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Diurnal Variations of Airborne Pollen and Spores in Taipei City, Taiwan

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ABSTRACT: The diurnal variation of airborne pollen and spores in Taipei City, Taiwan, was investigated during a two-year survey from 1993 to 1994. The pollen and spores were sampled using a Burkard seven-day volumetric pollen trap. The diurnal trends of the total amount of pollen and spores in 1993 and in 1994 were similar to each other, and peaked at 3 to 10 o'clock. The diurnal patterns of airborne pollen and spores of *Broussonetia, Fraxinus*, *Cyathea* and Gramineae in 1993 were similar to those in 1994. High concentrations of *Broussonetia* and *Fraxinus* were obtained from midnight to the next morning. *Cyathea* spores peaked from morning till noon, and Gramineae peaked in the afternoon. The diurnal patterns of airborne pollen of *Bischofia*, *Juniperus, Mallotus*, *Morus*, *Trema* and Urticaceae in 1993 were different to those in 1994. Regular diurnal patterns also associated with the taxa, which produce large pollen or spores, such as Gramineae and *Cyathea*. In contrast, *Bischofia, Juniperus, Mallotus*, *Morus*, *Trema* and Urticaceae produce relatively small pollen and the diurnal patterns of their airborne pollen were found irregular. The source plants *Broussonetia* and *Fraxinus* were close to the collection site so the diurnal patterns of their airborne pollen were regular, suggesting that the diurnal fluctuations of the pollen or spores in air might be affected by the source of plants and the sizes of pollen or spores. The transportation of the smaller pollen or spores in air is probably more easily affected by instability of air currents; they are therefore more likely to exhibit irregular diurnal patterns.

KEY WORDS: Airborne pollen and spore, Diurnal variation, Taipei.

INTRODUCTION

Aeropalynology has become important in the last few decades because of serious problem of pollen-induced atopic diseases (D'Amato and Liccardi, 1994; Stock and Morandi, 1988). In Taiwan, continuous aeropalynological investigations at various locations have yielded useful information on the pollen calendars for use in further aeroallergen studies (Chen and Huang, 1980; Tsou and Huang, 1982; Chen, 1984; Chen and Chien, 1986; Peng and Chen, 1997; Tsou *et al.*, 1997; Huang, 1998; Yang and Chen, 1998; Kuoh *et al.*, 1999; Chen and Huang, 2000). However, the allergenic effects of most dominant airborne pollen and spores in Taiwan have not yet been studied, only the pollen of Bermuda grass (Shen *et al*., 1988; Han *et al.*, 1993), rice (Tsai *et al.*, 1990) and *Ambrosia* (Tsai *et al*., 1997) have been determined to be allergens. The present investigation was focused on and the pollen of *Bischofia*, *Broussonetia*, *Fraxinus*, Gramineae, *Mallotus*, *Morus*, *Juniperus*, *Trema* and Urticaceae and the spores of *Cyathea*, most of which were found to dominate not only in Taipei City (Yang and Chen, 1998) but also in other cities around Taiwan, such as Taipei county (Tansui) (Peng and Chen,

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Fig. 1. Location of Taipei City(★) and the other sampling locations in Taiwan, Tansui(☆), Taitung, Tainan, Pingtung(△), Hualien and Taitung.

1997), Taichung (Tsou *et al.*, 1997), Tainan (Kuoh *et al.*, 1999), Pingtung (Huang, 1998), Hualien and Taitung (Huang *et al.*, 1998) (Fig. 1). Several of these pollen have been recognized as important airborne allergens of rhinitis in many other areas, including *Broussonetia* in mainland China (Yang *et al.*, 1998), *Fraxinus*, Gramineae and Urticaceae in Europe (Peeters, 1998; D'Amato and Liccardi, 1994; D'Amato and Spieksma, 1991), *Morus* and *Trema* in India (Mondal *et al.*, 1998; Chakraborty *et al.*, 1998) and *Juniperus* in Europe and Australia (Patrizia *et al.*, 1998; Pham *et al.*, 1994).

