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Pollinators and Their Behaviors on Mango Flowers in Southern Taiwan【Research report】

台灣南部地區的檬果授粉昆蟲與其行為【研究報告】

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Abstract

One hundred and twenty-six individual insects belonging to 39 species in 23 families and five orders were recorded as a visitor or pollinator on mango flowers from February 13 to March 17, 2005 in southern Taiwan. Most of these insects belonged to the Diptera and Hymenoptera. The former contained 15 species and accounted for 42.0% of the number of collected individuals, while the latter contained 14 species accounting for 39.7%. Major pollinators included honeybees (Apis cerana and A. mellifera) and an allodapine bee (Braunsapis hewitti) of the Apidae and sweat bees (Halictus sp. and Lassioglossum spp.) of the Halictidae among the Hymenoptera, and Chrysomya megacephala, Ch. pinguis, and Musca domestica of the Diptera, which were considered to be the dominant species due to their frequent appearance. Some other insects were also commonly seen such as Cantharis sp. and Menochilus sexmaculatus of the Coleoptera, and Idioscopus spp. of the Hemiptera. The sex ratio was biased to females (69.1%), probably because of their needs for both pollen and nectar which are used for brood rearing. The number of flower-visiting pollinators per hour was on average 12.9 (range, 1-35) individuals/h, suggesting that pollinators of mangos are insufficient in the area investigated. On each visited flower, bees usually spent a shorter time than did Oriental latrine flies (Chrysomya) and soldier beetles
(Cantharis), and soon moved on to a neighboring flower. Judging from the behavioral characteristics of these pollinators, honeybees and sweat bees, and the Oriental latrine fly seem to be more effective for this purpose than others, and are recommended to be utilized in pollination programs for mangos in Taiwan.

摘要

本研究於2005年2月13日至3月17日調查台灣南部檬果的訪花及授粉昆蟲種類，結果收集之昆蟲共計5目23科39種126隻，其中授粉昆蟲以雙翅目與膜翅目為主。雙翅目有15種，佔42.0%；膜翅目14種，佔39.7%。重要的計有膜翅目東洋蜜蜂 (Apis cerana)、西洋蜜蜂 (A. mellifera)、何威布朗蜂 (Braunspis hewitti)、二種隧蜂 (Halictus sp. 及 Lassioglossum sp.)；雙翅目大頭金蠅 (Chrysomya megacephala)、一種麗蠅 (Ch. pinguis) 及家蠅 (Musca domestica)。所收集授粉昆蟲中，雌性佔多數，有69.1%，因其需要採集花粉與花蜜，以補充育幼所需之資源。每一小時訪花之昆蟲為1～35隻、平均12.9隻，顯示調查區域缺乏足夠之訪花昆蟲。蜜蜂類停留於每一朵小花上之時間比麗蠅及菊虎為短，不久便飛行至鄰近的花上。另比較訪花行為特徵，其中以蜜蜂、隧蜂及麗蠅類在檬果花授粉功能似乎較其他昆蟲為佳，因此建議利用此等昆蟲於檬果授粉上。

Key words: mango, pollinator, visiting insect, bee, behavior
關鍵詞: 檬果、授粉者、訪花昆蟲、蜜蜂、行為

