

Daily variations of airborne pollen in Beijing Olympic Park during August of three consecutive years and their relationships with meteorological factors

XU Jing-xian^{1*}, ZHANG De-shan²

¹ Beijing Museum of Natural History, Beijing 100050, P. R. China

² Beijing Specialized Meteorological Observatory, Beijing 100089, P. R. China

© Beijing Forestry University and Springer-Verlag Berlin Heidelberg 2010

Abstract A three-year aeropalynological study was carried out in the month of August for each of the three years 2005, 2006 and 2007 in the Beijing Olympic Park. A total of 19550 pollen grains were counted (15057 grains in 2005, 2717 in 2006 and 1776 in 2007) for the following taxa: Gramineae, Chenopodiaceae, *Humulus* L., *Artemisia* L., *Ambrosia* L. and *Pinus* L. The analysis indicated that in the three consecutive years of 2005–2007, airborne pollen types and daily number of pollen in August in the Beijing Olympic Park were closely related to environmental change and vegetation composition. The daily variations of airborne pollen displayed similar patterns in August in each of the three years, which were affected positively by periods of daily sunshine, negatively by daily relative humidity and daily precipitation. Continuously high daily temperatures and stable daily wind speeds seemed to have little effect on the fluctuation of airborne pollen.

Key words daily variations, aeropalynology, airborne pollen, Beijing Olympic Park

1 Introduction

Pollen grain suspended in the air is one of the principal particles of atmospheric pollution. Their composition and concentration in a particular region vary markedly in response to geographical location, vegetation components and meteorological parameters. These days, aeropalynological studies have aroused worldwide interest and become part of a global project with relevance to agriculture (Rodriguez et al., 2000), the environment (Grandjouan et al., 2000; D'Amato and Liccardi, 2003), medicine and human health (D'Amato et al., 1998; Sin et al., 2001).

In China, pioneering studies on aeropalynology were mainly carried out in Beijing. Song (1959) investigated the composition of airborne pollen in Baiwanzhuang of Beijing and analyzed their annual and seasonal variations in the course of one year. Zhang (1964) conducted a one-year aeropalynological investigation from March 1962 to February 1963 in the Beijing Zoo. In the 1980s, a nationwide investigation of airborne pollen was conducted in 60 cities of 29 provinces. More than two hundred researchers joined this

project, which stimulated the development of aeropalynology. Since then, more studies have been undertaken on a continuous basis (Lai et al., 1982; Zhang et al., 1984; Zhang and Wu, 1987; Ye et al., 1988; Fang et al., 1989; Wang and Wu, 1990; ITAAPGC, 1991; Fang et al., 1992; Chen et al., 1994; Sun et al., 1994; Zheng, 1994; Ma et al., 1996; Li et al., 1997; Yang et al., 1998; Fang et al., 2001; Han et al., 2001; Ji, 2001; Su and Du, 2002; Xie et al., 2004; Zeng et al., 2004; Meng et al., 2005; Shen et al., 2006).

In 1999, six monitoring stations were established in urban areas of Beijing (Dai and Lu, 2000). The temporal and spatial changes of airborne pollen in Beijing and their relationships with meteorological factors were discussed (Li et al., 2000; He et al., 2001; Zhang et al., 2003; Xu et al., 2008). Using statistical methods, short-term models were devised and used to forecast the daily changes of airborne pollen (Zhang et al., 2006). Given the development and construction of the city, airborne pollen should be analyzed continuously at more sites, especially in dense population zones. It will be helpful in the treatment of patients suffering from pollen related diseases due to allergies.

* Author for correspondence. E-mail: xjx18@hotmail.com

The aim of this study was to provide an aeropalynological survey in Beijing Olympic Park and present the type and abundance of airborne pollen during August of three consecutive years (2005–2007). Furthermore, we discussed the daily variations of airborne pollen and their relationships with meteorological factors. These studies would be important in helping to ameliorate the atmospheric environment and prevent the occurrence of pollen related allergies of people in Beijing.

2 Materials and methods

The sampling station (40°01'21"N, 116°23'19"E, 74.0 m a.s.l.) was situated in the Beijing Olympic Park. The airborne pollen was collected during August of 2005, 2006 and 2007. A Durham sampler was used to capture the airborne pollen. The instrument was installed at a height of 1.5 m above the ground. Before exposure, the slides were covered with glycerine jelly mixed with basic fuchsin (Charpin and Surinyach, 1974). Slides in the Durham sampler were replaced at 08:00 h each morning and examined every day. Pollen grains in the cover-glass area (24 mm × 24 mm) were counted. The identification and counting of pollen grains were performed under a Nikon Eclipse 80i light microscope. The identification of pollen grains was performed according to references published by Wang et al. (1995) and Qiao (2005).

