A comparative, volumetric survey of airborne pollen in Philadelphia, Pennsylvania (1991–1997) and Cherry Hill, New Jersey (1995–1997)

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Background: Aeroallergen sampling provides information regarding the onset, duration, and severity of the pollen season that clinicians use to guide allergen selection for skin testing and treatment.

Objective: This atmospheric survey reports: 1) airborne pollen contributors in Philadelphia, Pennsylvania (1991 to 1997) and suburban Cherry Hill, New Jersey (1995 to 1997); 2) pollen onset, duration, and peak level; and 3) the relationship between airborne pollen and selected meteorologic variables.

Methods: At both locations, separated by 11 km, sampling was performed with a volumetric Rotorod Sampler (Sampling Technologies, Minnetonka, MN).

Results: In Philadelphia and Cherry Hill, respectively, 3-year average measurements included 75.0 and 74.2% tree pollen, 10.2 and 8.3% grass pollen, and 14.8 and 17.5% weed pollen. Prominent airborne pollen taxa were *Acer*, *Quercus*, *Betula*, *Pinus*, Cupressaceae, Poaceae, *Ambrosia*, and *Rumex*. The tree, grass, and weed pollen seasons extended from mid-March to mid-June, late April to mid-June, and mid-August to late September, respectively. A secondary Poaceae pollen peak occurred in September. There was a statistically significant correlation between simultaneous weekly average pollen levels in Philadelphia and in Cherry Hill (*Acer,* $r_p = 0.987$, *Quercus*, $r_p = 0.645$, *Betula*, $r_p = 0.896$, *Pinus*, $r_p = 0.732$, Cupressaceae, $r_p = 0.695$, Poaceae, $r_p = 0.950$, *Ambrosia*, $r_p = 0.903$, and *Rumex,* $r_p = 0.572$, $P < 0.001$). Daily Poaceae pollen levels were positively influenced by same-day high temperature ($r_s = 0.333$ in Philadelphia and $r_s = 0.426$ in Cherry Hill, $P < 0.05$). Daily *Ambrosia* pollen levels were inversely influenced by same-day total precipitation ($r_s = -0.174$ in Philadelphia and $r_s = -0.257$ in Cherry Hill, $P < 0.05$).

Conclusions: This is the first volumetric survey performed in either Philadelphia or Cherry Hill. Copious amounts of airborne pollen were seen from late April to early May and in early September. Pollen onset, duration, and year-to-year variability were similar at both sites. An awareness of local aeroallergen patterns is critical in the effective testing and treatment of atopic individuals.

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INTRODUCTION

Aeroallergen analysis has become a widespread practice since 1873 when Blackley identified grass pollen as a causative agent of allergic rhinitis.[1] Sampling has evolved from the passive gravitational fallout techniques used by Blackley to continuous, volumetric collections that provide quantitative data. Clinicians use this information to identify appropriate allergens for skin testing and to guide pharmacologic and immunotherapeutic intervention and allergen avoidance.

This outdoor aeroallergen survey represents the first volumetric analysis conducted in either Philadelphia, Pennsylvania or Cherry Hill, New Jersey. Early studies, performed separately by Clarke and Wilmer in 1927, used gravity slide techniques.[2] They determined the period and prevalence of *Ambrosia* (ragweed) pollen in Philadelphia and neighboring Swarthmore and Germantown, PA, suburbs located southwest and north of Philadelphia, respectively.

Philadelphia is situated in the southeast corner of Pennsylvania, at the confluence of the Schuylkill and Delaware Rivers. Fairmount Park, the largest urban park in the United States,[3] represents a significant potential pollen source within Philadelphia. Suburban Cherry Hill is located in western New Jersey, 11 km east of Philadelphia. The entire survey area lies within the eastern agricultural floristic zone.[4] Prominent plant species in this area are representative of the Eastern mixed deciduous forest and, in Cherry Hill particularly, of the ecologically unique Pine Barrens.

The expansive Eastern mixed deciduous forest is comprised of over three dozen species of broad-leafed trees, including *Acer saccharum* (sugar maple), *Quercus rubrum* and *Q. alba* (red and white oak), *Tilia heterophylla* (white basswood), *Fraxinus americana* (white ash), and members of the *Betula* (birch) and *Fagus* (beech) genera. Many of these species produce copious amounts of airborne pollen that have been implicated in allergic rhinitis. Although present in the deciduous forest, *Pinus* (pine) and other evergreens constitute the minority (Table 1).[5–7]

The Pine Barrens begin east of Cherry Hill and occupy approximately 2,250 km^2 of southern and central New Jersey. Prominent species in the region include *Pinus rigida* (pitch pine), *P. echinata* (short leaf pine), and *P. virginiana* (Virginia pine), interspersed

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with *Quercus velutina* (black oak), *Q. marilandica* (blackjack oak) and *Q. alba* (white oak). *Chamaecyparis thyoides* (Atlantic white cedar) and *Acer rubrum* (red maple) swamps are also found throughout the area (Table 1).[8]

The temperate climate of the survey area consists of four distinct meteorologic seasons: spring (March to May), summer (June to August), fall (September to November), and winter (December to February), with average temperatures of 11°, 24°, 14°, and 0° C, respectively. Approximately 104 cm of precipitation is uniformly distributed throughout the year.[9]

This atmospheric survey 1) identifies the most significant airborne pollen taxa in Philadelphia, PA during the period 1991 to 1997 and in Cherry Hill, NJ during the period 1995 to 1997; 2) reports patterns in pollen onset, duration, peak period, peak level, and year-to-year variability; 3) compares these patterns between sampling locations; and 4) examines the relationship between pollen prevalence and selected meteorologic variables.