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ABSTRACT

One hundred and twenty-six individual insects belonging to 39 species in 23 families and five orders were recorded as a visitor or pollinator on mango flowers from February 13 to March 17, 2005 in southern Taiwan. Most of these insects belonged to the Diptera and Hymenoptera. The former contained 15 species and accounted for 42.0% of the number of collected individuals, while the latter contained 14 species accounting for 39.7%. Major pollinators included honeybees (*Apis cerana* and *A. mellifera*) and an allodapine bee (*Braunsapis hewitti*) of the Apidae and sweat bees (*Halictus* sp. and *Lassioglossum* spp.) of the Halictidae among the Hymenoptera, and *Chrysomya megacephala*, *Ch. pinguis*, and *Musca domestica* of the Diptera, which were considered to be the dominant species due to their frequent appearance. Some other insects were also commonly seen such as *Cantharis* sp. and *Menochilus sexmaculatus* of the Coleoptera, and *Idioscopus* spp. of the Hemiptera. The sex ratio was biased to females (69.1%), probably because of their needs for both pollen and nectar which are used for brood rearing. The number of flower-visiting pollinators per hour was on average 12.9 (range, 1-35) individuals/h, suggesting that pollinators of mangos are insufficient in the area investigated. On each visited flower, bees usually spent a shorter time than did Oriental latrine flies (*Chrysomya*) and soldier beetles (*Cantharis*), and soon moved on to a neighboring flower. Judging from the behavioral characteristics of these pollinators, honeybees and sweat bees, and the Oriental latrine fly seem to be more effective for this purpose than others, and are recommended to be utilized in pollination programs for mangos in Taiwan.

Key words: mango, pollinator, visiting insect, bee, behavior

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Introduction

The mango, *Mangifera indica* Linnaeus is an important fruit in Taiwan. It was introduced to Taiwan by the Dutch during the colonial period of the 16th century (Yang, 1959). It is widely cultivated in low-elevation areas of the southern counties, especially in Tainan, Kaohsiung and Pingtung Counties (Yang, 1959; Lieu, 1999). The fruit production in these three counties reached 206,295 tons, which was 93.6% of the total production for Taiwan in 2003 (COA, 2004). During the past centuries, more than 70 varieties of mango have been introduced from foreign countries and these have been hybridized to create better varieties. However, only nine varieties, such as Irwin, Jinhwung No. 1, Tainong No. 1, and Tsai-Swain, are grown by farmers as they have a high commercial value (Lieu, 1999; Shu *et al*., 2000).

Although some varieties of this plant are self-pollinated, adequate pollinators are needed for pollen transfer to increase fruit set (Popenoe, 1917; Singh, 1954; Free and Williams, 1976). The kinds and biology of pollinators of mangos have been studied in India and Israel, and their results demonstrated that insects of the Diptera and Hymenoptera play major roles in pollinating of this fruit (Singh, 1988; Bhatia *et al*., 1995; Singh, 1997; Dag and Gazit, 2000). In Taiwan, there is a pollination program of mass-rearing and releasing the Oriental latrine fly, *Chrysomya megacephala* (Fabricius), in mango fields. This certainly increased the production of fruit; however, this method seems to have several disadvantages from the point of environmental conservation (Wu and Lin, 1994; Chen and Chen, 1997; Hung, 1997). Free and Williams (1976) stated that mango flowers are inadequate as pollen resources, and honeybees are attracted to other flowers nearby. Many other authors have, however, considered several hymenopteran species to be suitable for pollination of mangos (DuToit, 1994; Jyothi, 1994; Manning, 1995; Gibbs and Muirhead, 1998).

This paper aims to clarify what kinds of insects visit mango flowers and are their pollinators in southern Taiwan. Foraging behaviors of some selected insects were also observed on mango flowers.

Materials and Methods

Collection and identification of insects

The following nine localities were chosen for the collection of insects on mango flowers in the field from February 13 to March 17, 2005 (Fig. 1): Abachuan and Chiayinungchang (Chiayi County) on March 7 and 8; Nanshi, Danei, Doulioushan and Yujing (Tainan County) on February 24, 15, 13 and 16, respectively; Shinhua (the former Shinhua Branch Station of the Tainan District Agricultural Research and Extension Station, Tainan County), two times on March 2 and 17; Liouguei (Kaohsiung) on March 14; and Fangshan (Pingtung County) on February 27. Insects were collected using an insect net with a 2-m-long rod. Each collection was made for 60 min between 09:00 and 13:00. The starting time depended on the distance to the chosen site. We ignored very small insects and animals, such as thrips, mites and other minute arthropods. Furthermore, we assumed that the kinds of pollinators did not differ among different varieties of mango. Collected insects were mostly identified to family, while some were identified to genus and species when possible.

