THE STUDY OF BEE-COLLECTED POLLEN LOADS IN NANTOU, TAIWAN[3]

SU-HWA LIN[1], SHU-YOUNG CHANG[2] and SU-HWA CHEN[1][4]

Abstract: This study analyzes the content of the pollen loads collected by honeybees in the town of Ming-Chien in Nantou County, located in the middle of Taiwan, during the one year period of 1991 and investigates the pollen gathering activity of *Apis mellifera*. This study identified 106 pollen taxa belonging to 56 angiosperm families, one *Lycopodium* spore and one fungus spore. Among the pollen identified, 12 species belong to Compositae, 9 to Leguminosae, 7 to Euphorbiaceae, 5 to Solanaceae and 4 to Gramineae. Pollen of *Camellia sinensis* occupies the highest frequency (28.69%), followed by the *Ageratum conyzoides* and *A. houstonianum* (18.95%), *Mimosa pudica*(6.85%), *Oryza sativa* (5.98%), *Citrus grandis* (5.80%) and *Humulus scandens*(4.72%). Honeybee collects pollen from both entomophilous and anemophilous plants. Cultivated plants and wild plants are both equally important pollen sources. Factors that affect pollen gathering activity of bees include the morphology and color of the flower, time of anthesis, distribution of plants, temperature and humidity. Most of the pollen source plants have the following features: yellow or white flowers with opened petals and exposed anther, noon-time anthesis and location close to the hive.

INTRODUCTION

The pollen grain is a male gametophyte of seed plant. Different plant species have different chemical compositions in pollen grains. A mature pollen grain is comprised of 3-15% water, 10-40% protein and 1-50% carbohydrates (Barbier, 1970). Also present are lipids, vitamins and minerals. Nectar is an important source of carbohydrate needed in the honeybee's growth and develoment, while pollen is its main protein source (Paul *et al.*, 1987). When the honeybee collects pollen, it molds it into a pollen load, places it in the "pollen basket" of its hind legs and carries it back to the hive to be stored for future use (Hodges, 1952).

Bonnier (1906, in Sharma, 1970) was the first to observe a fidelity tendency when the honeybee collected pollen grains. Others after him have subsequently come to the same conclusion (Betts, 1935; Vansell & Griggs, 1952; Eckert & Shaw, 1960).They found that over 90% of the pollen loads brought back to the hive were uniflora while only 2%-7% were multiflora.

The honeybee is known to collect pollen of entomophilous as well as anemophilous plants (Parker, 1926; Chaturvedi, 1973; Wills et al., 1990). Analyzing the pollen species in a pollen load reveals information about the pollen source plants used by the honeybee, the preference for each of these sources, and the biological and environmental

(1) 林淑華，陳淑華。Department of Botany, National Taiwan University, Taiwan, ROC.`

(2) 張世揚。Apiculture Section Director, Taiwan Apicultural and Sericultural Experiment Station.

(3) This research is based partly on a M. S. thesis of the first author to the Research Institute of Botany, NTU.

(4) To whom correspondence should be addressed.

factors affecting the collection activity of the honeybee. Biological factors associated with the plant include its distribution, morphology and color of the flower, degree of attraction the honeybee has for the flower, anthesis time, pollen productivity and the amount of protein contained in the pollen grains (Vansell, 1942; Beutler, 1951; Ribbands, 1955 ; Percival, 1965).

Environmental factors that affect the collection activity of the honeybee include temperature, light intensity, humidity and windspeed. Temperature affects anthesis (Nowakowski & Morse, 1982) and the honeybee's flight activity (Park, 1922). A weak light intensity interferes with the honeybee's ability to orient itself with its surroundings.In high humidity the honeybee becomes sluggish and is less likely to venture out to collect pollen; while in low humidity, the pollen is not as easy to collect (Ribbands, 1953). A high windspeed can impede the honeybee's flight (Paton, 1991).

In 1991, there were 850 beekeepers and 141,087 active hives in Taiwan. Information on pollen and honey source plants is very important to the beekeepers because they are dependent on the production of royal jelly, honey and pollen loads for their income. Researchers in Taiwan have studied the pollen contained in honey and are familiar with the different taxa of honey source plants (Chen & Wu, 1976 in Chinese; Chen, 1979). Chen *et al.* (1984), observed 53 types of pollen in 88 honey samples from Taiwan. Longan (*Euphoria longana*) and lichee (*Litchi chinensis)* were found to be the most important honey source plants in mid- and southern Taiwan. Jeng et al. (1986) identified 134 taxa of honey source plants in Taiwan. However, few researchers here have investigated pollen source plants using an analysis of pollen loads.

This study analyzes the content of the pollen loads collected by honeybees in the town of Ming-Chien in Nantou County, located in the middle of Taiwan, during the one year period of 1991 and investigates the pollen gathering activity of *Apis mellifera.*

The weather is relatively mild in Ming-Chien. The temperature ranged from 12.9-32°C in 1991 and the rainy season typically runs from June through September. Ming-Chien has a highly developed agricultural area with many cultivated and economic plants. The cultivation area of the tea (*Camella sp.*) is 2100 hectares. Rice (*Oryza sativa*) has two harvesting periods, June and September, and the cultivation areas are 650 and 663.49 hectares respectively. Citrus (*Citrus grandis*) has a cultivation area of 650 while Longan's (*Euphoria longana*) is 663.49 hectares.

The results of this study can give beekeepers in the area a suitable reference in determining the best location to place hives for maximum benefit. Also, this information can help establish the ideal timing to chemically spray these pollen source plants to avoid exposing the honeybees to toxic chemicals as they seek to gather pollen grains.

MATERIAL AND METHODS

All pollen loads analyzed in this study were collected by the *Apis mellifera* of Ming-Chien Station in Nantou County, located in the middle of Taiwan during the one year period of 1991. During the flowering of *Oryza sativa,* pollen traps were placed in the front of the hives and pollen loads were retrieved five times a day (9:00, 11:00, 13:00,15:00 and 17:00), five days a week, from the periods of May 9 to June 8 and October 1 to November 9. All other times during the year the pollen loads were collected four times a day (9:00, 12:00, 15:00 and 18:00), three days a week. Pollen load samples were weighed in grams while fresh, dried in an oven and weighed again, then placed in cold storage.

Pollen loads retrieved every Wednesday were used as the weekly sample batch. The pollen loads gathered at the various collection times for the day were mixed together and three samples of 1/10 the total amount were taken. These sample pollen grains were then dispersed in water, acetolysed (Erdtman, 1952) and mounted in glycerine jelly. The

species frequency percentages were based upon a count of at least 500 pollen grains per sample. The pollen grains of the pollen loads were identified by light microscope (Leitz Diaplan) and scanning electron microscope (Hitachi S-520) and were also compared with fresh pollen samples.

RESULTS

This study identified 106 pollen taxa belonging to 56 angiosperm families, one *Lycopodium* spore and one fungus spore (Tab. 1). Among the pollen identified, 12 species belong to Compositae, 9 to Leguminosae, 7 to Euphorbiaceae, 5 to Solanaceae and 4 to Gramineae (Fig. 1). The results and discussion focus primarily on the pollen species.

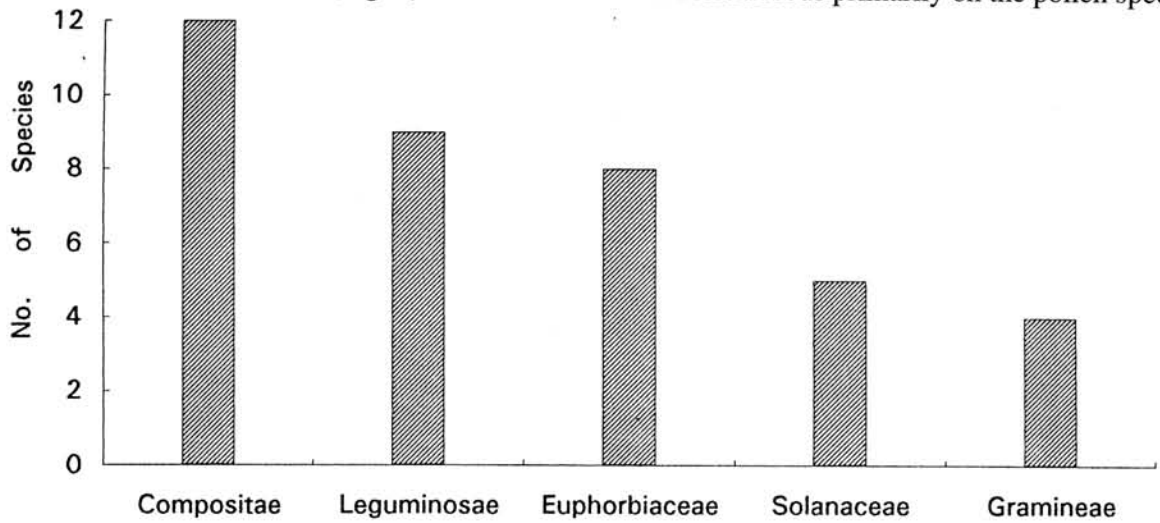


Fig. 1. Top five families of pollen source plants observed in 1991 in Ming-Chien.

