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Aeropalynological Study of Kinmen Island, Taiwan

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ABSTRACT: Hay-fever and allergic rhinitis have been a serious problem in Kinmen, an island close to mainland China. To elucidate the relationship of pollen and spores to such a problem, an aeropalynological study was conducted during 2003 in Kinmen. In Kinmen's Kin-Hu City, a Burkard seven-day volumetric pollen trap was installed on the roof of a house, about 10 m above the ground, to collect airborne pollen samples. Over a study period of one year, a total of 50,278 pollen grains and fern spores, belonging to 51 taxa of 39 families were identified. Among them, 33 families were angiosperms, two families gymnosperms, and four families ferns. Twelve taxa produced a higher percentage of airborne pollen in this survey. They are *Casuarina* (27.5%), *Morus* (15.2%), *Fraxinus* (12.3%), *Pinus* (11.3%), *Dicranopteris* (7.0%), *Celtis* (5.0%), *Juniperus* (4.2%), *Ambrosia* (4.0%), Gramineae (2.8%), *Liquidambar* (1.3%), *Podocarpus* (1.1%), and *Artemisia* (0.5%). The highest concentrations of airborne pollen were detected over the period from mid February to mid June. The dominant pollen species varied with seasons, with *Morus*, *Juniperus* and *Liquidambar* dominating in February and the beginning of March, *Pinus* in February and March, *Celtis* in March, *Casuarina* in April, May, June, and August, *Podocarpus* from the end of April to the beginning of May, *Fraxinus* in June, *Dicranopteris* in June and July, *Ambrosia* in August, *Artemisia* in October, and Gramineae in November. Throughout the study time, arboreal pollen (79.9%) was more abundant than non-arboreal pollen (8.5%) and fern spore (8.1%). Ragweed pollen, the allergenic one, reached its maximum in the atmosphere in August and showed a peak of diurnal periodicity at 7:00-9:00 am. As a result of this study, a pollen calendar for Kinmen was established to illustrate the seasonal variations in the quantitative and qualitative characteristics of airborne pollen and spores. The data of the present study provide a basis for further pollinosis studies in Kinmen .

KEY WORDS: aeropalynology, *Ambrosia*, Kinmen, pollen calendar, Taiwan.

INTRODUCTION

Aerobiological data provide important information for studies of the relationship between airborne pollen and flowering development (Latorre and Bianchi, 1998), ecology (Cour et al., 1999; Woo et al., 1998), and agriculture (García-Mozo et al., 2008). Such data is particularly important for establishing a chronological correlation between air pollen concentrations and hay-fever and asthma symptoms (García-Mozo et al., 2006).

In the past, numerous studies have been done to clarify the relationship between airborne pollen and pollinosis in Taiwan (Chao et al., 1962; Chen et al., 1972; Wang, 1973; Han et al., 1976; Tsai, et al., 1990). In Kinmen, two species of weeds, *Ambrosia artemisiifolia* (ragweed) and *Parthenium hysterophorus* (Santa Maria feverfew), were considered potential causes of the allergic rhinitis in Kinmen (Tsai et al., 1997). In testing 101 patients in Kinmen, 79 patients (78%) tested positive in a skin test for ragweed pollen extract and ragweed pollen-specific immunoglobulin E (IgE). Through the skin test, Western blot, and an ELISA inhibition analysis, Lin (1997) confirmed that allergic rhinitis in Kinmen was caused mainly by these two weeds. Chuang (1999) showed that the concentration of serum ragweed specific IgE was associated with seasonal rhinitis. Similar results were also obtained by Liang (2003).

In Taiwan, a number of aerobiological studies have been done in a variety of areas in the past (Huang and Chung, 1973; Chen and Huang, 1980; Tsou and Huang, 1982; Chen, 1984; Chen and Chien, 1986; Peng and Chen, 1996, 1997; Tsou et al., 1997; Huang, 1998; Huang et al., 1998; Yang and Chen, 1998; Kuoh et al., 1999; Chen and Huang, 2000; Huang and Liu, 2001; Yang et al., 2003). However, no such investigation was done in the Kinmen area.

A pollen calendar provides information about qualitative and quantitative characteristics of pollen present in the atmosphere, temporal data on the occurrence of pollen species, and the effect of

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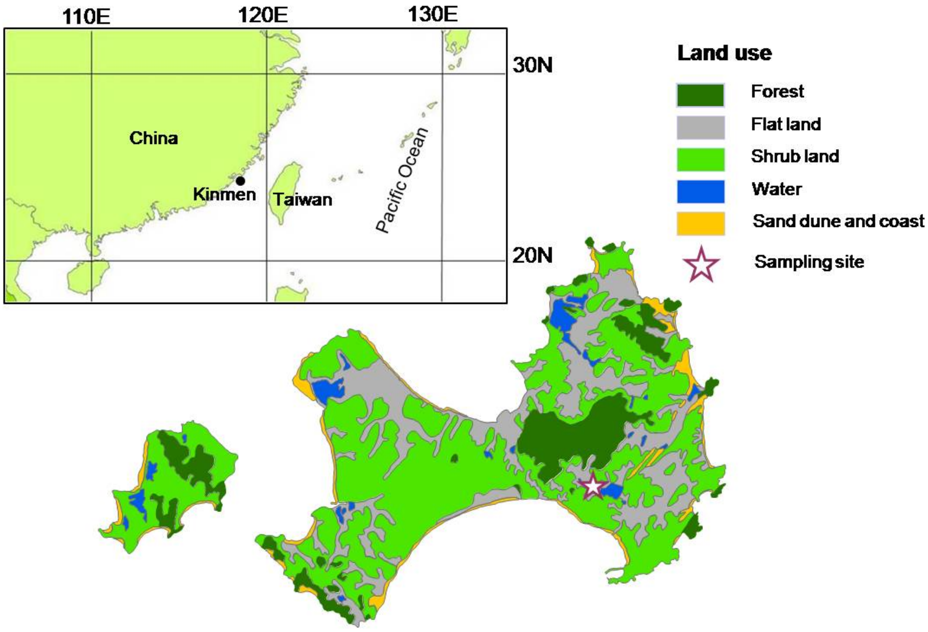

Fig. 1. The geographical location and vegetation map of Kinmen Island.

weather factors on daily airborne pollen concentrations. Therefore, a pollen calendar is very important in highly populated cities and hot tourist spots (Bilisiki et al., 2008) and can serve a need with special reference to allergies.

The present study was supported partially by the "Project on the Prevention and Treatment of Allergic Rhinitis in Kinmen." It attempts to analyze atmospheric pollen and fern spores encountered in Kinmen－with special emphasis on the allergenic airborne pollen of *Ambrosia* and *Artemisia* and to assess the level of exposure of Kinmen inhabitants to these allergenic pollen types.