More than two million people live in Taipei, the capital and largest city in Taiwan, and are exposed to possible allergenic pollen and spores. Avoidance is practical as long as the time of daily maximal aeroallergen concentration - that is, the diurnal variation - is provided (Jaeger, 1990; Stock and Morandi, 1988). Apart from the extensive investigations of a limited number of taxa of airborne pollen and spores by Peng (1994), Peng and Chen (1997) and Huang (1998), only the annual variations of the airborne pollen and spores concentrations of a few dominant taxa in Taiwan have been studied (Huang *et al.*, 1998). This study seeks to analyze the diurnal changes in concentration of airborne pollen and spores of individual dominant taxa. The diurnal variations of airborne pollen and spores in Taipei City are compared with those in Taipei county (Tansui) in the northwestern tip of Taiwan, from which some pollen may be transported to nearby Taipei City or vice versa, and those in Pingtung City, in the tropical south of Taiwan (Fig. 1).

MATERIALS AND METHODS

Pollen concentrations were monitored from January 14, 1993 to December 31, 1994 using a Burkard seven-day recording volumetric pollen trap. The trap was located on the roof of a building, about 9 m above ground level, in Hondau Junior High School in Taipei City (25°03´N, 121°31´E) (Fig. 1). The flow rate through the trap was adjusted to 10 L per min and the pollen collections were checked weekly. A tape was attached to the roller, which moved at a rate of 2 mm / hr. After one-week of collection, the tape on the roller had spun for 336 mm and the segment of this length was cut into seven 48 mm-long pieces, which were removed to glass slides to identify and count the adhered pollen and spores. According to Peng and Chen (1996), the number of pollen and spores collected in an hour on a transverse band of a tape was used to estimate the number of pollen in m^3 of air.

The diurnal variations of total airborne pollen and spores during the study period were calculated, and the diurnal variations of ten individual dominant taxa were analyzed. Data on rainless days, with relatively high counts during the flowering season, were used to analyze diurnal variation. The number of pollen and spores per hour on all selected days were summed and the mean values per hour were calculated. Table 1 lists the three selected days in the flowering seasons of *Bischofia*, *Broussonetia*, Cyathea, *Fraxinus*, Gramineae, *Juniperus, Mallotus*, *Morus*, *Trema* and Urticaceae. The references for identification of airborne pollen and spores included Pollen Flora of Taiwan (Hang, 1972), Spore Flora of Taiwan (Huang, 1981) and a SEM survey of airborne pollen grains in Taipei City (Chen, 1988).

The sizes of pollen grains and spores were measured using ten samples of each taxon on slides, in which the pollen and spores were embedded in glycerine- gelatine.

Most parts of Taipei City are at low altitude, and vegetation is influenced by excessive urbanization and biotic interference. The common sources of airborne pollen and spores include native species and trees along the avenues in the city or in the mountainous areas around the city.

Table 1. Three selected days of ten dominant pollen and spore taxa.

Taxon	1993	1994
Bischofia	2/28, 3/12, 3/14	3/16, 3/26, 3/28
Broussonetia	3/24, 3/26, 3/28	4/4, 4/6, 4/12
Cyathea	8/18, 9/4, 9/12	7/2, 7/6, 7/8
Fraxinus	5/22, 5/24, 5/30	5/22, 5/24, 5/26
Gramineae	11/8, 11/10, 11/14	11/6, 11/8, 11/12
Juniperus	2/6, 2/18, 2/20	2/10, 2/22, 3/5
Mallotus	9/10, 9/12, 10/2	9/20, 9/22, 9/24
Morus	2/19, 2/20, 3/4	2/4, 2/22, 3/12
Trema	4/24, 4/28, 4/30	5/8, 5/10, 5/14
Urticaceae	3/6, 3/14, 3/24	3/26, 4/6, 4/8

RESULTS

Total concentration of airborne pollen and spores

In this two-year survey, approximately 43% of all airborne pollen and spores recorded were found from 3 to 10 o’clock (Fig. 2); the maximum concentration was at 9 o’clock and the minimum concentration was at 19 o’clock. The diurnal trend of total pollen and spores in 1993 was similar to that in 1994, and that the correlation was high significant ($r=0.92$. $p<0.01$).

