Bot. Bull. Acad. Sin. (1997) **38:** 57–62

Aeropalynological investigation in Taichung, Taiwan, 1993–1995

Chih-Hua Tsou[1], Ing-Jen Tseng, Rey-Feng Lin, and Hsin-Yu Hong

Institute of Botany, Academia Sinica, Taipei, Taiwan, Republic of China

(Received September 14, 1996; Accepted November 23, 1996)

Abstract. The airborne pollen spectrum was investigated in Taichung, Taiwan, in two consecutive years using a 7-day volumetric recording trap. In total, 323,745 pollen grains of seed plants and fern spores were counted, with a mean of pollen concentration of 30.8 grains/m^3. In the course of a year, airborne pollen was most abundant in spring and least in summer. In dry days from late March to mid April, the pollen concentration usually remained around 1,000 to 2,000 grains/m^3 for two or three hours in the morning. During these two years, the highest hourly pollen value was recorded during 11–12 A.M., on 15 April 1994, with a mean of 5,306.7 grains/m^3. The pollen spectrum obtained did not reflect the floristic composition of Taichung city. The important pollen taxa were *Broussonetia* (66.83%), *Casuarina equisetifolia* (5.66%), *Trema orientalis* (5.02%), Poaceae (4.15%), *Humulus scandens* (2.77%), *Alnus* (1.99%), *Morus* (1.38%), *Mallotus* (1.14%) and *Macaranga* (1.04%). Most of them are common wild Amentiferae plants in lowland Taiwan. *Broussonetia* is extremely important for future studies of pollen allergy in Taiwan, not only for the allergenicity of its pollen, but also for the superiority of its pollen productivity and pollen dispersibility.

Keywords: Aeropalynology; *Broussonetia*; Taichung; Taiwan.

Introduction

Chao et al. (1962) conducted the first study of airborne pollen in Taiwan. Huang (1982) and Tsou (1982) reviewed the seven investigations in this field published in Taiwan during the period from 1962 to 1982. Only two more investigations have been completed (Chen and Chien, 1986; Peng, 1994) since then. Essentially, most of these works were designed to provide basic information for allergenic researches. Of these original investigations, most were undertaken in Taipei City and its suburban areas in northern Taiwan, and only one was sited central Taiwan. From 1992 to 1995, an integrated aeropalynology project was supported by the National Science Council, Republic of China. Six collection sites were established at different times in the various parts of Taiwan (N, W, SW, S, E, SE), and were taken charge of by different principal investigators. In this report, we shall present the results of a daily, two-year investigation from the western collection site of this integrated project.

Materials and Methods

Airborne palynomorphs were collected in Taichung city from 1 May 1993 to 30 April 1995, using a seven-day volumetric recording trap. The trap was placed 14 m above the ground on the roof of a four-story building in National Chung-Hsing University (10 m asl., 24°07'N, 120°40'E). The adhesive layer on the cellophane tape was a mixture of gelvatol (35 g), glycerol (50 ml), phenol (2 g), and distilled water (80 ml). The air flow rate was adjusted to 10 l/min, and the moving rate of the tape was 2 mm/h. Finally, one 48 mm long segment of the tape was obtained for each daily collection and was mounted as a permanent slide.

Pollen grains of angiosperms and gymnosperms and fern spores collected were identified and counted on an hourly basis at 400× magnification. Besides referring to the Pollen Flora of Taiwan (Huang, 1972) and the Spore Flora of Taiwan (Huang, 1981) for identification, pollen grains and fern spores were collected fresh from more than 100 species growing in the vicinity of the trap to make reference slides. Twenty-four transverse travels were observed for a daily slide, i.e., one travel per hour. The total count for each hour was then converted by multiplying an adjusting factor (total area/observed area).

The vast majority of the woody plants growing in the vicinity of the collection site were cultivated ones. Wild individuals were comparatively much fewer, being found only along roadside and in small abandoned patches scattered in the city. The closest natural vegetation was more than 6 km away.