Geography and Topography

Kinmen proper is an island close to mainland China and 227 km west of Taiwan (Fig. 1). With a size of 131.7 km^2, its topography is mainly composed of flat plains and hillsides, usually 30-80 m above sea level, except for Mt. Tai-Wu, which is 253 m in elevation. The major stratum of the island is granophyres gneiss, and the soil is made up of sand and bare red soil (Editorial Committee, 1992).

Meteorology

Kinmen occupies a subtropical climate zone, under the strong influence of a monsoon climate. The records of more than forty years (1954~1995) portray it as dry cold in winter and foggy in spring, with southwest cyclones and typhoons occurring in the summer (Kinmen Weather Station, 2008) (Fig. 2a). The annual precipitation was 1047 mm. In contrast, the amount of evaporation was as high as 1684 mm. The humid season and closely-related rainy season occurred from April to June, and typhoons from July to September. Average annual temperature was 20.8°C, with the lowest temperature recorded in January (12.7°C) and the highest in July or August (28.2°C). Due to the low annual precipitation, Kinmen has sometimes been recognized as tropical savanna (Liu et al., 1983).

Basically, the climate conditions in 2003 fell into the variation ranges of the long-term data, except that no precipitation fell in July of 2003 (Fig. 2b).

Vegetation

Kinmen has been populated since the Jin Dynasty (317 AD) by the Han people although four Neolithic sites were found on the coast of this island (Chen, 1997). Based on the historical records, which include many big trees and root residues found by coal digging and pond digging, and some extant old tress, Kinmen should have been a lush or luxuriant island. Unfortunately, it holds now only sparse forest, possibly due to the continuous destruction of war and excessive logging over the Yuan (1206-1368 AD), Ming (1368-1644 AD) and Ching (1644-1911 AD) dynasties.

As many as 427 species, belonging to 299 genera and 94 families of indigenous vascular plants have been reported by Liu et al. (1983). Yang et al. (1998) reported 106 families, 352 genera and 542 species of indigenous and naturalized vascular plants. Later, more than 548 species of indigenous and naturalized

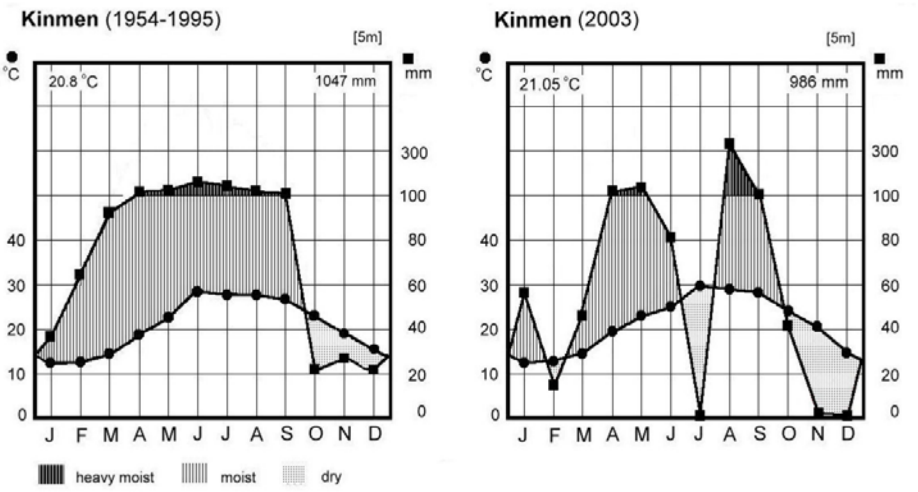

Fig. 2. Meteorological data from pollen collecting Station in Kinmen during 1954-1995 (a) and 2003 (b).

vascular plants were registered by Sun (2001). Thus, more than 120 species have been introduced and cultivated or newly naturalized over last 18 years. Those species such as *Casuarina equisetifolia*, *Pinus massoniana*, *P. elliottii*, *P. luchuensis*, *P. thunbergii*, *Acacia confusa*, *Eucalyptus citriodora*, *Fraxinus griffithii*, *Albizzia lebbeck*, *Bauhinia galpinii*, *Ficus microcarpa*, *Maytenus diversifolia*, *Liquidambar formosana*, *Cinnamomum camphora*, *Cassia surattensis*, *Sesbania cannabiana*, *Lagerstroemia indica*, *Eucalyptus robusta*, *E. exserta*, *Melaleuca leucadendron*, were introduced and cultivated for roadside, ornamental, or reforestation trees mostly by the Kinmen Forest Bureau. Other plants such as *Ambrosia artemisiifolia*, *Eupatorium catarium*, *Parthenium hysterophorus*, and *Rhynchelytrum repen* were newly naturalized species.

In Kinmen, there exist four types of vegetation communities (Chiu, 1999), namely evergreen forests, shrubs, herb fields, and wetlands. The dominant trees in the granite areas are *Pinus massoniana*, *Acacia confusa*, *Ficus microcarpa* var. *microcarpa*, *Celtis sinensis* and *Casuarina* sp. The subdominant species are *Litsea glutinosa*, *Pittosporum tobira*. The species of shrubs distributed on the hills and plains are: *Melastoma candidum*, *Syzygium buxifolium*, *Litsea rotundifolia* var. *oblongifolia*, *Abelia chowi*, *Gardenia jasminoides*, *Eurya emarginata*, and *Dodonaea viscosa*. The other shrubs distributed on the shore or coast are *Clerodendrum inerme*, *Lantana camara*, *Pandanus odoratissimus* var. *sinensis*, *Vitex rotundifolia*, *Scaevola taccada*, *Grewia rhombifolia*, and *Elaeagnus oldhamii*. The dominant herbal species are *Spinifex littoreus*, *Imperata cylindrica* var. *major*, *Artemisia capillaries*, *Ipomoea pes-caprae* subsp. *brasiliensis*, *Wedelia prostrata* var. *prostrata*, *Erigeron canadensis*, *Ipomoea cairica*, *Panicum repens*, and many kinds of ferns on/near seashore areas and wastelands. Parasitic plants, such as *Cuscuta australis*, *Cassytha filiformis*, *Orobanche coerulescens*, and insectivores, such as *Drosera indica*, *D. burmannii* were also found. The wetland plants were distributed in swamps, ponds, river mouths, and intertidal areas. They were *Zostera japonica*, *Ruppia maritima*, *Phragmites australis*, *Typha angustifolia*, *Nympha* spp., *Eichhornia crassipes*, *Azolla pinnata*, and *Kandelia candel* (Chiu, 1999).

