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AIRBORNE POLLEN FLORA OF A DECIDUOUS MESIC FOREST IN TURKEY

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Abstract

Airborne pollen composition of a deciduous mesic forest in northwestern Turkey is compared with the flora of the forest and a wider area. The airborne assemblage is constituted by 641.553 pollen belonging to 32 orders, 54 families and 96 genera. Of these, 380.000 (59.2%) belong to native and 257.180 (40.1%) to non-native plants. Among the native taxa arboreal pollen (AP) is represented by 55.7% and non-arboreal (NAP) by 44.3%. All of the arboreal elements of the forest are *Quercus, Castanea, Carpinus, Ulmus, Alnus, Populus, Salix, Fagus, Tilia, Acer, Corylus, Prunus, Rubus, Ligustrum, Phillyrea* which represented in the airborne assemblage. Incorporation of NAP to airborne composition is less than AP and they more likely provide an indication of the composition of local plant communities and hence represent vegetation of immediate vicinity. The most common NAP taxa are Poaceae, Plantaginaceae, Asteraceae, Urticaceae, Apiaceae, Cannabaceae, Polygonaceae and Cyperaceae. Pollen of climbers are less represented than AP but more than NAP taxa. *Platanus orientalis* (30.7%) and *Pinus* and *Cupressus* (20.2%) constitute half of the non-native flora; the rest is the pollen of exotic, alien and horticultural taxa from numerous parks and gardens in İstanbul.

Introduction

Large quantities of pollen are released from anemophilous plants during dissemination period; they are carried by air currents and eventully settle on the ground. Most of the grasses, gymnosperms and a significant number of angiosperms are anemophilous that produce airborne pollen. Composition of atmospheric pollen provides a picture of surrounding vegetation, yet several factors such as differential pollen production of the plants, limitations in dispersal, falling velocity, etc. are considered in the assessment of 'vegetation' versus 'airborne pollen' relationship. Some plant taxa produce pollen in much greater quantities than the others, which is a factor determined by the genetic potential of each species (Molina *et al.,* 1996). Some plant taxa produce large and heavy grains whose falling rate is much faster and hence they more reflect the vegetation of a closer area, while some others produce small and light pollen which are easily drifted by wind and falls onto earth far from the maternal plant reflecting vegetation of far distant places. The amount of sporopollenin content and the morphological features such as the thickness and even the sculpture types of exine determine the falling rate of pollen. The height of trees, woodland density and canopy

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cover may additionally alter the quantity and consequently pollen in the air becomes over-, equally-, or under- represented than the plant in the vegetation.

The relationship between the airborne pollen assemblage of a forest area and the floristic composition of the surrounding vegetation in NW Turkey is investigated in this study. A pollen calendar has been prepared with selected allergenic taxa by Aytuğ (1974) and Aytuğ *et al.* (1974) for the İstanbul region; however, no attempt has been made in comparing airborne pollen with the surrounding vegetation. The airborne pollen data is compared here with the forest in the vicinity and the vegetation of a much wider area both of whose floristic compositions are well known with the aim of elucidating how reliably vegetation is represented by the atmospheric pollen composition under aforementioned constrains.

Materials and Methods

The airborne pollen was collected in Bahçeköy, Belgrade Forest, İstanbul covering an area of about 5060 ha. (50 km^2) between the 28°59′-29°00′ latitude and 41° 09′-41°12′ longitude; which is 20 km far from Istanbul, 5 km to both the Blacksea in the north and the Bosphorus in the east with the highest altitude being 230 m in the North. The wider region around the sampling site and the forest, designated as 'grid A2E' by Davis *et al*. (1965-1985) covers an area of approximately 4200 km^2 in the western part of the Bosphorus and bounded by the Black Sea and the Sea of Marmara from the north and south respectively (Fig. 1). The grid, among the thirty, exhibits the highest floristic diversity (Kutluk and Aytuğ, 2004) and comprises five out of '122 Important Plant Areas' of Turkey (Özhatay *et al.,* 2003).

Pollen has been collected by an Hirst volumetric trap and hourly counts per unit volume of air (10 lt/hour) for a three-year-period. Counts of a three-year-period can be assumed as a 'long term average pollen assemblage period' which are required for vegetation construction because diurnal cyclic variation in pollen production were eliminated. The trap has been located at 1.60 cm above the ground level at an elevation of 129 meters above sea level in the forested area. The height of the trap is an average height of human breathing system as well as a height of both many arboreal (AP) and non-arboreal (NAP) pollen co-exist.