Observation of behavioral characteristics

Foraging behaviors of two honeybees (*Apis cerana* Fabricius and *A. mellifera* Linnaeus), a sweat bee (*Lasioglossum* sp.), an Oriental latrine fly (*Ch. megacephala*) and a soldier beetle (*Cantharis* sp.) were observed on mango flowers for 3 h from 09:00 on March 8 and 17, 2005 at

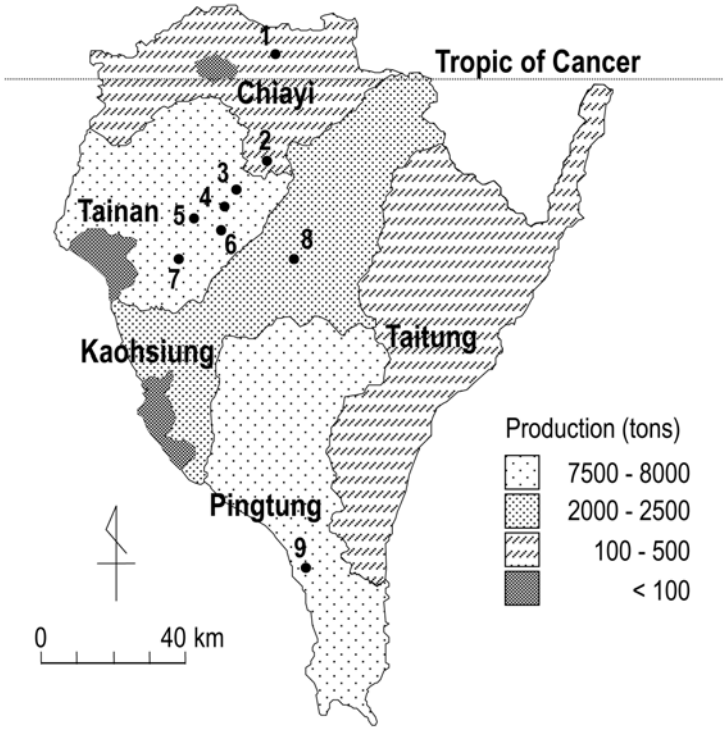

Fig. 1. Collection localities of insect visitors to mango flowers in Chiayi, Tainan, Kaohsiung and Pingtung Counties of southern Taiwan. The shading for each county indicates the amount of mango production in 2003. Surveyed localities were: 1, Abachuan (400 m in elevation); 2, Chiayinungchang (350 m); 3, Nanshi (200 m); 4, Danei (50 m); 5, Doulioushan (150 m); 6, Yujing (100 m); 7, Shinhua (100 m); 8, Liouguei (250 m); 9, Fangshan (50 m).

Shinhua. The length of time each insect remained on a flower was measured, and its behaviors were recorded. Descriptive and non-parametric statistical analyses were carried out using SPSS vers. 8.0.

Results

Species and numbers of visiting insects

In total, 126 insects were collected, belonging to 39 species in 23 families and five orders (Table 1). In all the collection localities except Abachuan and Yujing, collected insects belonged to more than two orders. The major insect groups were the Diptera and Hymenoptera (Table 1, Fig. 2). If specimens collected at all nine sites are combined, the Diptera was the largest group consisting of 53 individuals (24 females and 29 males, accounting for 42.0% of all collected insects) in 15 species. The Hymenoptera was the second largest group, consisting of 50 individuals (40 females and 10 males, accounting for 39.7% of the total) in 14 species. Pollen lumps were examined on the hind legs of apid and halictid bees. Four *A. cerana* (Asian honeybee) workers were not carring pollen, and two workers had small lumps of pollen on the corbicula. Thirteen *A. mellifera* (Western honeybee) workers had no pollen, but four had a little. *Braunsapis hewitti* (Cameron) was not carring pollen (n = 2) or only a little (n = 1), while the scopa of four of five

Table 1. Species and numbers of insects collected on mango flowers in 2005 at nine localities in three southern counties of Taiwan

