asian Gastrozonini, a tribe of the Ceratitidinae, the host plants are grass, particularly bamboo (Hardy, 1988; Permkam, 1995; Hancock, 1999). Hancock and Drew (1999) reviewed the bamboo-shoot breeding Gastrozonini of Asia and reported that 86 species were recognized in 17 genera as follows: *Acroceratitis*, *Acrotaeniostola*, *Carpophthorella*, *Chaetellipsis*, *Chelyophora*, *Cyrtostola*, *Dietheria*, *Enicoptera*, *Galbifascia*, *Gastrozona*, *Paragastrozona*, *Paraxarnuta*, *Phaeospila*, *Phaeospilodes*, *Spilocosmia*, *Taeniostola*, and *Xanthorrhachis*. Several genera of Acanthonevrini are also associated with bamboo, namely, *Acanthonevra*, *Felderimyia*, *Pseudacrotoxa*, *Ptilona*, *Rioxa*, *Themara*, and *Tritaeniopteron* (Hardy, 1988; Hancock and Drew, 1994; Permkam, 1995).

Totally 159 species of fruit flies belonging to five subfamilies have thus far been recorded in Taiwan (Shiraki, 1933, 1968; Munro, 1935; Chen, 1948; Hardy, 1977; Tseng and Chu, 1983; Tseng *et al.*, 1992a, b, c; Norrbom, 1994; Han, 1996; Wang, 1996; Hancock and Drew, 1999; Sueyoshi, 1999). Among them, 15 species belong to the Ceratitidinae, ten to the Phytalmiinae, and 50 to the Trypetinae. In Taiwan, *Acroceratitis plumosa* Hendel and *Gastrozona fasciventris* (Macquart) (as *Gastrozona macquarti* Hendel) were the earliest species recorded as bamboo pests (Issiki *et al.*, 1928). Thereafter, *Acanthonevra formosana* Enderlein, *Euphranta chrysopila* Hendel, *Taeniostola connecta* Hendel, *Ptilona confinis* (Walker) (as *Ptilona nigriventris* Bezzi), and *Ptilona persimilis* Hendel were recorded as being associated with bamboo (Shiraki, 1933). Yen *et al.* (1979) reported nine fruit fly species under seven genera that were associated with bamboo, in which *Acanthonevra speciosa* (Hendel) and *Acrotaeniostola sexvittata* Hendel were recorded as bamboo feeders.

Bamboo is an important resource in

many Asian communities, particularly with the use of bamboo shoots as a vegetable. In Taiwan, 40 species, three varieties, and three cultivars of bamboo have so far been recorded, in which the following species are widely cultivated throughout the island: *Bambusa dolichoclada* Hayata, *Bambusa olahami* Munro, *Bambusa stenostachya* Hackel, *Dendrocalamus latiflorus* Munro, *Phyllostachys makinoi* Hayata, and *Phyllostachys pubescens* Mazel (Lin, 1978). All of these bamboo species were recorded as hosts of *Acroceratitis plumosa* and *Gastrozona fasciventris* (Shiraki, 1933). The importance of tephritid flies as pests of bamboo has been highlighted, and losses from these and other pests in Thailand are often severe, with damage reaching 100% (Hancock and Drew, 1999). However, because the larvae of *Acroceratitis plumosa* and *Gastrozona fasciventris* only feed on cut bamboo or bamboo shoots as a decomposer, they are not economically important and have not received much attention.

Beginning in 1996, we initiated a long-term field survey of seasonal fluctuations of fruit fly species in bamboo stands and adjacent areas in Taipei, Taiwan. We herein report the results of (1) the species composition of fruit flies in bamboo stands, (2) the seasonal abundance of fruit flies, and (3) the response of both male and female fruit flies to colored sticky traps. Since little is known about the ecology of bamboo shoot fruit flies, we review and compare our results with species of frugivorous fruit flies, such as *Anastrepha* and *Bactrocera*.

Materials and Methods

This study was conducted from January 1996 to May 1999 in and around four bamboo cultivation areas near Taipei City at elevations of 85 to 320 m. Three bamboo stands were selected from each of the three areas; Tachichiao, Changsansyh, and Sancherng, as well as two from Nankang. In these stands, planted bamboo

consisted of green bamboo, *Bambusa oldhami*; edible green bamboo, *Bambusa edulis* (Odashima); Makino's bamboo, *Phyllostachys makinoi*; and some patches of long-shoot bamboo, *Bambusa dolichoclada*. The bamboo shoot harvest seasons in Taipei are as follows: green bamboo and edible green bamboo from May to October, with two production peaks one from mid-June to mid-July and the other one in late August; and Makino's bamboo from April to May. Vegetation adjacent to those selected bamboo stands varied. In general, bamboo stands were surrounded by patches of native vegetation. Several fruit fly host plants, such as guava, *Psidium guajava* L., papaya, *Carica papaya* L., tankan, *Citrus tankan* Hayata, wen-tan pomelo, *Citrus grandis* (L.), grapefruit, *Citrus paradisi* Macfady, sponge gourd, *Luffa aegyptiaca* Mill., bitter melon, *Luffa charantia* L., angled luffa, *Luffa acutangula* (L.), and bottle gourd, *Luffa siceraria* (Mol.) were found along roadsides or in small patches in close proximity to the study stands.

Yellow, blue, green, and white sticky traps (adhesive paper, 21.5 × 21.5 cm) from the Kao-kung Co., Taiwan, were used in different phases of this survey. Yellow traps were used from January 1996, blue traps from May 1996, green traps from June 1996, and white traps from August 1996. All of the traps were rolled up, suspended vertically, and fixed by staplers on bamboo stems, or tree branches or trunks about 100-200 cm above the ground. About 20 traps of each color were used for each survey, depending on the size of the bamboo stand. Traps were distributed in bamboo stands and their bordering areas in patches. The distance between any two patches was more than 10 m. Traps were replaced every 2 weeks. The captured flies were counted in the laboratory. At each count, the number and the sex of captured fruit flies were recorded. After each count, some of the specimens were removed from the sticky paper and pinned for taxonomic use.

We measured tephritid species

diversity in each study area by computing the Simpson-Yule indices (Southwood, 1978). Trap captures were expressed as flies per trap every 2 weeks. Data were subjected to analysis of variance (ANOVA); mean differences of different color traps were tested by the least significant difference (LSD) test. The preferences of males and females for a specific color trap were tested by paired *t*-test. All statistical analyses were conducted using SAS (SAS Institute, 1990) with $P < 0.05$ as the significant criterion.

Results

Species diversity

From January 1996 to May 1999, a total of 136,160 flies was captured and classified according to the classification system of Thompson (1998), Korneyev (1999), and Hancock and Drew (1999). The captured flies were composed of 107,635 (79.1%) Ceratitidinae; 14,440 (10.6%) Dacinae, 7,599 (5.6%) Phytalmiinae, 6,426 (4.7%) Trypetinae, and 60 (< 0.01%) Tephritinae. The percentages of the preponderant species in descending order were 46.7% *Acrotaeniostola sexvittata*, 18.9% *Acroceratitis plumosa*, 13.3% *Gastrozona fasciventris*, 8.4% *Bactrocera tau*, 4.8% *Ptilona persimilis*, and 3.5% *Euphranta chrysopila*.

