RESEARCH ARTICLE

Dispersal of Airborne Pollen in Chatienshan Nature Reserve, Northern Taiwan, with Emphasis on Taiwan Beech

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ABSTRACT: In this first study on the pollen rain in natural forest in Taiwan using pollen traps, the dispersal patterns of airborne pollen were determined, with emphasis on *Fagus hayatae* and some major plant species, and the relationship between pollen assemblages and vegetation was elucidated. Seventeen pollen traps were installed on the western slope of Mt. Takai, northern Taiwan, from March 21 to May 10, 2008. Pollen and spores belonging to 37 families and 43 genera were identified. The results of correspondence analysis suggested differentiation of three vertical zones of pollen assemblages that corresponded to three vegetation types. Three patterns of occurrence were identified for the major pollen taxa, namely ubiquitous occurrence, local occurrence, and peak occurrence. The pollen influx of *F. hayatae*, a taxon characterized by local occurrence, was remarkably lower at a distance of over 200 m away from the pure stands. This suggests that pollen-mediated gene flow between the beech populations in Taiwan is unlikely. Besides providing basic data on the pollen dispersal of some important taxa in the middle altitudes of Taiwan, the present study also points out that caution should be taken in interpreting pollen percentage data from sediments.

KEY WORDS: Aeropalynology, airborne pollen, *Fagus hayatae*, pollen rain, pollen trap, Taiwan.

INTRODUCTION

Aeropalynological data are important for understanding the processes and patterns of pollen dispersal and deposition in an area. Also, these data are commonly used as a reference for reconstruction of past vegetation and assessment of the degree of pollen-mediated gene flow among populations (e.g., Belmonte et al., 2008). In Taiwan, most aeropalynological studies have been focused on monitoring pollen levels in cities in order to clarify their relationship to allergy and flowering phenology (Chen and Huang, 1980; Chen, 1984; Chen and Chien, 1986; Peng and Chen, 1997; Huang et al., 1998; Yang and Chen, 1998; Yang et al., 2003; Huang et al., 2008). Very few studies have been done on the modern pollen rain in natural forests. The first such study was carried out in Jhushan in Nantou County, using adhesive medium on slides to collect airborne pollen (Huang and Chung, 1973). Liew (1997) sampled surface soil and moss in plots of a study on vegetation on the northwestern slope of Mt. Lopei in northern Taiwan, thus constructing representative pollen spectra for major altitudinal vegetation zones by comparing the percentage of pollen with the percentage of source plants. Liew and Chung (2001) compared surface-soil pollen assemblages corresponding to different altitudinal zones with fossil pollen assemblages from sediments, thereby inferring migration of forest zones in the past.

Although soil samples are widely used because of the ease of sampling and ubiquitous occurrence (Gosling et al., 2003), they have two major drawbacks, namely poor pollen preservation due to oxidation and unknown rates of sedimentation (Wright, 1967). These drawbacks, however, can be overcome by using pollen traps. This method allows the quantitative estimation of absolute pollen-accumulation rate of a species and the study of flowering phenology in natural forests. In this study, such traps were used to determine the dispersal patterns of the pollen of some dominant species, with emphasis on Taiwan beech.

Study area

Chatienshan Nature Reserve spans the southeastern part of the boundary between New Taipei City and Taoyuan County and is the largest nature reserve in northern Taiwan. Major mountains in this region include, Mt. Taman, Mt. Lala, Mt. Luping, Mt. South Chatien, Mt. Takai and Mt. Lopei. The main ridge belongs to the northern Hsueshan Range (Liu and Su, 1972) and extends in a south-southeast to north-northwest direction from Mt. Taman to Mt. Luping and in a southwest to northeast direction from Mt. Luping to Mt. Lopei. The study area is centered on the western slope of Mt. Takai, extending about 3 km in a roughly east-west direction (Fig. 1).