The meteorological data of Taichung used in the present report were obtained from the Central Weather Bureau, R. O. C. The Taichung meteorological station is about 2.5 km away from our pollen collection site.

[1] Corresponding author. Fax: 886-2-7827954; E-mail: botsou@ccvax.sinica.edu.tw

Results and Discussion

During the two consecutive years from 1 May 1993 to 30 April 1995, a total number of 323,745 pollen grains and fern spores were collected. Of them, 164,541 grains appeared in the first year, with a pollen concentration of 31.3 grains/m^3 on average; in the second year, 159,204 grains were counted, averaging 30.3 grains/m^3. The pollen spectra of the two years are rather similar in both pollen contributors and their individual significance (Figure 1 & Table 1). The pollen concentration was rather low on most days. It was lowest in January, averaging only about 3 grains/m^3, but increased greatly in March and April with the mean rising to around 120 grains/m^3. The highest daily peak in a year was recorded on April 3, 1994 with a daily mean of 627 grains/m^3 and on March 23, 1995 with 833 grains/m^3. On dry days from late March to mid April, the pollen concentration usually remained around 1,000 to 2,000 grains/m^3 for two or three hours in the morning. On an hourly basis, the highest value appeared during 11–12 A.M. on 15 April 1994. In that one hour period, 0.6 m^3 air was sucked and 3,184 grains were collected, with a mean of 5,306.7 grains/m^3. 97% of these 3,184 grains was of *Casuarina equsetifolia*. Since a tree of *Casuarina equsetifolia* stood just 10 m away from the trap and no other casuarina individuals were nearby, this pollen peak must be attributed to a sudden burst of the abundant anthers produced by that casuarina tree.

In terms of plant habits, arboreous palynomorphs including the spores of tree ferns were dominant; they comprised about 89.95% of the total grains. Grass pollen amounted to 4.15% only. The remaining 5.90% was contributed by herbaceous plants (incl. herbaceous ferns). Taxonomically, the palynomorphs collected included 3,088 (0.95%) gymnosperm pollen grains (belonging to three or four families), 318,944 (98.52%) angiosperm pollen grains (of more than 48 families), and 1,713 (0.53%) fern spores (of more than ten families) (see Table 1). Of all these families, Moraceae was decisively dominant, accounting for 70.98% of the total grains; Casuarinaceae and Ulmaceae, though taking the second and the third positions respectively, each representing only 5.66% and 5.20% of the grains.

Pollen and spores from more than 110 genera were identified. The percentage representations of the ten most significant taxa are as follows: *Broussonetia* 66.83%, *Casuarina* 5.66%, *Trema* 5.02%, Poaceae 4.15%, *Humulus* 2.77%, *Alnus* 1.99%, *Morus* 1.38%, *Mallotus* 1.14%, *Macaranga* 1.04%, and *Bischoffia* 0.98% (Figure 2). They were also very important in an earlier aeropalynological investigation conducted in northern Taiwan (Peng, 1994), in which they ranked 1st, 6th, 2nd, 7th, 9th, 15th, 13th, 5th, 6th, and 18th, respectively. Two basic patterns of pollen representation in the air throughout a whole year can be recognized in the pollen calendar. *Broussonetia*, *Casuarina equsetifolia*, and *Trema orientalis* conform to the first pattern—their pollen grains appear in one or two short-sustaining but strong concentrations in a year (Figure 3). The second pattern is found in the remaining seven taxa—they have many peaks throughout the year (Figure 4). It is notable that three of these seven taxa, *Bischoffia*, *Humulus*, and *Macaranga* are each represented by only one species on Taiwan Island.