Tab. 1. Taxa of pollen source plants in Ming-Chien.

Dicotyledon	
1. Aizoaceae	*Mollugo pentaphylla* L.
2. Amaranthaceae	*Amaranthus viridis* L.
3. Anacardiaceae	*Rhus semialata* Murr. var. *roxburghiana* DC
4. Annonaceae	*Annona squamosa* L.
5. Araliaceae	*Aralia decaisneana* Hance
6. Asclepiadaceae	*Cryptolepis sinensis* (Lour.) Merr.
7. Balsaminaceae	*Impatiens balsamiana* L.
8. Begoniaceae	*Begonia semperflorens* Link & Otto
9. Bignoniaceae	*Doxantha capreolata* Mieis.
10. Caprifoliaceae	*Sambucus formosana* Nakai
11. Caricaceae	*Carica papaya* L.
12. Caryophyllaceae	*Stellaria aquatica* (L.) Scop.
13. Combretaceae	*Quisqualis indica* L.
14. Compositae	*Ageratum conyzoides* L.
	Ageratum houstonianum Mill.
	Bidens bipinnata L.
	Cosmos bipinnatus Cav.
	Eclipta prostrata (L.) L.
	Emilia sonchifolia (L.) DC.
	Erechites valerianaefolia (Walf.) DC.

Tab. 1. Taxa of pollen source plants in Ming-Chien. (continue)

	Heliantthus annuus L.
	Siegesbeckia orientalis L.
	Dahlia pinnate Cav.
	Sonchus arvensis L.
	Wedelia Chinensis (Osbeck) Merr.
	Zinnia elegans Jacq.
15. Convolvulaceae	*Ipomoea obscura* (L.) Ker.
16. Cruciferae	*Brassica alboglabra* Bail. var. acephala DC.
	Brassica campestris L.
17. Cucurbitaceae	*Gymnopetalum cochinchinensis* (Lour.) Kurs.
	Luffa cylindrica (L.) Roem.
	Momordica charantia L.
18. Ebenaceae	*Diospyros oldhamii* Maxm.
19. Euphorbiaceae	*Aleurites fordii* Hemsl.
	Codiaeum variegatum (L.) Bl.
	Macaranga tanarius (L.) Muell-Arg.
	Mallotus japonicus (Tbumb.)Muell-Arg.
	Phyllanthus urinaria L.
	Sapium sebiferum (L.) Roxb.
20. Gentianaceae	*Gentiana parvifolia* Hay.
21. Gesneriaceae	*Trichosporum acuminatum* (Wall.) O. ,Kuntze
22. Labiatae	*Agastache rugosa* (Fisch. & Mey.) Ktze.
	Hyptis suaveolens (L.) Poit.
	Ocimum basilicum L.
23. Leouminosae	*Acacia confusa* Merr.
	Arachis hypogea L.
	Cassia mimosoides L.
	Crotalaria juncea L.
	Erythrina corallodendron L.
	Leucaena glauca (L.) Benth.
	Mimosa pudica L.
	Sophora flavescens Ait.
	Uraria crinita (L.) Desv. ex DC.
24. Lythraceae	*Lagerstroemia indica* L.
25. Magnoliaceae	*Michelia alba* DC.
26. Malpiohiaceae	*Malpighia glabra* L.
27. Malvaceae	*Hibiscus rosa -sinensis* L.
	Sida rhombifolia L.
28. Moracceae	*Humulus scandens* Sieb. & Zucc.
29. Myrsinaceae	*Ardisia squamulosa* Presl.
30. Myrtaccae	*Eucalyptus robusta* Smith
	Psidium guajava L.
	Syzygium samarangense Miq.
31. Oenotheraceae	*Ludwigia octovalvis* (Jacq.) Raven
32. Oleaceae	*Jasminum hemsleyi* Yam.
33. Oxalidaceae	*Averrhoa carambola* L.
	Oxalis violacea L.

Tab. 1. Taxa of pollen source plants in Ming-Chien. (continue)

34. Passifloraceae	*Passiflora edulis* Sims
	Passiflora foetida L.
	Passiflora suberosa L.
35. Plantaginaceae	*Plantago major* L. var. *kimurae Yam.*
36. Polygonaceae	*Fagopyrum esculentum* Moench
	Polygonum chinense L.
37. Portulaceae	*Portulaca pilosa* L.
38. Rosaceae	*Fragaria chiloensis* var. *ananassa* Chiloensis Duch.
39. Rubiaceae	*Diodia virginiana* L.
	Ixora chinensis Lamk.
	Paederia scandens (Lour.) Merr.
40. Rutaceac	*Citrus grandis* Osb.
41. Sapindaceae	*Euphoria longana* Lamk.
	Litchi chinensis Sonn.
42. Solanaceae	*Capsicum annum* L. var.
	acuminatum Fingerh
	Solanum hidetaroi Masam.
	Solanum melongena
	Solanum nigrum L.
	Solanum verbascifolium L.
43. Sterculiaceae	*Firmiana simplex* (L.) W. F. Wight
	Sterculia nobilis R. Br.
44. Theaceae	*Camellia sinensis* L.
45. Tiliaceae	*Corchorus acutangulus* Lam.
	Muntingia calabura L.
46. Ulmaceae	*Trema orientalis*(L.) Bl.
47. Umbelliferae	*Sanicula lamelligera* Hance
48. Urticaceae	*Boehmeria densiflora* Hook & Arm.
49. Verbenaceae	*Callicarpa formosana* Rolfe
	Clerodendrun cyrtophyllum Turcz.
	Clerodenron thomsonae Balf.
50. Vitaceae	*Cayratia japonica* Lam.
Monocotyledon	
51. Araceae	*Colocasia formosana* Hay.
52. Cannaceac	*Canna edulis* Ker.
53. Commelinaceae	*Tradescantia viroiniana* L.
54. Gamineae	*Miscanthus sinensis* Anders.
	Oryza sativa L.
	Pennisetum purpureum Schumach.
	Zea mays L.
55. Palmae	*Areca catechu* L.
56. Typhaceae	*Typha angustifolia* L.
Ferns	
57. Lycopodiaceae	
Fungi	
58. Fungus spore	

Tab. 2. Thirty-three taxa of main pollen source plants with a pollen frequency more than 0.2%.

percentae >10		10 > percentage > 1		1 > percentage > 0. 2percentag	
**Camellia sinensis*	28.69%	*Mimosa pudica.*	6.85%	* *Uraria crinita*	0.97%
Ageratum sp.	18.95%	* *Oryza sativa*	5.98%	*Acacia confusa*	0.95%
		* *Citrus grandis*	5.80%	* *Zea mays*	0.79%
		Humulus scandens	4.72%	*Lagerstroemia indica*	0.75%
		Erechites valerianaefolia	3.33%	* *Litchi chinensis*	0.66%
		* *Areca catechu*	2.52%	*Momordica charantia*	0.55%
		Amaranthus viridis	1.83%	*Fagopyrum esculentum*	0.50%
		Boehmeria densiflora	1.60%	*Eucalyptus robusta*	0.45%
		* *Euphoria longana*	1.35%	*Pennisetum purpureum*	0.43%
		Bidens bipinnata	1.16%	*Oxalis violacea*	0.32%
		Solanum nigrum	t.12%	*Ardisia squamulosa*	0.31%
		* *Psidium guajava*	1.09%	* *Capsicum annum*	0.31%
		Muntingia calabura	1.00%	*Fungus spore*	0.28%
				* *Solanum melongena*	0.26%
				* *Syzygium samarangense*	0.25%
				Sapium sebiferum	0.22%
				Wedelia chinensis	0.22%
				* *Brassica alboglabra*	0.21%

*: Caltivated plants

Pollen of thirty-three species had a frequency of more than 0.2% for the year (Tab.2). Pollen of *Camellia sinensis* had the highest frequency (28.69%) and *Ageratum* (including *A. conyzoides* and *A. houstonianum*) was second highest (18.95%). The frequency of the other pollen species was less than 10% (Tab. 2). Thirteen of these species are large area crops with a total frequency of 48.88% for the year. The other twenty species include sparsely distributed cultivers and wild plants had a total frequency of 45.52% for the year. Therefore, wild plants and crops are both equally important pollen sources.