Order/Family	Genus	Species	No. of individuals[1)]	Locality[2)]
Coleoptera				
Cantharidae	*Cantharis*	sp.	3 (0)	7
Coccinellidae	*Menochilus*	*sexmaculatus* (Fabricius)	2 (0)	7, 8
Dascillidae ?		sp.	1 (0)	7
Diptera				
Calliphoridae	*Chrysomya*	*megacephala* (Fabricius)	3 (5)	3, 5, 9
		pinguis (Walker)	1 (2)	4, 7
	Lucilia	*caesar* (Linnaeus)	1 (0)	7
Culicidae		sp.	1 (0)	7
Lonchaeidae		sp.	2 (7)	2, 4, 7
Muscidae	*Musca*	*domestica* Linnaeus	8 (12)	9
		sp.	1 (0)	3
Sarcophagidae		sp. 1	2 (0)	4
		sp. 2	1 (0)	7
Syrphidae	*Episyrphus*	sp. 1	1 (0)	3
		sp. 2	0 (1)	7
		sp. 3	0 (2)	7
		sp. 4	1 (0)	7
		sp. 5	1 (0)	4
Tachinidae		sp.	1 (0)	8
Hemiptera				
Cicadellidae	*Idioscopus*	*niveosparsus* (Lethierry)	7 (0)	3, 7, 8
		clypealis (Lethierry)	5 (0)	3, 7
Lygaeidae	*Graptostethus*	*servus* Fabricius	1 (0)	7
Piesmatidae	*Piesma*	sp.	1 (0)	3
Plataspidae	*Megacopta*	*cribraria* (Fabricius)	1 (0)	4
Hymenoptera				
Apidae	*Apis*	*cerana* Fabricius	6 (0)	5, 7, 8
		mellifera Linnaeus	17 (0)	2 - 5, 7, 9
	Braunsapis	*hewitti* (Cameron)	3 (0)	6
Braconidae ?		sp.	1 (0)	6
Chalcididae		sp. 1	1 (0)	7
		sp. 2	1 (0)	7
Crabronidae	*Rhopalum*	*bohartorum* Tsuneki	1 (0)	6
Formicidae	*Anoplolepis*	*longipes* (Jerdon)	1 (0)	8
Halictidae	*Halictus*	sp. 1	1 (0)	8
		sp. 2	1 (0)	1
		sp. 3	0 (10)	2, 3, 6 - 8
	Lassioglossum (Ctenonomia)	sp. 1 (in *albescens* group, Sakagami, 1989)	5 (0)	6, 7
Sphecidae ?		sp.	1 (0)	6
Tenthredinidae		sp.	1 (0)	3
Lepidoptera				
Ctenuchidae	*Amata*	*fortunei matsumurai* (Sonan)	1 (0)	3
		perixanthia (Hampson)	1 (0)	7
Total		39 species	87 (39)	

[1)] Numbers of individuals shown are of females, with numbers of males in parentheses.

[2)] 1, Abachuan; 2, Chiayinungchang; 3, Nanshi; 4, Danei; 5, Doulioushan; 6, Yujing; 7, Shinhua; 8, Liouguei; 9, Fangshan.