Floristic composition and climate of the study area: The Belgrade forest is composed mainly of mesophytic deciduous trees associated with evergreen shrubs of macchie formation. Only one taxon, out of a total of 381, belongs to gymnosperms and 380 taxa to angiosperms in the forest (Yaltırık, 1966). There are 1818 species/ infraspecies belonging to 639 genera and 119 families in the wider region, A2E (Kutluk and Aytuğ, 2001, 2004). Pure oak and some mixed oak stands with *Carpinus* and/or *Fagus* cover three fourths of the forested area. The second abundant tree taxon in the forest is *Castanea sativa.* Together with *Quercus* and *Castanea*, *Carpinus betulus, Fagus*

orientalis, Tilia tomentosa, Acer campestris, A. trautvetteri and *Ulmus campestre* appear as the most prominent arboreal taxa. The valleys of Alibey and Kağıthane which drain the forested area favor the growth of woody elements characteristic of humid habitats with a predominance of the species *Alnus glutinosa, Populus tremula, Salix alba* and *S. cinera*. There are also macchie elements of the Mediterranean origin mixed such as *Erica arborea, E. verticillata, Calluna vulgaris, Arbutus unedo, Cistus salviifolius, C. creticus, Spartium junceum, Laurus nobilis, Osyris alba, Lavandula cariensis, Pyracantha coccinea, Poterium spinosum,* etc. among and under the stands of arboreal taxa. Pollen trap is closest to *Q. petraea* and *Carpinus betulus* association in the southeastern part; out of four associations defined by Mayer and Aksoy (1998).

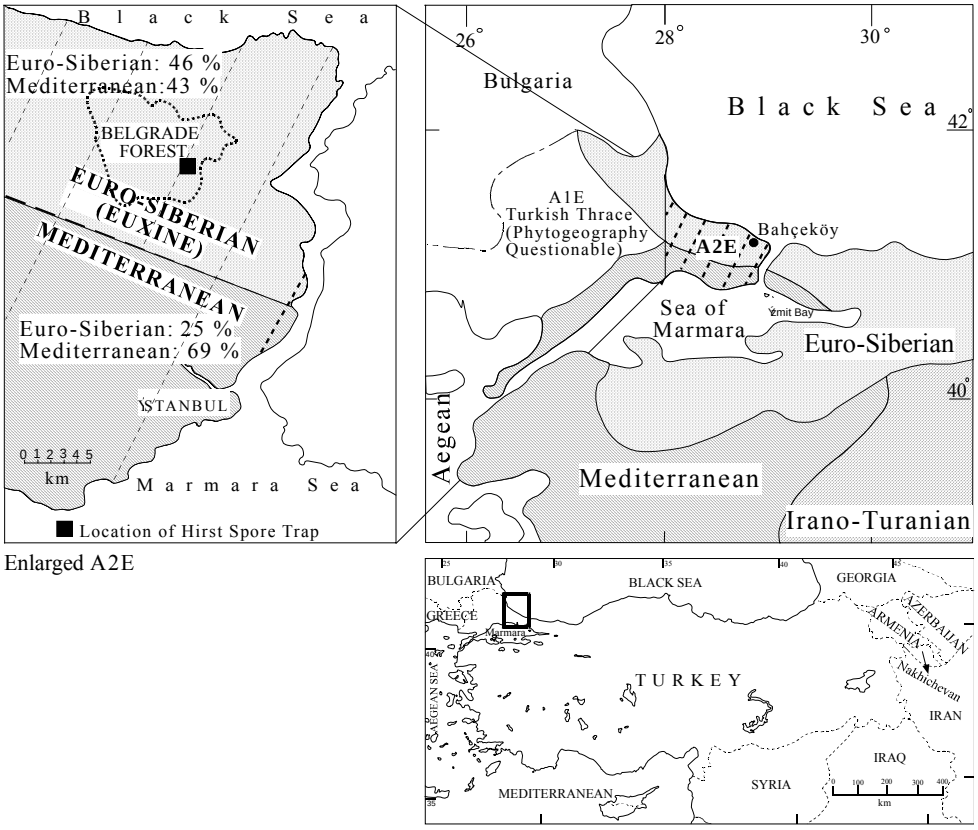

Fig. 1. Location map and phytogeographical regions of the study area

The study area is under the joint influence of two phytogeographical regions; the Euro-Siberian and the Mediterranean. The tree flora of the forest has a very close resemblance to eastern Europe, however, the ground flora and ruderal cover reflect a typical Mediterranean origin. Based on 788 taxa whose phytogeographical regions are known, among the 1818 in the wider area (A2E), Kutluk and Aytuğ (2001, 2004)

