Chinese Science Bulletin

Pollen flux and vertical dispersion in coniferous and deciduous broadleaved mixed forest in the Changbai Mountains

XU QingHai[1†], LI YueCong[1], ZHOU LiPing[2], LI YiYin[2], ZHANG ZhenQing[1] & LIN FengYou[3]

[1] College of Resources and Environmental Sciences, Hebei Normal University, Shijiazhuang 050016, China;
[2] College of Environmental Sciences, Peking University, Beijing 100871, China;
[3] Changbaishan Forest Ecosystem Station of Chinese Academy of Sciences, Antu 133613, China

The pollen flux in coniferous and deciduous broadleaved mixed forest in the Changbai Mountains is presented in one year's experiments. The results indicate that arboreal pollen percentages are more than 65% and pollen flux is higher than 5000 grain·cm^{-2}·a^{-1}, while less than 2% and lower than 1000 grain·cm^{-2}·a^{-1} for shrubby pollen, and less than 20% and lower than 3000 grain·cm^{-2}·a^{-1} for herbaceous pollen for most samples at different heights. The pollen assemblages are similar to those in the samples under 8 m height where *Pinus* and *Quercus* are dominant and followed by the few non-local pollen types, and *Fraxinus* percentages are high with a few non-local pollen types at 16 m to 32 m height as well as non-local pollen clearly increased at 40 m height. Comparisons between pollen assemblages and vegetation composition suggest that similarities are higher for pollen trap samples than for surface moss samples.

Changbai Mountains, coniferous and deciduous broadleaved mixed forest, pollen flux, pollen dispersion, vertical change

1 Introduction

As one of the major parts of Quaternary palynology, pollen dispersion has been discussed since the 1960s[1−4]. While in China, most reports about pollen dispersion have concentrated on surface pollen assemblages and relationships between pollen and vegetation. The process and mechanism of pollen dispersal were rarely discussed. Although there are some reports about surface moss pollen assemblages in the Changbai Mountains[5−8], only little work was related to pollen flux in coniferous forest[9]. The results about vertical pollen dispersion in coniferous and deciduous broadleaved mixed forests in one year will be presented in this paper.

2 Study area

The study area is located in the 1# plot of coniferous and deciduous broadleaved mixed forests in the Changbai Mountains (42°24′N, 128°6′E, 738 m a.s.l.), where the annual average temperature is 3.6 ℃, and annual average precipitation is 713 mm. The topography is rather smooth around the sample site. The vegetation belongs to mature wildwood, where *Pinus koraiensis*, *Tilia amurensis*, *Quercus mongolica*, *Fraxinus mandshurica*, *Acer mono*, etc. are the dominant arbors[10], and the influences from human activities are not very clear[11].

3 Material and methods

3.1 Field work

There is a weather tower in the 1# plot of coniferous and

Received October 26, 2006; accepted January 31, 2007
doi: 10.1007/s11434-007-0187-z
†Corresponding author (email: Xuqinghai@mail.hebtu.edu.cn)
Supported by the Preliminary Special Foundation for National Key Basic Research (Grant No. 2003CCA01800), the National Natural Science Foundation of China (Grant Nos. 40571166 and 40672107), Hebei Special Foundation for Ph.D (Grant No. 06547006-3) and the Key National Natural Science Foundation of China (Grant No. 40331011)

deciduous broadleaved mixed forest in the Changbai Mountains, where 6 Tauber traps were set up on the tower at the heights of 8 m, 16 m, 22 m, 26 m, 32 m and 40 m in June, 2004. Two Tauber traps were set up on the ground near the tower, and 2 surface moss samples were collected near the ground Tauber traps. The Tauber traps were taken back in June, 2005.

The vegetation composition was investigated within 50 m around the tower, and referring to some data from Zhang et al.[11] and Sun[12]. The total coverage of a community, percentage coverage, and frequencies of all vascular species were logged in the field, respectively.

3.2 Laboratory work

Pollen was extracted with HF method[13]. More than 400 pollen grains were examined in each sample.

3.3 Data analysis

Pollen flux was calculated as following:

$$\text{Pollen flux (grain/cm}^2\text{/a)} = (P_{ij}\times N) / (C_j \times S),$$

where P_{ij} = numbers of pollen type i at sample j; N = added numbers of *Lycopodium* tracer in samples (in this paper N =11670 in all samples); C_j = recorded numbers of *Lycopodium* tracer in sample j; S = opening area (cm^2) of Tauber trap.

Similarity coefficients (C) are cited from refs. [5,14] to describe the similarity between pollen assemblages and surrounding community composition:

$$C=2c/[(a + c)+(b + c)],$$

where c is the number of pollen types where parent plants are present in the surrounding community, a the number of pollen types where parent plants are absent in the surrounding community, and b the number of plant types where association pollen types are absent in the pollen assemblages.