The mean annual temperature is about 16.2 °C at an

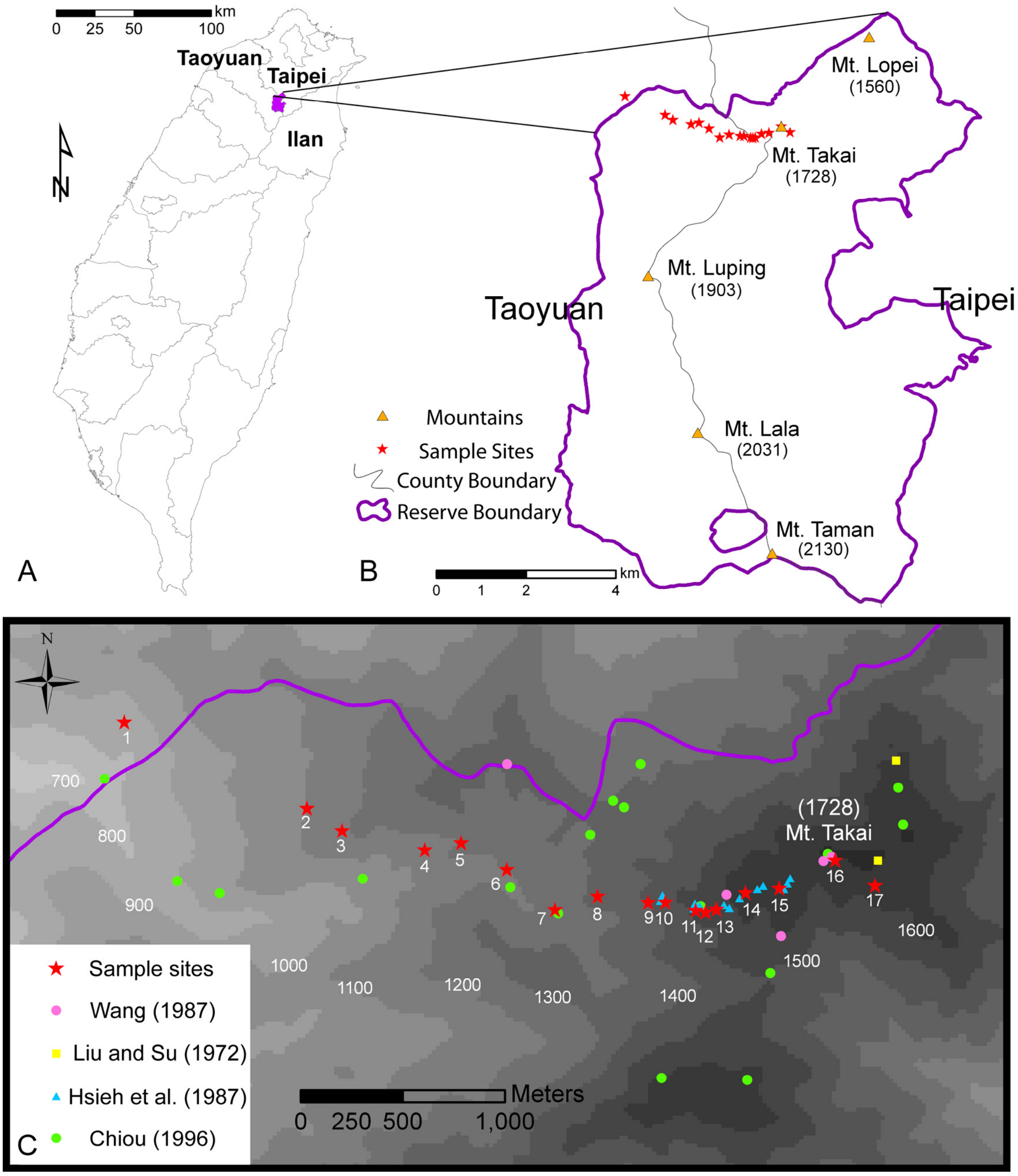

Fig. 1. Study Area. A: Location of Chatienshan Nature Reserve in Taiwan. B: Distribution of the seventeen sampling sites and the locations of major mountains in the reserve. C: Close-up of the study area, showing the topography and the locations of the quadrats of previous vegetation surveys (Liu and Su, 1972; Hsieh et al., 1987; Wang, 1987; Chiou, 1996).

altitude of 1300 m on the northwestern slope of Mt. Lopei (3 km to the northeast of Mt. Takai), with a mean annual precipitation of 3000–3500 mm (Hsieh et al., 1998). This region is characterized by high relative humidity (87% at Fushan Weather Station, 5 km east of Mt. Takai) and the prevalent cloud zone.

Flora and vegetation

A number of studies on the vegetation in or surrounding the study area have been done in the past (Tsoong and Chang, 1954; Liu and Su, 1972; Hsieh et al., 1987; Wang, 1987; Hsieh, 1989; Chiou, 1996; Hsieh et al., 1998; Lin et al., 2005). The vegetation in this region falls into two zones in the system of Su (1984): the *Quercus* zone (900–2000 m) and the *Machilus-Castanopsis* zone (< 900 m) (Chiou, 1996), which are 500–600 m lower than the same zones in central Taiwan, probably due to latitudinal difference

(Hsieh et al., 1998) and the Massenerhebung effect in central Taiwan (Su, 1984). Most of the sampling sites in this study were in the *Quercus* zone and close to 17 quadrats of Chiou (1996).

One of the two largest *F. hayatae* populations in Taiwan is found in Chatienshan Nature Reserve. It generally occurs on the ridges (Hsieh et al., 1987) and forms pure stands which were regarded as the only typical summer-green forest in Taiwan (Liu and Su, 1972). According to the detailed surveys of Hsieh et al. (1987) and Chiou (1996), the *Fagus* population on Mt. Takai occurs at an altitude over 1500 m. Since the beech is concentrated on ridges, rather than scattered throughout the study area, it is possible to compare the levels of pollen deposition between inside and outside of the pure stands.

MATERIALS AND METHODS

The methods for sampling airborne pollen and constructing pollen traps were modified from Gosling et al. (2003). Each pollen trap consisted of five parts: a typical kitchen funnel, a plastic water pipe 30 cm in length, polyester staple fiber, 1.5-mm plastic mesh, and a Whatman GF/D glass-fiber filter paper (Fig. 2). The pipe was inserted into the ground to a depth of about 10 cm. Seventeen pollen traps were installed along a transect on Mt. Takai (24˚47′31.4″N, 121˚27′9.4″E, 25 km south of Taipei City) at altitudes from 858 to 1728 m (Fig. 1). Sites were chosen so that no trees would cover the traps. The descriptions of the sampling sites and their locations (TWD97) are given in Table 1. Sampling was conducted from March 21 to May 10, 2008.

During treatment, polyester staple fiber from each pollen trap was boiled for 10 min in 10% potassium hydroxide (KOH) along with *Lycopodium* spore tablets (manufactured by Lund University, Sweden). After being left for 10 hours, each sample was filtered through a 125-μm sieve and a Whatman GF/D filter paper which was later treated overnight in 40% hydrofluoric acid (HF) at room temperature to release the pollen grains and spores, together with the filter paper from the pollen trap. The samples were then acetolysed (Erdtman, 1952), filtered by a 10-μm filter in a sonicator to remove small particles and eventually preserved in glycerol.

A minimum of 800 pollen grains were counted for each sample under a light microscope (Leitz DMRB, Leica, Wetzlar, Germany). For samples dominated by a single pollen taxon (e.g., *Cyclobalanopsis*, *Symplocos caudata*), more than 1200 pollen grains were counted. Samples were also examined under a scanning electron microscope. Identification was achieved with the help of books (Huang, 1972; Huang, 1981; Wang, 2000) and articles (Chen, 1988; Chen and Wang, 1999; Chen and Wang, 2001; Wang and Chen, 2002).