suggested that 53.6% of taxa belongs to the Mediterranean, 42.9% to the Euro-Siberian and only 3.6% to the Irano-Turanian phytogeographical regions. Further deliniation of the area into two exhibits that the Euro-Siberian and the Mediterranean ratios become 46 and 43 percent respectively in the north, however, the Mediterranean elements (69%) become dominant over the Euro-Siberian (25%) in the south (Fig. 1).

Results and Discussion

Airborne pollen composition: Airborne pollen assemblage of the study area is composed of trees, shrubs, and grasses of both native and also introduced or cultivated taxa belonging to 32 orders, 54 families and 96 genera. The results revealed that a total of 641.553 pollen has been recorded during the three years' period. Distribution of the total pollen with respect to three years appeared to be uniform, *i.e.,* pollen sum of each individual year is almost one third of the three years' grand total. Out of 641.553 pollen, 380.000 (59.2%) belongs to native, 257.180 (40.1%) to non-native plant taxa, but 4.373 (0.7%) remains unidentified. The airborne pollen assemblage is divided into three; the arboreal (AP), the non-arboreal (NAP) and the cultivated and/or alien taxa. Of the 380.000 pollen, 55.7% (211.713) is constituted by trees and shrubs (AP) and 44.3% (168.287) by herbs, grasses and weeds (NAP). The AP, NAP and non-native taxa are grouped with respect to their abundances for convenience in comparisons with the surrounding vegetation. The first and second groups are over- and equally represented, whereas the third and the lower groups are under-represented. The native AP, NAP and non-native taxa in descending order, are given in Table 1.

Arboreal Pollen Flora (AP): Various *Quercus* species (*Q. dschorochensis, Q. polycarpa, Q. dalechampii, Q. frainetto, Q. cerris* subsp. *austriaca, Q. pedunculifera, Q. haas, Q. infectoria*) and *Castanea sativa* predominate in the AP taxa by producing the largest amount of pollen in the airborne spectra. They are also the dominant plant taxa covering three fourths of the forested area, revealing that a significant correlation exists between the abundance of their pollen and the trees in vegetation. The members of only these two wind-pollinated genera constituted 64.9% of the AP and 36.2% of the overall native flora.

The ratio of each taxon in the second abundant group ranges between 1 and 10%. The AP flora includes Oleaceae (*Ligustrum vulgare*, *Phillyrea* sp.); *Erica arborea* and *E. verticillata*; *Corylus avellana, Alnus glutinosa*, *Carpinus betulus*; Rosaceae including a variety of species belonging to the genera *Prunus, Rubus, Fragaria, Geum, Agrimonia, Sanguisorba, Poterium, Rosa, Sorbus, Pyrus, Malus, Pyrancantha, Crataegus* and *Mespilus*; *Populus tremula* and *Ulmus campestris*. The pollen of all these trees and shrubs contributed with a 32.6% to the AP and with a 18.3% to the overall flora. Pollen

Table 1. Airborne pollen assemblages grouped according to their abundance in AP, NAP and Non-Native flora.