Pearson correlation coefficients describe the correlation between pollen assemblages at different heights. Based on Pearson correlation coefficients, cluster analysis has been done[15].

4 Results and discussion

4.1 Pollen assemblages at different heights

Fifty-nine pollen types (17 arbors, 12 shrubs, 29 herbs, 1 fern) were retrieved from all samples totally. Arboreal pollen percentages were more than 65% in most samples with *Pinus*, *Betula*, *Quercus*, *Fraxinus* and *Tilia* dominating pollen assemblages. Shrubby pollen percentages were less than 2%, with Araliaceae, Celastraceae and Rosaceae as the major pollen types. Herbaceous pollen percentages were less than 20 % in most samples, with abundant *Artemisia*, Chenopodiaceae, Compositae, Scrophulariaceae, Poaceae, Ranunculaceae, etc. Ferns spores were rare (Figure 1).

4.2 Pollen flux at different heights

The average total pollen flux was 19972 grain·cm^{-2}·a^{-1} at the study site with maximum of 69718 grain·cm^{-2}·a^{-1}

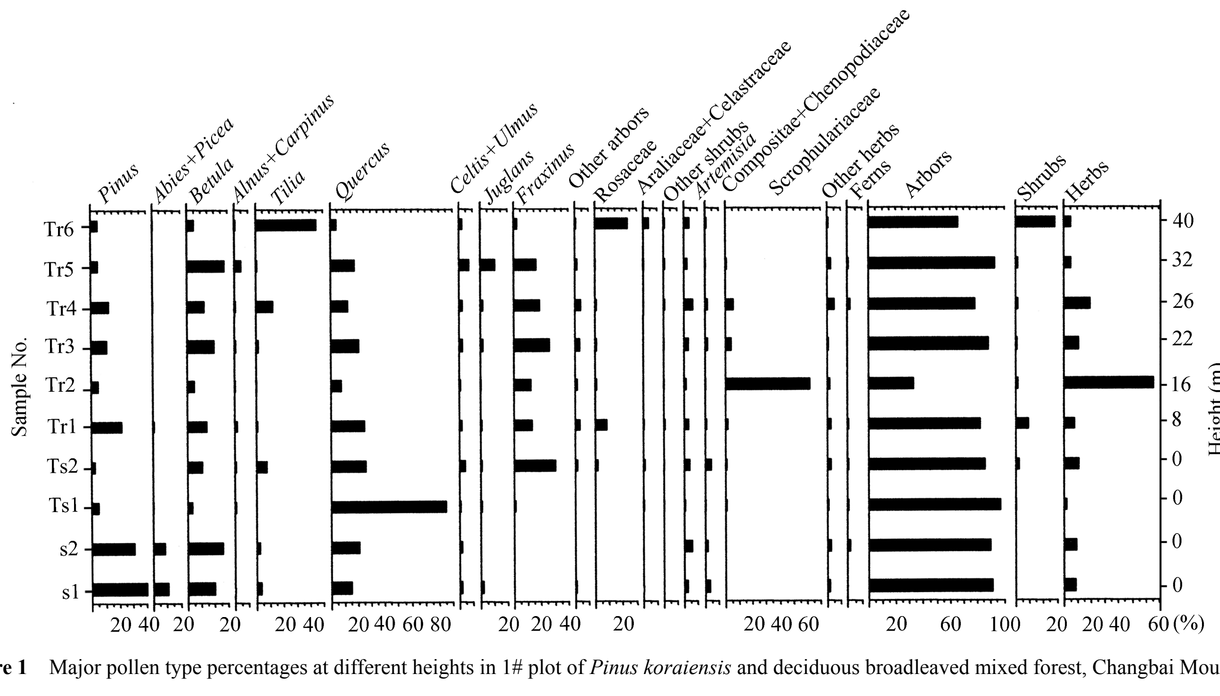

Figure 1 Major pollen type percentages at different heights in 1# plot of *Pinus koraiensis* and deciduous broadleaved mixed forest, Changbai Mountains.

at 16 m (Tr2), and minimum of 5782 grain·cm^{-2}·a^{-1} at 22m (Tr3). Arboreal pollen average flux was 12602 grain·cm^{-2}·a^{-1} with maximum of 23010 grain·cm^{-2}·a^{-1} at 16m (Tr2), and minimum of 5100 grain·cm^{-2}·a^{-1} at 22m (Tr3). Herbaceous average flux was 6606 grain·cm^{-2}·a^{-1}, also with maximum of 45815 grain·cm^{-2}·a^{-1} at 16m, but with minimum of 366 grain·cm^{-2}·a^{-1} at 32m (Tr5). The shrubby pollen flux was very little and the average value was only 715 grain·cm^{-2}·a^{-1}. As fern spores are large and heavy, it is difficult to be carried to higher height by wind[16] , fern spores flux reached maximum of 110 — 165 grain·cm^{-2}·a^{-1} on the ground, with some less than 100 grain·cm^{-2}·a^{-1} or absent at the other heights (Figure 2).