To calculate influx rates (grains cm-2 day-1) for each taxon at each sampling site, numbers of pollen grains and spores counted were multiplied by "total exotic *Lycopodium* spores added"/ "exotic *Lycopodium* spores observed" and divided by both the area of the funnel mouth and the number of days in the study period. The software package C2 (Juggins, 2004) was used to draw pollen diagrams (pollen influx of individual taxon against sample number). Pollen percentage data of selected taxa were analyzed using the Correspondence Analysis (CA) contained in C2. The excluded taxa are those occurring at less than six sites and a few type III taxa. In addition, all herbaceous pollen taxa and all fern taxa were treated as NAP (non-arboreal pollen) and Fern, respectively.

The sampling sites and the quadrats of previous vegetation surveys were plotted using ArcGIS 9.3 (ESRI, Redlands, CA). The locations of the quadrats were inferred from their recorded altitudes, aspects, dips, and the original hand drawings of the study areas. The raw data of arboreal plants with DBH (diameter at breast height) greater than 1 cm in Liu and Su (1972) and Hsieh et al. (1987) were transformed into the importance value index (IVI) (Curtis and McIntosh, 1951) through the following equations:

$$\text{Relative density} = \frac{\text{No. of individuals of a species}}{\text{No. of individuals of all species}} \times 100$$

$$\text{Relative dominance} = \frac{\text{cross - sectional area at breast height of a species}}{\text{cross - sectional area at breast height of all species}} \times 100$$

$$\text{IVI} = \text{Relative density} + \text{Relative dominance , where the maximum is 200.}$$

For simplification, the IVIs calculated from the data of Liu and Su (1972) and Hsieh et al. (1987), along with the IVIs in Wang (1987) and Chiou (1996), were designated integers from 0 to 9 in the octave scale (Gauch, 1982).

RESULTS

Taxonomic composition

In this study, a total of 20,669 pollen grains and fern spores were identified. They belonged to 37 families and 43 genera (Table 2). Less than 1% could not be identified or were indeterminable (damaged). Fern spores accounted for about 3% of the total counts of pollen and spores, gymnosperm pollen 2.3% and angiosperm pollen 94.7%. Over 96% of angiosperm pollen belonged to woody taxa. As a whole, pollen from arboreal angiosperms predominated. Site 1 was the only locality where herbaceous pollen (non-arboreal pollen, NAP) dominated over arboreal pollen (AP).

Spatial variation and pollen zones

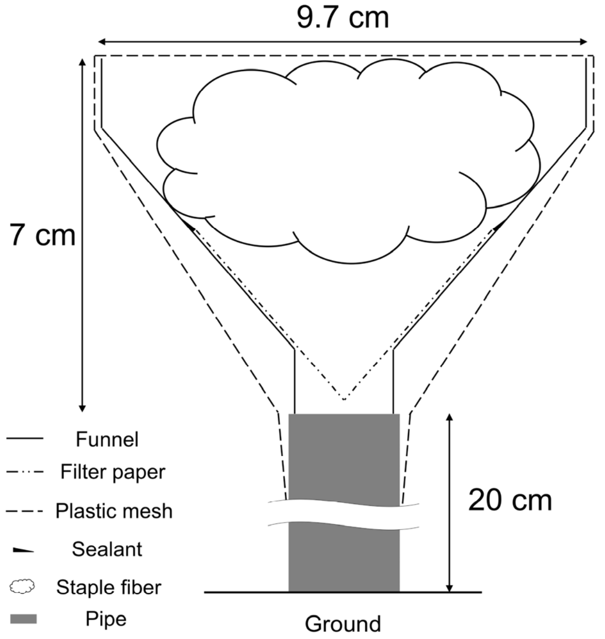

Fig. 2. Cross-sectional view of the pollen trap modified from Gosling et al. (2003). Drain holes were drilled on the upper part of the pipe to avoid flooding inside the pollen trap (not shown). Besides preventing unwanted litter or debris falling into the pollen trap, the mesh also helps hold the staple fiber in place. The inner and outer radii of the pipe are 1.6 cm and 2.2 cm, respectively. The lowest 10-cm part of the pipe is buried underground.

Fig. 3 shows the pollen influx of 18 spermatophyte taxa (accounting for 95.4% of the total pollen throughout the study area), total arboreal pollen (AP), total non-arboreal pollen (NAP), total pollen and total fern spores (Fern) at each sampling site. The highest influx of total pollen, about 301 grains cm^{-2} day^{-1}, was observed at site 6, and the lowest, about 18 grains cm^{-2} day^{-1}, at site 15. The sampling sites could be divided into three zones on the basis of total pollen, with the influx of total pollen in zone II remarkably higher than that in zone I or III (Fig. 3). The influx of fern spores was low throughout the study area, except at sites 3 and 14. Higher generic richness was observed at sites 12, 14, and 15, with 31, 30 and 28 genera, respectively.

Among woody taxa, *Cyclobalanopsis* was the most abundant, accounting for more than 60% of the total pollen at sites from 2 to 10 (zone 2) except site 6, at which over 70% of the total pollen was contributed by *Trochodendron aralioides* (Fig. 4). At sites from 11 to 17 (zone 3), *Cyclobalanopsis* accounted for about 40–50%. The only exception was observed at site 16, where over 80% of the total pollen was from *Symplocos caudata*.

Type I taxa: ubiquitous occurrence

Type I taxa were characterized by low influx, but occurred throughout the study area or showed a random pattern of occurrence. They included eight arboreal taxa, *Abies kawakamii*, *Tsuga chinensis*, *Cryptomeria japonica*, *Pinus*, *Ulmus uyematsui*, *Acacia*, *Liquidambar formosana* and *Oreocnide pedunculata*, and one herbaceous taxon, *Achyranthes*. About one eighth of the pollen sum of the 18 dominant taxa came from taxa of this type.