Totally of 62 species of fruit flies from 31 genera were recorded. Among them, five species belonged to the Ceratitidinae, 11 to the Dacinae, eight to the Phytalmiinae, 33 to the Trypetinae, and five to the Tephritinae (Table 1). The trypetines were in two tribes: Adramini (eight species), and Trypetini (25 species). In the survey, *Carpophthoracidia matsumotoi* was a new record for Taiwan.

Table 2 shows the proportion of the total catches of 27 fruit fly species in the four study areas from September 1996 to August 1998. Although the species composition varied among study areas, the total number of preponderant species of

Table 1. Fruit fly species captured by colored traps from January 1996 to May 1999

Ceratitidinae
Gastrozonini
Acroceratitis plumose Hendel, *Acrotaeniostola flavoscutellata* Shiraki, *Acrotaeniostola sexvittata* Hendel, *Gastrozona fasciventris* Macquart, *Spilocosmia punctata* (Shiraki).

Phytalmiinae
Acanthonevrini
Acanthonevra formosana Enderlein, *Acanthonevra speciosa* (Hendel), *Acanthonevra unicolor* (Shiraki), *Phorelliosoma hexachaeta* Hendel, *Ptilona confinis* (Walker), *Ptilona persimilis* Hendel, *Tritaeniopteron excellens* Hendel.

Blepharoneurini
Hexaptilona palpata Hendel

Trypetinae
Adamiini
Ceolotrypes sp., *Euphranta apicalis* Hendel, *Euphranta chrysopila* Hendel, *Euphranta jucunda* Hendel, *Euphranta lemniscata* Enderlein, *Euphranta sexsignata* Hendel, *Euphranta* sp. A., *Euphranta* sp. B.

Trypetini
Acidiella fomosana (Shiraki), *Acidiella longipennis* Hendel, *Acidiella persimilis* (Hendel), *Acidiella sonani* Shiraki, *Acidiostigma* sp., *Anomoia approximata* (Hendel), *Anomoia formosana* (Shiraki), *Carpophthoracidia matsumotoi* Shiraki*, *Chaetostoma* sp., *Chenacidiella purpureisetae* (Chen), *Feshya musaensis* (Shiraki), *Fusciludia* sp., *Hemilea praestans* Bezzi, *Hemilea* sp., *Machaomyia caudata* Hendel, *Philophylla fossata* (Fabricius), *Philophylla superflucta* (Enderlein), *Philophylla* sp. A, *Philophylla* sp. B, *Trypeta luteonota* Shiraki, *Trypeta* sp. A, *Trypeta* sp. B, *Vidalia bidens* Hendel, *Vidalia* sp.

Dacinae
Dacini
Bactrocera cilifer (Hendel), *Bactrocera cucurbitae* (Coquillett), *Bactrocera diaphora* (Hendel), *Bactrocera dorsalis* (Hendel), *Bactrocera ferruginea* (Fabricius), *Bactrocera parvula* (Hendel), *Bactrocera synnephes* (Hendel), *Bactrocera scutellata* (Hendel), *Bactrocera tau* (Walker), *Callentra formosana* Tseng & Chu, *Callentra* sp.

Tephritinae
Dioxyna sororcula (Wiedemann), *Elaphromyia* sp., *Sphenella sinensis* Schiner, *Spathulina acroleuca* Schiner, *Rhabdochaeta asteria* Hendel, *Rhabdochaeta formosana* Shiraki.

* New record for Taiwan.

Acrotaeniostola sexvittata, *Acroceratitis plumosa*, *Gastrozona fasciventris*, *Bactrocera tau*, *Euphranta chrysopila*, and *Ptilona persimilis* accounted for 96.87%, 96.07%, 93.54%, and 89.97% of all individuals captured in Tachichiao, Changsansyh, Sancherng, and Nankang, respectively. Moreover, *Euphranta sexsignata* was a more common species in Nankang. The pattern of species dominance represented a basic pattern of niche utilization. For example, five of the predominant species, except *Bactrocera tau*, are known as bamboo

shoot feeders. Interestingly, the proportion of *Bactrocera tau* also reached 12.79% in Sancherng. We believe this relative abundance was attributable to patches of their host plants, sponge gourd and bottle gourd, being planted in the vicinity of the study areas.

Simpson-Yule indices for each study area are list in Table 2. The highest and lowest diversity was found in Nankang and Changsansyh, respectively.

Seasonal abundance of fruit flies

Table 2. Fruit fly species diversity in four bamboo stands in Taipei from September 1996 to August 1998

Fly species	Percent of total captured			
	Tachichiao	Sancherng	Changsansyh	Nankang
<i>Acrotaeniostola sexvittata</i>	43.225	42.701	49.599	41.723
<i>Acroceratitis plumosa</i>	24.681	23.659	10.702	14.035
<i>Gastrozona fasciventris</i>	13.918	5.375	19.457	13.192
<i>Bactrocera tau</i>	6.820	13.360	3.722	7.629
<i>Euphranta chrysopila</i>	2.200	2.453	8.366	9.572
<i>Ptilona persimilis</i>	6.036	5.996	4.219	3.825
<i>Euphranta sexsignata</i>	0.331	0.379	0.373	4.976
<i>Bactrocera dorsalis</i>	1.350	2.203	0.741	1.892
<i>Ptilona confinis</i>	0.478	1.600	0.429	0.637
<i>Carpophthoracidia matsumotoi</i>	0.057	0.054	0.902	0.679
<i>Bactrocera cucurbitae</i>	0.355	1.036	0.124	0.298
<i>Bactrocera synnephes</i>	0.191	0.421	0.361	0.442
<i>Spilocosmia punctata</i>	0.158	0.189	0.321	0.247
<i>Tritaeiopteron excellens</i>	0.000	0.000	0.260	0.072
<i>Philophylla fossata</i>	0.055	0.064	0.056	0.144
<i>Euphranta apicalis</i>	0.000	0.175	0.068	0.031
<i>Acidiella persimilis</i>	0.019	0.046	0.012	0.062
<i>Acanthonevra speciosa</i>	0.036	0.075	0.088	0.031
<i>Coelotrypes</i> sp.	0.011	0.014	0.004	0.082
<i>Bactrocera scutellata</i>	0.030	0.071	0.024	0.031
<i>Acanthonevra formosana</i>	0.019	0.025	0.028	0.082
<i>Anomoia formosana</i>	0.000	0.004	0.056	0.021
<i>Euphranta jucunda</i>	0.008	0.036	0.004	0.010
<i>Bactrocera ferruginea</i>	0.008	0.029	0.004	0.010
<i>Fusciludia</i> sp.	0.003	0.014	0.032	0.000
<i>Acanthonevra unicolor</i>	0.011	0.007	0.000	0.000
<i>Phorelliosoma hexachaeta</i>	0.000	0.014	0.020	0.000
Total flies captured	37,517	26,809	22,018	11,138
Simpson-Yule index	3.621	3.785	3.271	4.337