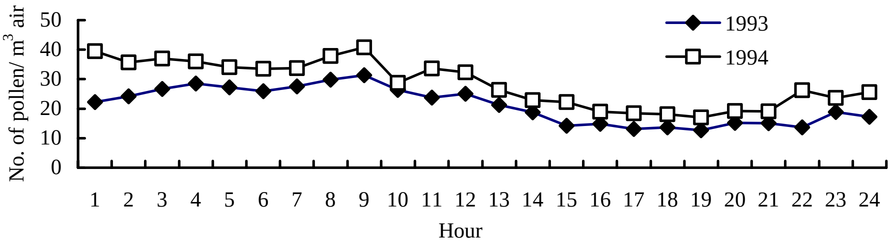

Fig. 2. Diurnal variations of total airborne pollen in Taipei City, 1993 and 1994.

Dominant airborne pollen and spores

The diurnal variations of airborne pollen and spores of *Broussonetia*, *Cyathea*, *Fraxinus* and Gramineae in 1993 were significantly correlated with those in 1994 (Table 2 and Fig. 3). The diurnal variations of airborne pollen of *Bischofia*, *Juniperus*, *Mallotus*, *Morus*, *Trema* and Urticaceae were negatively correlated between the two years (Table 2 and Fig. 4).

Table 2. Data on the taxa with the largest concentrations was recorded over two years and regression analysis of diurnal trends over 1993 and 1994 was conducted.

Taxon	Time of maximum concentration (o'clock)		Correlation coefficient
	1993	1994	
Broussonetia	3	9	**r= 0.92
Cyathea	13	12	*r= 0.39
Fraxinus	7	7	**r= 0.72
Gramineae	18	17	**r= 0.67
Bischofia	4	22	r= -0.1
Juniperus	8	24	r= 0.01
Mallotus	10	1 and 5	r= 0.27
Morus	11	19	r= 0.16
Trema	1	11	r= -0.05
Urticaceae	6	2	r= 0.27

* : result significant at p< 0.1
** : result significant at p< 0.01

In 1993, concentrations of *Bischofia*, *Broussonetia*, *Fraxinus*, *Juniperus*, *Mallotus*, *Trema* and Urticaceae pollen were high from midnight to next morning, peaking at 4, 3, 7, 8, 10, 1 and 6 o'clock, respectively. Concentrations of *Cyathea* spores and *Morus* pollen were high from morning to midday, peaking at 13 and 11 o'clock, respectively. The concentration of Gramineae pollen was high from afternoon to night, peaking at 18 o'clock.

In 1994, the concentrations of *Broussonetia*, *Fraxinus*, *Mallotus* and Urticaceae pollen were high from midnight to next morning, peaking at 9, 7, 5 and 2 o'clock, respectively. High concentrations of *Cyathea* spores and *Trema* pollen were recorded from morning to midday, peaking at 12 and 11 o'clock, respectively. High concentrations of *Bischofia*, Gramineae, *Juniperus* and *Morus* pollen were recorded from afternoon to midnight, peaking at 22, 17, 24, and 19 o'clock, respectively.

Source areas of pollen and spores

The sources of pollen of *Bischofia*, *Broussonetia, Fraxinus, Juniperus, Morus* and *Trema* were probably in the city; however the pollen and spores of *Cyathea*, Gramineae, *Mallotus* and Urticaceae were probably from vegetation in the surrounding mountainous areas.