Type II taxa: local occurrence

These taxa were characterized by high pollen influx at a few consecutive sites and low influx at other sites. They included *Fagus hayatae* (at sites 11–17), *Rhododendron* (at site 11), *Cyclobalanopsis* (at sites 2–10) and *Myrica rubra* (at sites 2–6). Nearly 70% of the pollen from the 18 dominant taxa belonged to this type.

Type III taxa: peak occurrence

The taxa characterized by an extremely high peak at a single study site included *Symplocos caudata* (site 16), *S. wikstroemifolia* (site 2), *Trochodendron aralioides* (site 6), Asteraceae (site 1) and Poaceae (site 1). The pollen influx peak ranged from 13 (Poaceae) to 212 (*T. aralioides*) grains cm^{-2} day^{-1}. Type III taxa accounted for 18.3% of the sum of the 18 dominant taxa.

Correspondence analysis (CA)

On the basis of pollen percentage data, CA was applied to analyze the similarity between sampling sites. Fig. 5 shows that the 17 sampling sites are grouped into three zones. Axis 1 generally represents a gradient of the percentage of NAP. All samples from zone 2 have negative scores, while site 1 is located on the positive extreme of this axis. Axis 2 roughly reflects a gradient in elevation. Taxa occurring at lower altitudes such as *Cyclobalanopsis* and *Myrica* have negative scores on axis 2, whereas *Fagus* and *Rhododendron* positive values. In addition, values on axis 2 may also reflect the percentage of type I pollen, which is higher in zone 3 than in zone 2.

Dispersal of *Fagus hayatae* pollen

Fig. 6A shows the range of the beech forest on Mt. Takai, which was drawn on the basis of previous vegetation studies (Liu and Su, 1972; Hsieh et al., 1987; Wang, 1987; Chiou, 1996) and personal observation. The quadrats with IVIs greater than 7 are considered "pure stands" in this study, which are enclosed by the yellow line in Fig. 6A. Because the quadrats are not uniformly distributed, some parts of the border line, especially the northwestern and southeastern, are only

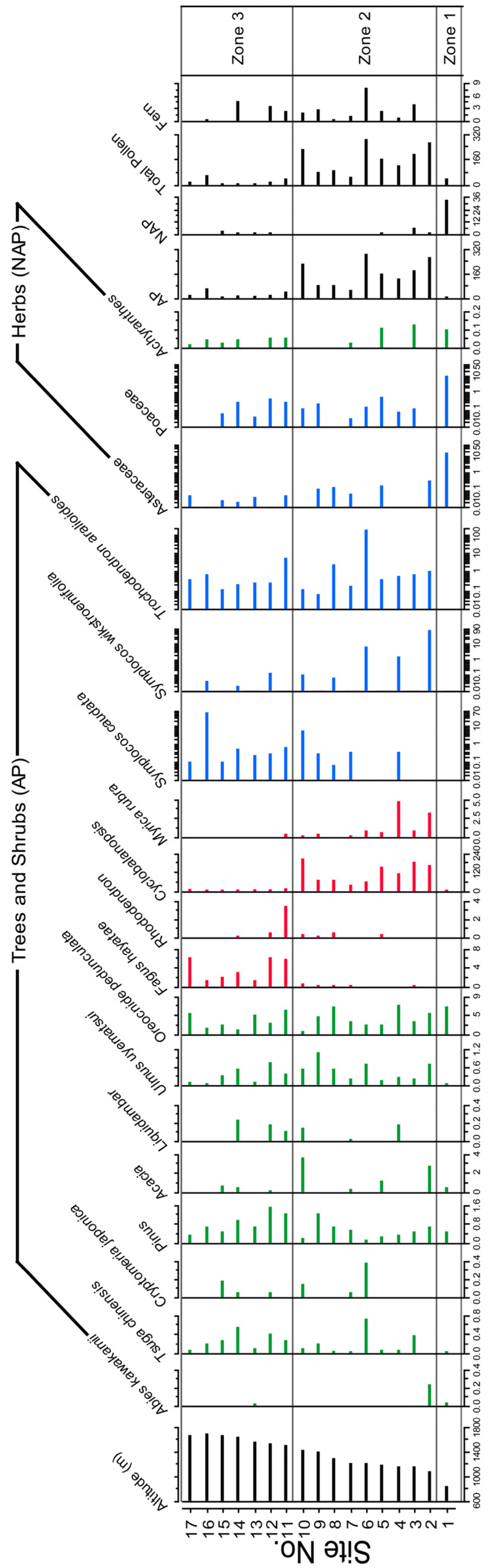

Fig. 3. Absolute pollen influx (grains cm^{-2} day^{-1}) of 18 major taxa measured at 17 sampling sites in northern Chatienshan Nature Reserve, Taiwan, over the time from March 21 to May 10, 2008. The abscissae for *Symplocos caudata*, *S. wikstroemifolia*, *Trochodendron*, Asteraceae, and Poaceae are in log scale whereas those for the others in linear scale. The colors indicate the three types of pollen occurrence designated in the results: green – type I, red – type II, blue – type III.

estimates based on altitudes. The blue line encloses the area in which the IVIs are less than 8. The beech pollen flux was closely related to the distance to the beech forest. Within zone 3, the pure stands, the flux of *Fagus* pollen was much higher (Fig. 6B), while Fig. 7 shows that the flux declined drastically outside the pure stands. However, beech pollen was still detectable at 1.7 km away from the pure stands, though the flux was very low.

DISCUSSION

In this study, the majority of airborne pollen collected in the pollen traps belonged to AP, which is consistent with the studies on airborne pollen in the cities (Huang et al., 1998; Yang et al., 2003; Huang et al., 2008). The dominance of AP from sites 2 to 17 might be attributed to the higher pollen production of the trees than that of the herbs. The sites with high richness of pollen and spore genera (No.12, 14, 15) were generally at higher altitudes. One reason for this is that no single dominating pollen taxon (> 50%) was present at these sites and taxa with low influx would have higher representation. Although extra pollen grains were counted for samples in which a single taxon dominates, it seemed that the large quantity of its pollen might still have made taxa with low influx less detectable.