Camellia sinensis provides the most pollen in October, November, December, January and February. Its frequency is more than 60% during the months of November, December and January (Fig.2). Pollen source plants with anthesis throughout the whole year include *Ageratum* sp. and *Solamum nigrum. Bidens bipinnata* and 13 other species have a flowering period that lasts for more than half the year while *Oryza sativa* flowers twice within a year. *Litchi chinensis, Euphoria longana, Citrus grandis* and *Oryza sativa* have shorter flowering periods but they still provide a lot of pollen. When these crops are not flowering, wild plants such as *Ageratum* sp. become the main pollen source.

The anthesis times are different for different plants. Most of the 33 important pollen source plants (e.g. *Amaranthus viridis*) flower before 9:00, placing it in the Type I category as identified in Figure 3. *Ageratum* sp. flowers between 9:00 and 12:00, as Type II. The Type III group, which has a flowering period from 12:00-15:00, include *Areca catechu* and *Euphoria longana. Citrus grandis* flower before 15:00, making them Type IV. It is interesting to note that *Mimosa pudica* flowers twice a day, once before 9:00 and once at 15:00 (Type V). *Oryza sativa* displays an

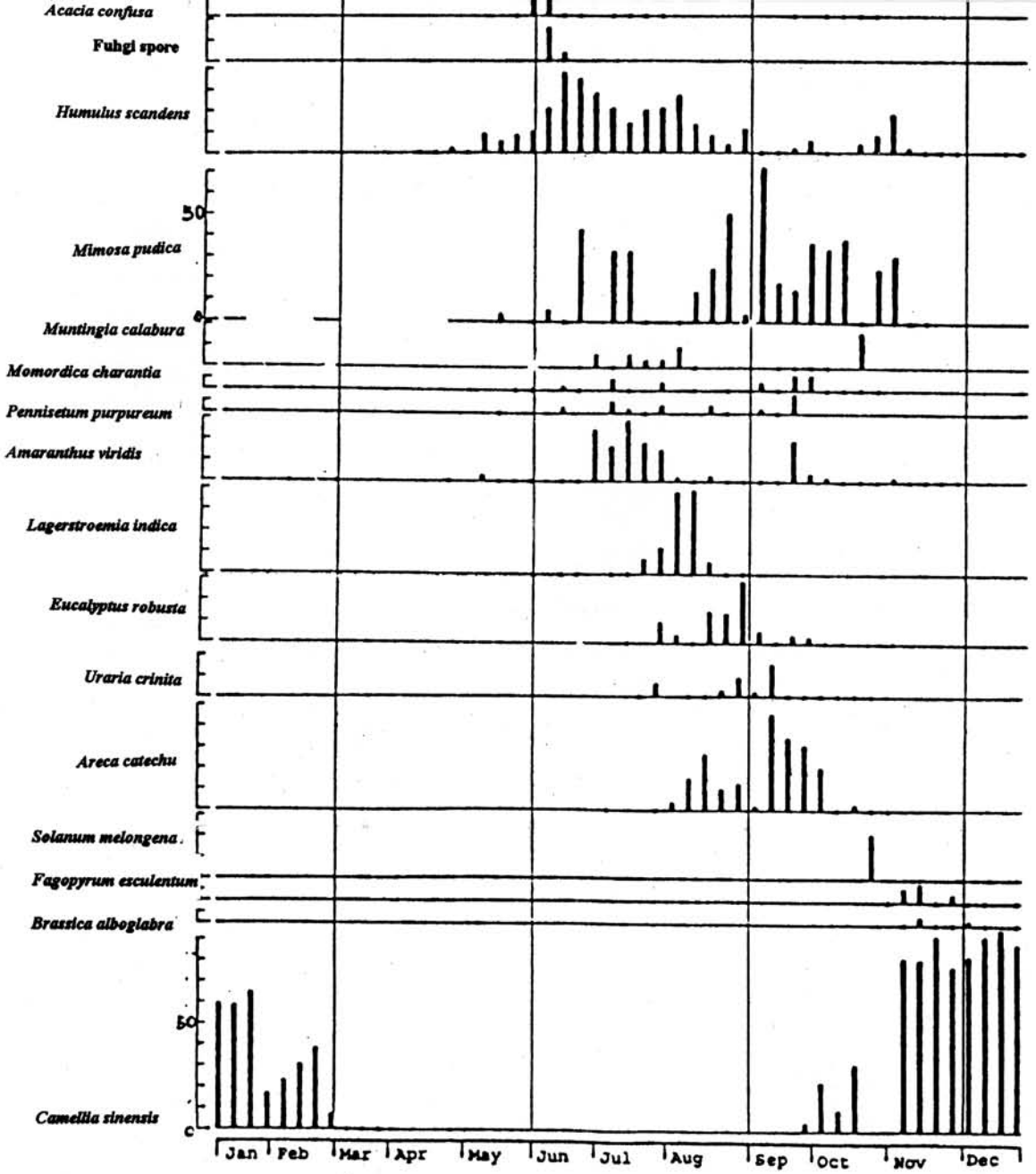
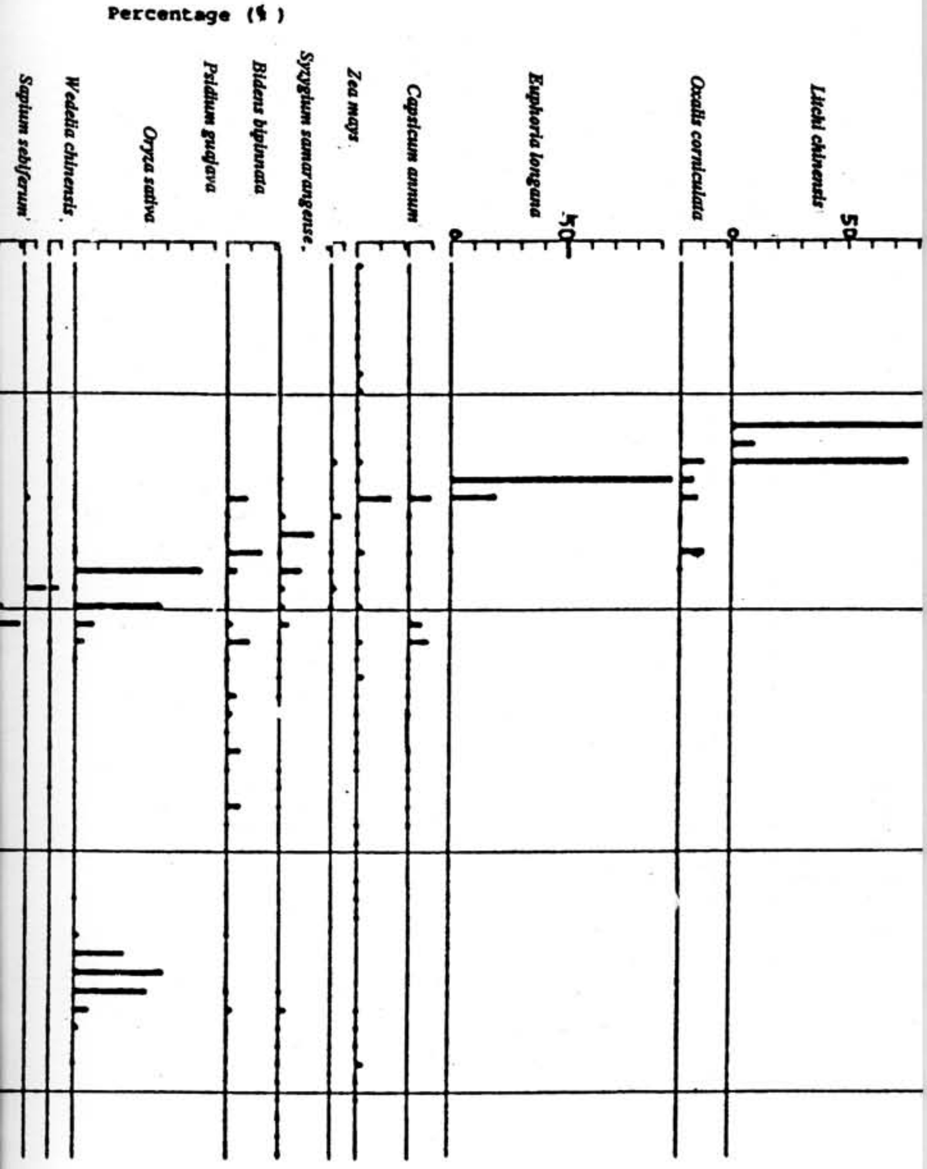
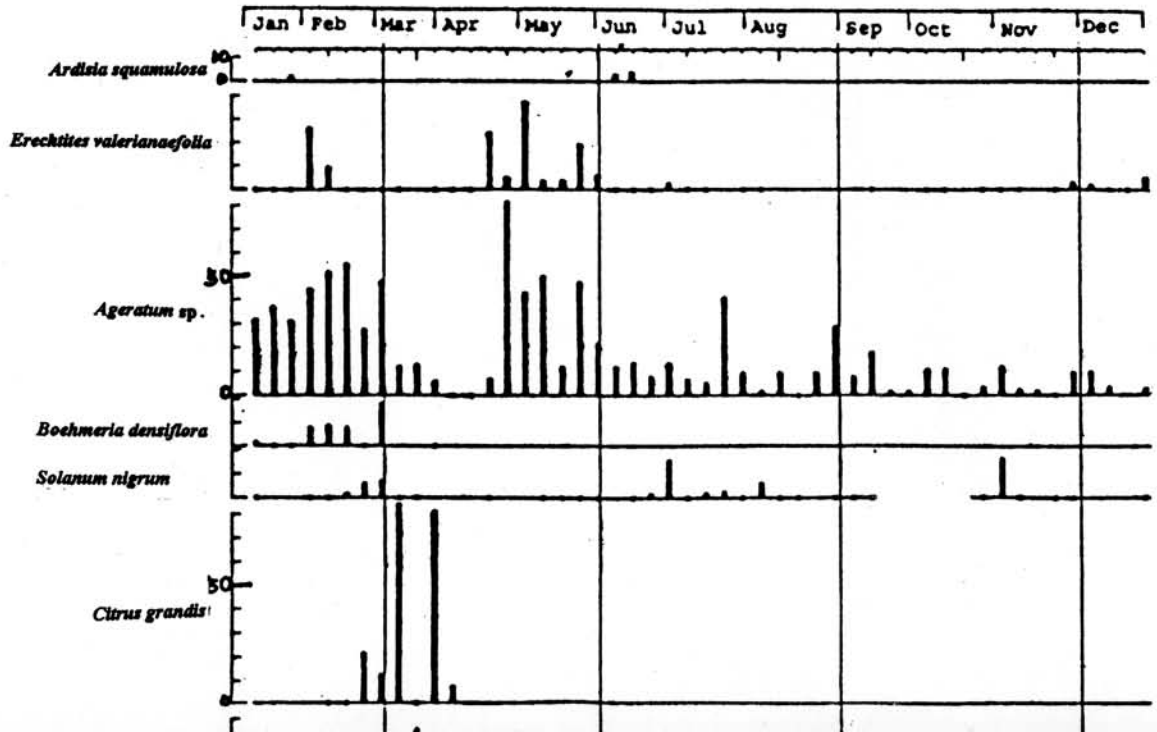