Among the 62 species of fruit flies trapped in this survey, the following 13 species were the major ones: *Acroceratitis sexvittata*, *Acroceratitis plumosa*, *Gastrozona fasciventris*, *Bactrocera tau*, *Euphranta chrysopila*, *Ptilona persimilis*, *Euphranta sexsignata*, *Bactrocera dorsalis*, *Ptilona confinis*, *Carpophthoracidia matsumotoi*, *Bactrocera cucurbitae*, *Bactrocera synnephes*, and *Spilocosmia punctata*. Their seasonal fluctuations in the four areas during the period of 41 months of the study are shown in Figures 1-3. Fluctuations in the number of captured

fruit flies varied greatly among years, within stands, and among stands or areas. The duration during which the highest and lowest population levels were detected were almost the same in the four study areas. The mean catches per trap were 10.26, 7.09, 6.27, and 3.47 in Tachichiao, Sancherng, Changsansyh, and Nankang, respectively. The fruit fly population was significantly higher in Tachichiao, being almost three times higher than that in Nankang.

The highest number of *Acroceratitis sexvittata* was recorded from April to June, and the lowest in February and from July to

November. However, its population peak in 1998 was relatively flat. Analysis of the annual fluctuations showed that the mean catch was significantly higher in 1996 and 1997 with an average of 4.52 and 4.46 flies per trap, respectively, but with an average of only 1.66 flies per trap in 1998 (Fig. 1). A pooled average across the four areas indicated that the highest capture was 14.4, *Acroceratitis plumosa* population reached its peak from July to November. Its population fluctuations were synchronized with the harvest season of bamboo shoots (Fig. 1). Its population density in 1996 averaged 1.73 flies per trap, which was higher than those for all other years, with the highest average number 3.68 flies per trap in July 1996.

A large number of *Gastrozona fasciventris* were caught from April to August. However, from December to February, only a few individuals were captured. The annual population of *Gastrozona fasciventris* reached its peak in June from 1996 to 1998 (Fig. 1). The average population density was the highest in 1996, with an average of 1.31 flies per trap. The highest average number of this species was 4.0 flies per trap from June to July of 1996 and in July 1997, coinciding with the bamboo shoot production season.

The maximum capture of *Ptilona persimilis* occurred from June to November (Fig. 1). The highest average number was 0.75 flies per trap in August 1997. Its annual population density averaged 0.3 flies per trap in 1996 and 0.4 flies per trap in 1998. The population of *Euphranta chrysopila* maintained a high level from June to November with the highest number at 0.83 flies per trap in August 1998 (Fig. 1). In contrast to the higher population density of the former four predominant species found in Tachichiao and Sancherng, *Euphranta chrysopila* population density was higher in Changsansyh and Nankang.

Seasonal population fluctuations of *Bactrocera* in the four study areas are shown in Fig. 2. The highest number of

Bactrocera tau reached 10.58 flies per trap in Sancherng in January 1996. The average monthly population in the four areas peaked in January at 6.25 flies per trap. The annual population peaked from October to January 1997. We observed that this peak coincided with the sponge gourd production season in the Taipei area. It is interesting to note that, although the population density of *Bactrocera cucurbitae* was much lower than *Bactrocera tau* in this study, the seasonal fluctuations of both species were similar. The highest average number of *Bactrocera cucurbitae* was 0.57 flies per trap in January 1996. The population of *Bactrocera dorsalis* peaked from August to January, and very small numbers of this species were captured in the remaining months of the year. We found mature guava and citrus fruits available in the vicinity of bamboo stands from August to January. The highest numbers of *Bactrocera synnephes* caught were recorded from February to July; however, its population was at a low level from March to May in 1997. The highest average number of this fly was 0.14 flies per trap in June 1997 in Changsansyh.

Figure 3 shows the seasonal fluctuations of *Carpophthoracidia matsumotoi*, *Ptilona confinis*, *Euphranta sexsignata*, and *Spilocosmia punctata* in the study areas. The number of fruit flies trapped varied greatly with time and location in this study (Fig. 3). The highest numbers of *Carpophthoracidia matsumotoi* occurred from April to June. A total of 402 flies was captured, with most of them being trapped in Changsansyh. The highest average was 0.26 flies per trap in April 1997. *Ptilona confinis* peaked from July to November, with a total of 829 flies captured in the four study areas. The highest number was 0.79 flies per trap in August 1997 in Sancherng. *Euphranta sexsignata* was mostly trapped in Nankang, with a total of 873 flies captured in the four study areas. Its population peaked from July to October. 257 *Spilocosmia punctata* were caught in