MATERIAL AND METHODS

During study period from May 2002 to December 2003, a Burkard seven-day recording volumetric pollen trap was installed on the flat roof of the Kinmen County Bureau of Health (N24º26'26", E118º25'02"), which is ca. 10 m above the ground. An air inflow of 10 L min^{-1} was passed through trapping tape to give a continuous length of 336 mm $week^{-1}$. The tape was cut into 48 mm pieces and embedded in Entellan for light microscopic observations. The pollen grains and fern spores on the tape were identified and recorded, using an estimated sampling method of one transverse traverse per hour from trapping tape (Peng and Chen, 1996). Reports by Huang (1972, 1981) and Chen (1988) were used to aid identification of pollen and spores. Average daily concentrations are expressed as the number of pollen grains per cubic meter of air. In this article, we presented the data collected from January to December, 2003.

The main pollen season was determined by taking 90% of the annual total recorded pollen concentration using cumulative values (Nilsson and Persson, 1981; Emberlin et al., 1993). Starting and ending dates were established to correspond to the days when the sum of the daily concentrations reached 5% of the total sum and when the sum reached 95%, respectively.

For this study, we collected 26 families, 54 genera, and 55 species of floral material one year along the roadside between May and December 2002 as floral phenological data (Checklist 1). The vouchers specimens were deposited at TAI-Herbarium, Taipei, Taiwan.

RESULTS

Yearly pollen taxa

Over the study time, from January to December, 2003, a total of 50,278 pollen grains and fern spores were identified. They belonged to 51 genera and 39 families (Table 1). Among them, 33 families and 44 genera were of angiosperms, two families and three genera of gymnosperms, and four families and four genera of ferns.

Pollen composition

The airborne pollen and spores were mainly composed by twelve genera, including *Casuarina* (27.5%), *Morus* (15.2%), *Fraxinus* (12.3%), *Pinus* (11.3%), *Dicranopteris* (7.0%), *Celtis* (5.0%), *Juniperus* (4.2%), *Ambrosia* (4.0%), Gramineae (2.8%), *Liquidambar* (1.3%), *Podocarpus* (1.1%) and *Artemisia* (0.5%) (Fig. 3, Table 2). The abundance of the collected pollen was closely correlated with the density of these plants near the pollen trap site. Most of them were arboreal pollen (AP) species (79.9%). Pollen grains of herbaceous species (NAP) and fern spores (FS) occurred in the atmosphere in lower frequency, at 8.7% and 8.1%, respectively (Table 2).

Seasonal variation

A remarkable seasonal fluctuation was observed in the daily density of pollen and spores throughout the study time (Fig. 4). The highest density was recorded in the spring, from March to May. This contributed up to 22.8% of the total annual pollen and spore counts. The highest daily density was recorded on the 2nd of March, with 3,619 pollen grains m^{-3} (Fig. 4). The lowest density was found in autumn and wintertime, from September to January, which contributed as little as 2% of the yearly total. (Fig. 5).

Over the study period, the highest diversity of pollen taxa was observed from February to April, with as many as 22-25 taxa (Fig. 6). The lowest diversity of air-borne pollen was observed in December, with as few as 3 taxa.

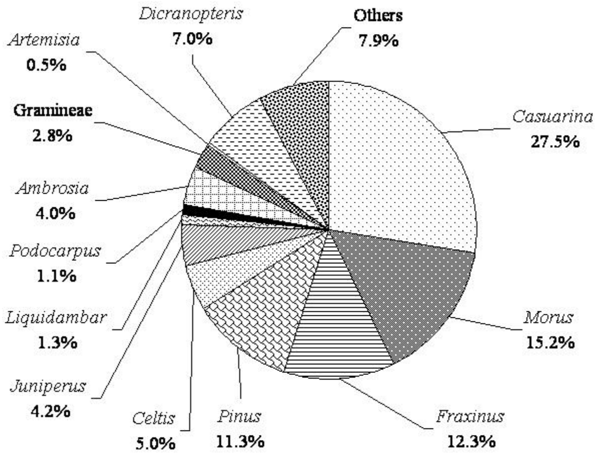

Fig. 3. Composition of pollen and fern spore taxa in Kinmen during 2003.

Ratio of AP/NAP/FS

It was shown that AP predominated (79.9%) over NAP (8.7%) from January to June (Fig. 7). This predominance was then replaced by that of NAP or FS after July. In the present study, fern spores contributed only a small part (8.1%) to the pollen and spore assemblages throughout the study time. July was the only time in which FS predominated over AP and NAP. This resulted from a massive occurrence of spores of *Dicranopteris* in the atmosphere toward the end of July.

In addition, the total pollen and fern spore counts per month are listed in Table 3.

Pollen calendar

Based on the results demonstrated above, a pollen calendar for Kinmen Island was established (Fig. 8). *Artemisia* and those taxa with an occurrence frequency over 1% were presented. There was a noticeable seasonal variation in the dominance of pollen taxa. In January, *Morus* dominated. Toward the end of February, the amounts of arboreal pollen, such as *Morus*, *Pinus*, *Juniperus*, *Liquidambar,* and *Casuarina,* increased, when the temperature rose. The dominant pollen taxa in March were of *Pinus*, *Celtis*, *Morus*, *Casuarina*, and *Juniperus* while in April and May they were of *Casuarina* and *Podocarpus*. On April 22nd, the daily density of *Casuarina* peaked (2,957 pollen grains m^{-3} day^{-1}). Pollen of *Fraxinus* appeared first at the end of May. It dominated throughout June. *Dicranopteris* was the subdominant species in pollen and spore assemblages in June. The maximum occurrence of this species was found in July.

Table 1. List of fifty-one airborne pollen and fern spore taxa in Kinmen during 2003.

Arboreal Pollen taxa (AP)			
Angiosperms			
Aquifoliaceae	*Ilex*	Lythraceae	*Lagerstroemia*
Betulaceae	*Alnus*	Moraceae	*Broussonetia*
Caprifoliaceae	*Viburnum*		*Humulus*
Caryophyllaceae			*Morus*
Casuarinaceae	*Casuarina*	Myrtaceae	*Melaleuca*
Elaeagnaceae	*Elaeagnus*		*Syzygium*
Euphorbiaceae	*Bischofia*	Oleaceae	*Fraxinus*
	Glochidion	Palmae	
	Ricinus	Salicaceae	*Salix*
Fagaceae		Sapindaceae	*Koelreuteria*
Flacourtiaceae	*Scolopia*	Saxifragaceae	*Hydrangea*
Hamamelidaceae	*Liquidambar*	Theaceae	*Eurya*
Lauraceae		Ulmaceae	*Celtis*
Leguminosae	*Acacia*		*Trema*
	Leucaena		*Ulmus*
Gymnosperms			
Cupressaceae	*Juniperus*		
Pinaceae	*Pinus*		
	Podocarpus		
Non-arboreal Pollen Taxa (NAP)			
Amaranthaceae	*Amaranthus*	Cruciferae	
Araceae		Cyperaceae	
Chenopodiaceae	*Chenopodium*	Gramineae	
Compositae	*Ambrosia*	Solanaceae	*Solanum*
	Artemisia	Typhaceae	*Typha*
	Bidens	Urticaceae	
	Pathenium	Violaceae	*Viola*
Fern Spore Taxa (FS)			
Cyatheaceae	*Alsophila*	Lycopodiaceae	*Lycopodium cernuum*
Gleicheniaceae	*Dicranopteris*	Pteridaceae	*Pteris*

Table 2. Taxa of source plants with airborne pollen and spore frequency (F) more than 0.06%.