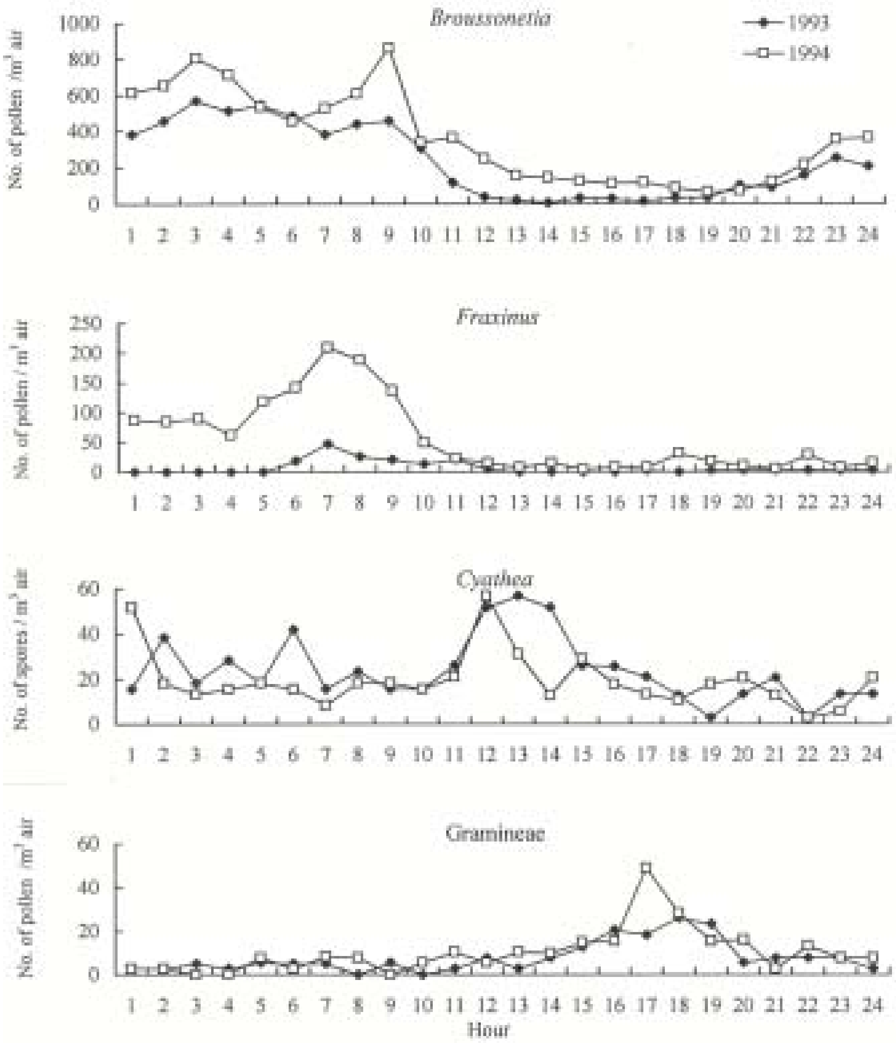

Fig. 3. Regular diurnal variations of *Broussonetia*, *Fraxinus, Cyathea* and Gramineae. Mean values per hour were for three selected days (listed in Table 1) with high pollen counts.

Bischofia javanica is a native tree common on the streets and gardens of Taipei City, and is the possible source of *Bischofia* pollen in air. *Broussonetia papyrifera, Morus australis* and *Trema orientalis,* common native pioneer trees, are common in the city and the possible source of *Broussonetia*, *Morus* and *Trema* pollen in air, respectively. *Fraxinus griffithii, a* major source of *Fraxinus* pollen is a common native tree, too, but it is uncommon in Taipei City. *Juniperus* pollen probably originated from individual ornamental trees in the gardens and parks in the city, such as *Juniperus chinensis* var. *kaizuka* and *J. chinensis* var. *pyramidalis*.

Cyathea lepifera, C. podophylla and *C. spinulosa*, the major sources of *Cyathea* spores, are common native ferns in the lower mountainous areas throughout Taiwan. *Miscanthus floridulus* is common native species from low to medium altitudes throughout Taiwan. In Taipei City, large populations of *Miscanthus floridulus* in mountainous areas may be the major sources of Gramineae pollen. *Mallotus paniculatus* is a common native tree in the lower mountainous areas throughout Taiwan and the source of the *Mallotus* pollen. The sources of Urticaceae pollen include many species, such as *Boehmeria densiflora*, *Debregeasia edulis*, which are also common in lower mountainous areas throughout Taiwan.