METHODS

Sampling was conducted in accordance with standards outlined by the Aeroallergen Monitoring Network of the American Academy of Allergy, Asthma, and Immunology (Milwaukee, WI). Rotorod Samplers (Sampling Technologies, Minnetonka, MN) were situated on the roof of a six-story (25 m) office building in downtown Philadelphia and on the roof of a two-story (7.5 m) school in residential Cherry Hill. A distance of 11 km separated the two sampling stations. Each Rotorod Sampler was equipped with two polystyrene I-rods (Sampling Technologies), measuring 1.52 × 1.52 × 31.0 mm, that were coated with adhesive silicone grease (General Electric G-697, General Electric, Waterford, NY) and rotated at 2,400 rpm. The equipment was operated for 60 seconds every 10 minutes, 24 hours per day, 3 days per week in Philadelphia

Table 1. Common Tree, Grass, and Weed Species of Native and Naturalized Origin Found Throughout Philadelphia, PA and Cherry Hill, NJ[4–8]

Family	Common name	Genus/species
Trees		
Aceraceae	Box elder	*Acer negundo*
	Red maple	*Acer rubrum*
	Silver maple	*Acer saccharinum*
	Sugar maple	*Acer saccharum*
Betulaceae	Smooth alder	*Alnus serrulata*
	Sweet birch	*Alnus lenta*
	Yellow birch	*Betula alleghaniensis*
	River birch	*Betula nigra*
	Gray birch	*Betula populifolia*
Cupressaceae	Common juniper	*Juniperus communis*
	Atlantic white cedar	*Chamaecyparis thyoides*
	Red cedar	*Juniperus virginiana*
Fagaceae	American beech	*Fagus grandifolia*
	White oak	*Quercus alba*
	Scarlet oak	*Quercus coccinea*
	Southern red oak	*Quercus falcata*
	Bear oak	*Quercus ilicifolia*
	Blackjack oak	*Quercus marilandica*
	Pin oak	*Quercus palustris*
	Willow oak	*Quercus phellos*
	Dwarf chestnut oak	*Quercus prinoides*
	Northern red oak	*Quercus rubra*
	Post oak	*Quercus stellata*
	Black oak	*Quercus velutina*
Hamamelidaceae	Sweet gum	*Liquidambar styraciflua*
Juglandaceae	Bitternut hickory	*Carya cordiformis*
	Shagbark hickory	*Carya ovata*
	Mockernut hickory	*Carya tomentosa*
	Butternut	*Juglans cinerea*
	Black walnut	*Juglans nigra*
Moraceae	White mulberry	*Morus alba*
	Red mulberry	*Morus rubra*
Oleaceae	White ash	*Fraxinus americana*
	Black ash	*Fraxinus nigra*
	Red ash	*Fraxinus pennsylvanica*
Pinaceae	Short leaf pine	*Pinus echinata*
	White pine	*Pinus strobus*
	Virginia pine	*Pinus virginiana*
	Pitch pine	*Pinus rigida*
Platanaceae	American sycamore	*Platanus occidentalis*
	London planetree	*Platanus x acerifolia*
Salicaceae	White poplar	*Populus alba*
	Bigtooth aspen	*Populus grandidentata*
	Quaking aspen	*Populus tremuloides*
	Weeping willow	*Salix babylonica*
	Pussy willow	*Salix discolor*
	Black willow	*Salix nigra*
Tiliaceae	American basswood	*Tilia americana*
Ulmaceae	American elm	*Ulmus americana*
	Red elm	*Ulmus rubra*
	English elm	*Ulmus procera*

(Table continues)

Table 1. Continued

Family	Common name	Genus/species
Grasses		
Poaceae	Sweet vernal grass	*Anthoxanthum odoratum*
	Smooth brome	*Bromus inermis*
	Canada brome	*Bromus secalinus*
	Orchard grass	*Dactylis glomerata*
	Smooth crabgrass	*Digitaria ischaemum*
	Crabgrass	*Digitaria sanguinalis*
	Common ryegrass	*Lolium perenne*
	Fall panicum	*Panicum dichotomiflorum*
	Timothy	*Phleum pratense*
	Annual bluegrass	*Poa annua*
	Johnson grass	*Sorghum halepense*
Weeds		
Amaranthaceae	Pigweed	*Amaranthus hybridus*
	Green amaranth	*Amaranthus retroflexus*
Asteraceae	Short ragweed	*Ambrosia artemisifolia*
	Giant ragweed	*Ambrosia trifida*
	Sage wort wormwood	*Artemisia campestris*
	Rough marsh elder	*Iva annua*
	Canada goldenrod	*Solidago canadensis*
Chenopodiaceae	Maple leaved goosefoot	*Chenopodium nybridum*
	Lamb's quarters	*Chenopodium album*
Plantaginaceae	English plantain	*Plantago lanceolata*
	Rugel's plantain	*Plantago rugelii*
	Pale seeded plantain	*Plantago virginica*
Polygonaceae	Pale dock	*Rumex altissimus*
	Sheep sorrel	*Rumex acetosella*
	Curly dock	*Rumex crispus*
	Bitter dock	*Rumex obtusfolia*

and 5 days per week in Cherry Hill, from mid-March to the end of October each year.

After each 24-hour sampling period, the rods were collected, transferred to a grooved stage adapter, and stained with Calberla solution (16% glycerol, 33% ethyl alcohol, and 0.02% basic fuchsin by volume, Sampling Technologies). The same physician (DJD), certified as a pollen grain and mold spore counter by the Aeroallergen Monitoring Network, inspected all rods microscopically at 400 × and counted pollen grains manually.

Raw measurements were converted to volumetric equivalents expressed as the average daily (24-hour) concentration of pollen grains per cubic meter of air sampled (grains/m^3). Corresponding weekly mean concentrations from each year were averaged to facilitate data presentation. For the purposes of defining regional metropolitan Philadelphia pollen seasons for individual taxa, daily counts from both sites were combined into a single series. Seasons were defined by the first and last days of a consecutive series during which counts >1% of total pollen were observed. Isolated counts more than 1 week from the nearest reading >1% of total pollen were excluded.[10]

The National Weather Service Forecast Office in Mt. Holly, NJ, measured meteorologic conditions at the Philadelphia International Airport, Philadelphia, PA, located 15.5 km from the Philadelphia sampling station and at Moorestown, NJ, located 11.1 km from the Cherry Hill sampling station. Meteorologic data examined in this study were obtained through the Northeast Regional Climate Center, Ithaca, NY, of the National Climatic Data Center, Asheville, NC, under the auspices of the National Oceanic and Atmospheric Administration, Washington, DC.