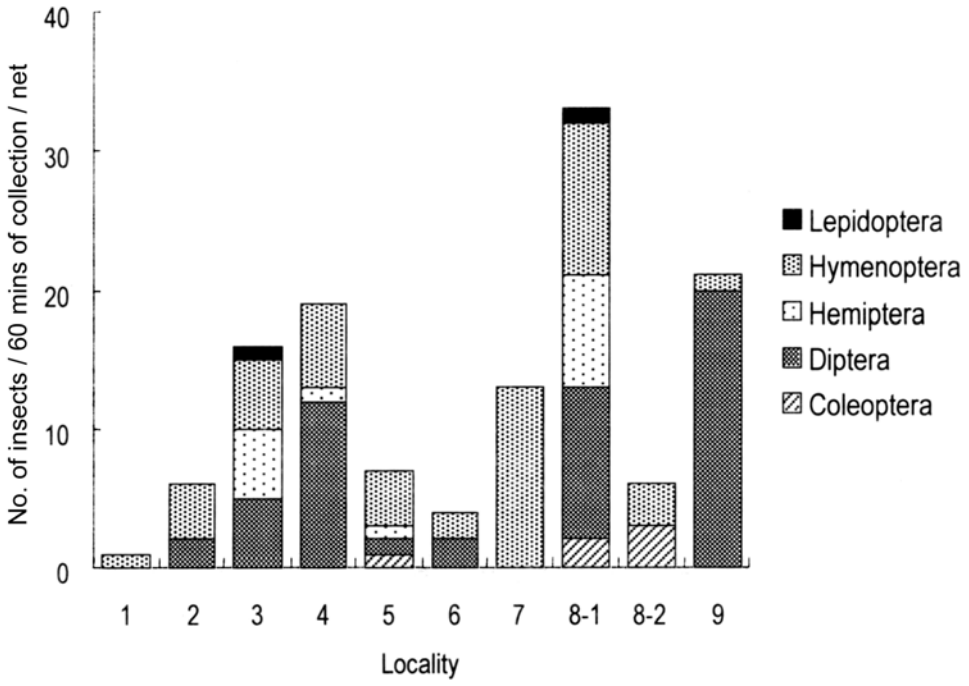

Fig. 2. Number of insects in different orders collected on mango flowers at nine localities in southern Taiwan.

bees of *Lasioglossum* spp. was full of pollen on the hind femurs. The Coleoptera consisted of six females (4.8%) in three species. The Hemiptera consisted of 15 females (11.9%) in five species, and among them, *Idioscopus niveosparsus* (Lethierry) and *I. clypealis* (Lethierry) are regarded as major pests of mango during the flowering season. Only 1.6% of insects belonged to the Lepidoptera, e.g., *Amata fortunei matsumurai* (Sonan) and *Am. perixanthia* (Hampson).

Female individuals accounted for nearly 70% of the total insects collected on all surveys, and this shows that more females are attracted to mango flowers than are males. Among all species, *A. mellifera* and *Halictus* sp. 3 were collected in more localities than the others (Table 1, Fig. 2). The number of visiting insects increased after 10:00, and at that time most of the flowers had opened and the air temperature was sufficiently high for insect activity.

Behavioral characteristics

First, a single visit to a given flower was examined (Table 2). Although statistically insignificant, it tended to be short in the two honeybees (4.5 ± 2.9 s in *A. cerana*; 3.9 ± 2.2 s in *A. mellifera*), longer in *Lasioglossum* sp. (7.9 ± 7.0 s), and much longer (› 12 s) in *Cantharis* sp. and *Ch. megacephala*.

Next, foraging behaviors of each insect were documented. Landing on a target flower, honeybees of both *A. cerana* and *A. mellifera* extended their tongues to suck nectar secreted near the ovary of the flower. The ventral side of their body touching the anthers was clearly seen. They did not stay in a fixed position but frequently turned while sucking nectar along the dome-shaped

Table 2. Time (in seconds) which insect visitors remained on individual mango flowers

Species of insect (code)	Mean time ± SD of visit, (range, sample size)	Significance
Apis cerana (AC)	4.5 ± 2.9 (1-13, 61)	
Apis mellifera (AM)	3.9 ± 2.2 (2-9, 37)	AC vs. AM, CM vs. Cs, Cs vs. Ls (non-significant)[1], AC < Cs ($p < 0.01$) [1], AC < Ls < CM ($p < 0.001$)[2], AM < Ls < CM ($p < 0.001$) [2]
Lassioglossum sp. (Ls)	7.9 ± 7.0 (2-36, 37)	
Chrysomya megacephala (CM)	12.3 ± 11.4 (3-51, 38)	
Cantharis sp. (Cs)	15.3 ± 14.2 (3-42, 9)	

[1] Mann-Whitney *U*-test for two independent samples.