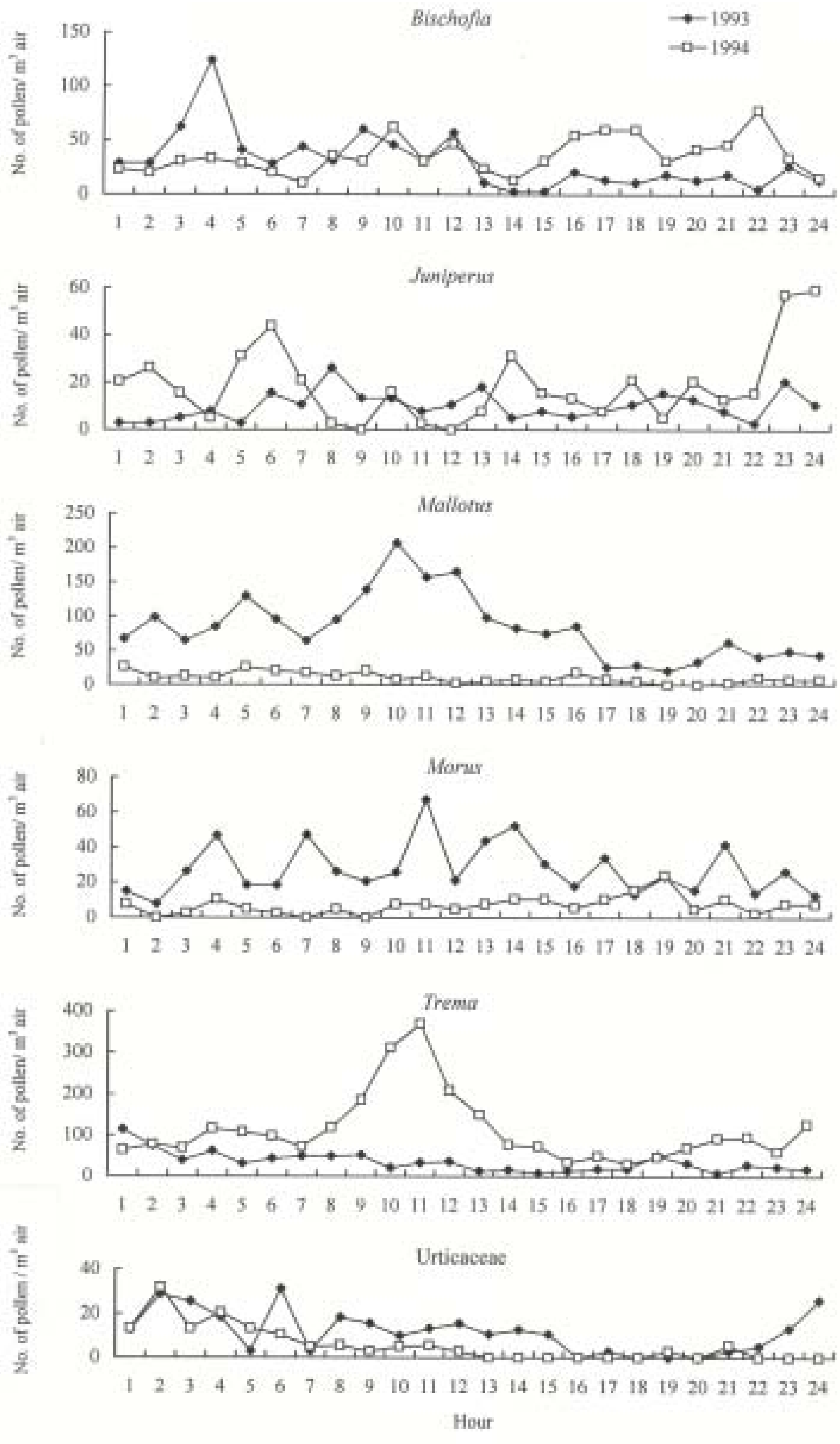

Fig. 4. Irregular diurnal variations of pollen of *Bischofia*, *Juniperus*, *Mallotus*, *Morus*, *Trema* and Urticaceae. The mean values per hour were for three selected days (listed in Table 1.) with high pollen counts.