Statistical Analysis

The Pearson statistical test for parametric data was used to determine the relationship between weekly average pollen measurements in Philadelphia and in Cherry Hill. The Spearman statistical test for nonparametric data was used to evaluate the relationship between daily airborne pollen measurements and same-day total precipitation, maximum temperature, and minimum temperature. Data for analysis included pollen and meteorologic measurements taken within the particular pollen season under study, from 1991 to 1997 in Philadelphia and 1995 to 1997 in Cherry Hill. Statistical significance was assigned at $P < 0.05$. Computer analysis used the JMPIN statistical software package (SAS Institute Inc, Cary, NC).

RESULTS

Prevalence

Tables 2 and 3 illustrate the 24 airborne pollen taxa identified in Philadelphia and Cherry Hill. Because of the variability in the number of days sampled per year, taxa are listed in descending rank order based upon the average percentage of pollen recovered. At both sampling locations, the eight most prevalent pollen types were *Acer* (maple), *Quercus* (oak), *Betula* (birch), *Pinus* (pine), Cupressaceae (cypress), Poaceae (grass), *Ambrosia* (ragweed), and *Rumex* (dock/sorrel). Different Cupressaceae (cypress) or Poaceae (grass) genera were not determined by light microscopy because of morphologic similarities throughout each family. These eight taxa comprised 86.6 and 90.8% of annual airborne pollen in Philadelphia and Cherry Hill, respectively. There were 16 minor taxa (12 trees and 4 weeds) also identified. Each minor pollen comprised <2.5% of the annual total and will not be discussed.

Sampling began in mid-March every year with the exception of 1991 when sampling commenced in early April. During the 1991 season, pollen prevalence for the early spring flowering trees, including *Acer* and Cupres-

Table 2. Pollen Grains Recovered per Year (grains/m^3), Percent of Annual Recovery, and 7-Year Average for Individual Pollen Producers in Philadelphia, PA during the Period 1991–1997

	1997 (131 days)		1996 (130 days)		1995 (89 days)		1994 (129 days)		1993 (86 days)		1992 (92 days)		1991 (88 days)		AVG
Trees															
Acer	835	4.1%	14227	51.1%	8723	33.5%	8499	27.3%	3678	17.4%	1965	6.7%	1659	5.0%	20.7%
Quercus	6118	30.1%	1774	6.4%	2721	10.4%	1823	5.9%	5044	23.8%	3607	12.3%	4984	14.9%	14.8%
Betula	3983	19.6%	862	3.1%	3758	14.4%	3659	11.8%	2342	11.1%	4022	13.8%	2773	8.3%	11.7%
Pinus	1203	5.9%	1327	4.8%	1938	7.4%	1077	3.5%	2089	9.9%	3092	10.6%	3555	10.6%	7.5%
Cupressaceae	557	2.7%	1325	4.8%	2269	8.7%	559	1.8%	798	3.8%	2937	10.0%	452	1.4%	4.7%
Ulmus	147	0.7%	260	0.9%	172	0.7%	363	1.2%	228	1.1%	1590	5.4%	836	2.5%	1.8%
Populus	302	1.5%	296	1.1%	87	0.3%	114	0.4%	552	2.6%	630	2.2%	356	1.1%	1.3%
Morus	442	2.2%	334	1.2%	11	0.0%	828	2.7%	68	0.3%	0	0.0%	0	0.0%	0.9%
Liquidambar	62	0.3%	147	0.5%	330	1.3%	773	2.5%	194	0.9%	193	0.7%	0	0.0%	0.9%
Platanus	23	0.1%	36	0.1%	239	0.9%	127	0.4%	110	0.5%	102	0.4%	994	3.0%	0.8%
Salix	299	1.5%	141	0.5%	88	0.3%	159	0.5%	0	0.0%	740	2.5%	0	0.0%	0.8%
Juglans	30	0.1%	388	1.4%	8	0.0%	154	0.5%	180	0.8%	218	0.7%	425	1.3%	0.7%
Fraxinus	73	0.4%	51	0.2%	28	0.1%	8	0.0%	34	0.2%	74	0.3%	156	0.5%	0.2%
Alnus	41	0.2%	35	0.1%	41	0.2%	58	0.2%	11	0.1%	75	0.3%	103	0.3%	0.2%
Fagus	16	0.1%	0	0.0%	0	0.0%	0	0.0%	3	0.0%	17	0.1%	234	0.7%	0.1%
Carya	109	0.5%	0	0.0%	14	0.1%	5	0.0%	29	0.1%	8	0.0%	25	0.1%	0.1%
Tilia	11	0.1%	68	0.2%	0	0.0%	39	0.1%	0	0.0%	59	0.2%	0	0.0%	0.1%
Grasses															
Poaceae	2472	12.2%	2782	10.0%	2217	8.5%	4457	14.3%	1973	9.3%	5838	20.0%	5163	15.5%	12.8%
Weeds															
Ambrosia	2199	10.8%	1440	5.2%	1571	6.0%	4409	14.2%	1892	8.9%	1051	3.6%	6260	18.7%	9.6%
Rumex	861	4.2%	1454	5.2%	956	3.7%	3310	10.6%	1063	5.0%	824	2.8%	674	2.0%	4.8%
*Chnpd/Amrth**	124	0.6%	153	0.5%	169	0.7%	228	0.7%	279	1.3%	922	3.2%	3506	10.5%	2.5%
Artemisia	262	1.3%	413	1.5%	308	1.2%	361	1.2%	374	1.8%	337	1.2%	1029	3.1%	1.6%
Plantago	147	0.7%	331	1.2%	312	1.2%	72	0.2%	183	0.9%	882	3.0%	49	0.1%	1.1%
Asteraceae†	0	0.0%	17	0.1%	82	0.3%	48	0.2%	51	0.2%	54	0.2%	161	0.5%	0.2%
TOTAL	20317	100%	27861	100%	26045	100%	31130	100%	21175	100%	29240	100%	33396	100%	100%

* Includes all members of the morphologically similar Chenopodiaceae and Amaranthaceae (Chnpd/Amrth) families.
† Includes all members of the Asteraceae family except *Ambrosia*.
Number of sampling days per year is indicated in parentheses.

saceae, may not have been fully documented. Additionally, high levels of Cupressaceae pollen were already airborne when sampling began in 1995, indicating unusually early onset. As a result, Cupressaceae pollen prevalence during this season may be underreported. Overall, however, pollen capture was sufficient to ascertain patterns of prevalence, onset, peak, and season duration for individual taxa each season.