Among these ten important taxa, *Mallotus*, *Macaranga,* and *Bischoffia* are members of Euphorbiaceae, and their pollen grains are tricolporate. The remaining seven taxa are anemophilous and produce porate pollen. Except for Poaceae, all of them are of the Hamamelidae. The porate pollen produced by the six Hamamelidae taxa are small or medium in size, each having an air chamber inside its 2–5 pores; among them, the genus *Broussonetia*, represented by *B. kazinoki* and *B. papyrifera* in Taiwan and also in Taichung, is newly found to be an important pollen contributor in Taiwan. *Broussonetia* pollen amounted to 73.7%

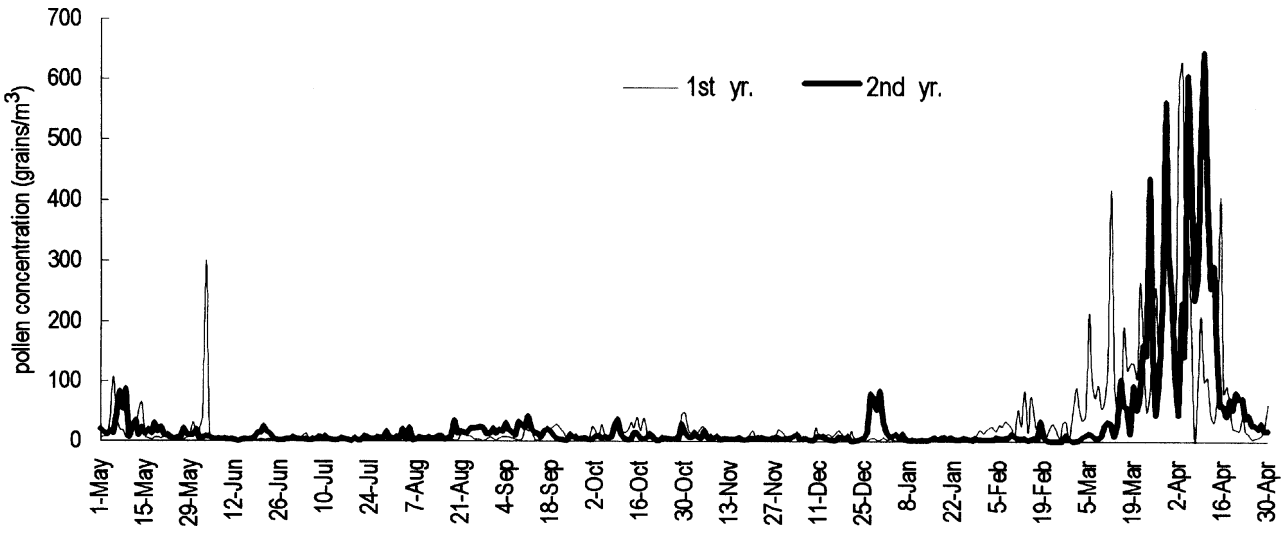

Figure 1. Daily pollen concentration in the atmosphere in Taichung, Taiwan, from 1 May 1993 to 30 April 1995, showing in two yearly curves.

Table 1. Annual totals and percentages of daily pollen counts in Taichung, Taiwan, from May 1, 1993 to April 30, 1995.