Fig.2. Pollen calendar in Ming-Chien for 1991, ir



dicating the flowering period and frequencies of pollen species present.


Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Ardisia squamulosa
Erechtites valerianaefolia
Ageratum sp.
Boehmeria densiflora
Solanum nigrum
Citrus grandis

unusual flowering behavior depending on the season; it flowers at 11:00-13:00 in May and 13:00-15:00 in October.

The most important pollen source plants have either a white or yellow flower which have opened petals and an easily detectable anther (Tab. 3). In this study, there were 181 collection days for a total of 609 retrieval times during the one year period of 1991. The pollen loads collected weighed a total of 6.37 Kg for the year. The highest average weight of collected pollen loads was 63.99 g/day in May; 21.9 g/day in July was the lowest (Fig.4). In the months of January, February, May, June, October, November and December over 40 grams of pollen per day was able to be collected. The average collection amount did not exceed 40 g/day in March, April, July, August and September.

The pollen loads were first weighed fresh, then dried and weighed again. Comparing the resulting differences in weight revealed the amount of moisture contained in the pollen loads. Pollen loads collected in June and November had the most moisture, followed by January and February. The least moist pollen loads were gathered in March, April and July (Fig.5). On average, pollen loads collected before 9:00 were the most moist and the amount of moisture tended to decrease throughout the day (Fig.6).

Every month, 10 pollen loads (a total of 120 for the year) were randomly compared for purity. Based upon the frequency of one species of pollen in the pollen loads, four categories of purity were identified: Type A (one dominant

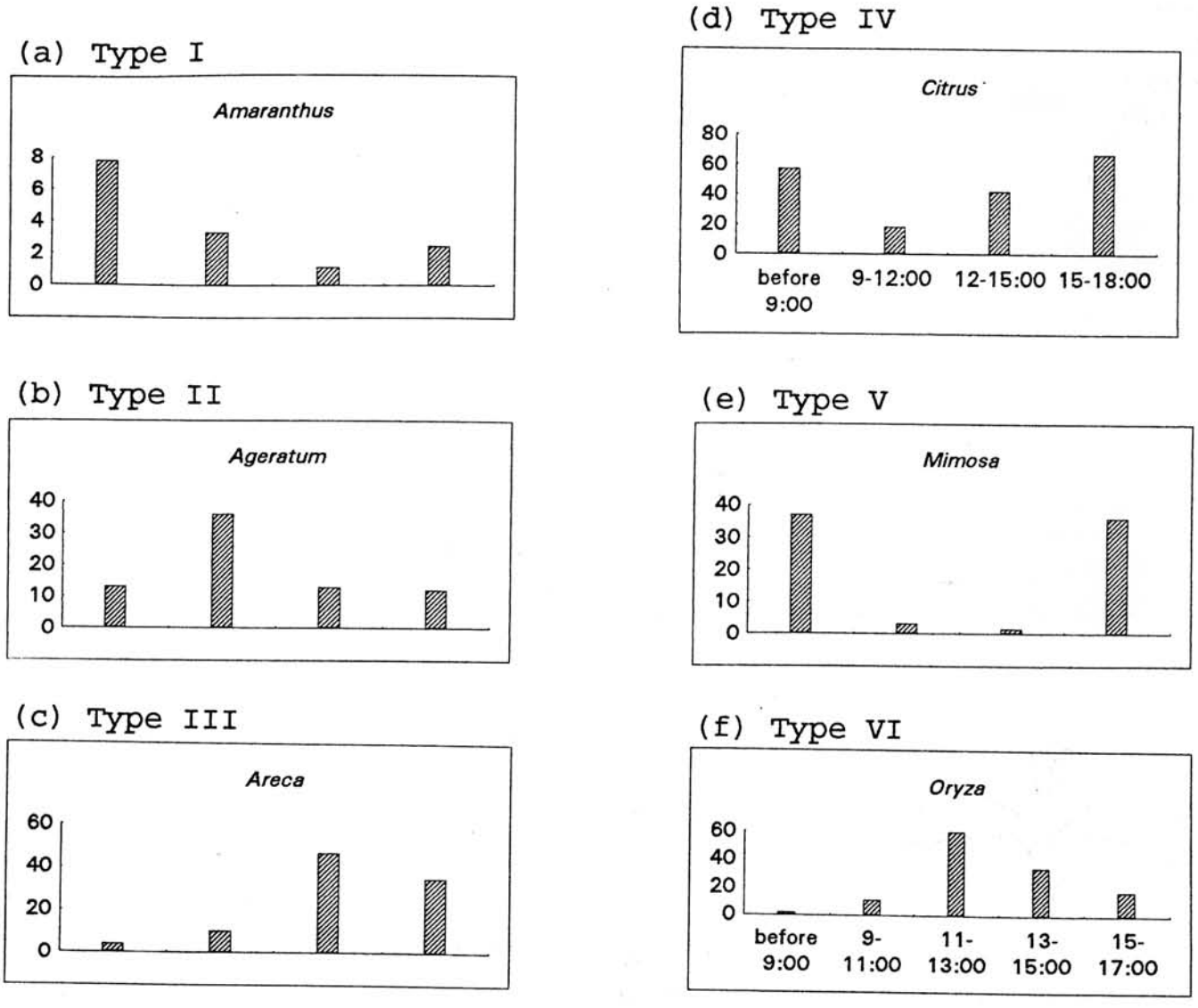
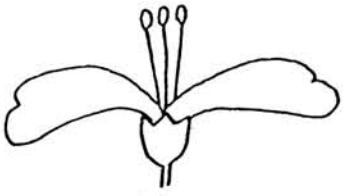


Fig.3. Frequencies of the present pollen during sampling time in 1991 in Ming-Chien.