In order to verify the correlation between airborne pollen and meteorological parameters, the daily values of meteorological parameters were obtained at the sampling station, i.e., precipitation, temperature, relative humidity, sunshine duration and wind speed.

3 Results

3.1 Number of airborne pollen

As shown in Table 1, a total of 19550 pollen grains were identified in this study. In August of 2005, 15057 pollen grains were observed; the average number of daily pollen grains was 486, with the maximum (2235 grains) on the 31st and the minimum (39 grains) on the 3rd and 4th. In August of 2006, 2717 pollen grains were counted, with an average number of 94 grains, a maximum of 253 grains on the 20th and a minimum of 9 grains on the 8th. In August of 2007, 1776 pollen grains were counted, with an average of 57 grains, a maximum of 190 grains on the 31st and a minimum of 2 grains on the 3rd (Fig. 1, Table 1). The total number of pollen grains in August displayed a pronounced decreasing trend from 2005 to 2007.

3.2 Composition and daily variation of airborne pollen

Six pollen types were identified during the three observation periods. The pollen producers were mainly Gramineae, *Humulus* L., *Artemisia* L. and Chenopodiaceae. The pollen grains of *Ambrosia* L. and *Pinus* L. were found sporadically in August of 2005 and 2006 (Table 1). Daily variations of each pollen type are shown in Figs. 2–6.

Humulus pollen, occurred continuously in August 2005, was absent 3 d in 2006 and for 8 d in 2007. Daily variation of the number of pollen showed a fluctuating increase during August in the three consecutive years (Fig. 2).

Artemisia pollen was missing for 8 d in 2005, for 7 d in 2006 and for 10 d in 2007. The daily number of pollen increased in August 2005, while in August of both 2006 and 2007, they showed an increase followed by a decrease (Fig. 3).

Chenopodiaceae pollen was present continuously and the daily numbers showed a fluctuating increase in August in the three consecutive years (Fig. 4).

Gramineae pollen was recorded during August of 2005 and 2006 and occurred intermittently during August of 2007 with a 10-day absence. The daily number of pollen showed a fluctuating increase in August of 2005 and 2006, while it showed an increase followed by a decrease during August of 2007 (Fig. 5).

The daily number of *Ambrosia* pollen showed a multimodal pattern in August 2005 with a 6-day absence. In August 2006, *Ambrosia* pollen appeared sporadically and was entirely absent during August of 2007 (Fig. 6).

Pinus pollen was found sporadically in August of 2005 and 2006; there was no record in August 2007.

3.3 Daily variation of meteorological factors

Figure 7 shows the daily variations of temperature throughout August of the three consecutive years. It indicates continuously high values, which were generally between 20 and 30°C, with only three days above 30°C (two days with 30.7°C and one day with 30.2°C) in 2007.

As shown in Figs. 8–9, weather conditions were characterized by a greater number of rainy days and shorter mean daily periods of sunshine in the first half of August than those in the second half of August. From 1 to 17 August 2005, there were 9 rainy days and 12 d with daily periods of sunshine of less than 7 h, while 1 rainy day and 8 d with daily periods of sunshine of more than 7 h occurred from 18 to 31 August 2005. From 3 to 13 August 2006, there were

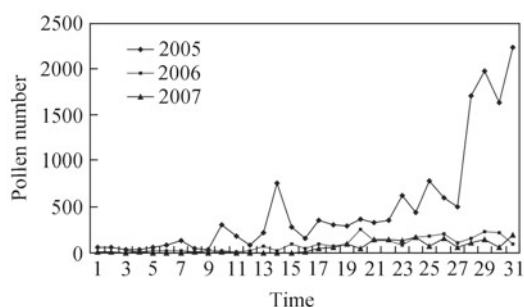


Fig. 1 Daily variation of airborne pollen in Beijing Olympic Park, August 2005–2007

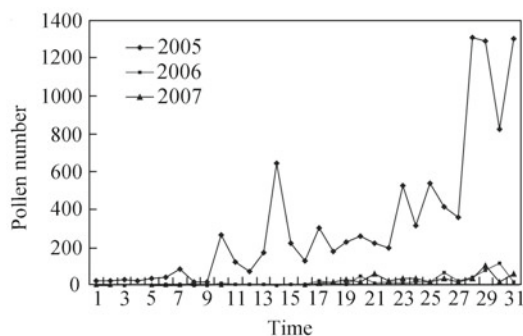


Fig. 2 Daily variation of *Humulus* pollen in Beijing Olympic Park, August 2005–2007