F＞1%		1%＞F＞0.5%		0.5%＞F＞0.1%		0.1%＞F＞0.06%	
Casuarina (AP)	27.49%	*Chenopodium* (NAP)	0.67%	*Artemisia* (NAP)	0.47%	*Alsophila* (FS)	0.08%
Morus (AP)	15.19%	Monolete spore (FS)	0.55%	Trilete spore (FS)	0.41%	*Ulmus* (AP)	0.07%
Fraxinus (AP)	12.25%			*Pathenium* (NAP)	0.39%	*Syzygium* (AP)	0.07%
Pinus (AP)	11.27%			Leguminosae (AP)	0.38%		
Dicranopteris (FS)	7.02%			Lauraceae (AP)	0.37%		
Celtis (AP)	5.03%			*Scolopia* (AP)	0.36%		
Juniperus (AP)	4.19%			*Melaleuca* (AP)	0.18%		
Ambrosia (NAP)	3.95%			*Acacia* (AP)	0.18%		
Gramineae (NAP)	2.80%			*Trema* (AP)	0.13%		
Liquidambar (AP)	1.34%			Euphorbiaceae (AP)	0.13%		
Podocarpus (AP)	1.10%			*Typha* (NAP)	0.13%		
Unknown	2.87%			*Bischofia* (AP)	0.12%		
				Cyperaceae (NAP)	0.12%		

AP: Arboreal Pollen; NAP: Non-arboreal Pollen; FS: Fern Spores.

Pollen of *Ambrosia* appeared mainly in August while *Artemisia* dominated in October. Pollen of Gramineae appeared year-round, but peak occurrence was in November.

Ambrosia

The airborne ragweed pollen could be found in every month of the year (Table 3). However, the peak occurrence began from mid June to mid October. The annual total of ragweed pollen had been as high as 1,987 grains (Table 3). The highest daily concentration occurred on August 16th with 656 pollen grains m^{-3} (Fig. 8). The density of pollen was related to the flowering time of this plant.

Ragweed pollen are allergenic to pollinosis patients. The duration with daily pollen density above the threshold concentration for ragweed (i.e. 13 pollen grains m^{-3} day^{-1}) was 36 days.

Artemisia

The annual total of *Artemisia* pollen was 235 grains (Table 3). The main pollen season of *Artemisia* began from the end of August to mid November, with the highest daily concentration of 60 pollen grains m^{-3} on October 16th. The duration with daily pollen density above the threshold concentration for mugwort (i.e. 13 pollen grains m^{-3} day^{-1}) was 12 days.

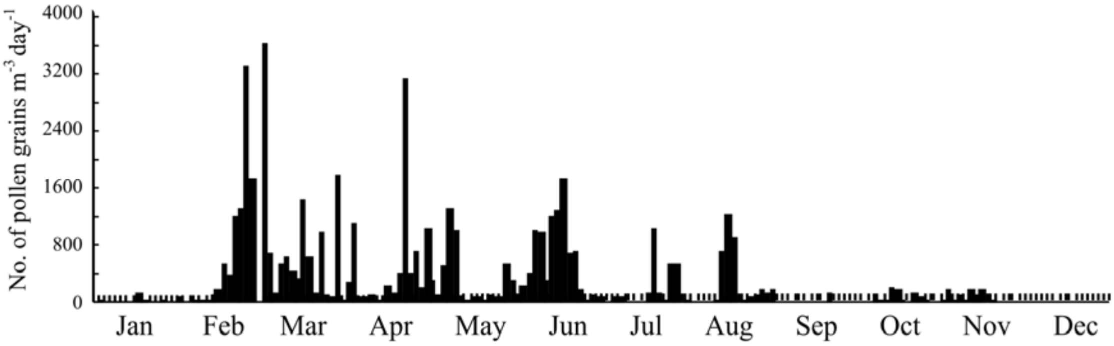

Fig. 4. Variation in daily pollen and fern spore density in Kinmen during 2003.

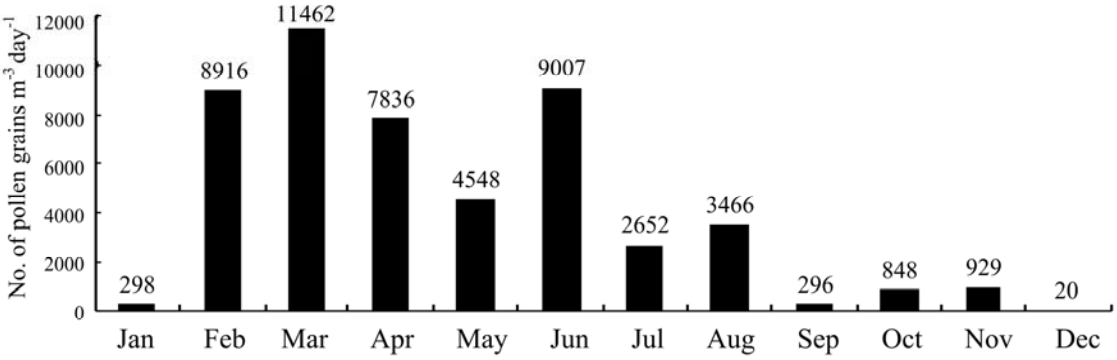

Fig. 5. Variation in total pollen and fern spore counts per month in Kinmen during 2003.

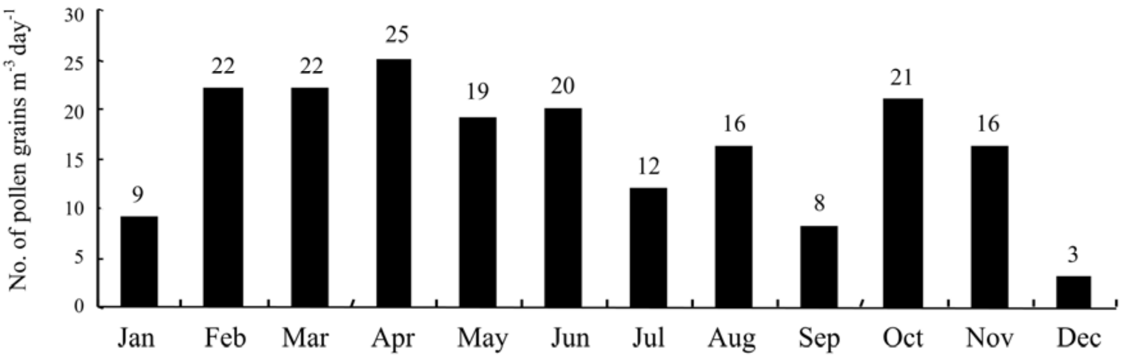

Fig. 6. Variation in number of pollen and fern spore taxa per month in Kinmen during 2003.