AP					NAP					Non-Native				
1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**6**	**1**	**2**	**3**	**4**	**7**
I	*Quercus*	73937	19,5	34,9	I	Poaceae	101596	26,7	60,4		Gymnosperms:			
	Castanea	63476	16,7	30,0		*Plantago*	30803	8,1	18,3	I	*Pinus*	70322	11	27,3
	Total:	137413	36,2	64,9		Total:	132399	34,8	78,7		*Cupressus*	59026	9,2	23,0
											Total:	129348	20,2	50,3
II	*Phillyrea, Ligustrum* & undiff.Oleaceae	15852	4,2	7,5	II	Asteraceae	12412	3,3	7,4					
	Erica	12673	3,3	6,0		*Urtica*	6043	1,6	3,6	II	Pinaceae	4280	0,7	1,7
	Corylus	12001	3,2	5,7		Apiaceae	4113	1,1	2,4		*Abies*	915	0,1	0,4
	Alnus	10156	2,7	4,8		*Humulus*	3920	1,0	2,3		*Picea*	814	0,1	0,3
	Carpinus	7503	2.0	3,5		*Polygonum*	3875	1,0	2,3		*Cedrus*	541	0,1	0,2
	Undiff.Betulaceae	869	0,2	0,4		*Carex*	1684	0,4	1,0		*Taxus*	36	0	0
	Prunus, Rubus & undiff. Rosaceae	4922	1,3	2,3		Total:	32047	8,4	19,0		*Larix*	28	0	0
	Populus	3114	0,8	1,5							*Ephedra*	16	0	0
	Ulmus	2120	0,6	1.0	III	*Echium*	1106	0,3	0,7		*Chamaecyparis*	3	0	0
	Total:	69210	16,3	31,7		Brassicaceae	702	0,2	0,4		Total:	6633	1,0	2,6
						Ranunculaceae	451	0,1	0,3		Total Gymnosperm:	135981	21,2	52,8
III	*Tilia*	1911	0,5	0,9		*Luzula*	322	0,1	0,2					
	Fagus	1444	0,4	0,7		*Vicia* & undiff.Fabaceae	298	0,1	0,2		Angiosperms:			
	Salix	1092	0,3	0,5		Solanaceae	225	0,1	0,1	III	*Platanus*	79029	12,3	30,7
	Sambucus	446	0,1	0,2		*Potentilla*	146	0	0,1		Total:	79029	12,3	30,7
	Total:	4893	1,3	2,3		*Galium*	110	0	0,1					
						Total:	3360	0,9	2,1	IV	Poaceae	12872	2,0	5.0
IV	*Cistus*	76	0,020	0,04							Amaranthaceae	9900	1,5	3,8
	Hedera	53	0,014	0,03	IV	Liliaceae	78	0,021	0,046		*Morus*	8407	1,3	3,3
	Acer	31	0,008	0,01		*Scrophularia*	62	0,016	0,037		*Artemisia*	3301	0,5	1,3
	Laurus	17	0,004	0,01		Caryophyllaceae	52	0,014	0,031		*Fraxinus*	2848	0,4	1,1
	Ilex	12	0,003	0,01		*Rumex*	43	0,011	0,026		*Juglans*	2077	0,3	0,8
	Total:	189	0,049	0,10		Lamiaceae	36	0,009	0,021		*Ostrya*	1099	0,2	0,4
						Salvia	28	0,007	0,017		*Aesculus*	762	0,1	0,3
V	*Cornus*	3	0,001	0,001		*Juncus*	21	0,006	0,012		*R.pseudoacacia*	640	0,1	0,2
	Daphne	3	0,001	0,001		*Anagallis*	18	0,005	0,011		*Buxus*	87	0,014	0,034
	Lonicera	1	0,0	0,0		*Mentha*	18	0,005	0,011		Anacardiaceae	79	0,012	0,031
	Clematis	1	0,0	0,0		*Geranium*	17	0,004	0,010		Papaveraceae	73	0,011	0,028
	Total:	8	0,002	0,003		*Hypericum*	17	0,004	0,010		*Onobrychis*	12	0,002	0,005
	Grand Total:	211713	33.0	100		*Symphytum*	14	0,004	0,008		*Crataegus*	3	0,0	0,001
						Lythrum	14	0,004	0,008		*Lotus*	3	0,0	0,001
						Campanula	11	0,003	0,007		*Scabiosa*	3	0,0	0,001
						Primula	10	0,003	0,006		*Syringa*	2	0,0	0,001
						Lamium	10	0,003	0,006		*Liquidambar*	2	0,0	0,001
	Explanations:					*Linaria*	8	0,002	0,005		Total:	42170	6,4	16,2
						Verbascum	6	0,002	0,004		Total Angiospem:	121199	18,9	47,1
	1. Group					*Veronica*	5	0,001	0,003		Grand Total:	257180	40,1	100
	2. Taxon					*Lathraea*	4	0,001	0,002					
	3. Number of Taxon					*Cardaminae*	3	0,001	0,002					
	4. Percentage within the overall flora					*Epimedium*	3	0,001	0,002					
	5. Percentage within AP					Convolvulaceae	3	0,001	0,002					
	6. Percentage within NAP					Total:	481	0,126	0,20					
	7. Percentage within non-native					Grand Total:	168287	26,2	100					