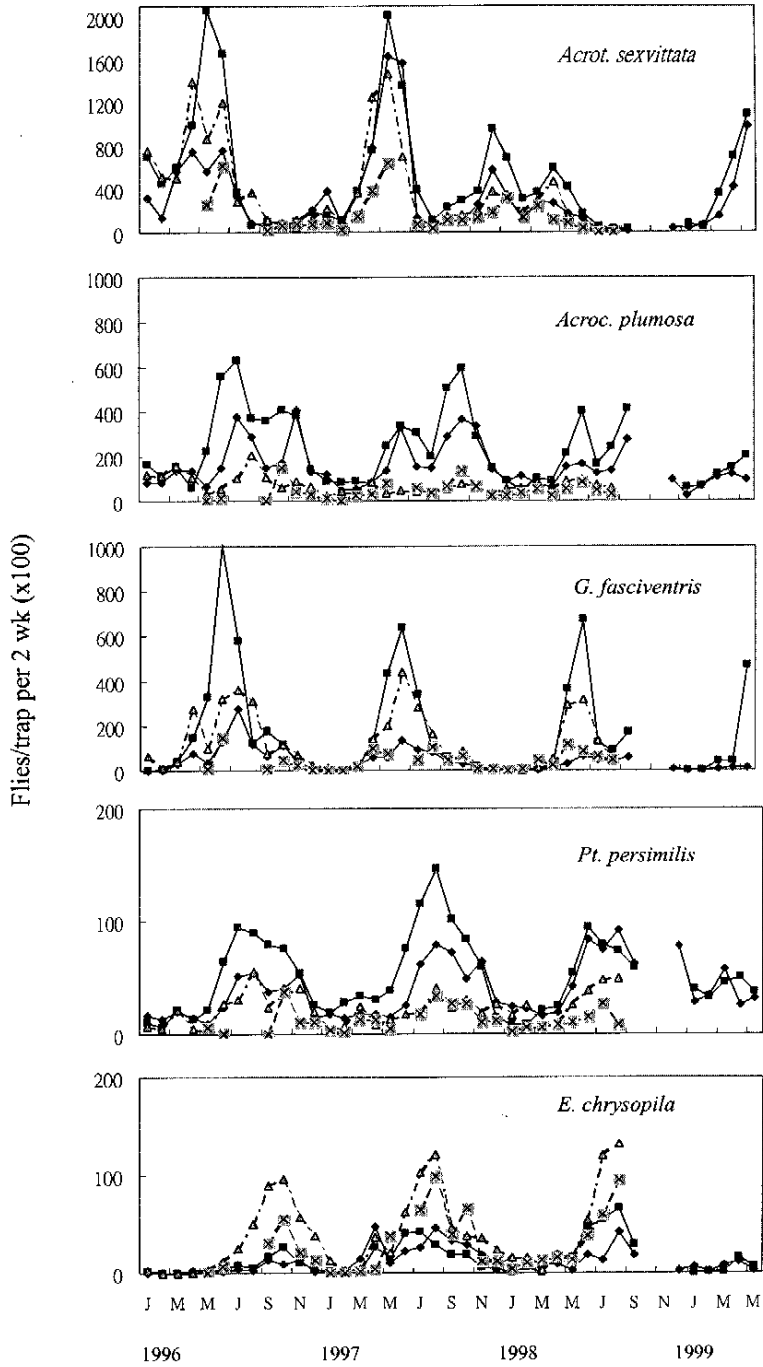


Fig. 1 Seasonal fluctuatinons of five predominant fruit flies in four bamboo cultivation areas in Taipei from January 1996 to May 1999. —◆— : Sancherg; —■— : Tachichiao; - -△- - : Changsansyh; - -×- - : Nankang.

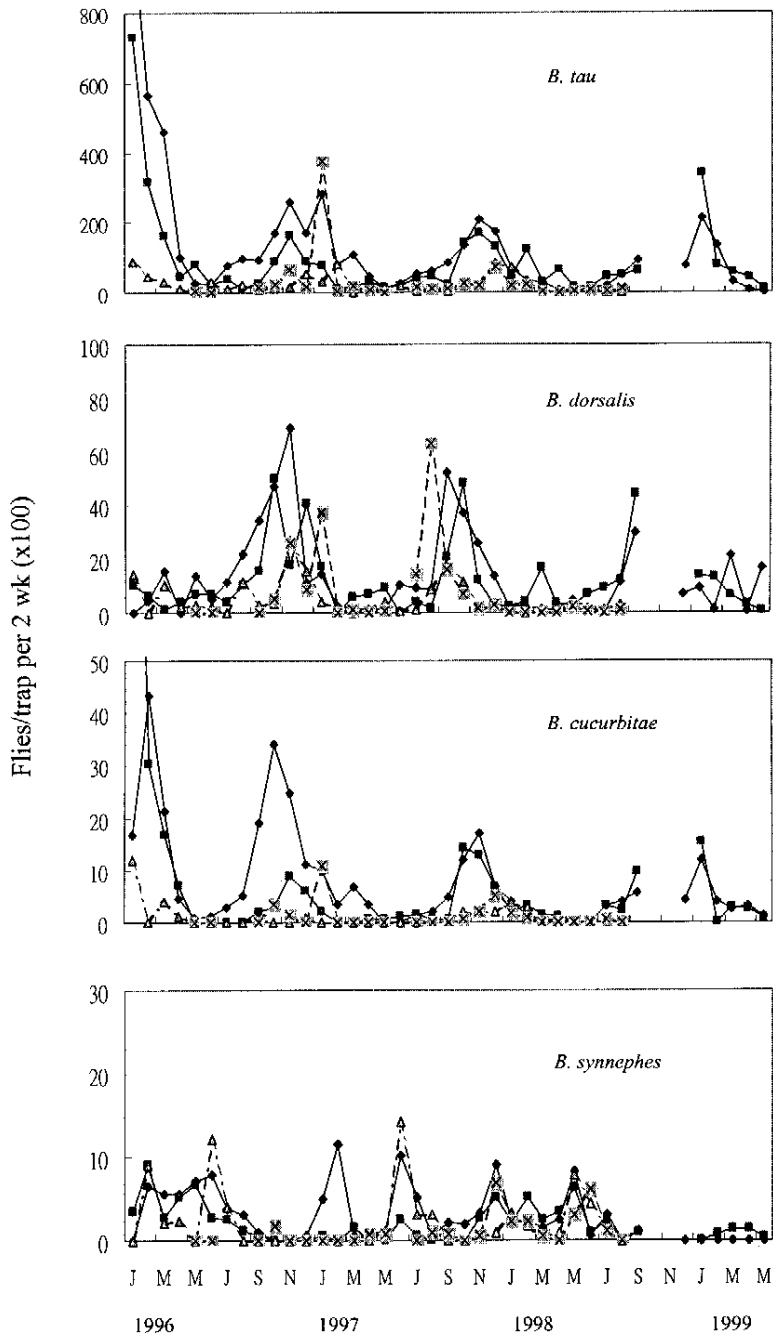


Fig. 2 Seasonal fluctuatinons of *Bactrocera* fruit flies in four bamboo cultivation areas in Taipei from January 1996 to May 1999. —◆— : Sancherg; —■— : Tachichiao; - - -△- - - : Changsansyh; - - -×- - - : Nankang.