As a whole, the occurrence of pollen taxa in this study is consistent with the records of the phenology of flowering or pollen release (Huang et al., 1993–2000; Wang, 1996; Wang, 2000). Pollen of Theaceae, a major floristic component in Chatienshan Nature Reserve, was not observed, since most of them flower in fall or winter. However, for those taxa whose flowering season overlaps with the study period, not all their pollen was observed. Besides the possible differences between the actual flowering season in the study area in 2008 and that recorded in the literature, there may be several other reasons. Pollen of Lauraceae (*Machilus*, *Neolitsea*), which is characterized by low sporopollenin content in the exine and tends to be fragmented after acetolysis (Erdtman, 1969), should have been filtered out by the 10-μm filter. Pollen of some other taxa might have also been released into the atmosphere, but was not detected, possibly due to the small population size of its source plants or low pollen production per individual.

Patterns of pollen occurrence and dispersal

The 18 spermatophyte taxa were classified into three categories (types I–III) based on the patterns of the occurrence of their pollen. The taxa characterized by ubiquitous occurrence (type I) were not the dominant

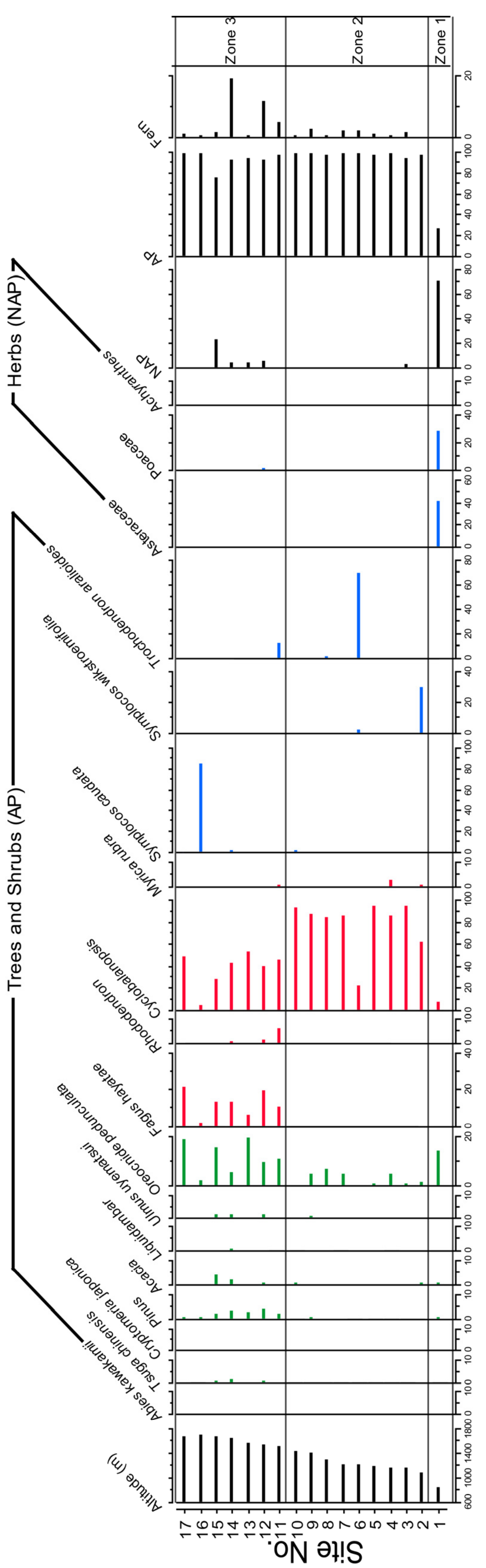

Fig. 4. Percentages (%) of total pollen influx at each study site in northern Chatienshan Nature Reserve, Taiwan, over the time from March 21 to May 10, 2008, showing that *Cyclobalanopsis* was the main contributor to airborne pollen at the study area.

species at any site. Pollen of *Abies kawakamii*, *Tsuga chinensis*, *Pinus*, *Cryptomeria japonica*, *Acacia*, *Liquidambar formosana,* and *Ulmus uyematsui* was collected in the traps, but their source plants were not found in the quadrats of Liu and Su (1972), Hsieh et al. (1987), Wang (1987) and Chiou (1996) near the sampling sites. Thus, the source plants were possibly outside the study area. This hypothesis is supported by the fact that the pollen flux at each site did not differ greatly, which is a pattern characteristic of long-range dispersal (Bush and Rivera, 1998). Pollen of *Oreocnide pedunculata* (another arboreal taxon) and *Achyranthes* (a herbaceous taxon) was also found to occur in low quantities at sites from low to high altitudes. However, their occurrence was not due to long-range dispersal because the source plants were found near the sampling sites (Chiou, 1996; Ku, per. obs.).

Fagus hayatae and *Cyclobalanopsis* were classified as type II taxa. *Cyclobalanopsis* produced copious amounts of pollen and accounted for two-thirds of the total pollen. Most of its pollen was found in zone 2 (sites 2–10), where it had much higher IVIs than in zone 1 and zone 3 (sites 11–17) (Liu and Su, 1972; Hsieh et al., 1987; Chiou, 1996). In contrast, the pollen of *F. hayatae* was generally limited to zone 3, with pollen influx as high as 1.6–6.6 grains cm^{-2} day^{-1} (Fig. 3). At a distance of 200 m from the pure stands on the ridge (i.e., site 9), the influx rate dropped to less than 0.3 grains cm^{-2} day^{-1}. The airborne pollen of these two taxa, which showed local occurrence in zone 2 and zone 3, respectively, is basically an unbiased indicator of the abundance of the source plants.