4.3 Similarities between community composition and pollen assemblages at different heights

As all the samples were collected in the forest where arbors controlled community composition, only the similarity coefficients between community composition and arboreal pollen assemblages were calculated (Table 1). The results indicated that the similarity coefficients between community composition and arboreal pollen assemblages were more than 0.5 with maximum of 0.76 at 8 m (tr1) for the trap samples, and 0.46 for the surface moss samples.

4.4 Correlation of pollen assemblages at different heights

To investigate the correlations of pollen assemblages for moss samples and pollen trap samples at different heights, the Pearson correlation coefficients of all the samples were calculated (Table 2). The results showed that correlation was significant for most of samples with maximum of 0.96 correlation coefficients excluding tr2 (at 8 m) and tr6 (at 40 m).

To describe the correlations of samples more definitely, cluster analysis was done based on Pearson correlation coefficients with MVSP program (Figure 3). Based on cluster analysis, three groups are divided for all the samples. Group 1 (including s1, s2, Ts1, Ts2, Tr1, Tr2) was collected below 8 m height where *Pinus* and *Quercus* were dominant with few non-local pollen types.

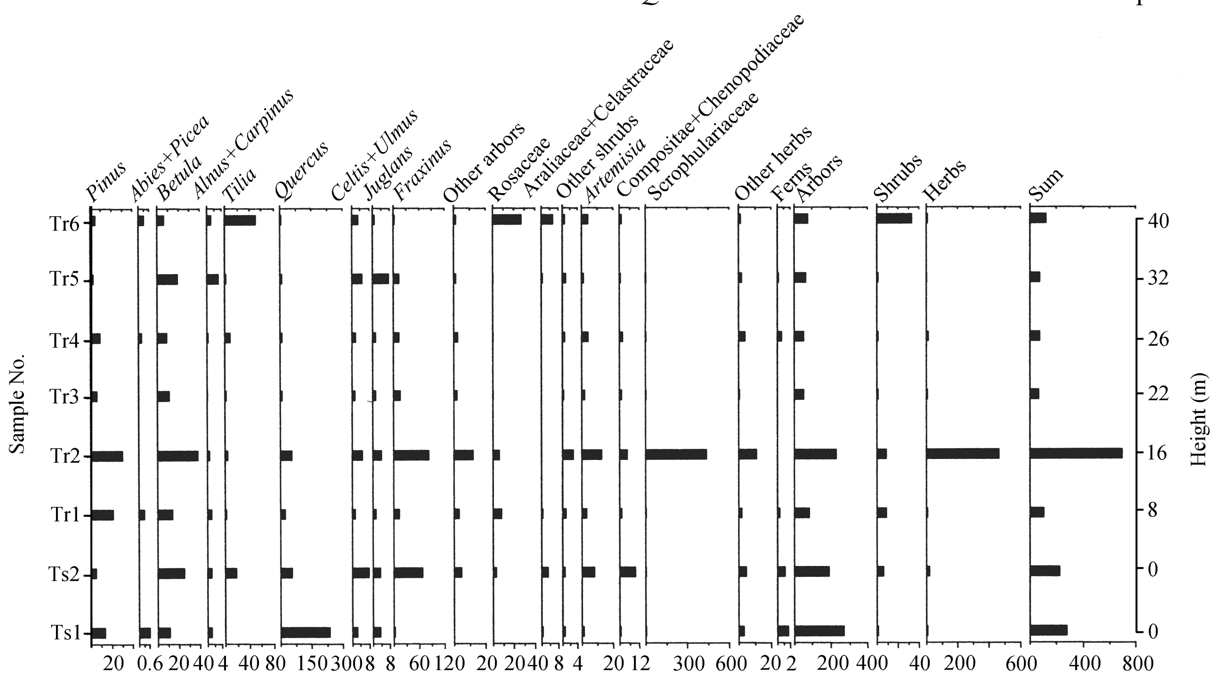

Figure 2 Major pollen type flux at different heights in 1# plot of *Pinus koraiensis* and deciduous broadleaved mixed forest, Changbai Mountains.