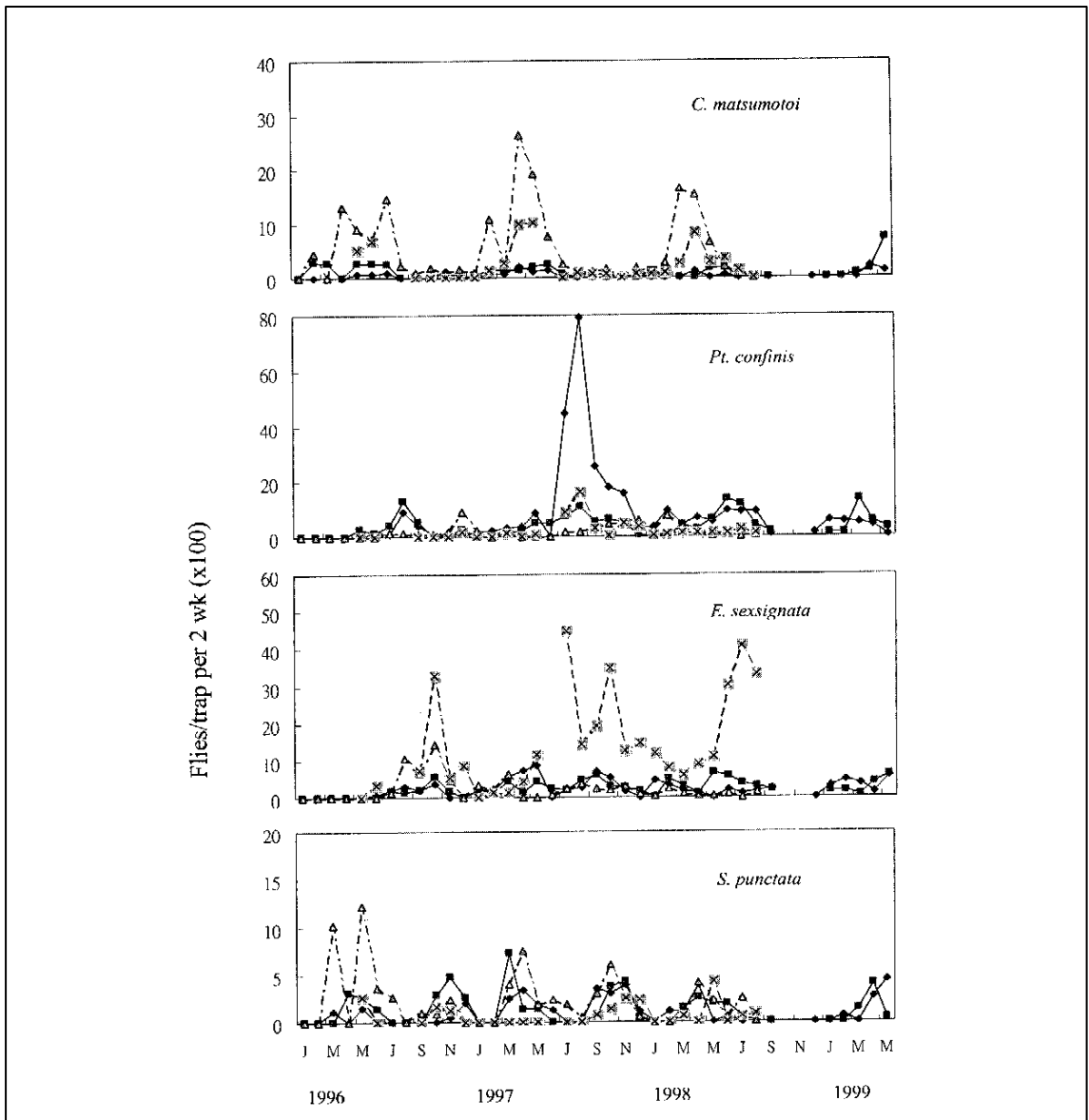


Fig. 3 Seasonal fluctuatinons of four predominant fruit flies in four bamboo cultivation areas in Taipei from January 1996 to May 1999. —●— : Sancherg; —■— : Tachichiao; - -▲- - : Changsansyh; - -×- - : Nankang.

the study areas, with the largest proportions captured from March to June and from October to December.

With respect to the remaining fruit flies, Table 3 presents the seasonal occurrences of 14 fruit flies per trap in May 1997. The *Acroceratitis* fly species captured in lesser numbers in the four study areas. In

Acanthonevrini, *Acanthonevra formosana* and *Acanthonevra speciosa* were trapped from April to May and the former had a peak from October to November. Only seven *Acanthonevra unicolor* individuals were captured from April to September. *Phorelliosoma hexachaeta* occurred only from December to the following April.

Table 3. Monthly capture of 14 fruit fly species in four bamboo stands in Taipei 1996-1998.

Species	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Acanthonevrini													
<i>Acanthonevra formosana</i>	0	0	0	8	6	5	0	1	3	7	6	1	37
<i>Acanthonevra speciosa</i>	1	8	5	12	15	3	1	0	3	5	4	5	62
<i>Acanthonevra unicolor</i>	0	0	0	2	1	1	1	1	1	0	0	0	7
<i>Phorelliosoma hexachaeta</i>	8	0	0	1	0	0	0	0	0	0	0	5	14
<i>Tritaeiopteron excellens</i>	0	0	0	11	53	18	1	1	0	0	0	0	84
Dacini													
<i>Bactrocera ferruginea</i>	1	2	0	1	0	0	2	15	1	1	3	1	27
<i>Bactrocera scutellata</i>	6	10	7	9	2	1	10	8	10	1	1	0	65
Adramini													
<i>Coleotrypes</i> sp.	5	1	2	0	2	3	0	1	0	0	2	2	18
<i>Euphranta apicalis</i>	10	8	10	1	2	4	2	0	1	12	14	19	83
<i>Euphranta jucunda</i>	2	2	1	6	0	0	0	0	0	1	2	1	15
Trypetini													
<i>Acidiella persimilis</i>	6	7	6	11	2	0	0	2	0	0	3	4	41
<i>Anomoia Formosana</i>	5	2	5	3	0	1	0	0	0	0	0	1	17
<i>Philophylla fossata</i>	18	8	4	1	1	0	2	6	14	22	6	10	92
<i>Fusculudia</i> sp.	9	0	1	0	0	0	0	0	0	0	1	2	13

Tritaeiopteron excellens only occurred from April to August, and its peak was in May. In Dacini, *Bactrocera ferruginea* was mostly caught in August, and *Bactrocera scutellata* was trapped mainly from January to April and from July to September. Totally 116 Adramini fruit flies were captured in the study areas. Among them, the populations of *Euphranta apicalis* and *Euphranta jucunda* were higher from October to the following March, but the peak of *Euphranta jucunda* occurred in April. *Coleotrypes* sp. was caught mainly in January and June. In Trypetini, *Acidiella persimilis* and *Anomoia formosana* were trapped from November to April. A relatively high population of *Philophylla fossata* was maintained from August to the following March. *Fusculudia* sp. occurred only from November to March.

If an average across all the study areas was calculated, a clear pattern showed that, on a regional basis, the population of the seven predominant species peaked from May to October. Among these species, the population of *Acrotaenostola sexvittata* peaked in May, and then it was followed by

Gastrozona fasciventris in June, *Ptilona persimilis* and *Euphranta sexsignata* in July, *Euphranta chrysopila* and *Ptilona confinis* in August, and *Acroceratitis plumosa* in October. Except for *Acroceratitis plumosa* in which males peaked 1 month earlier than its females, the males and females of the remaining species reached peaks at the same time. However, females outnumbered males during the months of high density. In *Acroceratitis plumosa*, females outnumbered males throughout the year.