of wind pollinated taxon, *Carpinus betulus* is widely distributed in the north facing humid slopes of the North Anatolian mountains in the Black Sea region up to the altitudes of 1200-1300 m and appeared as an equally represented taxon. The members of the Oleaceae (*Ligustrum vulgare*, *Phillyrea* sp.) on the other hand, are over-represented though they are not common in the forest. *Ulmus campestris* and the typical Mediterranean elements whose presence indicates a milder climate, *Erica* (*Erica arborea* and *E. verticillata*) are the other main constituents of the forest. Although they are entomophilous, their pollen exhibit an equal representation revealing that entomophiluous pollen may at times be airborne. The main under-storey element, *Corylus avellana* and the members of the Rosaceae whose many species having attractive flowers for bees and insects are also equally represented. Pollen of wind pollinated taxa *Alnus glutinosa* and *Populus tremula* are represented in fairly large quantities. *Alnus glutinosa* grows at altitudes between 0 and 1600 m in the Marmara and particularly in the eastern Black Sea regions where the mean of the minimum temperature of the coldest month (m) is 4-7°C, the mean of the maximum temperature of the hottest month (M) is 15-22°C and the annual precipitation is above 1000 mm. *Populus tremula* has an extensive distribution in all the forested areas of Turkey growing up to 2000-2300 m.

The ratio of *Tilia tomentosa, Fagus orientalis*, *Salix alba*, *S. cinera* and *Sambucus ebulus* in the third group ranges between 1 and 0.1%. The total contribution of the group to the AP is 2.3% and to the overall native flora is 1.3%. The insect pollinated *Tilia tomentosa,* a common element of the mid-Europe and the Balkans flora, is known as a taxon producing lesser amount of pollen. Also due to presence of a thick exine it is under-represented in the airborne assemblage. Pollen of *Fagus orientalis* is also reflected in insignificant amounts and extremely under-represented. Although *Fagus* is wind pollinated, it produces less amount of pollen having high settling velocities (Aytuğ, 1969; Prentice, 1985). *Fagus orientalis* has been growing in the wet, shady, north facing slopes in the north and northeastern parts of the forest, 5-10 km away from the sampling site, the areal distribution therefore also appears a limiting factor. Climax of the species is at 500-1000 m altitudes in the Euro-Siberian region where m is 2-5°C and M is 15-20°C. Entomophilous *Salix* species (*Salix alba* and *S. cinera*) are the other examples of low representation; their pollen is much lower than the other anemophilous, humid-habitat taxa of alder and poplar. Willow occupies the lowermost profiles of the valleys closer to the water than the other riparian taxa; topographical constrains seem responsible for its low representation.

The total contribution of the elements of the fourth group *Cistus salvifolius, C. creticus*, *Hedera helix*, *Ilex aquifolium*, *Laurus nobilis*, *Acer trautvetteri* and *A. campestris* is only 0.1% to the AP flora whereas *Cornus mas*, *C. australis*, *Lonicera etrusca*, *Daphne pontica* and *Clematis vitalba* are recorded only sporadically and have almost no quantitative contribution to the total pollen flora. Although, not frequent, their

presence however, in the airborne spectrum provides an insight about phytogeographical characteristics of the airborne assemblage; *Cistus*, *Laurus* and *Lonicera* are of the Mediterranean, whereas *Acer*, *Cornus* and *Daphne* are of the Euro-Siberian origin. Many entomophilous taxa, such as *Ilex aquifolium*, *Laurus nobilis*, *Acer trautvetteri* and *A. campestre* and lianas such as *Hedera helix*, *Lonicera etrusca*, *Clematis vitalba*, etc. are all extremely under-represented. The flowers of climbers are produced within the lower canopy and hence their pollen have lesser chance to incorporate into airborne assemblage.

Non-Arboreal Pollen Flora (NAP): A dense and diverse herbaceous taxa including many forbs and grasses are present under the forest, however, their chance to incorporate into the airborne assemblage is less than woody taxa. The NAP taxa displays the composition of the local plant communities and reflect the vegetation of immediate vicinity.