Tab. 3. Flower color and morphology of main pollen source plants.

scientific name	color of flower					type of flower[a]		
	yellow	white	green	red	purple	I	II	III
Ardisia squamulosa		*				*		
Wedelia chinensis	*							*
Solanum nigrum		*				*		
Boehmeria densiflora			*			*		
Erechites valerianaefolia				*				*
Ageratum conyzoides	*			*				*
Ageratum houstonianum					*			*
Litchi chinensis	*					*		
Citrus grandis		*				*		
Zea mays	*						*	
Syzygium samarangense		*				*		
Oxalis violacea				*		*		
Psidium guajava		*				*		
Euphoria longana	*					*		
Sapium sebiferum		*				*		
Bidens bipinnata		*						*
Acacia confusa	*						*	
Oryza sativa			*				*	
Capsicum annum		*				*		
Humulus scandens			*			*		
Pennisetum purpureum	*				*			
Muntingia calabura		*				*		
Amaranthus viridis			*				*	
Lagerstroemia indica				*		*		
Uraria crinita					*			*
Eucalyptus robusta	*					*		
Momordica charantia	*						*	
Areca catechu	*							*
Mimosa pudica				*			*	
Solanum melongena		*				*		
Brassica alboglabra	*					*		
Fagopyrum esculentum		*				*		
Camellia sinensis		*				*		
totle(species)	10	13	4	4	2	20	6	7

a:



type I
opened perianth

type II
closed perianth
exposed anther

type III
closed perianth

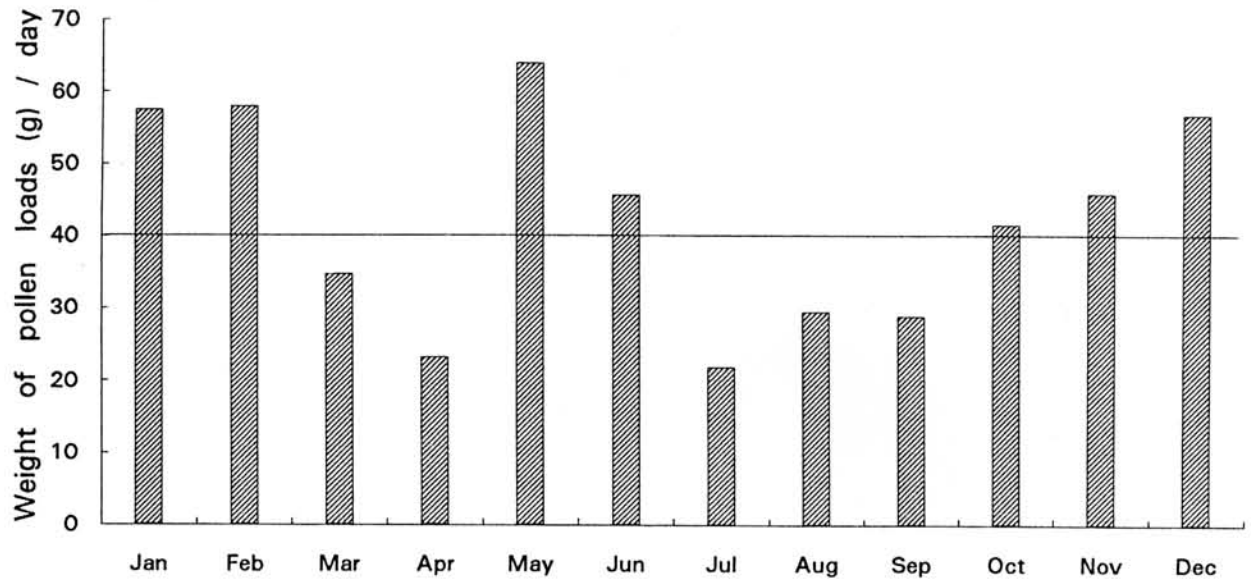


Fig.4. Mean weight of pollen loads collected per day for each month of 1991 in Ming-Chien.

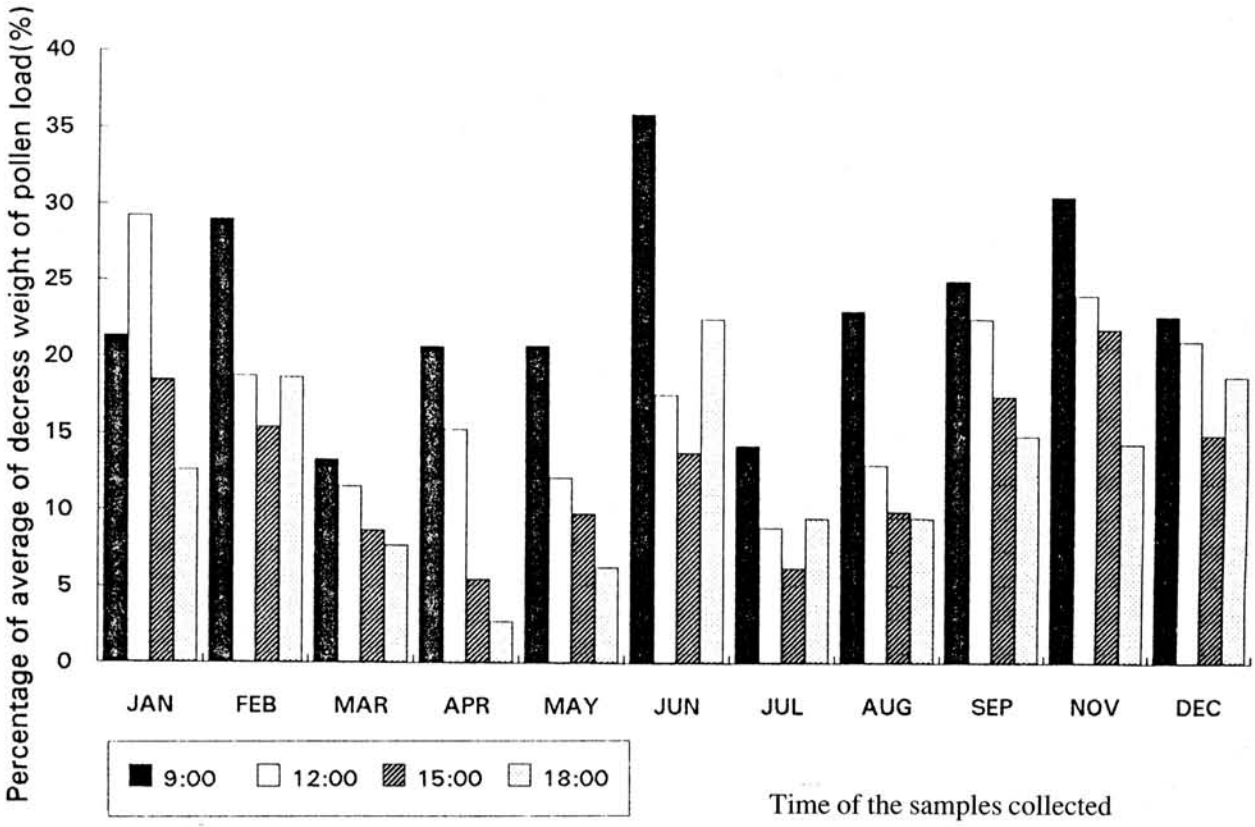


Fig. 5. Average percentages of the decrease in weight of pollen loads due to drying procedure of the samples collected at various time periods for each month of 1991 in Ming-Chien.