Though *Symplocos caudata* occurred in zone 2 and zone 3 (Liu and Su, 1972; Hsieh et al., 1987; Chiou, 1996), it was not a dominant species in the study area. Its pollen flux formed a high peak at site 16, but was very low or not detectable at other sites. Similar dispersal patterns were observed for the pollen of *S. wikstroemifolia* and *Trochodendron aralioides*, which were interspersed in the forest and could be found throughout the study area. *Symplocos* spp. (Fritsch et al., 2008) and *T. aralioides* (Chaw, 1992) are thought to be zoophilous and their pollen is generally sticky, heavy and not easily carried by wind. This might have resulted in sedimentation of pollen near the source plants. Therefore, the peak occurrence of these pollen taxa is an indication of the presence of source plants in the neighborhood.

Pollen zones and vegetation

The 17 sampling sites can be separated into three zones on the basis of total pollen influx, with the highest influx in zone 2 (Fig. 3). This mainly resulted from the capability of *Cyclobalanopsis*, a major component in zone 2, to produce large amounts of

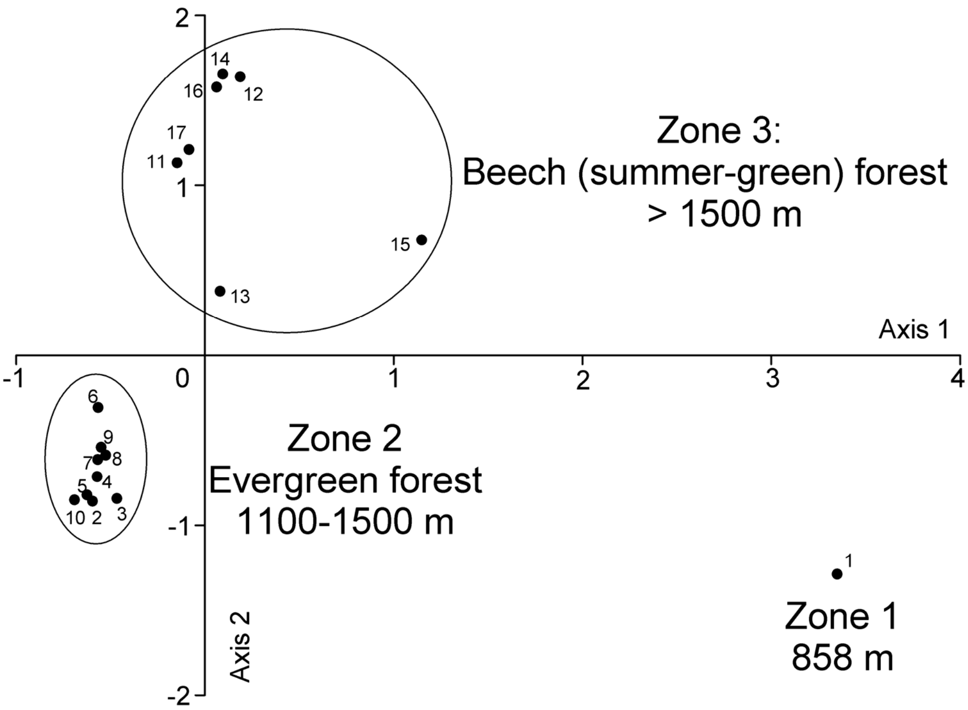

Fig. 5. Correspondence analysis with respect to the first two CA axes. Lines enclose sampling sites from different altitudinal zones. Axis 1 eigenvalue 0.47, axis 2 eigenvalue 0.23.

pollen. The pollen production per individual of *Cyclobalanopsis* was estimated to be nearly four times as much as that of *Fagus sylvatica* in Germany (Pohl, 1937). Since *Fagus* replaced *Cyclobalanopsis* as the major component in zone 3, the total influx there was much lower than that in zone 2.

The differentiation of the three zones is also supported by the results of correspondence analysis. Axis 1 and axis 2, which seem to represent gradients in NAP and elevation, respectively, clearly separate the three zones, with zone 1 having the highest NAP and the lowest altitude, zone 2 the lowest NAP, and the intermediate altitude, and zone 3 the intermediate NAP and the highest altitude.

However, since the data analyzed were percentages, taxa having the same absolute influx values at sites in zone 2 and zone 3 would generally have a lower percentage in zone 2 and a higher percentage in zone 3. For instance, the absolute influx of NAP in zone 3 was actually not higher than that in zone 2 (Fig. 3) and type I pollen taxa such as *Ulmus* and *Pinus*, which had positive scores on axis 2, actually had similar absolute influx in zone 2 and zone 3 due to long-range transport. Therefore, to some extent, axis 1 did not correctly reflect the amount of herbs in the surrounding vegetation, since their pollen was diluted by the amount of total pollen. Type I taxa, which had positive scores on axis 2, should also not be regarded as taxa more abundant at higher altitudes. This effect of total pollen on the percentages of individual taxa should be taken into consideration in interpreting pollen assemblages from sediments, since different taxa are usually counted as percentages and the absolute influx is usually unknown.

Dispersal of *Fagus hayatae* pollen

The present study shows that the pollen influx of *F. hayatae* is low outside the beech forest (Fig. 6), particularly at a distance of over 200 m from the pure stands. This is consistent with both the aeropalynological (Rempe, 1937) and population genetic (Wang, 2004) studies on *F. sylvatica*. Although long-range dispersal of *F. sylvatica* pollen exists under certain climatic conditions in Europe (Belmonte et al., 2008), the results in this study suggest that beech pollen does not travel far in northern Taiwan.