Response of fruit flies to colored traps

From 1997 to 1998, 89,841 fruit flies were caught in 13,649 traps, consisting of 3,629 yellow, 3,352 green, 3,382 blue, and 3,286 white traps. Among these fruit flies, 45.33% were male and 54.67% were female. The number of trapped fruit flies was strongly affected by trap color. The percentages of fruit flies caught by yellow, green, blue, and white color traps were 49.83%, 30.84%, 9.82% and 9.50%, respectively. Yellow traps captured signi-

Table 4. Fruit flies captured by different-colored traps in four study areas 1997-1998

(Unit: flies/trap per 2 weeks)

Fly species	Yellow trap		Green trap		Blue trap		White trap	
	Male	Female	Male	Female	Male	Female	Male	Female
	Total		Total		Total		Total	
Gastrozonini								
<i>Acroceratitis plumosa</i>	0.6548*	1.3805	0.45129*	1.1752	0.11981*	0.3429	0.13167*	0.3246
	2.0353 ^a		1.6265 ^b		0.4627 ^c		0.4563 ^c	
<i>Acrotaeniostala sexvittata</i>	3.5913	3.7389	2.1327	2.1306	0.1356	0.1284	0.1387	0.1200
	7.3311 ^a		4.2632 ^b		0.2640 ^c		0.2586 ^c	
<i>Gastrozona fasciventris</i>	0.6807*	0.7451	0.4569	0.4731	0.2390	0.2552	0.2069	0.2207
	1.4258 ^a		0.9300 ^b		0.4942 ^c		0.4276 ^c	
<i>Spilocosmia punctata</i>	0.0072*	0.0145	0.0080*	0.0125	0.0024	0.0020	0.0023	0.0025
	0.0217 ^a		0.0205 ^a		0.0044 ^b		0.0048 ^b	
Dacini								
<i>Bactrocera cucurbitae</i>	0.0239*	0.0138	0.0189*	0.0113	0.0076	0.0044	0.0055	0.0038
	0.0377 ^a		0.0302 ^a		0.0120 ^b		0.0093 ^b	
<i>Bactrocera dorsalis</i>	0.0836*	0.0367	0.0499*	0.0227	0.0530*	0.0142	0.0385*	0.0149
	0.1203 ^a		0.0727 ^b		0.0672 ^b		0.0534 ^b	
<i>Bactrocera scutellata</i>	0.0037*	0.0003	0.0018	0.0005	0.0010*	0	0.0016	0
	0.0040 ^a		0.0023 ^{ab}		0.0010 ^b		0.0016 ^{ab}	
<i>Bactrocera synnephes</i>	0.0232	0.0168	0.0113	0.0084	0.00661*	0.0029	0.0127	0.0037
	0.0400 ^a		0.0197 ^b		0.0095 ^b		0.0164 ^b	
<i>Bactrocera tau</i>	0.4235	0.4076	0.3189	0.2965	0.1142*	0.0959	0.1124*	0.0814
	0.8311 ^a		0.6154 ^a		0.2101 ^b		0.1938 ^b	
Acanthonevrini								
<i>Acanthonevra formosana</i>	0.0005	0.0012	0.0005	0.0008	0.0003	0.0003	0.0009	0.0004
	0.0017 ^a		0.0013 ^a		0.0006 ^a		0.0013 ^a	
<i>Acanthonevra speciosa</i>	0.0006*	0.0036	0.0005*	0.0032	0.0007*	0.0024	0.0009	0.0024
	0.0042 ^a		0.0037 ^a		0.0031 ^a		0.0033 ^a	
<i>Ptilona confinis</i>	0.0207	0.0238	0.0315*	0.0427	0.0237	0.0261	0.0209	0.0278
	0.0445 ^b		0.0742 ^a		0.0498 ^a		0.0487 ^{ab}	
<i>Ptilona persimilis</i>	0.1554	0.1601	0.2086	0.2134	0.1312*	0.1519	0.1632	0.1564
	0.3155 ^b		0.4220 ^a		0.2831 ^b		0.3196 ^b	
<i>Tritaeiopteron excellens</i>	0.0035	0.0048	0.0012	0.0016	0.0016	0.0019	0.0014	0.0034
	0.0083 ^a		0.0028 ^a		0.0035 ^a		0.0048 ^a	
Adramini								
<i>Coleotrypes</i> sp.	0	0.0003	0	0.0009	0.0003*	0.0026	0	0.0003
	0.0003 ^b		0.0009 ^b		0.0029 ^a		0.0003 ^b	
<i>Euphranta chrysopila</i>	0.0119*	0.0187	0.0265*	0.0404	0.2110*	0.3121	0.2419*	0.3329
	0.0305 ^b		0.0669 ^b		0.5230 ^a		0.5747 ^a	
<i>Euphranta sexsignata</i>	0.0014	0.0012	0.0031	0.0024	0.0356*	0.0558	0.0491*	0.0871
	0.0026 ^c		0.0055 ^c		0.0914 ^b		0.1362 ^a	
<i>Euphranta jucunda</i>	0.0002	0.0003	0	0.0006	0.0005	0.0008	0.0008	0.0009
	0.0005 ^a		0.0006 ^a		0.0013 ^a		0.0017 ^a	
<i>Euphranta apicalis</i>	0.0024	0.0039	0.0012	0.0022	0.0018	0.0021	0.0020	0.0010
	0.0063 ^a		0.0034 ^a		0.0039 ^a		0.0030 ^a	
Trypetini								
<i>Acidella persimilis</i>	0.0003*	0.0051	0*	0.0021	0	0.0003	0.0006	0.0003
	0.0054 ^a		0.0021 ^b		0.0003 ^b		0.0009 ^b	
<i>Anomoia formosana</i>	0.0002*	0.0023	0	0.0002	0.0002	0.0007	0.0002	0
	0.0025 ^a		0.0002 ^b		0.0009 ^b		0.0002 ^b	
<i>Carpophthoracidia matsumotoi</i>	0.0059*	0.0485	0.0045*	0.0234	0*	0.0044	0.0007	0.0029
	0.0544 ^a		0.0279 ^b		0.0044 ^c		0.0036 ^c	
<i>Fusculudia</i> sp.	0.0003*	0.0019	0.0004	0.0008	0	0	0	0
	0.0022 ^a		0.0012 ^{ab}		0 ^b		0 ^b	
<i>Philophylla fossata</i>	0.0019	0.0039	0.0018	0.0030	0.0006	0.0014	0.0013	0.0012
	0.0058 ^a		0.0048 ^{ab}		0.0020 ^b		0.0025 ^b	

* Designates that fruit flies captured significantly differed between sexes by paired *t*-test. Means in the same row followed by the same letter do not significantly differ from each other at the 5% level by LSD.

ificantly more Gastrozonini, Dacini, and most of the Trypetini fruit flies than did any of the other colored traps. This was followed in order by green, blue, and white traps (Table 4).

In Gastrozonini, most of *Acroceratitis plumosa*, *Acrotaeniostola sexvittata*, and *Gastrozona fasciventris* were attracted to yellow traps. However, yellow traps and green traps were equally attractive to *Spilocosmia punctata* (Table 4). There was no significant difference in the color preference between males and females; however, significantly more females of *Acroceratitis plumosa*, *Gastrozona fasciventris*, and *Spilocosmia punctata* were caught than males. The numbers of flies captured by blue and white traps were significantly less than those by yellow and green traps.

In Dacini, yellow traps caught significantly more *Bactrocera dorsalis* and *Bactrocera synnephes* than did other colored traps (Table 4). *Bactrocera cucurbitae*, *Bactrocera scutellata*, and *Bactrocera tau* responded more favorably to yellow and green traps. However, about 23.6% of *Bactrocera dorsalis* males were trapped on blue traps, and 23.6% of *Bactrocera synnephes* males were trapped on white traps, indicating that more male flies were attracted to the objects with high light intensity such as blue and white traps. Significantly more males than females of *Bactrocera cucurbitae*, *Bactrocera dorsalis*, and *Bactrocera scutellata* were caught on yellow traps.