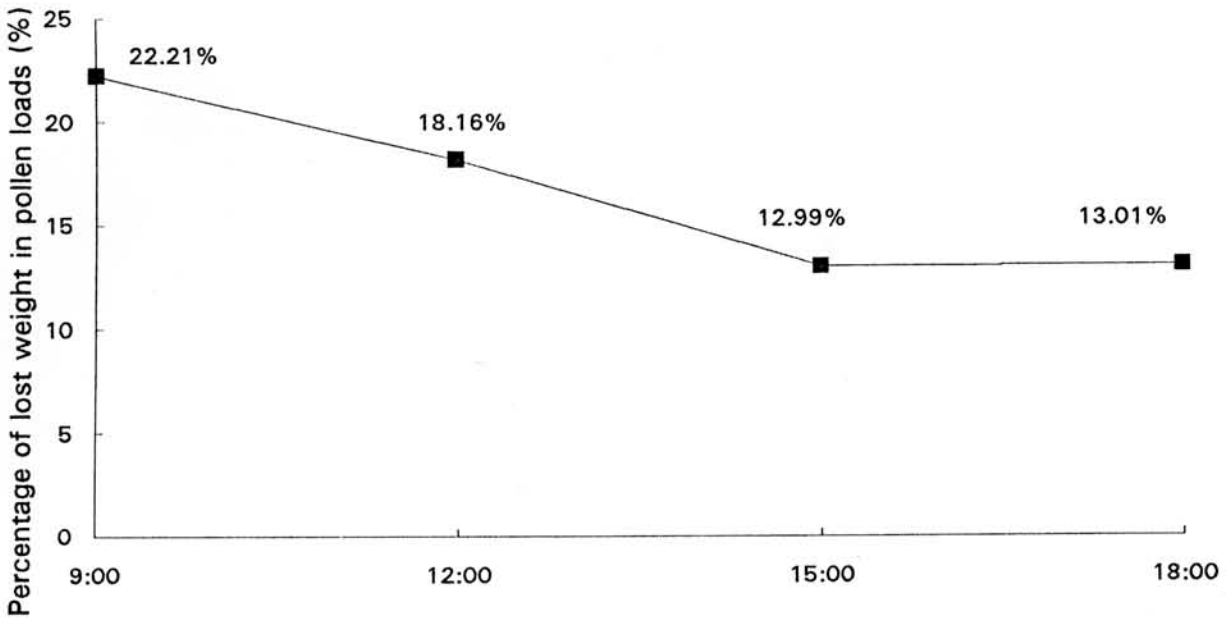


Fig.6. Comparison of the decrease in weight of pollen loads due to drying procedure of the samples collected at various collection periods.

species>95%), Type B (90%-94.9%), Type C (80%-89.9%) and Type D(<80%). Most of the pollen loads (86 out of 120) randomly analyzed for purity belong to the Type A group of highest purity(Fig. 7). When evaluated by month, most pollen loads still fall into the Type A category (Fig. 8).

DISCUSSION

1. Pollen source plants

This study has identified 106 taxa of angiosperm pollen, one type of fungus spore and one species of *Lycopodium* spore. Deodikar (1965) also observed the fungus spore present in pollen loads. Olesen (1988) found that when the honeybee collected the nectar of *Pteridium aquilinum*, this fern spore would stick to the honeybee's body. There have been no gymnosperm pollen observed in any of the pollen loads collected by the honeybee.

The honeybee gathers many different kinds of pollen to achieve a nutritional balance (Barbier, 1970). It has been found that if the honeybee confines its nourishment to a single species of pollen, its growth, development and reproductive activity will stop (Standifer, 1967). But consumption of a variety of pollen types tends to strengthen the bee colony (Testa *et al.*, 1981; Loper & Cohen, 1987). The protein count is low in anemophilous pollen (Stanley & Linskens, 1974), but in the United States (Severson & Parry, 1981; O'Neal & Waller, 1984), New Zealand (Pearson & Braiden, 1990), India (Chaturvedi, 1973; Sharma, 1970) and Australia (Moezeal *et al.*, 1987) the honeybee was found to collect it. This study also concludes that the honeybee collects both entomophilous and anemophilous pollen, such as *Humulus scandens*. Though this study did not test protein count and amino acid composition, its findings support the theory that the honeybee seeks to gather a wide variety of pollen species.

Honeybees often gather pollen from plants that are located close to its hive rather than venturing too far away (Moezetal *et al.*, 1987). When certain plants are in full bloom, the honeybee will frequently return to those plants and keep gathering their pollen. For example, *Camellia sinensis, Citrus grandis, Euphoria longana, Oryza sativa* and

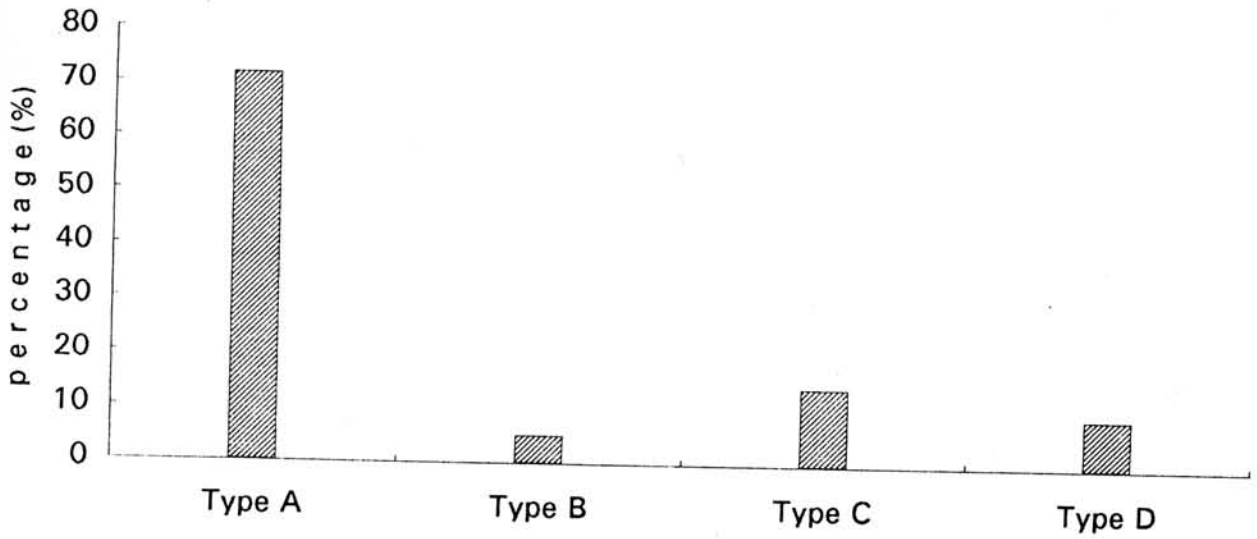


Fig. 7. Purity analysis of pollen loads collected in Ming-Chien in 1991.
Type A: frequency of one species > 95%;
Type B: frequency of one species 90~95%;
Type C: frequency of one species 80~90%;
Type D: frequency of one species < 80%.

Areca catechu are all the dominant species of pollen for a given month.When some of these cultivated plants are not in full bloom, wild plants- such as *Ageratum, Humulus, Chenopodium* and *Mimosa*- with their wide distribution, will become the dominant source of pollen for the honeybee. Therefore, cultivated plants and wild plants do not differ greatly in terms of their pollen composition.

2. Factors affecting pollen frequency

Pollen productivity, length of the flowering period and the distribution area of vegetation can affect pollen frequency in pollen loads. The cultivation area of *Camellia sinensis* is very large and its flowering period is very long. As a result, *Camellia* pollen has the highest frequency (28.69%) of any species (Tab.2). *Ageratum* found in earth banks, along the roadsides, in uncultivated land and in orchards-flowers all year round and its long extension lends to its having a very wide distribution area. Therefore, *Ageratum* pollen has the second highest frequency (18.95%). The *Humulus scandens* and *Mimosa pudica* also distribute widely. *Oryza sativa,* though it does not have a long flowering period (Fig. 7), has a wide cultivation area so the frequency of its pollen is relatively high throughout the year (5.98%, Tab.2). *Citrus grandis* with a flowering period of 6 weeks and *Euphoria longana* with a flowering period of 2 weeks- both do not have a wide cultivation area but make up 5.8% and 1.35% of the total pollen count, respectively (Tab.2). The honeybee likes to collect these two types of orchard pollen and their nectar, making the *Citrus grandis and Euphoria longana* a very important source of honey in Taiwan (Chen et al., 1984).