[2] Kruskal-Wallis *H* test for three independent samples.

ovary. No pollen lumps were observed on the corbicula (n = 8 in *A. cerana*, n = 3 in *A. mellifera*), but many pollen grains had been gathered on the hairs on the ventral mesosomal and metasomal segments. The bees flew to neighboring flowers and continued sucking in the same way. It was obvious that pollination could occur by pollen grains on body hairs reaching the stigma, when the bees visited different flowers.

The sweat bee, *Lassioglossum* sp., has a short tongue, and showed two types of foraging behavior; i.e., taking pollen with its mouth part from the stamen and then sucking nectar. This bee spent longer times on a single flower than did the honeybee. When ingesting pollen, bees ignored the four reduced stamens. Their forelegs grasped the filament of a regular (longer) stamen and ate the pollen in the anther (n = 4). The pollen was, thus, stored in the bees' crop. Pollen was also gathered by body hairs, and then removed from the hairs and put onto the scopa of the hind femur. They moved from one flower to the next, and in this way, pollen was conveyed to different flowers. When sucking nectar, bees stayed on one fixed side in relation to the stigma and did not turn around it (n = 5).

Oriental latrine flies, *Ch. megacephala*, stayed for a long time on a single flower; they hovered beside it and sucked nectar with their proboscis and often stopped and rested on it (n = 3). It was observed that the position of the body remained away from the anthers, but the legs did touch them. They often removed extraneous matter on their abdomen and wings with their mid and hind legs, and during this process, pollen grains may have been transferred to bristles of the body or legs. They visited several neighboring flowers to suck nectar, and then quickly left. Pollination may have occurred when the flies visited to different flowers.

Soldier beetles of *Cantharis* sp. visited flowers on warm days for mass foraging during their reproduction season. One of them approached a flower in a slow flight and landed on it, then extended its head and forelegs to a neighboring flower and ingested pollen. Pollination may have occurred when they visited to different flowers.

Discussion

From our observation records of insects that visited mango flowers, important potential pollinators of this plant seemed to be bees, such as *A. cerana*, *A. mellifera*, *Braunsapis hewitti*, *Lassioglossum* spp. and *Halictus* spp., and flies, such as *Chrysomya* spp. and *Musca domestica* Linnaeus. Some other insects, such as *Cantharis* sp. and *Menochilus sexmaculatus* (Fabricius) of the Coleoptera, and *Idioscopus* spp. of the Hemiptera, did not seem to efficiently contribute to the

pollination of mangos.

Each panicle of a mango consists of 200-4,000 flowers and a mature tree has 600-1,000 panicles (Manning, 1995). With a large number of flowers per tree, it would seem that these flowers would be attractive to flower-visiting insects. Studies carried out in India show that more than 25 species, which belong to the same orders seen in the present study, were confirmed on mango flowers (Singh, 1988, 1997). According to some other studies conducted in India (Bhatia *et al*., 1995) and Israel (Dag and Gazit, 2000), respectively 21 species and 46 species belonging to three orders, Diptera, Hymenoptera and Coleoptera, were recorded. The number of visiting insects was, however, small (12.9 (range, 1-35) insects/h) in the present study, and these insects seemed to be quite insufficient for pollinating the mangos, which are usually grown in large numbers on plantations in Taiwan. Indeed the insufficiency of pollinators on mango flowers has been a serious problem in Taiwan (Wu and Lin, 1994). The most likely reason for this may be the frequent use of pesticides to control leafhoppers of *Idioscopus* spp. during the flowering season of this plant (Wen and Lee, 1978; Singh, 1988).