A preponderance of tree pollen in atmospheric samples was evident. In Philadelphia and Cherry Hill, 3-year average levels included 75.0 and 74.2% tree pollen, 14.8 and 17.5% weed pollen, and 10.2 and 8.3% grass pollen, respectively.

Considerable year-to-year variation in pollen prevalence is evident in Tables 2 and 3. No single year was characterized by exceptional total pollen recovery. In any given year, a particular pollen may have been recovered in copious amounts whereas another type was collected in low levels. In 1996, for example, *Acer* pollen levels were exceptionally high although *Quercus* and *Betula* pollen levels were below average. Year-to-year variation in peak concentration and week is seen in Table 4. For most trees, grasses, and weeds, the peak week fluctuated from year to year within a 3- to 5-week period. *Pinus* pollen peaks, however, varied within a 7-week period because of multiple peaks within a single season. Peak concentrations fluctuated from year to year with no consistent pattern.

Seasons

Figure 1 presents approximate flowering periods for pollen types in this survey with discernible seasons. Figures 2 through 4 detail pollen onset, duration, peak week, and peak concentration for the major airborne pollen contributors. Together, April and May comprised 71.0 and 71.4% of total airborne pollen incidence in Philadelphia and Cherry Hill, respectively. A sharp decline in pollen levels during June, July, and August was followed by increasing levels of weed pollen in September, comprising 11.2 and 11.0% of total airborne pollen incidence in Philadelphia and Cherry Hill, respectively (Figs 2–4).

Early flowering trees. Cupressaceae pollen was recovered from mid-March to late April. In early April, average levels reached 108 and 112 grains/m^3 in Philadelphia and Cherry Hill, respectively. Statistical analysis determined a positive Cupressaceae pollen relationship between the two locations

Table 3. Pollen Grains Recovered per Year (grains/m³), Percent of Annual Recovery, and 3-Year Average for Individual Pollen Producers in Cherry Hill, NJ during the Period 1995–1997

	1997 (159 days)		1996 (157 days)		1995 (162 days)		AVG
Trees							
Acer	2038	5.4%	17377	43.8%	13008	33.9%	27.7%
Quercus	15594	41.1%	3406	8.6%	2039	5.3%	18.3%
Pinus	3009	7.9%	4442	11.2%	3307	8.6%	9.3%
Betula	3714	9.8%	966	2.4%	2944	7.7%	6.6%
Cupressaceae	1389	3.7%	1437	3.6%	4028	10.5%	5.9%
Salix	1017	2.7%	312	0.8%	139	0.4%	1.3%
Juglans	255	0.7%	799	2.0%	17	0.0%	0.9%
Morus	706	1.9%	257	0.6%	0	0.0%	0.8%
Ulmus	174	0.5%	279	0.7%	388	1.0%	0.7%
Liquidambar	98	0.3%	165	0.4%	464	1.2%	0.6%
Populus	289	0.8%	254	0.6%	119	0.3%	0.6%
Platanus	93	0.2%	213	0.5%	324	0.8%	0.5%
Fraxinus	173	0.5%	121	0.3%	24	0.1%	0.3%
Alnus	215	0.6%	38	0.1%	39	0.1%	0.3%
Carya	198	0.5%	0	0.0%	0	0.0%	0.2%
Tilia	44	0.1%	145	0.4%	0	0.0%	0.2%
Fagus	0	0.0%	0	0.0%	6	0.0%	0.0%
Grasses							
Poaceae	2960	7.8%	3548	8.9%	3147	8.2%	8.3%
Weeds							
Rumex	2233	5.9%	2393	6.0%	3940	10.3%	7.4%
Ambrosia	2700	7.1%	2573	6.5%	3159	8.2%	7.3%
Plantago	378	1.0%	514	1.3%	484	1.3%	1.2%
Artemisia	322	0.8%	261	0.7%	452	1.2%	0.9%
*Chnpd/Amrth**	314	0.8%	149	0.4%	260	0.7%	0.6%
Asteraceae†	39	0.1%	8	0.0%	66	0.2%	0.1%
TOTAL	37948	100%	39656	100%	38353	100%	100%

* Includes all members of the morphologically similar Chenopodiaceae and Amaranthaceae (Chnpd/Amrth*) families.
† Includes all members of the Asteraceae family except *Ambrosia*.
Number of sampling days per year is indicated in parentheses.

Table 4. Maximum Weekly Average Value (grains/m³) and Week Observed in Philadelphia, PA during the Period 1991–1997 and in Cherry Hill, NJ during the Period 1995–1997

	Acer		Cupressaceae		*Quercus*		*Betula*		*Pinus*		Poaceae		*Ambrosia*		*Rumex*	
Philadelphia, PA																
1991	120	Week 9	61	Week 7	463	Week 9	312	Week 11	378	Week 13	482	Week 13	519	Week 28	89	Week 26
1992	147	Week 9	564	Week 6	269	Week 12	640	Week 12	165	Week 15	350	Week 12	110	Week 28	75	Week 24
1993	1563	Week 9	68	Week 6	866	Week 9	538	Week 10	212	Week 13	204	Week 9	341	Week 27	113	Week 28
1994	804	Week 8	33	Week 6	181	Week 11	342	Week 9	59	Week 11	223	Week 11	313	Week 28	252	Week 27
1995	794	Week 10	246	Week 6	514	Week 12	410	Week 10	129	Week 13	129	Week 12	223	Week 27	104	Week 27
1996	2742	Week 9	114	Week 7	215	Week 12	71	Week 12	76	Week 9	135	Week 12	96	Week 26	76	Week 25
1997	49	Week 7	60	Week 5	336	Week 10	379	Week 10	70	Week 17	111	Week 11	163	Week 28	54	Week 27
Cherry Hill, NJ																
1995	803	Week 9	308	Week 3	153	Week 12	224	Week 10	225	Week 13	99	Week 13	168	Week 27	271	Week 28
1996	2425	Week 9	126	Week 6	166	Week 12	87	Week 8	199	Week 12	116	Week 12	174	Week 26	95	Week 27
1997	101	Week 6	212	Week 4	1479	Week 9	176	Week 10	119	Week 10	111	Week 11	146	Week 28	140	Week 27