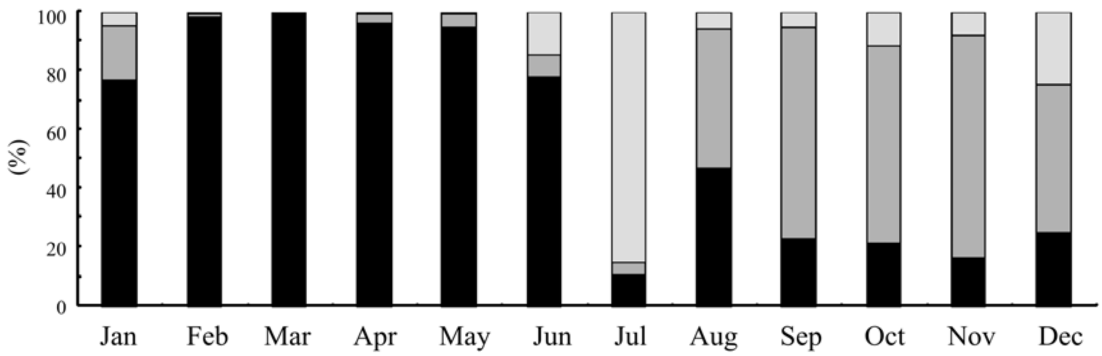

Fig. 7. Ratio of arboreal pollen (■AP), non-arboreal pollen (■NAP) and fern spores (■FS) in Kinmen during 2003.

Table 3. List of total pollen and fern spore counts per month in Kinmen during 2003.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	subtotal
Acacia	0	0	0	0	89	0	0	0	0	0	0	0	89
Alnus	0	5	5	0	0	0	0	0	0	9	0	0	19
Amaranthus	0	15	5	0	0	0	0	0	0	5	0	0	25
Ambrosia	24	10	5	14	10	120	14	1448	154	145	38	5	1987
Artemisia	14	0	0	5	5	0	5	14	24	153	15	0	235
Bidens	0	0	0	0	0	0	0	0	0	10	0	0	10
Bischoffia	0	0	43	19	0	0	0	0	0	0	0	0	62
Broussonetia	0	0	19	0	0	0	0	0	0	0	0	0	19
Casuarina	5	197	2120	6165	3324	715	233	957	42	28	37	0	13823
Celtis	0	0	2512	14	5	0	0	0	0	0	0	0	2531
Chenopodium	0	14	5	37	57	57	14	38	0	56	57	0	335
Compositae	0	0	5	9	0	0	0	0	0	10	5	0	29
Eleagnus	0	5	0	0	0	0	0	0	0	0	0	0	5
Euphorbiaceae	0	0	10	5	0	42	0	0	0	9	0	0	66
Eurya	0	0	0	0	0	0	0	0	0	0	10	0	10
Fagaceae	0	14	0	0	0	0	0	0	0	0	0	0	14
Fraxinus	0	0	0	0	293	5868	0	0	0	0	0	0	6161
Glochidion	0	0	0	10	0	0	0	0	0	0	0	0	10
Humulus	0	0	0	0	0	0	0	0	9	5	0	0	14
Hydrangea	0	0	0	5	0	0	0	0	0	0	0	0	5
Ilex	0	0	0	5	0	0	0	0	0	0	0	0	5
Juniperus	0	1233	802	19	0	0	0	0	0	14	37	0	2105
Koelreuteria	0	0	0	0	0	0	0	0	0	0	5	5	10
Lagerstroemia	0	0	0	0	0	0	0	5	0	0	0	0	5
Lauraceae	0	5	0	19	66	98	0	0	0	0	0	0	188
Leguminosae	5	5	5	0	9	121	0	5	0	37	5	0	192
Leucaena	0	0	0	0	15	5	0	0	0	0	0	0	20
Liquidambar	0	493	182	0	0	0	0	0	0	0	0	0	675
Melaleuca	0	0	0	0	0	0	5	29	0	34	23	0	91
Morus	195	4587	2126	19	14	42	28	586	23	10	5	0	7635
Myrtaceae	0	10	0	0	0	14	0	0	0	0	0	0	24
Pathenium	0	0	5	5	23	75	25	24	0	19	19	0	195
Pinus	20	2093	3307	193	25	10	5	5	0	10	0	0	5668
Podocarpus	0	0	0	294	256	5	0	0	0	0	0	0	555
Ricinus	0	0	0	0	0	0	0	0	0	0	19	0	19
Salix	0	0	0	5	0	0	0	0	0	0	0	0	5
Scolopia	0	0	42	93	43	5	0	0	0	0	0	0	183
Solanum	0	0	0	0	0	5	0	0	0	0	0	0	5
Syzygium	0	0	28	0	5	0	0	0	0	0	0	0	33
Trema	0	10	0	19	9	19	0	10	0	0	0	0	67
Ulmus	0	0	5	0	0	0	0	5	0	24	0	0	34
Urticaceae	0	10	0	0	0	0	0	0	0	0	0	0	10
Viburnum	0	0	0	5	0	0	0	0	0	0	0	0	5
Viola	0	5	0	0	0	0	0	0	0	0	0	0	5
Araceae	5	0	0	0	0	0	0	0	0	0	0	0	5
Cruciferae	0	5	5	0	0	0	0	0	0	19	0	0	29
Cyperaceae	0	5	0	0	0	9	0	28	5	10	5	0	62
Gramineae	10	34	57	154	80	337	42	62	14	85	529	5	1409
Palmae	0	10	0	0	0	0	5	0	0	0	0	0	15
Typha	0	0	0	5	19	42	0	0	0	0	0	0	66
Alsophila	0	0	0	0	0	0	15	15	10	0	0	0	40
Dicranopteris	5	29	5	0	0	1159	2124	145	0	10	53	0	3530
Lycopodium cernuum	0	0	0	5	0	0	0	0	0	0	0	0	5
Pteris	0	0	0	5	0	0	0	0	0	0	5	0	10
Monolete S.	0	5	14	5	19	89	56	37	0	43	5	5	278
Trilete S.	10	24	14	19	19	33	38	0	5	38	5	0	205
Unknown	5	93	136	684	163	137	43	53	10	65	52	0	1441
Subtotal	298	8916	11462	7836	4548	9007	2652	3466	296	848	929	20	Σ=50278

Diurnal periodicity

Over the study time, there were two diurnal patterns in changes of airborne pollen density. The first type was characterized by the occurrence of the maximum airborne pollen concentration constantly at the same time of day. Pollen of *Fraxinus*, *Pinus*, *Celtis*, and *Ambrosia* belonged to this type (Fig. 9). In contrast to this pattern, the second type was those species with an irregular occurrence of maximal pollen concentration within a day. Pollen of *Casuarina* and *Morus* were of this type (Fig. 10).