Item	1st year	%	2nd year	%	Sum	%	Rank
Gymnosperms	2233	1.357	855	0.537	3088	0.954	
Cupress./Taxodiac.	1754	1.066	432	0.271	2186	0.675	
Cryptomeria	144	0.088	20	0.013	164	0.051	
Pinus	335	0.204	403	0.253	738	0.228	
Angiosperms	161098	97.908	157846	99.147	318944	98.517	
Amaranthaceae	64	0.039	16	0.010	80	0.025	
Ilex	36	0.022	44	0.028	80	0.025	
Asteraceae	1983	1.205	1035	0.650	3018	0.932	
Alnus	3783	2.299	2655	1.668	6438	1.989	6
Brassicaceae	527	0.320	184	0.116	711	0.220	
Caryophyllaceae	16	0.010	20	0.013	36	0.011	
Casuarina	9449	5.743	8874	5.574	18323	5.660	2
Chenopodiaceae	1348	0.819	970	0.609	2318	0.716	
Cyperaceae	124	0.075	91	0.057	215	0.066	
Elaeocarpaceae	16	0.010	43	0.027	59	0.018	
Bischoffia	2147	1.305	1040	0.653	3187	0.984	10
Macaranga	2599	1.580	776	0.487	3375	1.042	9
Mallotus	3038	1.846	649	0.408	3687	1.139	8
other Euphorbiaceae	415	0.252	1008	0.633	1423	0.440	
Fagaceae	537	0.326	1362	0.856	1899	0.587	
Liquidambar	2121	1.289	624	0.392	2745	0.848	
Lauraceae	1211	0.736	244	0.153	1455	0.449	
Mimosa	454	0.276	1599	1.004	2053	0.634	
other Leguminosae	845	0.514	535	0.336	1380	0.426	
Liliaceae	28	0.017	70	0.044	98	0.030	
Magnoliaceae	220	0.134	128	0.080	348	0.107	
Broussonetia	103989	63.199	112358	70.575	216347	66.826	1
Humulus	4135	2.513	4837	3.038	8972	2.771	5
Morus	2228	1.354	2251	1.414	4479	1.383	7
Myrsinaceae	40	0.024	144	0.090	184	0.057	
Eucalyptus	535	0.325	114	0.072	649	0.200	
Melaleuca	591	0.359	341	0.214	932	0.288	
Syzygium	78	0.047	587	0.369	665	0.205	
Oleaceae	112	0.068	68	0.043	180	0.056	
Palmae	914	0.555	443	0.278	1357	0.419	
Poaceae	7377	4.483	6058	3.805	13435	4.150	4
Rosaceae	90	0.055	16	0.010	106	0.033	
Rubiaceae	184	0.112	78	0.049	262	0.081	
Salix	209	0.127	68	0.043	277	0.086	
Scrophulariaceae	208	0.126	130	0.082	338	0.104	
Solanaceae	62	0.038	67	0.042	129	0.040	
Eurya	95	0.058	48	0.030	143	0.044	
Trema	8540	5.190	7710	4.843	16250	5.019	3
Zelkova	555	0.337	39	0.024	594	0.183	
Miscellaneous	195	0.119	522	0.328	717	0.221	
Pteridophytes	1210	0.735	503	0.316	1713	0.529	
Asplenium	68	0.041	20	0.013	88	0.027	
Athyriaceae	12	0.007	63	0.040	75	0.023	
Cyatheaceae	865	0.526	146	0.092	1011	0.312	
Dryopteridaceae	4	0.002	49	0.031	53	0.016	
Gleicheniaceae	60	0.036	68	0.043	128	0.040	
Lycopodiaceae	12	0.007	22	0.014	34	0.011	
Nephrolepis	47	0.029	8	0.005	55	0.017	
Polypodiaceae	8	0.005	28	0.018	36	0.011	
Pteridaceae	32	0.019	16	0.010	48	0.015	
Miscellaneous	102	0.062	83	0.052	185	0.057	
Sum	164541	100.000	159204	100.000	323745	100.000	

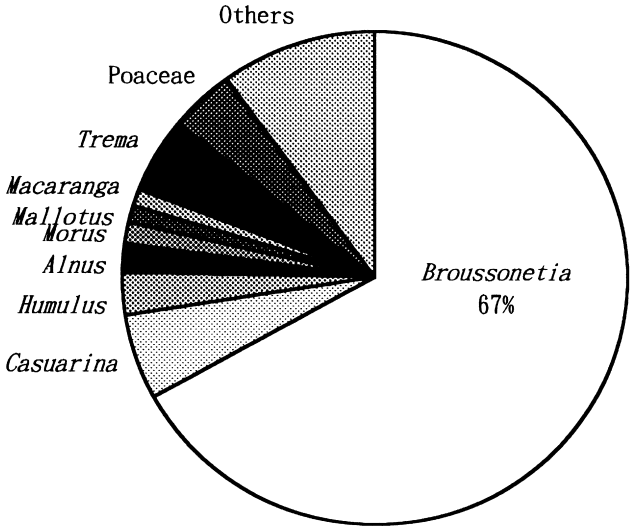

Figure 2. Important airborne pollen taxa in Taichung, Taiwan, from 1 May 1993 to 30 April 1995.