Week 1 corresponds to March 1–7 and so forth.

as indicated by Pearson's correlation coefficient, $r_p = 0.695$, $P < 0.001$. Early peaks were noted in March 1995 at both locations (Fig 2). The *Acer* flowering season began in mid-April, peaked in late April, and ended in mid-May. Average levels reached 1,140 and 1,079 grains/m³ in Philadelphia and Cherry Hill, respectively. A strong

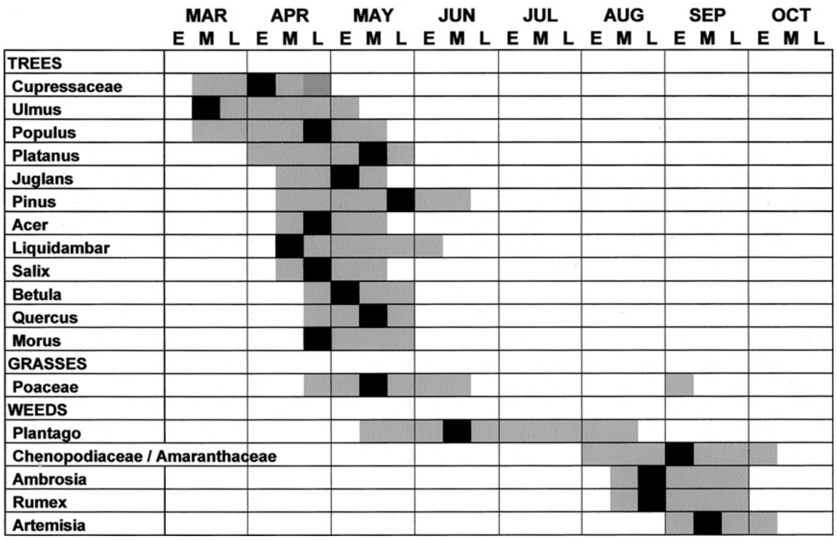

Figure 1. Pollen seasons for taxa with discernible flowering periods in Philadelphia, PA during the period 1991 to 1997 and in Cherry Hill, NJ during the period 1995 to 1997. Seasons (*gray*) were defined by the first and last days of a consecutive series during which counts >1% of total pollen were observed. The approximate period during which each taxon reached its maximum concentration (*black*). Months are subdivided into early (E), middle (M), and late (L) periods.

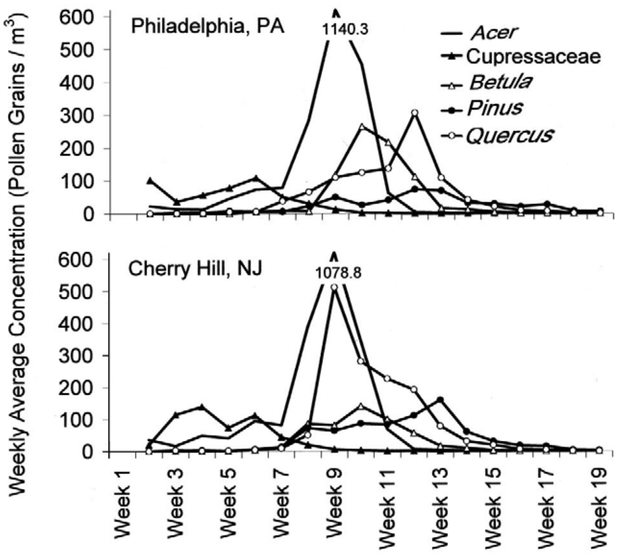

Figure 2. Aggregate average weekly *Acer*, Cupressaceae, *Betula*, *Pinus*, and *Quercus* pollen levels in Philadelphia, PA and Cherry Hill, NJ during the period 1995 to 1997, inclusive. Week 1 corresponds to March 1 to 7, and so forth.

positive correlation was determined for *Acer* pollen levels between the two locations, $r_p = 0.987$, $P < 0.001$.

Late flowering trees. The major late flowering tree seasons, *Quercus* (late April to late May), *Betula* (late April to late May), and *Pinus* (mid-April to mid-June), displayed considerable overlap. In late April, average *Quercus* levels peaked higher in Cherry Hill at 512 grains/m^3 than in Philadelphia at 306 grains/m^3. *Quercus* patterns were positively correlated between locations, $r_p = 0.645$, $P < 0.001$. During early May, weekly average *Betula* pollen levels reached 265 grains/m^3 in Philadelphia in contrast to 141grains/m^3 in Cherry Hill. A positive *Betula* pollen correlation was observed between sampling stations, $r_p = 0.896$, $P < 0.001$. Lastly, in late May, average *Pinus* levels peaked considerably higher in Cherry Hill than in Philadelphia, 160 and 70 grains/m^3, respectively. Two to three *Pinus* peaks were noted throughout the season. A positive *Pinus* pollen relationship existed between sampling locations, $r_p = 0.732$, $P < 0.001$.

Grasses. The primary Poaceae pollen season began in late April and continued through mid-June. Multiple Poaceae peaks were evident throughout the season. Highest average levels were recorded in mid-May at 114 and 96 grains/m^3 in Philadelphia and Cherry Hill, respectively. At both sites, a less prominent secondary peak was noted in early September. Poaceae pollen patterns were markedly similar between sampling locations, $r_p = 0.950$, $P < 0.001$.

Weeds. The *Ambrosia* and *Rumex* flowering seasons began in mid-August and ended in late September. *Ambrosia* pollen peaked in late August at 135 and 125 grains/m^3 in Philadelphia and Cherry Hill, respectively. A strong *Ambrosia* pollen relationship was determined between the two locations, $r_p = 0.903$, $P < 0.001$. In early September, average *Rumex* levels reached 63 grains/m^3 in Philadelphia in contrast to 141 grains/m^3 in Cherry Hill. In late September, a second *Rumex* peak in Cherry Hill reached 111 grains/m^3. A moderate *Rumex* correlation was seen between sampling locations, $r_p = 0.572$, $P < 0.001$.