Size of pollen and spores

Table 3 shows that *Cyathea* spores (41.81±3.18 x 42.53±2.75 μm) are the largest among those of the ten taxa, followed by those of Gramineae pollen. *Broussonetia* pollen (11.75± 1.10 x 11.43±0.91 μm) are the smallest.

Table 3. Mean size of airborne pollen and spores. The pollen and spores, embedded in glycerine- gelatine were measured in LM. P: polar axis; E: equatorial axis.

Taxon	Mean size of pollen and spores (P x E)
Bischofia	22.60±1.45 x 19.40±0.66 μm
Broussonetia	11.75±1.10 x 11.43±0.91 μm
Cyathea	41.81±3.18 x 42.53±2.75 μm
Fraxinus	16.54±0.80 x 15.54±0.88 μm
Garmineae	32.40±1.00 x 31.57±0.99 μm
Juniperus	32.03±2.33 x 31.58±1.87 μm
Mallotus	18.74±0.78 x 19.99±0.78 μm
Morus	15.20±0.59 x 15.29±0.86 μm
Trema	19.91±1.23 x 20.37±1.25 μm
Urticaceae	13.40±1.75 x 13.50±1.60 μm

DISCUSSION

Total concentration of airborne pollen and spores

The dynamics of the meteorological factors in a day could affect the diurnal variations of airborne pollen (Lee *et al*., 1996; Berggren *et al*., 1995; Galán *et al*., 1991; Norris-Hill and Emberlin, 1991). That is, increasing temperature and decreasing relative humidity were closely correlated with increasing amounts of airborne pollen and spores. Therefore, most airborne pollen and spores were collected from 3 to 10 o'clock (Fig. 2) not only in Taipei City, but also in Tansui (Pen and Chen, 1997) and Pingtung (Huang, 1998) on Taiwan Island.

Dominant airborne pollen and spores

Data obtained on rainless days were used, since rain can delay or suppress the release of pollen (Atluri and Appanna, 1988) and even wash away airborne pollen (Berggren *et al*., 1995).

All airborne pollen and spores taxa considered in this study, except for *Cyathea*, *Fraxinus*, *Juniperus* and Urticaceae are dominant in whole Taiwan Island, according to the mass of airborne pollen they produce (Peng and Chen, 1997; Tsou *et al.*, 1997; Huang, 1998; Huang *et al*., 1998; Yang and Chen, 1998; Kuoh *et al.*, 1999).

Although the source of Urticaceae pollen and *Cyathea* spore distribute throughout Taiwan, Urticaceae pollen were dominant in air only in Taipei City (Yang and Chen, 1998), Tansui (Peng and Chen, 1997), Tainan (Huang *et al*., 1998) and Hualien (Huang *et al*., 1998), while *Cyathea* spore were dominant in air only in Taipei City (Yang and Chen, 1998) and Tansui (Peng and Chen, 1997). There are mountainous areas, the source plants of Urticaceae pollen and *Cyathea* spore grow, around the locality of the pollen trap, such as Taipei City (Yang and Chen, 1998), Tansui (Peng and Chen, 1997), Tainan (Huang *et al*., 1998) and Hualien (Huang *et al*., 1998), which could collect those airborne pollen and spores.