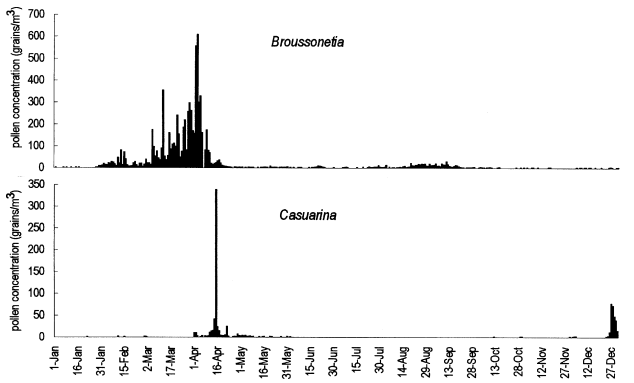

Figure 3. Pollen calendars of *Broussonetia* and *Casuarina* in Taichung in 1994.

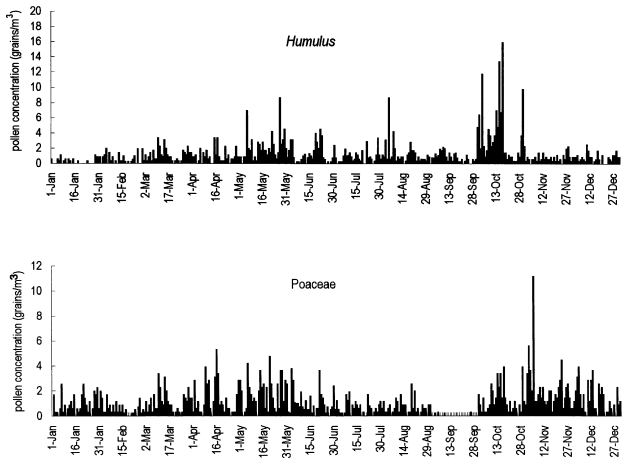

Figure 4. Pollen calendar of *Humulus* and Poaceae in Taichung in 1994.

of the total in a recent study in the Taipei area (northernmost Taiwan) (Peng, 1994) and 66.83% in the present study in the Western Coastal Plain, but it had never assumed an appreciable importance in earlier reports. In the present study from late March to mid April in both years, the daily mean of *Broussonetia* ordinarily varied between 200 to 550 grains/m^3 on dry days, and reached a high of 607 grains/m^3 on 3 April 1994. Its daily quantity in the air was much influenced by two meteorological factors: precipitation and temperature. As shown in Figure 5, the pollen curvature of March–April 1995 is much wavier and sharper and with higher peaks than that of 1994. This is intimately correlated with the weather: rain showers were much more frequent and heavier, and the temperature was much less steady in March and April of 1995 than in the same period of 1994. A rain shower always decreased the pollen concentration drastically, and a sharp pollen peak normally appeared following a rain shower (Figure 5). The positive effect of rain as reported by Berggren et al. (1995) that pollen counts increased rapidly concurrently with the beginning of a heavy rain shower was only observed once by us on 8 March 1994.

The dominance of *Broussonetia* is apparently much related to some superiority of its phenology and pollen features. In Taiwan, *Broussonetia papyrifera* is common in drier and more open vegetation in wild lowlands as well as in the abandoned land in many metropolitan areas. The mature male plant of this species is usually 4–5 m tall, has a spreading canopy, and produces ample descending male inflorescence at anthesis. Its pollen is spherical to ellipsoid, small (10–12 μm in diameter), thin-walled, and without pollenikitt. In the vicinity of our collection site, there were only a few male plants of *B. papyrifera*, 300 m to 1,000 m away from the trap.