In Acanthonevrini, *Acanthonevra formosana*, *Acanthonevra speciosa*, and *Tritaeiopteron excellens* were equally attracted by the four different-colored traps (Table 4). Although more *Ptilona persimilis* were caught on green traps, green, blue, and white traps were equally attractive to *Ptilona confinis*. More females than males of *Ptilona confinis* were caught on green traps. In Adramini, *Coleotrypes* sp. was most attracted to blue traps, *Euphranta chrysopila* to blue and white traps, and

Euphranta sexsignata to white traps. Moreover, significantly more females than males of these flies were trapped (Table 4). The numbers of these flies captured on yellow and green traps were significantly less than those on blue and white traps. In contrast, *Euphranta apicals* and *Euphranta jucunda* were equally attracted to the four different-colored traps.

In Trypetini, all five predominant trypetines were most attracted to yellow traps, followed by green, blue, and white traps (Table 4). More females than males of *Acidiella persimilis*, *Anomoia formosana*, *Carpophthoracidia matsumotoi*, and *Fusciludia* sp. were caught by yellow traps.

Discussion

Of the five subfamilies of Tephritidae caught by colored traps in bamboo cultivation areas in Taipei, *Acrotaeniostola sexvittata*, *Acroceratitis plumosa*, and *Gastrozona fasciventris* of Gastrozonini, *Ptilona persimilis*, *Ptilona confinis*, and *Acanthonevra formosana* of Acanthonevrini, and *Euphranta chrysopila* and *Euphranta sexsignata* of Adramini were the major species associated with bamboo (Table 2). Although 62 tephritid species were present in the study areas, six species accounted for more than 85% of all flies captured on traps (Table 2). Of these, *Acrotaeniostola sexvittata*, *Acroceratitis plumosa*, and *Gastrozona fasciventris* of Gastrozonini were by far the most preponderant species in bamboo stands in Taipei. This finding is consistent with studies conducted in Costa Rica, Brazil, and Mexico on *Anastrepha*, showing that a few fly species were captured in a consistently high proportion irrespective of the number of species present in the orchard (Aluja, 1994; Aluja *et al.*, 1996).

Annual analysis of fly populations shows that the fluctuations of most species of the Gastrozonini and some of the Adramini, whose larvae are known as bamboo shoot feeders, coincided with bamboo shoot

harvest seasons (Figs. 1 and 3). Our study showed that population densities of the 13 preponderant species varied sharply from bamboo stands in the four bamboo cultivation areas (Figs. 1-3). We believe that this results from the differences in the habitats surrounding the bamboo stands and their management. In bamboo stands surrounded by diverse eco- or agroecosystems, fly populations were greater and more diverse. In addition, management practices in the bamboo stands also greatly influenced the number of captured flies. We observed that pruning in the bamboo stands, mainly from January to March, significantly affected trap catches, because such practice decreased the bamboo canopy for shelters or resting. However, populations of bamboo shoot flies did not distinctively decrease, because the decaying cut bamboo placed in the vicinity of the bamboo stands also provided food for the larval development of these flies.

Species diversity varied in the four study areas. According to the Simpson-Yule index, there was a 1.32-fold difference in species diversity between Nankang and Changsansyh; however, the indices in Tachichiao and Sancherng were very similar (Table 2). Aluja (1994) stated that the degree of species dominance of *Anastrepha* was influenced by the ecological background and elevational gradients. Although the vertical distribution of green bamboo and Makino's bamboo were extend to 1,000 and 1,500 m above sea level, respectively, the elevation of the survey areas in our study ranged only from 85 to 180 m above sea level in Sancherng and Tachichiao, and 150 to 320 m above sea level in Changsansyh and Nankang. Our data suggest that the mean population density of fruit flies was higher in lower-elevation areas; however, the species diversity was higher in Nankang where the fruit fly population was the lowest.

The abundance of the host of larvae is one of the major factors regulating *Bactrocera* and *Anastrepha* populations

(Fletcher, 1987; Jiron and Hedstrom, 1991). Chen *et al.* (1996) reported that the *Bactrocera dorsalis* population density was highly correlated with the yield indicator of both guava and seasonal fruits with a 1- to 2-month time lag between them. In this study, we found that bamboo shoots may be a major factor regulating Gastrozonini populations. The odor of susceptible bamboo stems or shoots after cutting served as a specific stimulus to attract both males and females of *Acroceratitis plumosa* and *Gastrozona fasciventris*, but with a higher proportion of females. Therefore, a cut bamboo stem or shoot appears to play a role in host recognition in these flies. Hancock and Drew (1999) reported that all Asian Ceratitidine genera with species known to breed in bamboo shoots are attracted to cut bamboo shoots in the field. Since no species with a known non-bamboo host was attracted to cut bamboo, this habit appears to be a reliable indicator of host preference.

The Gastrozonini fruit fly populations were lowest at the end of winter. This may be due to the slowdown of breeding or egg laying of some species, which would not mature in the absence of hosts. However, the presence of hosts in early spring appears to strongly induce females to start heavily laying eggs. Interestingly, despite the large number of fruit fly species captured on the traps, none of these species presents a potential threat to bamboo plants. We observed that during the period when large numbers of *Acroceratitis plumosa* and *Gastrozona fasciventris* were captured on traps, infestation of cut bamboo or bamboo shoots by these two species was high. However, there was no threat to bamboo shoots after harvest because bamboo shoots are regularly harvested in the early morning in Taiwan.

Although *Bactrocera* and trypetines were also found to be associated with bamboo stands, their seasonal fluctuation patterns were not synchronized with the phenology of bamboo shoot production. We also observed that none of them was

attracted to cut bamboo shoots in the field. Hwang *et al.* (1997) in a 3-year survey of *Bactrocera dorsalis* reported an annual decrease of the population during winter, with a population peak from June to September. On the contrary, the highest numbers of *Bactrocera dorsalis* were recorded from September to February in 1995 and from September to December in 1996 in Taipei. Since the population fluctuation patterns of *Bactrocera dorsalis* in this study were similar to those reported by Hwang *et al.* (1997), we conclude that *Bactrocera dorsalis* and other *Bactrocera* species move into bamboo stands from nearby orchards where they forage for honeydew, rest, or find shelter from the late autumn to winter.

Tephritidae has been grouped into three categories based on their trophic strategies (Zwölfer, 1983). Category I includes polyphagous fruit-infesting species, and category II includes specific fruit-infesting species. Nonfrugivorous tephritines belong to category III. A previous review of the biology of nonfrugivorous tephritid fruit flies indicated that the majority of nonfrugivorous species studied are aggregative and display a variety of mating strategies, including resource defense and paternal assurance strategies (Headrick and Goeden, 1998). Since this review targeted only Tephritinae fruit flies, most of these fruit flies are known to use vegetative parts of a host or flower head as larval food, and many of them form galls in and on these plant structures.