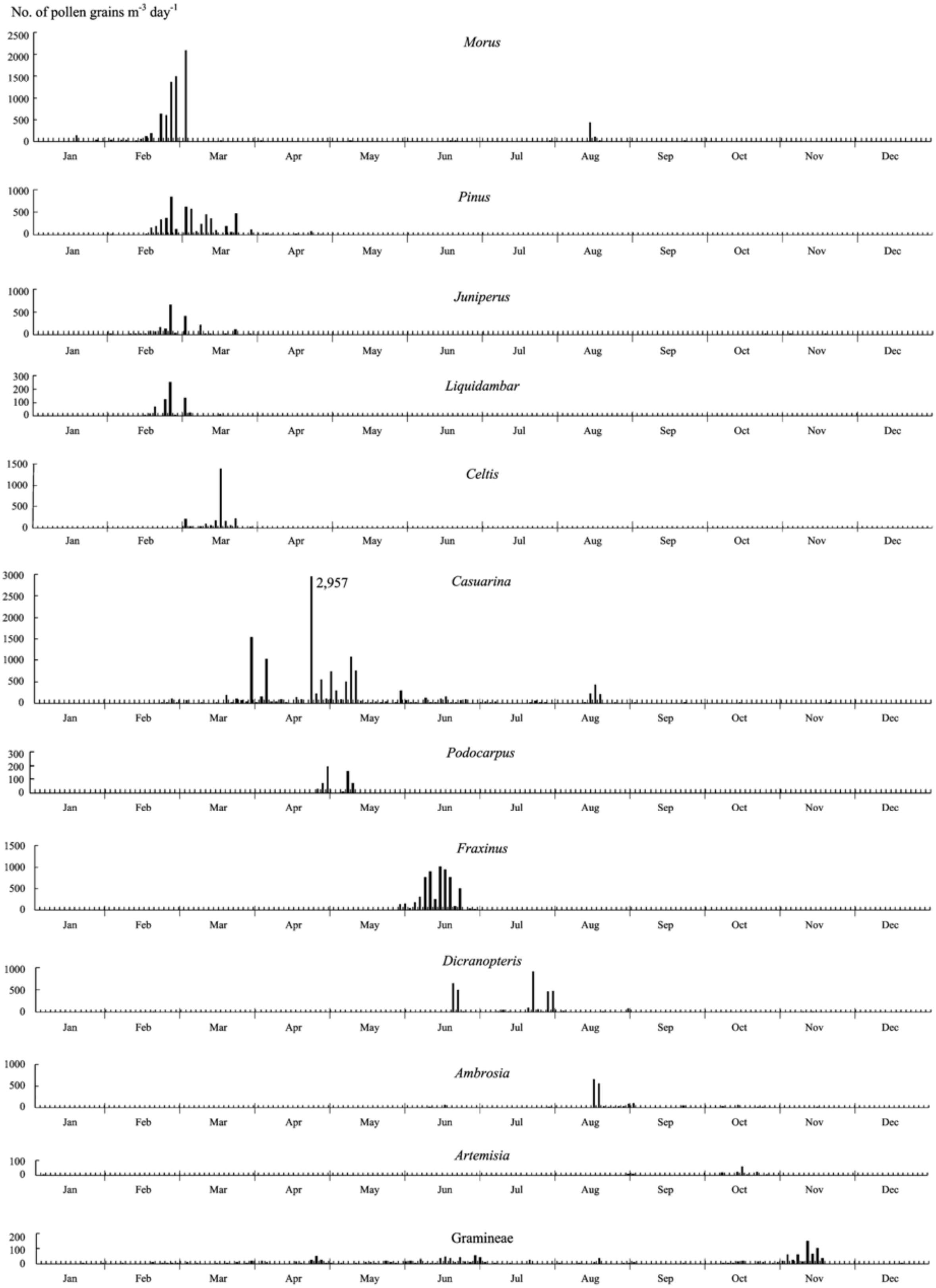

Fig. 8. Pollen and fern spore calendar of Kinmen during 2003.

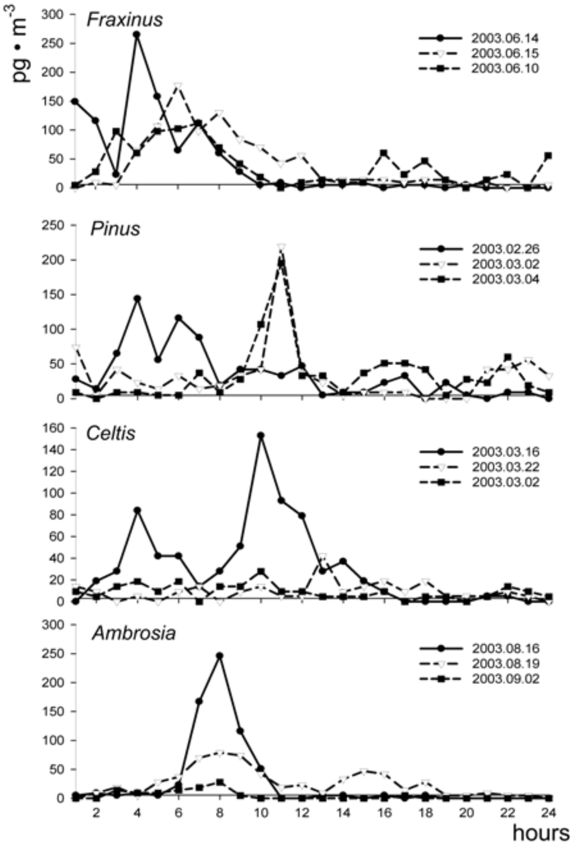

Fig. 9. Regular type of intradiurnal distribution of airborne pollen in Kinmen.

DISCUSSION

In this study, we recorded a total of 50,278 pollen and spores in Kinmen island. Remarkably, this is lower than the amount reported for the cities in Taiwan (Huang et al., 1998). Liu et al. (1983) has reported a high similarity (97.7%) in the phytogeographical relationship between Kinmen and Taiwan (Liu et al., 1983). However, the results of the present study show that the composition of airborne pollen is quite different between these two areas.

The type and density of local vegetation can be reflected in the composition and concentration of airborne pollen. In the present study, a great part of the taxa belongs to cultivated roadside or wind protection trees and ornamental plants. They are *Casuarina*, *Fraxinus*, *Pinus*, *Celtis*, *Juniperus*, *Liquidambar*, and *Podocarpus*. All of them have not been studied as allergenic plants in Kinmen. The allergenic ragweed (*Ambrosia*) is a naturalized plant that recently invaded Kinmen. It is thus suggested that control of invasive plants, particularly those of allergenic species, is of great importance.