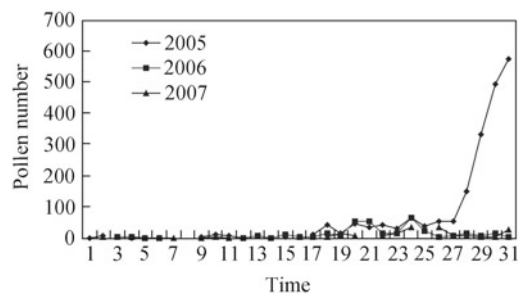


Fig. 3 Daily variation of *Artemisia* pollen in Beijing Olympic Park, August 2005–2007

4 rainy days and 9 d with daily sunshine lasting less than 5 h; from 14 to 31, 4 rainy days and 7 d with daily sunshine lasting more than 7 h. From 1 to 16 August 2007, there were 7 rainy days and 11 d with daily sunshine lasting less than 10 h; from 17 to 31, 1 rainy day and 12 d with daily sunshine lasting more than 7 h (Figs. 8–9).

Figure 10 indicates that the mean daily relative humidity in the first half of August of each of the three years was generally higher than that in the second half. From 1 to 17 August 2005, the daily relative humidity ranged between 66%–91% and 56%–78% from 18 to 31. From 3 to 13 August 2006, the daily relative humidity was between 71%–86%, while from 14 to 31, the humidity decreased (47%–81%). From 1 to 16 August 2007, the daily relative humidity was generally more than 60%; from 17 to 31, it ranged between 48%–82%.

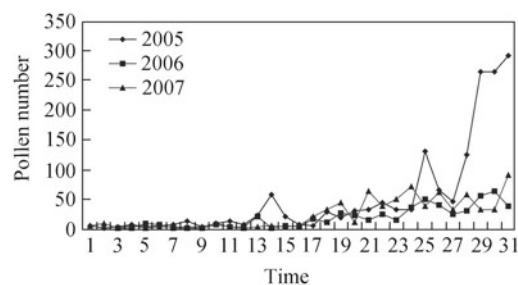


Fig. 4 Daily variation of *Chenopodiaceae* pollen in Beijing Olympic Park, August 2005–2007

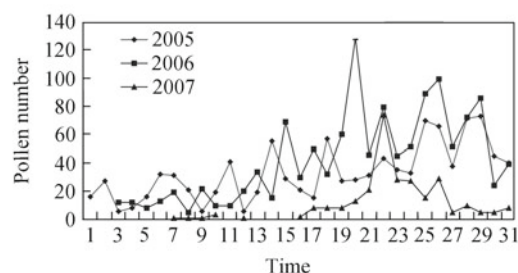


Fig. 5 Daily variation of *Gramineae* pollen in Beijing Olympic Park, August 2005–2007

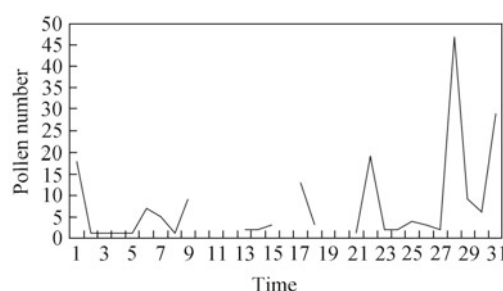


Fig. 6 Daily variation of *Ambrosia* pollen in Beijing Olympic Park, August 2005

The daily wind speed was less than $3.0 \text{ m}\cdot\text{s}^{-1}$ (generally between 1.5 and $2.5 \text{ m}\cdot\text{s}^{-1}$) during August of each of the three years, with the exception of the 20th ($3.3 \text{ m}\cdot\text{s}^{-1}$) of August 2006 (Fig. 11).

4 Discussion

4.1 Variation of airborne pollen

Previous studies indicated that two separate annual peaks of airborne pollen occurred in Beijing. The first one, in the spring–summer, was largely derived from trees and shrubs, while the second one, in the autumn, was attributed to herbaceous pollen (ITAAPGC, 1991; Xu et al., 2009). Generally, the autumn pollen peak started in mid-August and lasted until the end of September. The major constituents of airborne pollen in

Table 1 Airborne pollen types and their cumulative amounts in August of 2005, 2006 and 2007 in Beijing Olympic Park