This study gathered pollen loads from the hive several times throughout the day and from their retrieval time deduced the anthesis tendency of main pollen source plants. Most of them bloom in the morning before 9 a.m. and the honeybee is able to gather the pollen from these plants almost immediately after blooming. The pollen frequency of

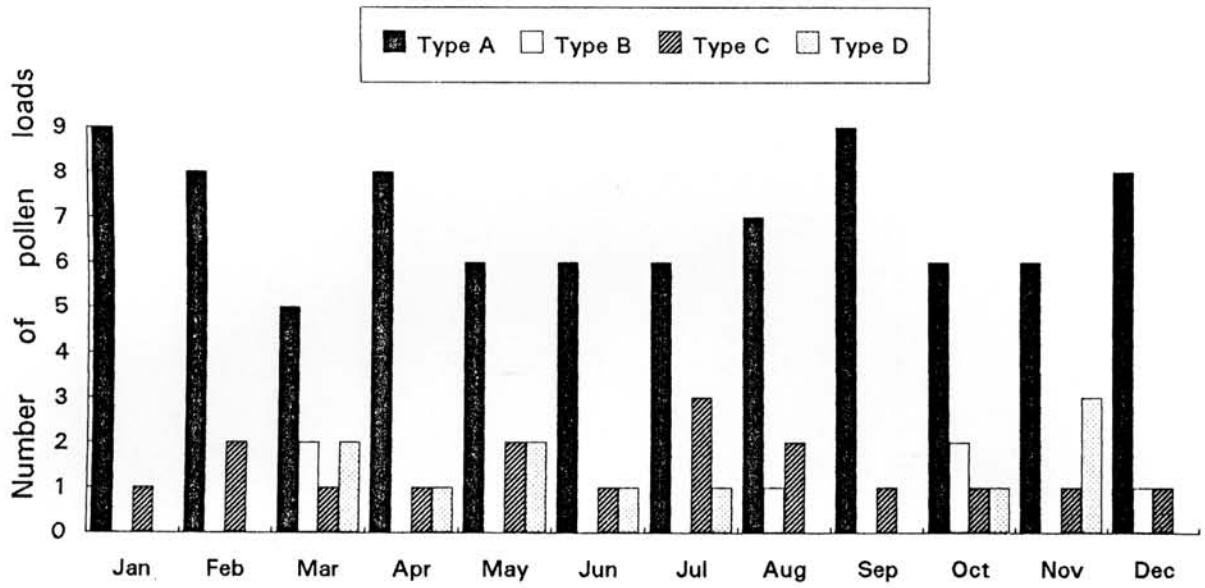


Fig. 8. Purity analysis of 10 randomly sampled pollen loads collected for each month in Ming-Chien during 1991. Types A, B, C, and D are the same as identified in the Fig. 7.

common plants does not always have the same peak as its bloom time (Synge, 1947). Most plants, like the *Ageratum* sp. and *Zea may*, have their maximum frequency at different times during the day but have only one peak each day (Fig. 3a-d & f). Only a few plants, such as the *Mimosa pudica* and *Litchi chinensis,* have two peaks in one day, morning and night (Fig. 3e). Anthesis, temperature and flowering habit of the plants are all closely related. Most plants begin anthesis at dawn and slowly increases with an increase in temperature. The anthesis of the *Oryza sativa* and *Zea may* can be delayed by cloudy weather and low temperature. It is the same as Flottum et al. (1983) observed. Because the *Camelia sinensis* undergoes continuous flowering, its pollen productivity is high and provides the honeybee a lot of opportunity to gather its pollen. Thus, it maintains a high frequency all day long.

3.Preference for certain types of plants by honeybee

The honeybee will not gather the pollen of certain plants (Moezel *et al.,* 1987; Wills *et al.,* 1990). In this study, although the actual gathering process of the pollen loads was not directly observed, the pollen loads analyzed do not contain or contain very little of the pollen of certain species of plants in Ming-Chien, namely the *Basella jubra, Passiflora edulis* and *Lantana camara*, although they also grow here.

In main pollen source plants, the honeybee also prefers certain plants when gathering its pollen. Although the *Ageratum* undergoes several flowering periods during the year, the honeybee seems to prefer the pollen of other plants, such as *Camellia sinensis, Citrus grandis, Litchi chinensis, Euphoria longana, Oryza sativa, Humulus scandens* and *Mimosa pudica*, to the *Ageratum*. During the months when these species are as dominant as the *Ageratum,* the honeybee prefers to collect its pollen from these plants rather than the *Ageratum,* making the *Ageratum* the honeybee's "second choice" plant.

It is still not completely clear how a flower attracts the honeybee. It is found that the flower's color, morphology and scent (Darwin, 1877; Vansell, 1942; Ribbands, 1953) as well as the sugar content in pollen (Herbert & Shimanuki, 1979) and the pollenkitt composition of the pollen wall (Dobson, 1988) might attract the honeybee to visit the plants. From this study of Ming-Chien's pollen source plants, the honeybee seemed to prefer the pollen of

white and yellow flowers (Tab. 3) and a mostly open perianth makes it easier for the honeybee to gather pollen. It is found in this study that flower color and morphology can affect the pollen gathering behavior of the honeybee.

4. Factors affecting the quantity of the pollen loads

The weight or quantity of the pollen loads gathered by the honeybee varies from month to month. The *Citrus grandis, Litchi chinensis* and *Euphoria longana* experience their blooming periods in March/April, and during this time, these three orchard plants have a lot of nectar, making them a very important source of nectar in Taiwan (Chen *et al.,* 1984). Most bees tend to switch to gathering the nectar during these months, leading to a decrease in pollen load activity. From July to September, the pollen load productivity is even lower because of Ming-Chien's rainy season (an average of 11-19 rainy days during these months) and high temperature (monthly mean temperature from 28.4-29.2 °C).

Temperature and humidity affect anthesis and these two factors plus windspeed affect the behavior of the honeybee. This study found that the pollen loads gathered by the honeybees in Ming-Chien were heavier in the moming (data not shown), which is the same as the findings of Olsen (1975). A possible reason is that the warmer temperature in the afternoon affects the activity of the honeybee. Also, morning air tends to be more humid. Humid air causes the pollen to become somewhat damp and makes it easier for collection (Szabo, 1980).

5. Purity of pollen loads

On a single excursion to collect pollen, the honeybee usually visits only one flower and often stays within the proximity of the hive (Moezel *et al.,* 1987). As a result, the pollen load collected is usually made up of one kind of pollen and is known as a pure or uniflora pollen load. Percival (1947), Maurizio (1953) and Free (1963) proposed that a typical pollen load has a maximum unpure percentage of 11%, while the remaining 89% is pure. Sharma (1970) and Moezel (1987) separately found a 79% purity rate in the pollen loads of India and a 52% - 79% purity rate of those in Australia. In this study, the 120 pollen loads analyzed for the year, comprised of 10 randomly selected pollen loads each month, had a 71.7% purity rate.

There is no main pollen source in Ming-Chien during the months of June and July, resulting in a low number of pure pollen loads (60%) over this two-month period (Fig. 8). *Camellia sinensis* pollen is dominant in October and November and *Oryza sativa* pollen and *Citrus grandis* pollen are dominant in May, but the pollen load purity is still not high (50%-600/o). This phenomenum is generally attributed to the presence of two taxa of plants in the gathering area to which the honeybee has an equal degree of attraction. However, if the pollen loads are analyzed on a day to day basis, it is found that there is a very high purity rate in pollen loads collected before 9 a.m. and the purity rate diminishes as the day goes on (data not shown). This probably indicates an insufficient pollen source, prompting the honeybee to look elsewhere for pollen to complete the load.

6. The size of pollen grains within the pollen load

Roberts & Vallespir (1978) observed that the honeybee gathered pollen grains ranging in diameter from 5-210 μ, with an average diameter of 34 μ. The diameter of the *Luffa cylindrica* in Ming-Chien is approximately 100-120 μ but it contains a low number of pollen grains. *Zea may* pollen has a diameter of 80-100 μ while the diameter of the smallest known pollen grain, *Muntingia calahura* ranges from 10-15 μ. The pollen grains of most pollen source plants is approximately 10-50 μ.

LITERATURE CITED

BARBIER, M., 1970. Chemistry and biochemistry of pollens. Prog. Phytochem. 2: 1-34.

BETTS, A.D., 1935. The constancy of the pollen collecting bees. Bee Wld. 16: 111-113.

BEUTLER, R., 1951. Time and Distance in the life of the foraging bee. Bee Wld 32:25-27.

CHATURVEDI, M., 1973. An analysis of honey bee pollen loads from Banthra, Lucknow, India. Grana 13: 139-144.

CHEN, S.C. 1979. The study of honey pollen in Taiwan.Cin-Yen Book Co. Tainan. 48pp. (In chinese)

CHEN, L.T. & T.Y. WU, 1976. Pollen grain in honey. I.The Relationship between the kinds and number of pollen with its flavor. Food Science. 3:54-61 (in chinese).

CHEN, S. H., J.T. Tsai,K. An & Y.C. Jeng. 1984. Melitopalynological study in Taiwan(l). Taiwania 29: 121-140.