Next, the superiority or inferiority of potential pollinators was a tentatively evaluated based on their behavioral characteristics on mango flowers. Each mango panicle has 50-89% male flowers, 17-47% hermaphrodites, and 0.2-2.4% imperfect flowers (Yang *et al*., 1990). Larger proportions of flower-visiting insects were females, and most of them collected pollen as well as nectar for rearing their broods (Roubik, 1989; Michener, 2000). The majority of pollinators choose nectar of mango flowers as their food resource (Anderson *et al*., 1982), and transferred pollen mostly originates from the anthers of hermaphroditic flowers. Sweat bees not only foraged for nectar but also very actively ate pollen. This suggests a possibility that they visit male flowers and bring pollen to the stigma of hermaphrodites, and probably increase the pollination efficiency. Honeybees collect only a small quantity of pollen and nectar due to limitations of these resources produced by mangos (Free and Williams, 1976; DuToit and Swart, 1993). We surmise from our observations that the quantity of pollen produced by mango flowers is insufficient for mass foraging by social bees. The major proportion of these bees may be attracted to flowers of the Compositae and Rosaceae, which bloom concurrently with mangos (Sung, 2005). This seems to be a problem in introducing honeybees for pollinating mangos. However, *A. cerana* has an advantage as a pollinator of mangos in Taiwan, because this species is capable of actively foraging even at temperature as low as 8°C (Sung, 2005; Sung, unpublished data). Air temperature lower than 10°C is often realized in February and March, when major varieties of mango are blooming. Some other authors have suggested that highly efficient pollinators are honeybees and stingless bees (*Trigona* spp.), which carry a number of pollen grains on their bodies and feed on nectar with their short proboscis and mouth parts (Singh, 1960; Anderson *et al*., 1982; Gibbs and Muirhead, 1998; Ish-Am *et al*., 1999). *Trigona ventralis hoozana* Strand, which is the only stingless bee species distributed in Taiwan, may also be a candidate for a pollinator, but its very low population density is a critical obstruction for realizing its potential (Sung *et al*., 2006).

Flies of the Calliphoridae and Muscidae seem to be potential pollinators of mango flowers, because pollen grains stick to their body and then will be transferred to the stigma (Wu, pers. comm.). In Taiwan, the Oriental latrine fly, *Ch. megacephala*, is considered to be an effective pollinator (Wu and Lin, 1994). Singh (1960) stated

that flies of the Syrphidae and *M. domestica*, as well as stingless bees of *Trigona* spp., are main pollinators of mango in India. According to this view, a program for pollination of mangos by a *Chrysomya* fly has been promoted since the 1990's, and flies of this species have been mass-reared and released in mango fields (Wu and Lin, 1994; Chen and Chen, 1997; Hung, 1997). Considering the pollinating efficiency as well as environmental advantages, we suggest that honeybees, *A. cerana* and *A. mellifera* and some other bees, such as sweat bees, should also be involved in pollination programs.

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台灣南部地區的檬果授粉昆蟲與其行爲

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摘 要

本研究於 2005 年 2 月 13 日至 3 月 17 日調查台灣南部檬果的訪花及授粉昆蟲種類，結果收集之昆蟲共計 5 目 23 科 39 種 126 隻，其中授粉昆蟲以雙翅目與膜翅目爲主。雙翅目有 15 種，佔 42.0%；膜翅目 14 種，佔 39.7%。重要的計有膜翅目東洋蜜蜂 (*Apis cerana*)、西洋蜜蜂 (*A. mellifera*)、何威布朗蜂 (*Braunspis hewitti*)、二種隧蜂 (*Halictus* sp. 及 *Lassioglossum* sp.)；雙翅目大頭金蠅 (*Chrysomya megacephala*)、一種麗蠅 (*Ch. pinguis*) 及家蠅 (*Musca domestica*)。所收集授粉昆蟲中，雌性佔多數，有 69.1%，因其需要採集花粉與花蜜，以補充育幼所需之資源。每一小時訪花之昆蟲爲 1～35 隻、平均 12.9 隻，顯示調查區域缺乏足夠之訪花昆蟲。蜜蜂類停留於每一朵小花上之時間比麗蠅及菊虎爲短，不久便飛行至鄰近的花上。另比較訪花行爲特徵，其中以蜜蜂、隧蜂及麗蠅類在檬果花授粉功能似乎較其他昆蟲爲佳，因此建議利用此等昆蟲於檬果授粉上。

關鍵詞：檬果、授粉者、訪花昆蟲、蜜蜂、行爲。