Day	<i>Humulus</i> L.						<i>Artemisia</i> L.						Chenopodiaceae						Gramineae						<i>Ambrosia</i>						<i>Pinus</i>						Total (2005)		Total (2006)		Total (2007)							
	2005			2006			2007			2005			2006			2007			2005			2006			2007			2005			2006			2007			Grain		%		Grain		%		Grain		%	
1	25		2	1						5			5			16			18														65	0.43			7	0.39										
2	24		3	8			2			2			9			27			1														62	0.41			14	0.79										
3	28	3			4					3	2		2	2		6	12		1			1										39	0.26	21	0.77	2	0.11											
4	22			1	2	2				7	2	5	5	2		8	12		1													39	0.26	16	0.59	7	0.39											
5	37	2	1		1	1				3	9	2	2	9		16	8		1													57	0.38	20	0.74	4	0.23											
6	46	4	1		1	1				6	7	3	3	32	13			7														91	0.60	25	0.92	5	0.28											
7	87	8	1			1				8	1	3	3	31	19		1	5														131	0.87	28	1.03	6	0.34											
8	19	3	11							13	1	4	4	21	5		1	1														54	0.36	9	0.33	16	0.90											
9	19	2		4		1				3	2	3	3	6	22	1	9															41	0.27	27	0.99	5	0.28											
10	266	11	1	11		3				9	7	9	9	19	10	3																305	2.03	29	1.07	16	0.90											
11	122	4		6		1				14	3	4	4	41	10																	183	1.22	18	0.66	5	0.28											
12	75	4		1	1					8	3	2	2	6	20	1																90	0.60	28	1.03	3	0.17											
13	175	7			7					23	21	3	3	19	34																	219	1.45	69	2.54	3	0.17											
14	646	1			1					58	2	5	5	55	15																	761	5.05	22	0.81	5	0.28											
15	224	9		2	12					21	5	3	3	29	69																	279	1.85	95	3.50	3	0.17											
16	127	6	1		4	2				8	3	6	6	21	30	2																156	1.04	43	1.58	11	0.62											
17	305	23	14	11	5					5	18	22	15	50	8																	350	2.32	96	3.53	44	2.48											

(To be continued)

Table 1 (continued)

Day	<i>Humulus</i>			<i>Artemisia</i>			Chenopodiaceae			Gramineae			<i>Ambrosia</i>			<i>Pinus</i>			Total (2005)		Total (2006)		Total (2007)	
	2005	2006	2007	2005	2006	2007	2005	2006	2007	2005	2006	2007	2005	2006	2007	2005	2006	2007	Grain	%	Grain	%	Grain	%
18	179	14	18	42	17	5	30	12	34	57	32	8	3						311	2.07	75	2.76	65	3.66
19	227	5	31	16	6	17	19	27	44	27	60	8							289	1.92	98	3.61	100	5.63
20	259	48	20	47	53	7	32	23	12	28	129	13							366	2.43	253	9.31	52	2.93
21	223	13	60	36	54		34	15	65	31	46	21	1	1					325	2.16	129	4.75	146	8.22
22	201	18	22	42	14	8	45	26	39	43	79	74	19		1				351	2.33	137	5.04	143	8.05
23	524	14	35	31	14	17	33	16	50	35	45	28	2						625	4.15	89	3.28	130	7.32
24	313	17	40	66	67	35	33	36	71	33	51	27	2						447	2.97	171	6.29	173	9.74
25	541	20	20	38	25		130	51	39	70	89	15	4						783	5.20	185	6.81	74	4.17
26	417	67	37	52	4	36	66	40	62	66	99	29	3						604	4.01	210	7.73	164	9.23
27	357	25	16	55	8	8	47	26	33	38	51	5	2	2					499	3.31	112	4.12	62	3.49
28	1308	45	38	151	15	8	124	31	58	71	72	10	47			1			1701	11.30	164	6.04	114	6.42
29	1290	78	105	331	7	5	264	56	34	73	86	5	9						1967	13.06	227	8.35	149	8.39
30	823	116	17	494	16	3	264	65	33	45	24	5	6						1632	10.84	221	8.13	58	3.27
31	1300	18	64	575	5	26	291	38	92	40	39	8	29						2235	14.84	100	3.68	190	10.70
Total (grain)	10209	585	558	2021	343	189	1608	548	756	1025	1231	273	191	4	3	6			15057	100	2717	100	1776	100
Total (%)	67.80	21.53	31.42	13.42	12.62	10.60	10.68	20.17	42.60	6.81	45.31	15.37	1.27	0.15	0.02	0.22			100					