Our studies showed that the seasonal occurrence of bamboo shoot fruit flies varied widely. For example, the population of *Acrotaeniostola sexvittata* peaked from April to June, and that of *Gastrozona fastriventris* from April to August, while very few of them were caught during the rest of the year. Relatively high proportions of *Acroceratitis plumosa*, *Ptilona persimilis*, and *Euphranta chrysopila* were maintained in June and from July to November. We conclude that a combination of selection

pressures from interspecific interactions, such as a type of synchronization with the abundance or development of host plants, occurred in these nonfrugivorous tephritids in nature. Moreover, the trophic strategies of bamboo shoot fruit flies are much more diverse than those of other category III tephritines, which prefer non-bamboo hosts.

Although 24 species of Trypetini were trapped in the survey, none of them is so far considered a bamboo feeder. Most of these rare fruit fly species were captured on traps placed at the periphery of bamboo stands or at the top layer of the foliage canopy. This implies that most flies captured in bamboo stands were migrating from neighboring vegetation into the bamboo stands. During the study, several of the fruit fly species, such as *Phorelliosoma hexachaeta*, *Fusculudia* sp., *Acidiella longipennis*, and *Acidiella sonani*, occurred only in winter. Some of these species could be found in higher mountain areas at elevations over 1,500 m. Therefore, we believed that these species migrated from mountain areas to the study areas for overwintering.

Many reports have shown that yellow is the most attractive color to adults of many genera of frugivorous fruit flies, such as *Anastrepha*, *Bactrocera*, *Ceratitis*, and *Rhagoletis*, which are serious pests of fruit crops in temperate and tropical areas (Economopoulos, 1989; Katsoyannos, 1989; Robacker and Moreno, 1990). Our data on *Bactrocera* showed similar results. Moreover, many genera of Gastrozonini and Trypetini, such as *Acrotaeniostola*, *Acroceratitis*, *Gastrozona*, *Carpophthoracidia*, *Acidiella*, and *Anomoia*, were also most attracted to yellow traps. However, green and yellow traps captured significantly more *Spilocosmia punctata*, *Philophylla*, and *Fusculudia* (Table 4). This result shows that the color preferences of these species are similar to those of *Anastrepha ludens* as reported by Robacker and Moreno (1990). Therefore, we conclude that the color preferences of nonfrugivorous fruit flies are the same as those of

frugivorous fruit flies. There was no significant difference in the catches of three species of Ancanthonevrini and two species of Adramini fruit flies by four different-colored traps. Since the catch of each of these flies was less than 85 flies in the study, we consider that additional studies are needed to clarify their real color preference in nature.

Chen (1997) observed that the yellow trap caught more *Bactrocera dorsalis* males than females when fewer guava fruits on the trees in winter. Our data showed a similar result. Significantly more males than females of *Bactrocera dorsalis*, *Bactrocera cucurbitae*, *Bactrocera synnephes*, and *Bactrocera scutellata* were caught in bamboo stands (Table 4). Vargas *et al.* (1991) reported that the high number of *Bactrocera dorsalis* captured on white spheres might also be an indicator of the attractiveness of certain objects such as fruits and flowers to *Bactrocera dorsalis* under natural conditions. In our study, the majority of individuals of the species, *Euphranta chrysopila*, *Euphranta sexsignata*, and *Coleotrypes* sp. of Adramini, were attracted to blue or white traps, indicating that these flies were more attracted to objects with high light intensity. Further research on the behavior of *Euphranta* spp. is needed to clarify if the color preference for their oviposition is the same as that of *Ceratitis capitata*.

It is evident that frugivorous fruit flies are attracted to colors. Results of this study support the usefulness of colored traps as a monitoring tool for non-frugivorous fruit flies. The effectiveness of these devices can be enhanced if they are used in combinations of yellow or green color traps with white or blue traps.

Acknowledgements

We gratefully acknowledge Chiou-Nan Chen, and Shwu-Bin Horng, Department of Entomology, National Taiwan University, Po-Yung Lai, Institute of Tropical

Agriculture, National Pingtung Univ. of Science and Technology, and Yi-Hsiung Tseng, Kaohsiung Branch, Bureau of Standards, Meteorology and Inspection, Ministry of Economic Affairs for their valuable suggestions on the interpretation of data and comments on an early version of this manuscript. The authors also thank Kun-Yaw Ho, Department of Plant Protection, Chiayi Experimental Station, Taiwan Agriculture Research Institute, and Shi-Wui Lo, Wen-I Chou, and Ya-Chun Hsu, Department of Entomology, National Taiwan Univ. for their assistance in the survey and data analysis. This research was supported by funds from the Council of Agriculture and Bureau of Animal and Plant Health Inspection and Quarantine, COA in 1995-1999.

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Received Nov. 16, 2000

Accepted. Dec. 23, 2000

台北竹林果實蠅(雙翅目：果實蠅科)種類多樣性及其季節變動

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摘 要

自 1996 年 1 月至 1999 年 5 月於台北地區四個竹筍栽培區，利用 4 種顏色的黏紙定期調查所發生之果實蠅種類。共捕獲 136,160 隻，62 種果實蠅，分屬於 5 個亞科：蠟實蠅亞科 5 種，植實蠅亞科 8 種，紋翅實蠅亞科 33 種，寡毛實蠅亞科 11 種，斑翅實蠅亞科 5 種。其中 *Carpophthoracidia matsumotoi* Shiraki 為新紀錄種。本文亦描述其中 27 種果實蠅之年度發生消長情形。在 4 個調查區所發生的果實蠅種類相近，但各種類所佔組成比例略有差異，其中 6 種優勢種的果實蠅佔所有捕獲蟲數的 89.97 至 96.87%。優勢種中的六條實蠅(*Acrotaeniostola sexvittata* Hendel)，黃斑實蠅(*Acroceratitis plumosa* Hendel)，腹帶實蠅(*Gastrozona fasciventris* (Macquart))，寬帶實蠅(*Euphranta chrysopila* Hendel)及黑翅實蠅(*Ptilona persimilis* Hendel)主要發生於竹林地區，其族群發生量在 4 個地區及調查點間差異很大。然而其週年發生之高峰期與竹筍產期一致，顯然竹筍之有無為影響竹筍果實蠅族群變動之主要因子。調查資料亦顯示，黃色黏紙對大多數的果實蠅最具引誘力，其次為綠色、藍色及白色；藍色及白色對優阜實蠅屬(*Euphranta*)的種類尤具引誘力。本試驗結果證實利用黏紙可作為非食果類果實蠅監測之工具，且如能並用黃、綠色及藍、白色黏紙則更可提高其效率。

關鍵詞：果實蠅科、竹林、種類多樣性、季節變動、顏色誘器。