Using random amplification of polymorphic DNA (RAPD), Wang and Lin (2002) showed that the genetic differentiation between the beech populations in Mt. Taiping and in Chatienshan Nature Reserve was low. From the results of this study, it is inferred that pollen-mediated gene flow between these two localities is very unlikely. Furthermore, the transport of *F. hayatae* seeds, another major carrier of plant genes, is also limited (Huang, 2000). Therefore, the low genetic differentiation between the beech populations suggests that the separation of the two populations should be a relatively recent event because sustained gene flow

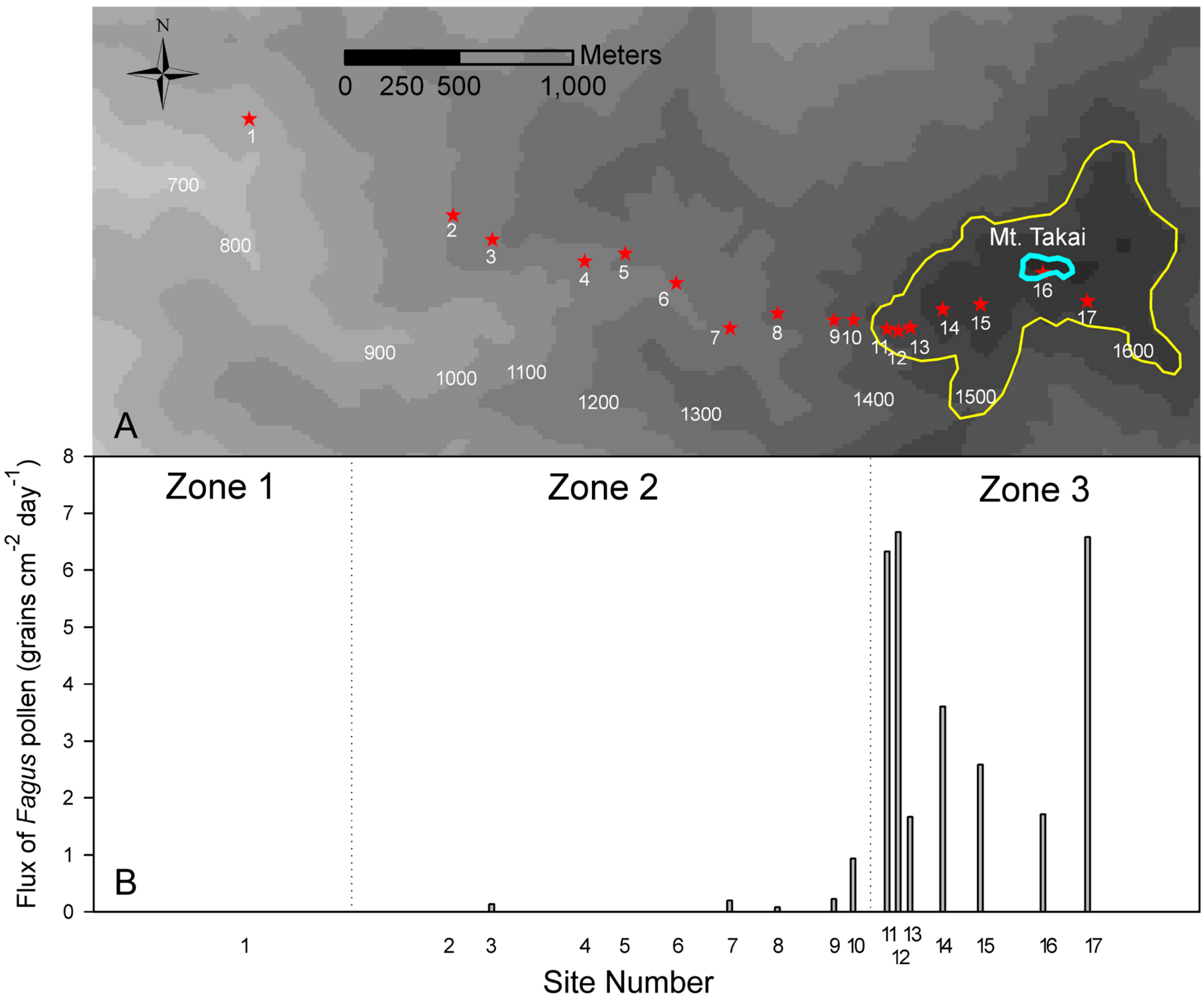

Fig. 6. Range of *Fagus* forest and its pollen influx throughout the study area. A: The range of the beech forest is enclosed by the yellow line. The peak of Mt. Takai is enclosed by the blue line because the IVIs of *F. hayatae* there are lower. B: Influx of *Fagus* pollen at sampling sites corresponding to those in A.

between them is unlikely. Besides, because fragmentation and thinning of populations of a wind-pollinated species with restricted pollen dispersal could result in higher levels of inbreeding and reduced reproduction (Koenig and Ashley, 2003; Jump and Peñuelas, 2006), the limited ability of pollen dispersal might have accelerated the decline of the beech populations in Taiwan, resulting in the present relic-like distribution pattern (Shen and Boufford, 1988) and senescent population structure (Hsieh, 1989; Huang, 2000).

Conclusions

Pollen traps were proven to be an effective method for sampling modern pollen rain in the mountain area of Taiwan. Based on the pollen diagrams and the correspondence analysis of the pollen percentage data, three pollen zones that corresponded to different

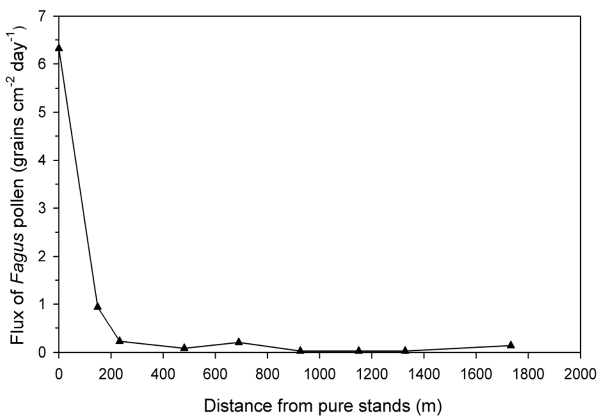

Fig. 7. Pollen influx of *Fagus hayatae* as a function of distance from the pure stands. Only sites 3–11 are shown in this diagram. Site 11, represented by the leftmost triangle, is the only site within the pure stands.