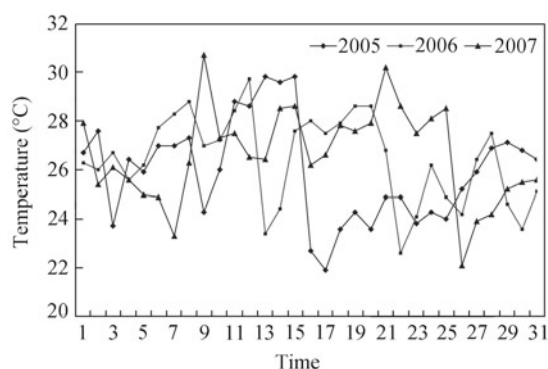


Fig. 7 Change of daily temperature in Beijing Olympic Park, August 2005–2007

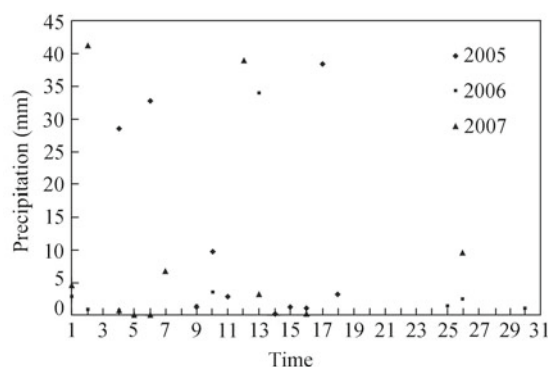


Fig. 8 Change of daily precipitation in Beijing Olympic Park, August 2005–2007

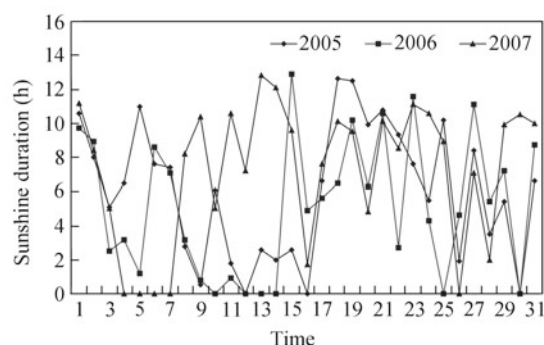


Fig. 9 Change of daily sunshine duration in Beijing Olympic Park, August 2005–2007

this period include *Humulus*, *Artemisia*, Chenopodiaceae and Gramineae (Song, 1959; Zhang, 1964; ITA-APGC, 1991; Xu et al., 2008).

In this study, the analytical results show a similarity in the major composition of airborne pollen in August of the three years. The dominant pollen types, Gramineae, *Humulus*, *Artemisia* and Chenopodiaceae, were similar to those of previous studies, although the total number of pollen show a decreasing trend from 2005 (15057 grains), 2006 (2717 grains) to 2007 (1776 grains) (Tables 1–2).

A previous study has demonstrated that environmental change might have an effect on the type and amount of airborne pollen (Katelaris and Burke,

2003). During the three years prior to the Olympic Games of 2008, especially in 2005 and 2006, Beijing Olympic Park experienced many changes in the environment as new facilities were built and many plantings undertaken. Therefore, many weeds, such as *Humulus*, *Artemisia* and Chenopodiaceae, were uprooted, which constituted the principal contributors to the autumn peak of airborne pollen in Beijing. These factors could be a major cause of the pronounced decrease in the number of pollen in August from 2005 to 2007 (Table 1, Figs. 1–6).

4.2 Correlation between airborne pollen and meteorological factors

Variations in airborne pollen concentrations result from their response to dynamic conditions of the medium in which the pollen grain is dispersed. The fluctuation in the number of pollen is related to environmental changes and the vegetation component in the local area. It is also strongly related to weather conditions, such as precipitation, temperature, relative humidity, the amount of sunshine and wind speed (Molina et al., 2001). Studies indicated that airborne pollen concentrations are affected positively by temperature, but negatively by relative humidity and rainfall (Molina et al., 2001). Although the total number

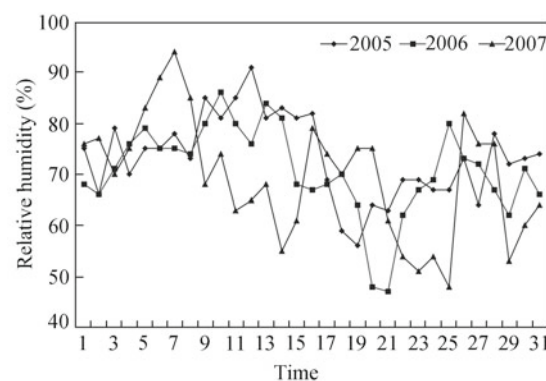


Fig. 10 Change of daily relative humidity in Beijing Olympic Park, August 2005–2007