Fraxinus griffithii, the source of *Fraxinus,* distributes throughout Taiwan, the pollen in air was dominant only in Taipei City (Yang and Chen, 1998). A great number of *Fraxinus* pollen was collected in the trap in Taipei City was probably related to the planted *F. griffithii* on the campus of Hondau Junior High School where the recording trap was located. Pollen of *Juniperus* was dominant only in Taipei City (Yang and Chen, 1998). There are more gardens and parks in Taipei City than those in other cities where planted many ornamental trees, such as *Juniperus chinensis* var. *kaizuka* and *J. chinensis* var. *pyramidalis*, the source of *Juniperus* pollen. The abundance of the pollen and spores may be affected by vegetation around the locality of the pollen trap.

The tendency of diurnal variation of *Broussonetia* pollen in 1993 was similar to that in 1994, with high concentration from midnight to following morning. In Southwest of Spain the airborne pollen of *B. papyrifera* was recorded to exhibit a similar diurnal pattern to that in Taipei City, with a high concentration from 10 to 12 o'clock in 1982 and 1983 (Galán *et al*., 1991), whereas those results are different with Tansui (Peng, 1994) and Pingtung(Huang, 1998). Most airborne *Broussonetia* pollen was collected from 13 to 15 o'clock and 23 to 24 o'clock in 1993 in Tansui and throughout the day in Pingtung.

The significantly large amount of *Miscanthus floridulus* pollen, the major source of Gramineae pollen in Taipei City, dominated the diurnal variation of the grass airborne pollen, which appeared to be regular. The irregularity in diurnal variations of grass airborne pollen in other areas was probably due to involvement of multiple species (Käpylä, 1981; Mullins *et al*., 1986; Pen and Chen, 1997).

The diurnal variations of *Bischofia*, *Mallotus*, *Morus* and *Trema* pollen showed irregularity in 1993 to those in 1994. As several authors have suggested, the dehiscence of pollen of *Morus* exhibits no regular pattern, and the release of *Morus* pollen continues throughout the day (Käpylä, 1984; Galán *et al.*, 1991). Although the diurnal variation of *Trema* pollen showed irregular pattern, most airborne *Trema* pollen was collected from morning to midday. The result is similar to that in Pingtung, high concentration of *Trema* pollen from 9 to 13 o'clock (Huang, 1998) and Indian, high concentration in early and late morning (Banik and Chanda, 1992). In Tansui, the tendency of diurnal variation of *Trema* pollen showed regular pattern with high concentration from 4 to 8 o'clock (Peng and Chen, 1997).

The diurnal variations of *Juniperus and* Urticaceae pollen in this study showed an irregularity that was probably related to the fact that at least two species were involved; similar result was obtained in Tansui (Peng, 1994; Peng and Chen, 1997).

Although the anthesis of the different species occurred different, most of them were in the morning to midday. For example, a study of 31 species in India revealed pollen release from 3 to 13 o'clock (Atluri and Appanna, 1988). Bhattacharya and Datta (1992) studied 35 species, including 25 anemophilous species, and found that release patterns of pollen varied but occurred within the period from 2 to 12 o'clock. Variations in diurnal rhythms of airborne pollen may reflect the release of pollen from different species (Käpylä, 1981; Käpylä, 1984). Many studies have found only slightly different diurnal patterns of airborne pollen at different times (Alcázar *et al.*, 1999; Diaz, *et al*., 1993; Galán *et al.*, 1991), but some other studies have indicated significant differences with time (Alcázar *et al*., 1999; Galán *et al*., 1991). This study revealed that high concentration of airborne pollen varied with species and that the diurnal variations of *Broussonetia*, *Cyathea*, *Fraxinus* and Gramineae in 1993 were similar to those in 1994 (Fig. 3). However, the diurnal variations of *Bischofia*, *Juniperus*, *Mallotus*, *Morus*, *Trema* and Urticaceae differed between the two years (Fig. 4).

Source areas of pollen and spores

The amount of airborne pollen does not necessarily reflect only the release of pollen, but also pollen dispersal and transport (Norris-Hill, 1999; Käpylä, 1984). The position of the trap in relation to the source of pollen influences the diurnal patterns of the pollen in air (Muñoz *et al.*, 2000; Norris-Hill and Emberlin, 1991). Käpylä (1981) revealed that when the airborne pollen collection site is far from the source plants, the movement of air is more important than the pollen liberation rhythm in determining the diurnal fluctuation of the airborne pollen.