The type and duration of the pollination seasons of the different pollen sources might vary from region to region, depending upon the climate conditions and vegetation type (D'Amato and Liccardi, 1994). In Taiwan, the pollen of *Broussonetia* was the most common species that occurred dominantly (up to15.3-79.4% in the atmosphere) in a variety of cities (Huang et al., 1998). In Kinmen, *Casuarina* was the most dominant species and contributed up to 27.5% of airborne pollen assemblages. This plant was planted in great masses (27,000,000 plants) between 1953 and 1971 (Kinmen Forestry Station, 1971), and this is why pollen of *Casuarina* was present in the atmosphere in nearly every season in Kinmen, except December.

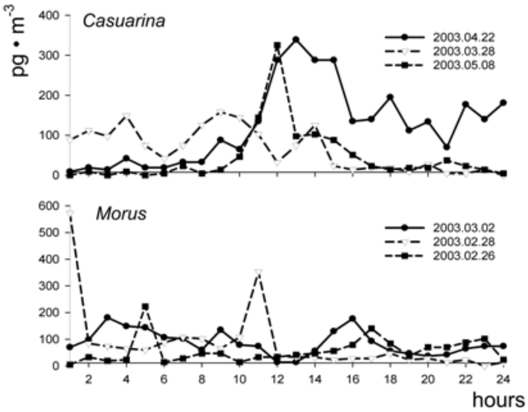

Fig. 10. Irregular type of intradiurnal distribution of airborne pollen in Kinmen.

It has been reported in a number of European countries that pollen grains of *Ambrosia* and/or *Artemisia* are related to the pollinosis (Laaidi and Laaidi, 1999; Heffer et al., 2005; García-Mozo et al., 2006; Puc, 2006). Similarly, pollen of these species are confirmed to account for pollinosis cases in Kinmen (Lin, 1997; Tsai et al., 1997; Chuang, 1999; Liang, 2003) despite their relatively low pollen densities compared with European countries. The sum of *Ambrosia* and *Artemisia* pollen contributed as much as 41.8% and 18%, to airborne pollen assemblages in August and October, respectively. This suggests that patients suffering from pollinosis should avoid exposure to these pollen at these times. In Kinmen, the airborne pollen density of *Artemisia* was remarkably lower than that of *Ambrosia.* As an allergenic plant, *Artemisia* should play a less important role than *Ambrosia*.

Mandrioli et al. (1998) reported that a daily pollen concentration exceeding 30 pollen grains m^{-3} is critical for those persons suffering from pollen allergy. However, Jäger and Litschauer (1998) and Laaidi and Laaidi (1999) reported that the symptoms of pollinosis occurred when the daily counts were above a threshold of 12-13 pollen grains m^{-3}. In Europe, the number of days with values exceeding a daily average of 30 pollen grains m^{-3} is 25-30 days in Hungary (Jarai-Komlódi 1998), 1-5 days in Poland (Stepalska et al., 2002), and 13-54 days in Croatia (Peternel et al., 2006). In the present study, there were 22 days with airborne ragweed pollen exceeding 30 pollen grains m^{-3} or 36 days with airborne ragweed pollen exceeding 13 pollen grains m^{-3} in the atmosphere in Kinmen. Apparently, the period of threat from either allergenic pollen species is similar to what happens in Europe.

In temperate regions, the maximum concentration of the diurnal periodicity of ragweed pollen varied from 10:00 am to 12:00 pm in Croatia (Peternel et al., 2006), between 9:00 am and 11:00 am in France (Laaidi et al., 2003), and between 4:00 pm and 8:00 pm in Poland (Piotrowska and Weryszko-Chmielewska, 2006). In our study in Kinmen, the peak of ragweed pollen occurred early in the morning, from 7:00 to 9:00 am (Fig. 9). Possibly, the earlier occurrence of the pollen peak is due to Kinmen's location in a subtropical climate zone, where the flowering time is earlier than in temperate regions.

Although the individual rhythm of plant pollination and phenological phenomena are species specific, they can be modified by weather conditions (Emberlin et al., 1993; Peternel et al., 2006). Warm and dry periods during anther formation can increase pollen density in the atmosphere (Galan et al., 1995). In Europe, *Ambrosia* requires a warm climate, dry soil, and sufficient humidity during the summer time (Dechamp, 1997), and the maximum concentration of airborne ragweed pollen were restricted to the time between August and September, the warmest and driest months of the year (D'Amato and Spieksma, 1990; Jäger et al., 1991; Lejoly-Gabriel and Leuschner, 1983; Štefanić et al., 2005; Peternel et al., 2006). The weather conditions in Kinmen may be more suitable for the growth and spread of *Ambrosia* than those in Taiwan, where less airborne ragweed pollen were found (Peng and Chen, 1997). Presumably, this is the reason why the rate of ragweed pollinosis in Taiwan is lower than in Kinmen (Tsai et al., 1997).

The dispersal pattern of *Fraxinus*, *Pinus*, *Celtis*, and *Ambrosia* is regular while that of *Casuarina* and *Morus* is irregular. These findings are in agreement with the results of Peng (1994) and Peng and Chen (1997).

In conclusion, this study confirmed the presence of the allergenic pollen species *Ambrosia* and *Artemisia* in Kinmen. On the basis of the present study, a pollen calendar for Kinmen was established to elucidate a quantitative and qualitative periodicity for the occurrence of airborne pollen. This information may aid allergologists in establishing an exact diagnosis. A further study should be done to verify the allergenic effects of each suspected taxa mentioned above.

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Checklist 1. Collection of flower materials during May and December 2002 by T.-C. Huang and Arthur Hsiao.

1. THELYPTERIDACEAE
   (1) *Cyclosorus parasiticus* (L.) Farw. (*Huang & Hsiao 18081*)
2. AIZOACEAE
   (2) *Tetragonia tetragonoides* (Pall.) Kuntze (*Huang & Hsiao 18037*)
   (3) *Trianthemum portulacastrum* L. (*Huang & Hsiao 18038*)
3. AMARANTHACEAE
   (4) *Gomphrena celosioides* Mart. (*Huang & Hsiao 18036*)
4. ANACARDIACEAE
   (5) *Rhus chinensis* Mill (*Huang & Hsiao 18077*)
5. ASCLEPIADACEAE
   (6) *Gymnema alterniflorum* (Lour.) Merr. (*Huang & Hsiao 18083*)
6. CAPRIFOLIACEAE
   (7) *Abelia chinensis* R. Br. (*Huang & Hsiao 18079*)