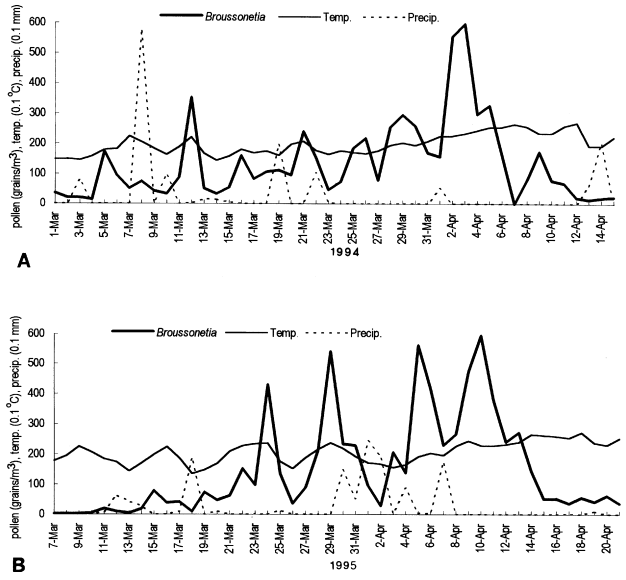

Figure 5. Correlation between pollen concentration of *Broussonetia* and meteorological factors (temperature and precipitation). A, in the 1994 flowering season; B, in 1995.

Throughout the year, pollen rain was heaviest in springtime during which *Broussonetia*, *Casuarina*, and *Trema* were major pollen contributors. Summer appeared to be the poorest season in both floristic composition and absolute quantity of the pollen spectrum, Poaceae, *Humulus,* and *Mimosa* being the significant members. In fall, pollen concentration rose moderately, due mainly to the increase of grass and *Alnus* pollen. After fall, the total amount dropped again and grasses, Urticaceae, and *Humulus* became important contributors.

The present investigation also showed that the airborne pollen spectrum did not reflect the floristic composition in the vicinity of the collection site. A great many individuals from more than 100 families grew naturally or in cultivation in the area within 1-km distance from the collection site. Of them, plants of Palmae (*Archontophoenix*, *Phoenix*, *Roystonea*), Myrtaceae (*Eucalyptus*, *Melaleuca*), Apocynaceae (*Alstonia*), and Moraceae (*Ficus*) were quantitatively most significant. However, because they were basically zoophilous, none of them proved to be important donors to the airborne pollen assemblage. Among the cultivated plants found around the collection site, only *Casuarina*, *Bischoffia*, and *Liquidambar* were remarkable. Thus, the present investigation illustrated a rather common incongruency between plant composition and aeropalynological spectrum in urbanized areas, where zoophilous cultivated plants abound, and on the other hand supported the notion that only anemophilous taxa are of great potential importance to the airborne pollen spectrum, particularly those of the so-called Amentiferae—they produce well-airborne pollen grains in quantity.

Pollen allergy is among the major topics in aeropalynology. Pollen of grasses, birches, alders, ragweeds, *Cryptomeria* and *Chamaecyparis* prove to be among the important aeroallergens in Australia, Europe, North America, mainland China, and Japan (Knox, 1979; Johansen, 1992; Galan et al., 1995; Berggren et al., 1995; Ye et al., 1988; Horiuti et al., 1991; Ogasawara et al., 1991); they might do so in some other extra-tropical regions in the world. In Taiwan, a mountainous subtropical island, the pollen spectrum in the air appears much more complicated than that of temperate regions. Grass pollen has been reported as the major component in some earlier aeropalynological investigations (Huang and Chung, 1973; Chen and Huang, 1980; Tsou and Huang, 1982); however, its proportion remained at 20% or so. In contrast, *Broussonetia* has come out to be predominant (70.37% & 66.83%) in recent studies (Peng, 1994, the present one) while grasses (4.15%) and Compositae (0.93%) were of minor importance. According to the skin tests of pollen allergenicity (Ye et al., 1988), nearly all of the significant pollen taxa ($f > 1\%$) revealed in the present study are allergic. Of them, one finds the five quantitatively most important taxa: *Broussonetia*, *Casuarina equsetifolia*, *Trema orientalis*, Poaceae, and *Humulus scandens*, constituting 84.43% of the total. In conclusion, further study of these five taxa on the correlation between their individual pollen concentration and the allergenicity, especially that of *Broussonetia papyrifera*, appears crucial.