Table 1 Similarity coefficients between community composition and arboreal pollen assemblages at different heights

Sample No.	s1	s2	Ts1	Ts2	Tr1	Tr2	Tr3	Tr4	Tr5	Tr6
Height above the ground (m)	0	0	0	0	8	16	22	26	32	40
c	6	6	8	10	13	7	8	8	11	10
a	2	1	2	5	4	6	4	5	5	7
b	12	13	10	5	4	6	8	7	4	3
C	0.46	0.46	0.57	0.67	0.76	0.54	0.57	0.57	0.71	0.67

Table 2 Correlation coefficients of pollen assemblages for moss samples and pollen trap samples at different heights

Sample No.	s2	Ts1	Ts2	Tr1	Tr2	Tr3	Tr4	Tr5	Tr6
S1	0.96**	0.36**	0.31*	0.79**	0.08	0.56**	0.60**	0.50**	0.14
S2	1	0.49**	0.42**	0.85**	0.10	0.66**	0.66**	0.67**	0.14
Ts1		1	0.61**	0.68**	0.10	0.54**	0.41**	0.48**	0.06
Ts2			1	0.74**	0.19	0.92**	0.86**	0.77**	0.23
Tr1				1	0.17	0.87**	0.81**	0.74**	0.20
Tr2					1	0.29*	0.22	0.16	−0.01
Tr3						1	0.90**	0.89**	0.11
Tr4							1	0.76**	0.42 **
Tr5								1	0.10

* Correlation is significant at the 0.05 level (2-tailed); ** Correlation is significant at the 0.01 level (2-tailed).

Group 2 (including Tr3, Tr4, Tr5) was located from 16 m to 32 m heights where *Fraxinus* was rich with a few non-local pollen types. Group 3 (including Tr6) was at 40 m height where non-local pollen types obviously increased.

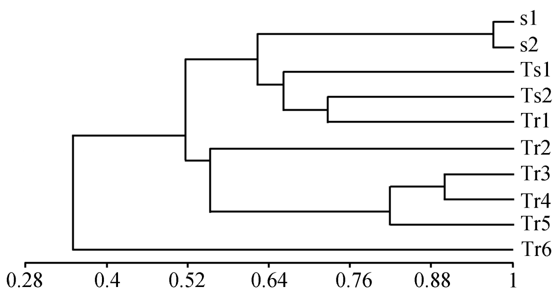

Figure 3 Results of cluster analysis of samples based on Pearson correlation coefficients.

4.5 Comparison with other results

Pollen flux not only is indispensable to reveal the quantitative relationship between pollen and vegetation, and to study pollen production, pollen dispersion and pollen source area, but also is the basis for quantitative recovery of paleo-vegetation and for establishing Pollen-Landscape Calibration[17]. At present, researches about pollen flux are rare in China, apart from Sun et al.[9], who investigated the pollen flux in *Pinus koraiensis* and dark coniferous mixed forests in the Changbai Mountains. The results in this paper suggested that average pollen flux was 19972 grain·cm^{-2}·a^{-1} with minimum of 5781 grain·cm^{-2}·a^{-1}, but the maximum obtained by Sun et al. was 2189 grain·cm^{-2}·a^{-1} with average value of 1324 grain·cm^{-2}·a^{-1}[9]. The difference may be caused by the different experimental methods. In this study, pollen traps were designed as "Tauber type" with bigger bottom and smaller top, where some preservatives (e.g. Glycerol, Formalin and Thymol) were put in the traps. But pollen traps used by Sun et al. were "tundish type" without preservative in the traps[9]. Thus, some pollen grains entering the trap may be oxidized or eroded by bacteria and fungi. The pollen flux of forest in the Changbai Mountains are approximative to that in Sweden and Estonia (9000—37000 grain·cm^{-2}·a^{-1})[18, 19].

5 Conclusions

(1) Pollen assemblages were similar for samples at different heights at a certain extent. For example, arboreal pollen percentages were more than 65% and flux was higher than 5000 grain·cm^{-2}·a^{-1}, and less than 2% and 20% for shrubby and herbaceous pollen, respectively.

(2) Pollen assemblages also showed some differences for samples at different heights. Under 8 m height, *Pinus* and *Quercus* were dominant with only few non-local pollen types, and at 16 m to 32 m height, *Fraxinus* percentages were rich in pollen assemblages with a few non-local pollen types, while at 40 m height, non-local pollen obviously increased in pollen assemblages. Pollen flux had maximum at 16m height and minimum at 40 m height.

(3) Similarity was apparent between community composition and pollen assemblages at different heights and the highest similarity coefficient was 0.76 at 8 m. The dominant plants in communities were also the major pollen types in pollen assemblages.

(4) Pollen assemblages had higher correlations for pollen trap samples than for surface moss samples. The results were obtained from experiments within one year and need further work to get more detailed information.

The authors would like to thank Prof. KANG ShiChang and editor for careful reviews.

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