In this study, the diurnal patterns of airborne pollen of *Broussonetia* and *Fraxinus* were regular because their source plants, *B. papyrifera* and *F. griffithii*, grow in the campus where the data were recorded and their pollen grains were captured by the trap almost immediately after they were released. The source plants of *Bischofia*, *Juniperus*, *Mallotus*, *Morus*, *Trema* and Urticaceae are scattered over the city or in the suburban mountains far from trap, so the diurnal patterns of their airborne pollen were irregular, while those of *Cyathea* and Gramineae were regular.

Size of pollen and spores

Weather conditions, especially wind conditions, affect the diurnal fluctuations of pollen concentrations in the air (Berggren, 1995; Käpylä, 1981). Mullins *et al.* (1986) pointed out that rising air currents lead to irregular diurnal patterns of airborne pollen. Strong agitation is required to transport large particles in the air, so the concentration of large pollen depend more strongly on the wind speed than does that of smaller pollen (Käpylä, 1984). Therefore, the diurnal pattern of larger airborne pollen is much more regular than that of smaller pollen. A previous paper, noted that smaller airborne pollen correspond to higher pollen concentration at greater heights, affected by thermal convection (Alcázar *et al*., 1998). Such a phenomena may explain why regular diurnal patterns are always associated with taxa with large pollen and spores, such as Gramineae and *Cyathea.* Also, if the source plants of *Broussonetia* and *Fraxinus* with small pollen are not in campus, the diurnal variation may be varied, like that of *Broussonetia* pollen in Pingtung (Huang, 1998) and Tansui (Pen and Chen, 1997)

The pollen and spore concentrations in the air and their diurnal patterns affected by many factors, such as meteorological variables, topography and distribution of source plant in relation to the pollen sampler (Alba, *et al*., 2000; Berggren, 1995). A more detailed study is required, especially the field studies because it may reveal the diurnal rhythm of airborne pollen and spores and it is helpful for the diagnosis and prevention of allergies through analysis.

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台北市空中孢粉每日的逐時變化

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摘 要

本研究以設在台北市市區的孢粉收集器（Burkard seven-day volumetric pollen trap）收集 1993 和 1994 兩年的空中孢粉，發現這兩年累計所有空中孢粉於一天出現的逐時變化（diurnal variation）趨勢相似，空中孢粉多數出現在清晨 3 時至 10 時，只有少數會出現在下午。今以出現最優勢的前 10 種空中孢粉的逐時變化分析，其中構樹屬（*Broussonetia*）、梣屬（*Fraxinus*）、莎欏屬（*Cyathea*）和禾本科（Gramineae）孢粉兩年的逐時變化趨勢相似，構樹屬和梣屬花粉多數出現在深夜至次日上午；莎欏屬孢子多數出現在上午至中午；禾本科花粉則多數出現在下午。重陽木屬（*Bischofia*）、柏屬（*Juniperus*）、野桐屬（*Mallotus*）、桑屬（*Morus*）、山黃麻屬（*Trema*）及蕁麻科（Urticaceae）的花粉兩年的逐時變化趨勢不規則。體積較大的孢粉逐時變化趨勢較規則，例如莎欏屬孢子和禾本科花粉；體積較小的花粉，逐時變化趨勢較不規則，例如重陽木屬、柏屬、野桐屬、桑屬、山黃麻屬及蕁麻科。構樹屬和梣屬花粉雖然體積小，但因花粉的來源很靠近孢粉收集器，而出現規則的逐時變化趨勢。空中孢粉逐時變化的規則性可能受到孢粉來源、孢粉大小及氣流所影響，即體積較小的孢粉較易受影響而使其逐時變化趨勢較不規則。

關鍵詞：空中孢粉、逐時變化、台北。

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