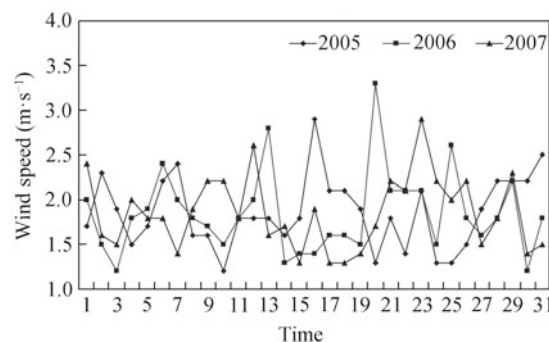


Fig. 11 Change of daily wind speed in Beijing Olympic Park, August 2005–2007

Table 2 Type and number of airborne pollen during August in different sites of Beijing

	Baiwanzhuang (Song, 1959)		Beijing Zoo (Zhang, 1964)	PUMCH (ITAAPGC, 1991)	MGHB (ITAAPGC, 1991)	BOP (Xu, 2008)	BOP (present study)	BOP (present study)
	1956	1957	1962	1986–1989	1986–1989	2005	2006	2007
Cupressaceae					8			
<i>Pinus</i> L.			2			3	6	
Betulaceae		5	4					
<i>Ulmus</i> L.			1					
Juglandaceae			3					
<i>Quercus</i> L.			1					
<i>Salix</i> L.			1					
Gramineae	15	34	215	216	24	1025	1231	273
<i>Zea mays</i> L.			57					
<i>Sophora</i> L.				20				
Compositae	2	3	14					
<i>Artemisia</i> L.	51	97	777	1773	1754	2021	343	189
<i>Ambrosia</i> L.				1		191	4	
<i>Helianthus</i> L.				1	16			
<i>Xanthium</i> L.				1				
Chenopodiaceae	10	76	158	283	139	1608	548	756
<i>Humulus</i> L.	12	158	12	1508	1427	10209	585	558
<i>Cannabis sativa</i> L.			252					
<i>Ricinus communis</i> L.			102					
Liliaceae		2		7				
Amaranthaceae			2					
<i>Plantago</i> L.			8					
Umbelliferae			1					
<i>Ricinus</i> L.				6	7			
Amaranthaceae				23				
Cyperaceae		2	3	4				
Cruciferae	12	11						
Total	102	388	1613	3843	3375	15057	2717	1776

Note: PUMCH, Peking Union Medical College Hospital; MGHB, the Military General Hospital of Beijing, BOP: Beijing Olympic Park.

of airborne pollen varied among August of each of the three years in our present study, the changing pattern of the daily number of pollen was remarkably similar during this one month.

During the first part of August, the number of pollen was low and increased slightly. During this period, the weather conditions were characterized by a great number of rainy days, daily sunshine lasting for short periods and high daily relative humidity (Figs. 8–10). High and continuous rainfall and high relative humidity might depress pollen dispersal in the air.

The daily number of pollen started to increase in mid-August, i.e., the 18th of August 2005, the 14th of August 2006 and the 17th of August 2007. The total

daily number of pollen reached its maximum on the 31st of August in 2005 and 2007 and on the 20th of August in 2006 (Fig. 1, Table 1). In the second half of the month, the number of rainy day was less, periods of daily sunshine were longer and the daily relative humidity was lower than those during the first half of the month (Figs. 8–10). High temperature and long periods of sunshine might accelerate the development of flower buds and would be helpful for the suspension and dispersion of pollen grain in the atmosphere.

Throughout August of each of the three consecutive years, daily temperatures showed continuously high values, ranging between 20 and 30°C, (Fig. 7). The daily wind speed was mostly less than 3.0 m·s⁻¹ dur-

ing August of the three years (Fig. 11). On the basis of these data, we infer that daily temperature and daily wind speed has little effect on the fluctuation of airborne pollen.

The comparison between airborne pollen data and meteorological factors showed that low numbers of daily airborne pollen were recorded during the first half of August 2005, 2006 and 2007, which could be attributed to high daily precipitation, high daily relative humidity and short periods of daily sunshine. The significant increase of airborne pollen during the second half of August could be correlated with low daily precipitation, low daily relative humidity and long periods of daily sunshine. During the entire month of August, there were continuously high daily temperatures and stable daily wind speeds, which should have therefore little effect on the fluctuation of the number of pollen in the atmosphere.

5 Conclusions

In August of 2005, 2006 and 2007, 19550 pollen grains were identified. Four dominant pollen types, including Gramineae, *Humulus*, *Artemisia* and Chenopodiaceae, were present. *Ambrosia* and *Pinus* pollen were found sporadically in 2005 and 2006. The total number of airborne pollen in August and daily values for the major pollen types showed pronounced decreases from 2005 to 2007.