Meteorologic Variables

Table 5 reports the results of statistical analysis between daily pollen levels and same-day maximum temperature, same-day minimum temperature, and same-day total precipitation. Spearman correlation coefficients, r_s, are presented for the examination of combined data from seven seasons in Philadelphia, 1991 to 1997, and three seasons in Cherry Hill, 1995 to 1997. Daily Poaceae pollen levels were moderately and positively influenced by same-day warm temperature, r_s = 0.333, $P < 0.05$ and $r_s = 0.426$, $P < 0.05$, in Philadelphia and Cherry Hill, respectively. Changes in daily *Ambrosia* pollen levels were weakly and inversely influenced by same-day total precipitation, $r_s = -0.174$, $P < 0.05$ and $r_s = -0.257$, $P < 0.05$, in Philadelphia and Cherry Hill, respectively. Daily variations in tree pollen levels were not significantly correlated with any meteorologic variable examined, $0.188 > r_s < -0.235$, P = not significant.

DISCUSSION

Seasons and Prevalence

When defined by the first and last days of a consecutive series during which 1% of annual pollen was recovered, similar seasons for individual taxa were determined in Philadelphia and in Cherry Hill. These seasons are consistent with previously reported patterns for the northeastern United States.[11,12]

The tree pollen season begins in mid-March with Cupressaceae pollen and ends in mid-June as *Pinus* pollen wanes. Late April to early May is a significant period of pollen prevalence as numerous tree seasons overlap. During this interval, airborne pollen levels may exceed 1,800 grains/m^3. Concurrent with the late flowering trees, the Poaceae pollen season extends from late April to mid-June, and a less prominent secondary peak appears in early September. This biphasic Poaceae season occurs throughout the United States and is particularly well documented in the eastern region.[11] After a sharp decline in airborne pollen during June and July, the fall weed season extends from mid-August to late September. Early September is a prominent weed period during which the *Ambrosia*, *Chenopodiaceae* (goosefoot), *Amaranthaceae* (amaranth), *Rumex*, and *Artemisia* (sage) pollen seasons coincide. Pollen levels during this period may exceed 250 grains/m^3. Incidentally, sampling was conducted throughout the winter months during the 2000 to 2001 season. Continuous sampling revealed no previously unidentified pollen taxa and no additional seasonal patterns.

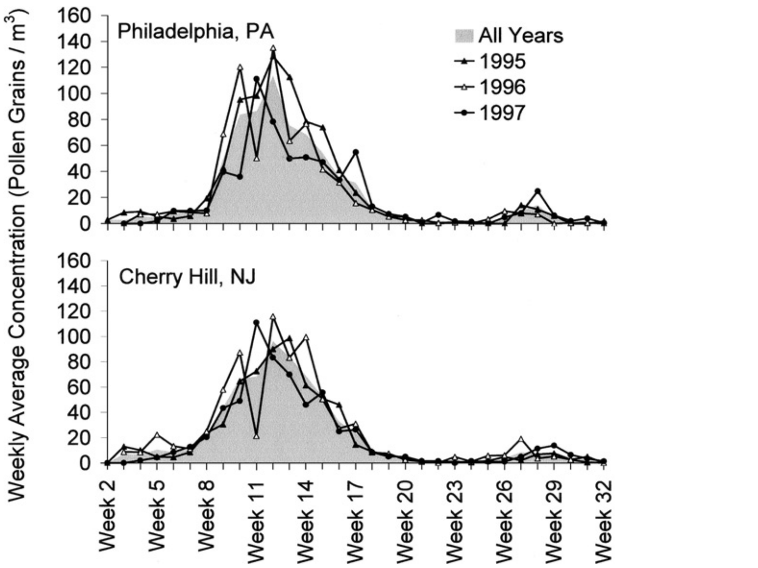

Figure 3. Aggregate average weekly Poaceae pollen levels in Philadelphia, PA and Cherry Hill, NJ during the period 1995 to 1997, inclusive. Week 1 corresponds to March 1 to 7, and so forth.

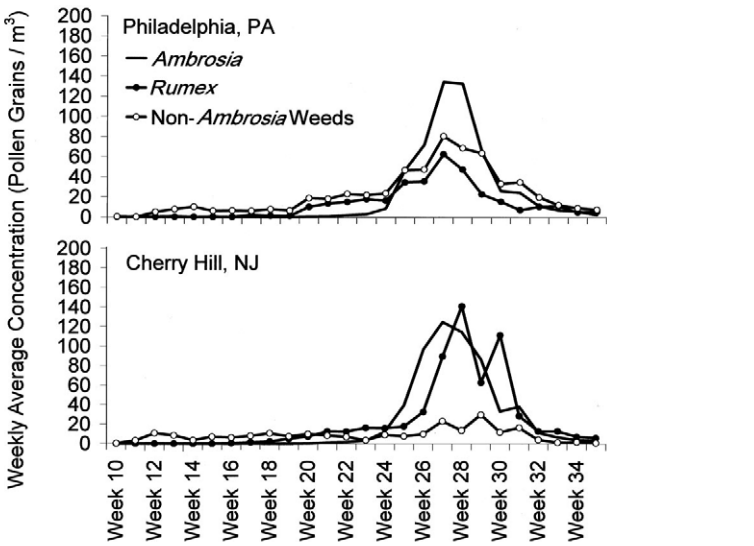

Figure 4. Aggregate average weekly *Ambrosia, Rumex,* and non-*Ambrosia* weed pollen levels in Philadelphia, PA and Cherry Hill, NJ during the period 1995 to 1997, inclusive. Non-*Ambrosia* weeds include *Artemisia, Plantago, Chenopodiaceae, Amaranthaceae,* and *Asteraceae.* Week 1 corresponds to March 1 to 7, and so forth.