The most common NAP in descending order belong to Poaceae, Plantaginaceae, Asteraceae, Urticaceae, Apiaceae, Cannabaceae, Polygonaceae and Cyperaceae (Table 1). All Poaceae and some species of *Plantago* constitute 60.4% and 18.3% of the NAP flora respectively. The Poaceae is represented by 35 species in the forest (Yaltırık, 1966) and by 190 in the wider area (Kutluk and Aytuğ, 2004). A general assignment at familial or generic level has been commonly made for the large group Poaceae in most of the aeropalynological studies; taxonomic precision at specific level however, prove that the pollen production capacity of the group varies significantly from species to species (Prieto-Baena *et al.*, 2003). *Plantago* has lesser chance to be transported long distance for having an exine of high specific gravity (Harrington and Metzger, 1963; Flenley, 1971) and hence reflect local vegetation. The pollen of wind-pollinated marsh plants, Sparganiaceae and Typhaceae were not represented in the NAP, although they are common in the wet and damp places of the forest. On the contrary, *Carex* pollen appeared sporadically. An entomophilous group Asteraceae, with its 204 and 28 species in the wider area and in the forest respectively, is the most diversified family; together with *Urtica diorica,* various species of Apiaceae and Polygonaceae, *Humulus* and *Carex* they reflect an equal-representation; with the aforementioned families of the first group they reach to a percentage of 97.7 in the NAP flora.

Fabaceae in the third group is the most diversified family of the forest represented by 38 species and is the second largest after Asteraceae in the wider area with 200 species. The fourth group is the most diversified one among the total nine groups of the pollen flora, however, contributed by only 0.2% to the overall flora revealing that representation of the NAP pollen is not consistent with their diversification rate in the vegetation in contrast to the AP flora.

Non-Native Pollen Flora: Out of 641.553 airborne pollen, 257.180 (40.1%) belongs to the plants which are not native indicating that a fairly large number of airborne pollen

have been captured from the plants of the reforestation areas and numerous parks and gardens in İstanbul housing a great variety of exotic, alien and horticultural taxa.

Of 257.180 non-native pollen, 135.981 belong to gymnosperms and 121.199 to angiosperms (Table 1). *Pinus* and *Cupressus* produced the greatest amount of pollen. The only coniferous forest in the region, a Neogene relict *Pinus nigra* forest, is in Kilyos (Kayacık *et al*., 1981), about 60 km away from the sampling site. Also some solitary native pines grow on the islands in the Sea of Marmara and northern part of the Bay of İzmit, about 40 and 70 km away respectively, from the pollen trap. The source of Pine pollen in the reforestation areas very close to the trap, however, some may have been transported long distance from the aforementioned areas. Natural distribution of *Cupressus sempervirens* is in the Mediterranean Taurus, but some scattered native cypress grow at the hillsides of the Bosphorus (Kayacık, 1966) and it is also widely planted in parks and gardens in İstanbul. One of the main aeroallergens *Platanus orientalis* has also been planted extensively close to the pollen trap.

Pollen of various cultivated trees, shrubs, forbs and herbs belonging to *Aesculus,* Amaranthaceae, Anacardiaceae, *Artemisia, Buxus, Crataegus, Fraxinus, Juglans, Liquidambar, Lotus, Morus*, *Onobrychis, Ostrya,* Papaveraceae*,* Poaceae, *Robinia pseudoacacia, Scabiosa* and *Syringa* are present in the non-native assemblage. *Artemisia* and *Scabiosa* might have been derived from the A2E region outside of the forested area where they scatteredly occur.

Conclusion

The present study reveals that the airborne assemblage is strongly influenced by the forest vegetation and the high taxonomic diversity is reflected in the pollen composition. Atmospheric pollen provided a picture of vegetation of the forest and wider area (A2E) in İstanbul region.

All of the arboreal elements of the forest are represented in the airborne assemblage, the non-arboreal elements on the contrary, is less represented than the arboreal taxa, some have not even been encountered. Insect-pollinated taxa have also been recorded in the airborne assemblage indicating that entomophilous pollen may at times be airborne. Pollen of the lianas and climbers whose flowers are produced below the lower canopy are represented in the assemblage, however, they are less than arboreal but more than the ground flora elements.

Pollen taxa are defined only at familial level in most of the researches for allergenic purposes rendering the potential value of airborne studies in comparisons with surrounding vegetation. Assignment of pollen taxa at generic and particularly at specific level, even when large quantities of data is involved as herein, provides more reliable picture of vegetation which would in turn enhance implications regarding phytogeography and climate.

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