A similar change of the daily number of pollen was recorded in August of three consecutive years. At the beginning of August, the daily number of pollen grains was low, started to increase from mid August, with maximum values occurring towards the end of August.

Comparative analysis of airborne pollen and meteorological factors indicated that the number of airborne pollen was affected positively by daily periods of sunshine, negatively by daily relative humidity and daily precipitation. Long-term high daily temperatures and stable daily wind speeds appeared to be less important parameters for the fluctuation of airborne pollen in this study.

Acknowledgements

We are grateful to Professor David K. Ferguson for having read the manuscript and provided helpful comments. We also thank Senior Engineer Du Nai-qiu for her kind help. This work was financially supported by the Beijing NOVA Program (No. 2005A41) and the Mengya Project of the Beijing Academy of Science and Technology (No. MY2008).

References

- Charpin J, Surinych R. 1974. Atlas of European Allergic Pollen. Paris: Sandoz
- Chen L, Wang Q X, Zhiu Q L. 1994. Original investigation about airborne allergic pollen in Lanzhou area. J Lanzhou Med Coll, (3): 154–155 (in Chinese with English abstract)
- D'Amato G, Speksma F T, Liccardi G. 1998. Pollen related allergy in Europe. Allergy, 53: 567–578
- D'Amato G, Liccardi G. 2003. Allergenic pollen and urban air pollution in the mediterranean area. Allergy Clin Immunol Int, 15: 73–79
- Dai L P, Lu C. 2000. The pollen and its measurement technique in spring. Meteorol Mon, 26(12): 49–52 (in Chinese with English abstract)
- Fang R Q, Xie S Q, Wei F. 2001. Pollen survey and clinical research in Yunnan, China. Aerobiologia, 17: 165–169
- Fang R Q, Xie S Q, Xiang S F. 1989. A investigation of the airborne pollen in Kunming. J Kunming Med Coll, 10(4): 70–71 (in Chinese with English abstract)
- Fang R Q, Xie S Q, Xiang S F, Zhang J T. 1992. A study of the airborne and allergenic spores and pollen grains in Kunming. Acta Bot Yunnanica, 14(3): 295–300 (in Chinese with English abstract)
- Grandjouan G, Cour P, Gros R. 2000. Reliability of abundance ratios between aeropalynological taxa as indicators of the climate in France. Grana, 39: 182–193
- Han L F, Tian H Y, Guo Z M, Ji S Q, Yang Y T. 2001. A correlation study between *Ambrosia* pollen and pollinosis in Qinhuangdao. Hebei Med J, (1): 59–60 (in Chinese with English abstract)
- He H J, Zhang D S, Qiao B S. 2001. Preliminary approach of the relationship between airborne pollen amount and meteorological factors in Beijing urban area. Chin J Microbiol Immunol, 21(4): 31–33 (in Chinese with English abstract)
- Investigational Team on Airborne and Allergenic Pollen Grains in China (ITAAPGC). 1991. An Investigation on Airborne and Allergenic Pollen Grains in China. Beijing: Beijing Press, 1–225 (in Chinese)
- Ji Y Y. 2001. Airborne pollen survey of Shanghai urban area. Chin J Microbiol Immunol, 21(suppl.): 44–45 (in Chinese with English abstract)
- Katellaris C H, Burke T V. 2003. A 7 year pollen profile of major Olympic Games venues in Sydney, Australia. Aerobiologia, 19: 121–124
- Lai N K, Zhai Y M, He Z L, Yuan Q B, Chen L J, Xu J H. 1982. A preliminary study between airborne pollen and pollinosis in some area of Guangzhou. Acad J Guangzhou Med Coll, (3): 1–11 (in Chinese)
- Li J S, Sun R Q, Lu J C, Sun Z H, Hu Q X. 2000. The study on space-time distribution of the atmosphere pollen in Beijing. China Public Health, 16(12): 1089–1091 (in Chinese with English abstract)
- Li M Z, Liu X M, Yang J, Zhong L H, Cao Z Y. 1997. A investigation on airborne and allergic pollen grains in Wuchang District, Wuhan City. J Wuhan Bot Res, 15(1): 66–72 (in Chinese with English abstract)
- Ma Y W, Liu G Q, Meng F Y, Guan L R, Duan R W, Zhao L H, Jing W H. 1996. A correlation study between airborne pollen and pollinosis in Jilin city. J Beihua Univ (Nat Sci), 16(4): 70–71 (in Chinese)
- Meng G, Li C L, Cai Q X, Xie C M. 2005. Survey on pollen sensitization of tropic plants in Haikou. J Clin Otorhinol, 19(22): 40–41 (in Chinese with English abstract)