Deodikar, G. B., 1965. Melitto-palynology. Indian Bee Journal 27: 59-72.

DARWIN, C.R., 1877. The different forms of flowers on plants of the same species. John Murray, Londom.

DOBSON, H. E. M., 1988. Survey of pollen and pollenkitt lipids-chemical cues to flower visitors? Amer. J. Bot.75 (2) : 170-182.

ECKERT, J. E. & F. R. Shaw, 1960. Bee Keeping. Macmillan, New York.

ERDTMAN, G., 1952. Pollen Morphology and Plant Taxonomy. An Introduction to Palynology. I Angiosperms. Almquist and Wiksell,Stockholm, 539pp.

FLOTTUM, P. K., E. H. Erickson and B. J. Hatmy, 1983. The honey bee-sweet corn relationship. Amer. Bee J. 123:293-299.

FREE, J. B. 1963. The flower constancy of honey bees. J. Anim. Ecol. 32: 119-13 1.

HERBERT, E. W. and H. SHIMANUKI, 1979. Seasonal protein preferences of free flying colonies of honeybees. Amer Bee J. 119 (4) : 298-302.

HODGES, D., 1952. The pollen loads of the honeybee. Chap 1-111. Bee Research Association Limited.

JENG, Y.C., J. T. TSAI, & K. ANN, 1986. Studies on the honey plants in Taiwan. Annual of Taiwan Museum. 29:117-155 (in chinese).

LOPER, G.M. and A. C. Cohen, 1987. Amino acid content of dandelion pollen, a honey bee (Hymenoptera: Apidae) nutritional evaluation. J. Econ. Entomol. 80: 14-17.

MAURIZIO, A. 1953, Weitere Untersuchungen an Pollenhoschen. Beitrag zur Erfassung der Pollen-Tractverhaltnisse in verschiedenen Gegenden der Schweiz, Schweizerische Bienenzeitung Beihefte 2: 485-556.

MOEZEAL, P. G., J. C. DELFS, J. S. PATE, W. A. LONERAGAN & D. T. BELL, 1987. Pollen selection by shrublands of the Northern Sandplains of Westem Australia. J. Apic. Res. 26: 224-232.

NOWAKOWSKI, J. and R. A. Morse, 1982. The behavior of honey bees in sweet corn fields in New York State. Amer. Bee. J. 122: 13 -16.

O'NEAL, R. J., & G. D. WALLER. 1984. On the pollen harvest by the honey bee (*Apis mellifera* L.) near Tucson, Arizona (1976-1981). Desert Plant 6: 81-94, 99-109.

OLESEN, J. M., 1988. Foraging behaviour of honeybees at the leaf nectaries of the fern, *Pteridium aquiilinum*. J. Apic. Res. 27: 22-25.

OLSEN. L. G., 1975. Pollen gathering by honey bees in Southem Michigan. Submitted to Michigan State University.

PARK, O.W. 1992 Time and labor factors involved in gathering nectar and pollen. Amer. Bee. J. 62: 254-255

PARKER, R. L., 1926. The collection and utilization of pollen by the honeybee. Mem. CornellAgric. Exp. Sta. 98: 1-55.

PATON, D. C., 1991. Variation in meliphagid morphology and its influence on pollen dispersal in Australian plants. PP. 1611-1616 in *Acta XX Congressus Internationalis Ornithologicii.* Paul, G.V. Der Moezel, J.C. Delfs, J.S. Pate, W. A.

PEARSON, W. D. and V. BRAIDEN, 1990. Seasonal pollen collection by honeybees from grass/shrub highlands in Canterbury, New Zealand. J. Apic. Res. 29 (4) : 206-213.

PERCIVAL, M. S. 1947, Pollen collecting by *Apis mellifera.* New Phytol,46:142-173.

PERCIVAL, M. S. 1965, Floral biology. Pergamon Press, Oxford, United Kingdom.

RIBBANDS, C. R., 1953. The behaviour and social life of honey bees. Bee Research Association, Ltd., London. 353 pp.

RIBBANDS, C. R., 1955. Communication between honeybees. II. The recruitment of trained bees and their response to improvement of the crop. Proc. R. Ent, Soc. Lond. (A) 30: 26-32.

ROBERTS, R.B. and S.R. VALLESPIR, 1978. Specialization of hairs bearing pollen and oil on the legs of bees (Apoidea: Hymenoptera). Ann. Ent, Soc. Amer. 71(4): 619-627.

SEVERSON, D. W & J. E. PANY, 1981. A chronology of pollen collection by honeybees, J. Apic. Res. 20: 97-103.

SHARMA, M., 1970. An analysis of pollen loads of honey bee from Kangra, India. Grana 10: 35 -42.

STANDIFER, L. N., 1967. A comparison of the protein quality of pollens for growth-stimulation of the hypopharyngeal glands and longevity of honey bees, *Apis mellifera* L. (Hymenoptera: Apidae). Insectes Sociaux, Paris, 14: 415-426.

STANLY, R.G. and H. F. LINSKENS, 1974. Pollen. Springer-Verlag. Heidleberg and New York.

Synge, A. D. 1947. Pollen Collection of honeybees (*Apis mellifera*), J. anim. Ecol. 16:122-138.

SZABO, T. I. 1980. Effect of weather factors on honeybee flight activity and colony weight gain. J.Apic. Res. 19: 164-171.

TESTA, R. R., A. N. SILVA, and F. S. ZUCOLOTO, 1981. Nutritional value of different pollen mixtures for *Nannotrigona (Scaptotrigona) povtica.* J. Apic. Res. 20 (2) : 94-96.

VANSELL, G.H. 1942 Factors affecting the usefulness of honeybees in pollination, Cire, U.S, Dept. Agric, 650: 1-31

VANSELL, G. and W. H. GRIGGS, 1952. Honey bees as agents of distribution. U.S.D.A. Year book PP. 88-107.

WILLS, R. T., M. N. LYONS and D. T. BELL, 1990. The European honey bee in Western Australian kwongan: foraging preferences and some implications for management. Proc, Ecol. Soc.Aust. 16: 167-176.

ACKNOWLEDGEMENT

The authors would like to thank Ms. Liang-Tsai Shi from Ming-Chien for her help during the course of this study and Ms. Bao-Yen Liu for her assistance in the treatmentof the pollen loads.

南投名間地區蜂蜜花粉團之研究

林淑華　張世揚　陳淑華

摘要

本文分析 1991 年自名間由蜜蜂採集之花粉團，鑑定其所含花粉之種類，並由花粉之出現頻率探討該地區之粉源植物。此結果可供蜂農作爲種植或尋找粉源植物時之參考，以提高花粉團產量，增加蜂農之收益。本研究利用光學顯微鏡及掃描式電子顯微鏡研究觀察花粉團內花粉的外部微細構造，並與現生植物花粉之微細構造做比較。藉此得知南投名間地區重要之粉源植物及其花期，並討論氣候、花部特徵及其它可能影響蜜蜂採集活動之因子。由花粉分析之結果得知：名間地區之粉源植物共計 57 科 108 種。其中菊科出現的種類最多，共 12 種，次爲豆科有 9 種，大戟科有 8 種，茄科有5種，禾本科有 4 種。另一方面，茶科的出現頻率最高，佔全年的 28.69%，次爲菊科佔 24.3%，豆科佔 8.77%，禾本科佔 7.44%。全年開花之植物爲霍香薊 (*Ageratum sp.*) 和龍葵 (*Solanum nigrum*)；花期長達半年以上者爲鬼針 (*Bidens bipinnata*) 等 13 種；一年兩次花期者僅有春不老 (*Ardisia squamulosa*) 和水稻 (*Oryza sativa*)。

1991年全年中有 152 天於蜂巢前裝置花粉收集器以收集花粉團。實驗中，一個蜂群可收取 6.3 公斤之花粉團，此量恰可維持蜂群之生存。蜜蜂上午（12 時以前）採集花粉之量多於下午採集之量。三至四月間蜜蜂偏重於採集荔枝和龍眼之花蜜，對花粉之採量大爲降低；六至九月爲雨季，且溫度常高於 30°C，大大影響蜜蜂之活動，因此亦使花粉團之產量減少，此爲全年中兩個花粉團之低產量期。影響蜜蜂的花粉採集活動之因子，包括花型、花色、花藥開裂之時間、植物分布及氣溫等。多數粉源植物具下列特徵：花冠開展或花藥明顯可見、花色爲黃或白色、花藥於上午開裂，以及植物生長地與蜂箱距離較近者。