Table 1. Description and locations of sampling sites.

Sample No.	Description	Latitude	Longitude	Altitude (m)
1	A parking lot (lawn) near the entrance of the Little Wulai trailhead	24°47'53.84"N	121°25'5.459"E	858
2	Bare ground	24°47'40.074"N	121°25'37.085"E	1100
3	Bare ground	24°47'36.056"N	121°25'43.756"E	1180
4	Bare ground	24°47'33.281"N	121°25'57.577"E	1180
5	Bare ground	24°47'34.314"N	121°26'4.265"E	1220
6	Beside the upstream portion of Yunei River; near No. 73 quadrat of Chiou (1996)	24°47'29.872"N	121°26'12.317"E	1235
7	Beside the upstream portion of Yunei River; between two *Chamaecyparis formosana* sacred trees (No. 6 and No. 7). Near No. 40 quadrat of Chiou (1996)	24°47'23.746"N	121°26'20.363"E	1230
8	Bare ground	24°47'25.407"N	121°26'27.975"E	1315
9	Bare ground on the ridge	24°47'24.75"N	121°26'36.502"E	1419
10	Bare ground on the ridge	24°47'24.951"N	121°26'39.96"E	1453
11	Bare ground on the ridge	24°47'23.463"N	121°26'45.026"E	1542
12	Bare ground on the ridge	24°47'23.247"N	121°26'46.869"E	1567
13	Bare ground on the ridge	24°47'23.873"N	121°26'48.484"E	1595
14	Bare ground on the ridge	24°47'26.173"N	121°26'53.564"E	1669
15	At the fork leading to Mt. Takai and Mt. Luping	24°47'26.997"N	121°26'59.329"E	1700
16	Trigonometrical station of Mt. Takai	24°47'31.175"N	121°27'9.486"E	1728
17	On the trail to Fushan village	24°47'27.367"N	121°27'16.157"E	1699

vegetation types were recognized. Besides, three patterns of occurrence were recognized for the major pollen taxa. *Fagus hayatae* pollen belongs to the type of local occurrence, making it a relatively unbiased indicator of plant abundance in the neighboring areas. The restricted pollen dispersal suggests that pollen-mediated gene flow between the different beech populations in Taiwan is highly unlikely. As for applications in reconstruction of past vegetation, this study provides data on the pollen dispersal of some major forest taxa and points out the discrepancy between pollen percentage data and floristic composition of vegetation.

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Table 2. List of airborne pollen and spore taxa.

Arboreal Pollen Taxa (AP)			
Gymnosperms			
Cupressaceae		Taxodiaceae	*Cryptomeria japonica*
Pinaceae	*Abies kawakamii*		
	Pinus		
	Tsuga chinensis		
Angiosperms			
Aceraceae	*Acer serrulatum*	Lythraceae	*Lagerstroemia subcostata*
Aquifoliaceae	*Ilex*	Moraceae	*Morus*
Betulaceae	*Alnus*	Myricaceae	*Myrica rubra*
	Carpinus	Myrsinaceae	*Ardisia*
Caprifoliaceae	*Viburnum*	Rosaceae	*Rhaphiolepis*
Ericaceae	*Rhododendron*	Rutaceae	*Skimmia reevesiana*
Fagaceae	*Castanopsis cuspidata*	Symplocaceae	*Symplocos caudata*
	Cyclobalanopsis		*Symplocos wikstroemifolia*
	Fagus hayatae	Trochodendraceae	*Trochodendron aralioides*
Hamamelidaceae	*Liquidambar formosana*	Ulmaceae	*Celtis*
Juglandaceae	*Juglans*		*Ulmus uyematsui*
Leguminosae	*Acacia*	Urticaceae	*Oreocnide pedunculata*
Non-Arboreal Pollen Taxa (NAP)			
Amaranthaceae	*Achyranthes*	Poaceae	*Miscanthus*
Asteraceae		Ranunculaceae	*Coptis quinquefolia*
Cyperaceae	*Carex filicina*	Rosaceae	*Rubus*
Gentianaceae			
Fern Spore Taxa			
Athyriaceae	*Diplazium*	Selaginellaceae	*Selaginella*
Davalliaceae	*Davallia*	Plagiogyriacea	*Plagiogyria*
Polypodiaceae	*Lepisorus*	Vittariaceae	*Vittaria*
Pteridaceae	*Pteris*	Dennstaedtiaceae	*Monachosorum*

*Botanical nomenclature in this study follows the Flora of Taiwan (Huang et al., 1993–2000).

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臺灣北部插天山自然保留區的空中花粉散播：特別著重於臺灣水青岡

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摘要：本文為首篇以花粉收集器探討臺灣森林中花粉雨的研究，特別著重於臺灣水青岡及一些主要物種的花粉散播型式，並嘗試釐清花粉組合與周圍植被之間的關係。共有十七個花粉收集器於 2008 年三月二十一日至五月十日，設置在北臺灣的北插天山西側。一共鑑定出 37 科 43 屬植物的花粉及孢子。對應分析的結果顯示，十七個樣點依花粉組合可分為三個垂直帶，對應三種不同的植被類型。主要的花粉分類群可分為三種出現型式，普遍出現型、局部出現型及高峰出現型。臺灣水青岡屬於局部出現型，在距離純林 200 公尺以外的花粉通量遠小於純林內的通量。這意味著現生臺灣水青岡族群間不太可能有以花粉為媒介的基因流。本研究除提供臺灣中海拔一些重要分類群花粉散播的基本資料外，也指出一些在解讀沉積物花粉百分率資料時所須注意的地方。

關鍵詞：空中孢粉學、空中花粉、臺灣水青岡、花粉雨、花粉收集器、臺灣。