As indicated in Tables 2 and 3, individual pollen prevalence varies considerably from year to year. Tree pollen demonstrates larger fluctuations than either the grasses or the weeds. For instance, in Philadelphia, total annual *Acer* pollen recovery ranged from 835 grains/m^3 in 1997 to 14,227 grains/m^3 in 1996. Similarly, total annual *Quercus* pollen recovery varied from 1,774 grains/m^3 in 1996 to 6,118 grains/m^3 the following year. Among the herbaceous plants, total annual Poaceae pollen recovery ranged from a low of 2,217 grains/m^3 in 1995 to a high of 5,838 grains/m^3 in 1992, and total annual *Ambrosia* pollen recovery ranged from 1,051 grains/m^3 in 1992 to

Table 5. Spearman Correlation Coefficient for Examination of Daily Pollen Measurements versus Daily Maximum Temperature, Daily Minimum Temperature, and Total Daily Precipitation in Philadelphia, PA during the Period 1991–1997 and in Cherry Hill, NJ during the Period 1995–1997

	Acer	Cupressaceae	*Quercus*	*Betula*	*Pinus*	Poaceae	*Ambrosia*	*Rumex*
Philadelphia, PA								
Max temperature	0.188	0.113	0.119	0.024	0.166	0.333*	0.175*	0.253*
Min temperature	0.090	0.034	0.095	−0.011	0.067	0.194	0.036	0.175
Precipitation	−0.113	0.019	−0.109	−0.089	−0.187	−0.084	−0.174*	−0.144
Cherry Hill, NJ								
Max temperature	0.110	−0.075	0.151	−0.126	0.113	0.426*	0.130	0.087
Min temperature	−0.007	−0.157	0.042	−0.110	0.012	0.238	−0.004	0.030
Precipitation	−0.235	0.001	−0.129	0.070	−0.063	−0.174	−0.257*	−0.196*

* $P < 0.05$.

6,260 grains/m^3 in 1991. Similar interannual variation was observed in Cherry Hill.

Previous investigators have also reported year-to-year differences in pollen prevalence; however, interannual variation remains incompletely understood.[12–17] The large variability in tree pollen prevalence is supported by the work of Solomon,[18] who indicated that in regions subject to harsh winters, such as the survey area, tree bud loss might be extensive and subsequent pollen prevalence unpredictable. Additionally, year-to-year cycles in pollen production have been documented for numerous tree genera including *Quercus*, *Betula*, and Cupressaceae.[19,20] A distinct biennial *Quercus* flowering pattern is observed in the present survey. In Philadelphia during the 1991, 1993, 1995, and 1997 seasons, *Quercus* pollen prevalence was significantly greater than in other years (Table 2). It is anticipated that with continued data collection in the survey area, particularly in Cherry Hill, additional patterns will be definitively established.

Meteorologic conditions have been implicated in the interannual variation of herbaceous plants. Davies and Smith[21] have indicated that the severity of the *Poaceae* season is largely a function of temperature during the months of April and May. Examination of meteorologic data showed that the maximum and minimum temperatures during April 1994, 70° and 49° F, respectively, were 7° above normal. These warm conditions could explain the above-average Poaceae pollen recovery in 1994 (Table 2). Similarly, July 1994 was the hottest July in Philadelphia since 1895.[9] Additionally, heavy rains during the latter part of the month led to an accumulation of 10.4 inches, in contrast to normal July rain of 4.3 inches. As previous investigators have established,[19,22] these warm, wet conditions may have promoted vegetative growth, flower development, and subsequent pollen production in *Ambrosia* and *Rumex* species (Table 2).

Comparison of Philadelphia and Cherry Hill

Qualitative characteristics such as pollen type, season onset, duration, peak week, and year-to-year variation were largely consistent between Philadelphia and Cherry Hill. For example, at both locations, *Acer* pollen prevalence was moderate in 1995, high in 1996, and exceptionally low in 1997 (Tables 2 and 3). *Acer* peaks occurred within 2 weeks of one another between locations and concentrations were markedly similar (Table 4). These qualitative consistencies were illustrated by Pearson statistical analysis. Comparison of simultaneous weekly average measurements in Philadelphia and Cherry Hill revealed a strong positive relationship ($r_p > 0.90$, $P < 0.001$) for *Acer*, Poaceae, and *Ambrosia* patterns and a moderate positive relationship ($0.90 > r_p > 0.55$, $P < 0.001$) for *Betula*, *Pinus*, Cupressaceae, *Quercus*, and *Rumex* patterns. Overall, higher correlation was determined for taxa with longer flowering seasons such as *Acer*, Poaceae, and *Ambrosia* than those with shorter seasons such as *Betula* and *Quercus*.

Despite these qualitative similarities, comparison of total annual concentration and peak concentration for individual taxa revealed quantitative differences between sampling locations. Airborne pollen was largely more abundant in Cherry Hill, particularly for *Pinus* and *Rumex*. Total annual *Pinus* and *Rumex* pollen recovery as well as peak concentration were consistently greater in Cherry Hill than in Philadelphia (Tables 2 and 3). Alternatively, total annual *Betula* pollen recovery and peak concentration were largely greater in Philadelphia than in Cherry Hill (Tables 2 and 3).

Previous studies investigating pollen incidence at neighboring locations have documented this same pattern of qualitative similarity and quantitative difference.[14,17,23–25] Among the numerous factors affecting airborne pollen distribution, including local flora, habitat pressures, microclimate, and differential transport,[26] two primary factors have been implicated in aeroallergen spatial variability. First, pollen from distant sources is not uniformly mixed within the atmosphere and second, pollen from nearby vegetation can have a profound local effect on aeroallergen sampling.[27] Examination of individual taxa in this study revealed that quantitative differences between sites were largely attributable to local vegetation as described below.

Acer. A prominent member of the Eastern deciduous forest, *Acer* was the most abundant pollen recovered in this survey, comprising an average 20.7 and 27.7% of annual pollen in Philadelphia and Cherry Hill, respectively. Common species in this area include *Acer saccharum* (sugar maple), *A. rubrum* (red maple), and *A. platanoides* (Norway maple). Interestingly, *Acer* is an amphiphilous genus, with members ranging from the anemophilous *A. negundo* (box elder) to the strictly insect-pollinated *A. platanoides*.[18] Although the role of insect-pollinated plants in pollinosis remains unclear, the prevalence of amphiphilous pollen in this and other surveys[28,29] warrants further investigation.