- Molina R T, Palacios I S, Rodríguez A F M, Muñoz J T, Corchero A M. 2001. Environmental factors affecting airborne pollen concentration in *Anemophilous* species of Plantago. *Ann Bot*, 87: 1–8
- Qiao B S. 2005. Color atlas of air-borne pollens and plants in China. Beijing: Peking Union Medical College Press, 1–385 (in Chinese)
- Rodríguez A F M, Palacios I S, Molina R T, Corchero A M, Muñoz I T. 2000. Dispersal of Amaranthaceae and Chenopodiaceae pollen in the atmosphere of Exramadura (SW Spain). *Grana*, 39: 56–62
- Shen W Z, Liu X M, Chen G L, Liu H, Zou F F. 2006. 10-year change of airborne pollen and vegetation of the urban area of Wuhan. *J Clin Otorhinol*, 20(17): 804–805 (in Chinese with English abstract)
- Sin B A, Inceoglu Mungan D, Celik G, Kaplan A, Hisirligil Z. 2001. Is it important to perform pollen skin prick tests in the season? *Ann Allerg Asthma Im*, 86: 382–386
- Song Z C. 1959. Airborne pollen in the suburb of Beijing. *Quatern Sci*, 2, 69–74 (in Chinese with English abstract)
- Su A L, Du Z C. 2002. Research on the air-carried pollens in southern Shandong Province and their pathogenic characteristics. *J Linyi Med Coll*, 24(1): 17–19 (in Chinese with English abstract)
- Sun X Z, Li Y F, Zhao Z S. 1994. The preliminary investigation on the trends of air-borne pollens in Xi'an area. *J Environ Health*, 11(2): 80–81, 86 (in Chinese with English abstract)
- Wang F H, Chie N F, Zhang Y L, Yang H Q. 1995. Pollen Flora of China, 2nd edn. Beijing: Science Press (in Chinese)
- Wang X H, Wu K J. 1990. Airborne pollen in Haerbin area and its relation with the pollinosis. *J Clin Otorhinol*, 4(1): 28–29 (in Chinese)
- Xie S X, Liu J X, Liu Z G, Wan W H, Chen L. 2004. The investigation on airborne pollen in urban districts of Nanchang. *J Environ Health*, 21(6): 381–383 (in Chinese with English abstract)
- Xu J X, Zhang D S, Zhang X L. 2008. Daily variations of airborne pollen in the Beijing Olympic Park and their relationship with meteorological parameters. *Natl Sci Mus*, 4: 71–83 (in Chinese with English abstract)
- Xu J X, Li Y N, Zhang D S. 2009. Advances in the variation of atmospheric pollen and its forecasting study. *Acta Ecol Sin*, 29(7): 3354–3863 (in Chinese with English abstract)
- Yang J, Hu S P, Zhong L H, Li M X. 1998. An investigation into the major allergic pollens in Wuchang district. *J Hubei Med Univ*, 19(1), 37–39 (in Chinese with English abstract)
- Ye S T, Zhang J T, Qiao B S, Lu Y J. 1988. Airborne and allergenic pollen grains in China. Beijing: Science Press, 1–92 (in Chinese)
- Zeng J H, Hong S L, Huang J J. 2004. A survey of pollens in Yuzhong district of Chongqing. *Chongqing Med J*, 33(2): 216–218 (in Chinese with English abstract)
- Zhang J T. 1964. Airborne pollen in the western part of Beijing city. *Acta Bot Sin*, 16(3): 282–285 (in Chinese with English abstract)
- Zhang J T, Chen K, Mo G Y, Chen X T. 1984. Study on the airborne pollen and its allergy in Nanning, Guangxi. *Acta Bot Sin*, 26(6): 567–573 (in Chinese with English abstract)
- Zhang L P, Wu Y. 1987. An investigation of airborne pollen in Changchun. *J Jilin Univ (Med Ed)*, 13(5): 466–467 (in Chinese)
- Zhang S L, Zhang D S, He H J. 2003. Analysis of weather conditions of pollen amount in Beijing urban area. *Meteorol Sci Technol*, 31(6): 406–408 (in Chinese with English abstract)
- Zhang S L, Zhang D S, He H J, Mu Q Z. 2006. Daily total pollen and allergic pollen forecasting in August in Beijing. *Meteorol Sci Technol*, 34(6): 724–727 (in Chinese with English abstract)
- Zheng Z. 1994. A primary study on airborne pollen grains on the campus of Zhongshan University. *Ecol Sci*, (2): 11–17 (in Chinese with English abstract)

(Received September 26, 2010 Accepted November 14, 2010)