Acknowledgements. We want to extend our appreciation to the National Science Council of the Republic of China for the financial support (grants NSC 83-0409-B-001-001-B08, 84-2311-B-001-010-B08, 85-2311-B-001-001-B14), to Mr. Yen-Liang Lai for maintaining our collection site, and to Dr. Chung-Fu Shen for commenting on the manuscript.

Literature Cited

Berggren, B., S. Nilsson, and G. Boethius. 1995. Diurnal variation of airborne birch pollen at some sites in Sweden. Grana **34:** 251–259.

Chao, I. T., L. F. Chen, and J.T. Ehieh. 1962. Study and survey of aeroallergens of Taiwan. Chinese Med. J. **9:** 233–243.

Chen, S. H. and M. C. Chien. 1986. Two-year investigation of the airborne pollen at Nankang, Taipei (Taiwan). Taiwania **31:** 33–40.

Chen, S. H. and T. C. Huang. 1980. Aerobiological study of Taipei Basin, Taiwan. Grana **19:** 147–155.

Galan, C., J. Emberlin, E. Dominguez, R. H. Bryant, and F. Villamandos. 1995. A comparative analysis of daily variations in the Gramineae pollen counts at Cordoba, Spain and London, UK. Grana **34:** 189–198.

Horiuti, T., S. Nouno, and K. Yamada. 1991. Skin tests of pollen grains of Taxodiaceae and Cupressaceae on children with bronchial asthma. Jpn. J. Palynol. **37:** 177–181.

Huang, T. C. 1972. Pollen Flora of Taiwan. Dept. Botany, Natl. Taiwan Univ. Taipei.

Huang, T. C. 1981. Spore Flora of Taiwan. Dept. Botany, Natl. Taiwan Univ. Taipei.

Huang, T. C. 1982. Review of palynological studies in Taiwan. Proc. Natl. Sci. Counc.(B) ROC **6:** 59–70. (in Chinese)

Huang, T. C. and T. F. Chung. 1973. Aeropalynological study of Taiwan (1)- Chushan station. Taiwania **18:** 160–168.

Johansen, S. 1992. Aerobiological studies in subalpine birch forest at Doverefjell, Central Norway, 1982–1984. Grana **31:** 131–142.

Knox, R. B. 1979. Pollen and allergy. - Edward Arnold, London, 59 pp.

Ogasawara, H., S. Yoshimura, T. Nakahara, T. Fujitani, and H. Okada. 1991. Airborne pollen survey of *Cryptomeria japonica* and *Chamaecyparis* spp. in Hyogo prefecture. Jpn. J. Palynol. **37:** 145–150.

Peng, M. 1994. Aeropalynological study in Tan-Shui area. Master thesis, Dept. Botany, Natl. Taiwan Univ., Taipei. (in Chinese)

Tsou, C. H. 1982. Aeropalynological study of Taipei suburban (New Flower Garden City). Master thesis, Dept. Botany, Natl. Taiwan Univ., Taipei. (in Chinese)

Tsou, C. H. and T. C. Huang. 1982. Aeropalynological study of Taipei suburban (New Flower Garden City). Taiwania **27:** 1–8.

Ye, S. T., J. T. Zhang, B. S. Qiao, and Y. G. Lu. 1988. Airborne and allergenic pollen grains in China. Scientific Press, Peiking. (in Chinese)