7. CELASTRACEAE
(8) *Maytenus diversifolia* (Maxim.) D. Hou (*Huang & Hsiao 18086*)
8. CHENOPODIACEAE
(9) *Chenopodium viride* L. (*Huang & Hsiao 18023, 18029*)
(10) *Chenopodium album* L. (*Huang & Hsiao 18041,18058, 18066*)
9. COMPOSITAE
(11) *Ambrosia artemisiifolia* L. (*Huang & Hsiao 18049, 18050*)
(12) *Artemisia* sp. (*Huang & Hs*iao *18061*)
(13) *Bidens pilosa L.* (*Huang & Hsiao 18069*)
(14) *Conyza canadensis* (L.) Cronq. (*Huang & Hsiao 18059*)
(15 *)Crepidiastrum taiwanianum* Nakai (*Huang & Hsiao. 18075*)
(16) *Eupatorium catarium* J. F. Veldkamp (*Huang & Hsia*o 18064, 18070)
(17) *Parthenium hysterophorus* L. (*Huang & Hsiao 18028*)
(18) *Pertya simozawai* Masam. (*Huang & Hsiao. 18076*)
(19) *Synedrella nodiflora* (L.) Gaertn. (*Huang & Hsiao 18084*)
10. CRUCIFERAE
(20) *Lepidium virginicum* L. (*Huang & Hsiao 18025*)
11. CYPERACEAE
(21) *Cyperus rotundus* L. (*Huang & Hsiao 18032*)
12. ELAEAGNACEAE
(22*) Elaeagnus oldhamii* Maxim. (*Huang & Hsiao 18089*)
13. EUPHORBIACEAE
(23*) Euphorbia cotinifolia* L. (*Huang & Hsiao 18060*)
(24) *Euphorbia* sp. (*Huang & Hsiao 18062*)
14. GRAMINEAE
25) *Chloris barbata* Sw. (*Huang & Hsiao 18027*)
(26) *Digitaria ciliaria* (Retz.) Koel. (*Huang & Hsiao 18035*)
(27) *Phragmites communis* L. (*Huang & Hsiao 18068*)
(28) *Rhynchelytrum repens* (Willd.) C. E. Hubb (*Huang & Hsiao. 18040*)
(29) *Setaria viridis* (L.) P. Beauv. (*Huang & Hsiao 18024*)
15. LABIATAE
(30) *Ajuga nipponensis* Makino (*Huang & Hsiao 18042*)
(31) *Lamium amplexicaule* L. (*Huang & Hsiao 18090*)
16. LEGUMINOSAE
(32) *Acacia confusa* Merr. (*Huang & Hsiao. 18057*)
(33) *Alysicarpus vaginalis* (L.) DC. (*Huang & Hsiao 18072*)
(34) *Bauhinia galpinii* N.E.Br. (*Huang & Hsiao 18091*)
(35) *Cassia surattensis* Burm. f. *Huang & Hsiao 18023*)
(36) *Indigofera hirsuta* L. (*Huang & Hsiao 18055, 18063*)
(37) *Leucaena leucocephala* (Lam.) de Wit (*Huang & Hsiao 18033*)
(38) *Medicago lupulina* L. (*Huang & Hsiao 18031*)
(39) *Melilotus officinalis* (L.) Pall. subsp. *suaveolens* (Ledeb.) H. Ohashi (*Huang & Hsiao 18039*)
(40) *Senna occidentalis* (L.) Link (*Huang & Hsiao 18054*)
(41) *Sesbania cannabiana* (Retz.) Poir (*Huang & Hsiao 18071*)
17. MALVACEAE
(42) *Malvastrum coromandelianum* (L.) Garcke (*Huang & Hsiao 18030*)
18. MYRTACEAE
(43) *Callistemon rigidus* R.Br. (*Huang & Hsiao 18026*)
(44) *Eucalyptus citriodora* (*Huang & Hsiao 18080*)
19. PLUMBAGINACEAE
(45) *Plumbago zeylanica* L. (*Huang & Hsiao 18034*)
20. RHAMNACEAE
(46) *Berchemia lineata* (L.) DC. (*Huang & Hsiao 18056, 18065, 18073, 18085, 18092*)
21. ROSACEAE
(47) *Pyracantha koidzumii* (Hayata) Rehder (*Huang & Hsiao 18093*)
(48) *Rosa cymosa* Tratt. (*Huang & Hsiao. 18078*)
22. RUBIACEAE
(49) *Mussaenda pubescens* W. T. Aiton (*Huang & Hsiao 18088*)
(50) *Serissa serissoides* (DC.) Druce (*Huang & Hsiao 1808*7)
23. SAPINDACEAE
(51) *Dodonaea viscosa* (L.) Jacq (*Huang & Hsiao. 18067*)
24. THEACEAE
(52) *Cleyera japonica* Thunb. (*Huang & Hsiao 8082*)
25. TILIACEAE
(53) *Triumfetta bartramia* L. (*Huang & Hsiao 18051*)
26. VERBENACEAE
(54) *Caryopteris incana* (Thunb. ex Houtt.) Miq (*Huang & Hsiao 18074*)
(55) *Vitex negundo* L. (*Huang & Hsiao 18053*)

金門的空中孢粉研究

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摘　　要

距中國大陸極近的金門，其花粉症及過敏性鼻炎近年來越來越嚴重，為確定花粉及孢子與此現象的關係，我們在 2003 年進行空中孢粉的研究。空中孢粉收集器設於金門的金湖鎮，裝在一棟 10 公尺高的房子屋頂。經過一年的收集，總共收得孢粉粒 50,278 個，有 51 個分類群已被鑑定出，其中被子植物 33 科，裸子植物 2 科及蕨類 4 科，共 39 科。本研究中有 12 個分類群具優勢比率，這些優勢分類群為：木麻黃屬 (27.5%)、桑屬 (15.2%)、楊屬 (12.3%)、松屬 (11.3%)、芒萁屬 (7.0%)、朴屬 (5.0%)、柏屬 (4.2%)、豬草屬 (4.0%)、禾本科 (2.8%)、楓香屬 (1.3%)、羅漢松屬 (1.1%)、和艾屬 (0.5%)。在二月中至六月中能收集到較高濃度的空中花粉。而孢粉優勢種類因季節而異，桑屬、柏屬及楓香屬出現在二月至三月初，松屬為二月及三月，朴屬為三月，木麻黃屬是四、五、六、八月，羅 漢松屬由四月底至五月初，楊屬為六月，芒萁屬為六、七月，豬草屬為八月，艾屬為十月，禾本科為十一月。研究期間，木本植物的空中花粉量 (79.9%) 較非木本植物花粉量 (8.5%) 及蕨類孢子量 (8.1%) 為多。引起過敏的豬草屬花粉，在八月達高峰，且日高峰出現於早晨七點至九點。本研究建立了金門地區的 2003 年孢粉曆，呈現了不同季節的空中孢粉種類和量的變化，並且提供花粉熱更進階研究的基礎。

關鍵詞：空中孢粉學、豬草屬、金門、孢粉曆、臺灣。

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