Poaceae. Despite the distinct urban and suburban characteristics of Philadelphia and Cherry Hill, respectively, Poaceae pollen patterns were markedly similar between sites, $r_p = 0.950$, $P < 0.001$. The early May trough of 1996 and the early May peak of 1997, seen at both locations, exemplify this qualitative consistency (Fig 5). In Philadelphia and Cherry Hill, similar species were identified by field investigation including *Anthoxanthum odoratum* (sweet vernal grass), *Dactylis glomerata* (orchard grass), and *Poa spp*. (bluegrass). Also observed at both sites, the late summer flowering *Digitaris spp*. (crabgrass) was perhaps responsible for the secondary grass pollen peak noted in September.[6]

Ambrosia. Ambrosia pollen patterns were strongly correlated between Philadelphia and Cherry Hill, $r_p = 0.903$, $P < 0.001$. Similar species were identified at both sampling locations including *Ambrosia artemisifolia* (short ragweed) and *A. trifida* (giant ragweed). A hardy weed, *Ambrosia* flourishes in the disturbed soil along construction zones and roadsides.[30] Most likely, sufficient areas of displaced soil existed in Cherry Hill and Philadelphia to allow prodigious *Ambrosia* growth and pollen production.

Betula. During the period 1995 to 1997, average *Betula* pollen levels peaked higher in Philadelphia than in Cherry Hill, at 265 grains/m^3 and 141 grains/m^3, respectively. Fairmount Park, which occupies approximately 17 km^2 of Philadelphia, possesses numerous *Betula lenta* (sweet birch) trees that were perhaps responsible for these higher readings (AF Rhoads, personal communication, September 2000).

Pinus. As indicated in Table 4, the weekly *Pinus* peaks observed during the 1996 and 1997 seasons differed greatly between sampling locations and concentrations were approximately twice as great in Cherry Hill. The numerous and varied *Pinus* species of the Pine Barrens, which include *Pinus rigida* (pitch pine), *P. virgiana* (Virginia pine), *P. echinata* (short leaf pine), and *P. strobus* (white pine),[8] strongly influenced collections in Cherry Hill and were most likely responsible for these differences.

Historically, *Pinus* has not been implicated in pollinosis because of its large size and thick, waxy exine.[31,32] However, recent studies have indicated clinical manifestations related to *Pinus* pollen in select geographic locations.[33,34] In Mt. Laurel, NJ, located 21 km east of Philadelphia and 10 km east of Cherry Hill, and in Forked River, NJ, located 105 km east of Philadelphia and 94 km east of Cherry Hill, we found that 31 of 231 (13.4%) atopic patients demonstrated skin test reactivity to *Pinus* pollen. Anecdotally, several of these individuals exhibited symptoms of allergic rhinitis from early April to June although they demonstrated no other tree pollen sensitivity, implicating *Pinus* pollen as the offending allergen. In light of these findings, *Pinus* should be considered in the treatment of patients who reside in areas of high *Pinus* density, such as southern and central New Jersey.

Cupressaceae. Only moderate Cupressaceae pollen correlation was determined between locations. This resulted from fluctuations in peak week, which were particularly evident during the 1995 season. A spring drought in 1995 may have amplified the differences attributable to local species. Additionally, *Chamaecyparis thyoides* (Atlantic white cedar) swamps, found within the Pine Barrens, may have influenced collections in New Jersey, whereas *Juniperus virginiana* (red cedar), found within the deciduous forest, most likely contributed to airborne pollen at both locations.

Quercus. More than 15 *Quercus* species are found within the survey area, and they release copious amounts of airborne pollen from late April to late May. These species include *Quercus velutina* (black oak), *Q. marilandica* (blackjack oak), *Q. alba* (white oak), and *Q. stellata* (post oak). This heterogeneous population is most likely responsible for the considerable year-to-year and site-to-site fluctuations in *Quercus* pollen prevalence, as well as for the diminished correlation observed between Philadelphia and Cherry Hill.

Rumex. Prominent *Rumex* species found throughout the survey area include *R. crispus* (curly dock), *R. obtusifolius* (bitter dock), and *R. acetosella* (sheep sorrel). Despite the commonly held belief that *Ambrosia* is the most abundant airborne weed pollen in the survey area, surprisingly high levels of *Rumex* pollen were recovered in Cherry Hill, surpassing those of *Ambrosia*. Peak *Rumex* concentrations were noticeably greater in Cherry Hill than in Philadelphia and two peaks were noted in Cherry Hill, in contrast to the single peak observed in Philadelphia (Fig 6). These disparities led to a diminished correlation between sites.

Meteorologic Influences

Although incompletely understood, compelling evidence has been presented which implicates temperature, percentage of sunshine, precipitation, and relative humidity in the daily variability in airborne pollen levels.[18,19,21,35,36] In this survey, daily Poaceae pollen levels were directly influenced by fluctuations in same-day warm temperature. This is consistent with extensive studies performed by Smith and Davies,[21] who demonstrated that Poaceae pollen levels were directly correlated with warm temperature and hours of sunshine and indirectly correlated with precipitation, strong wind, and convection. Warm temperatures are thought to promote anther dehiscence and produce airflow patterns that facilitate the distribution of airborne pollen.[18]

Changes in daily *Ambrosia* pollen levels were significantly and inversely influenced by same-day total precipitation. Steady rain (1- to 2-mm droplets) effectively washes the air free of pollen particles and temporarily inhibits further dehiscence as moisture accumulates on the anther.[18,35]

Daily fluctuations in tree pollen levels were not significantly correlated with any meteorologic variable examined in this study. Glassheim et al[36] also determined that tree pollen was seemingly unaffected by changes in temperature. Their studies, however, determined a significant, indirect relationship between tree pollen levels and precipitation that was not reproduced in this survey.

As indicated by previous researchers,[18,19] examination of multiple and accumulated weather parameters is necessary for a complete understanding of the relationship between meteorology and aerobiology. Continued study in this area may lead to predictive pollen forecast models that will assist clinicians in their therapeutic decisions.

CONCLUSION

This survey represents the first comprehensive, volumetric airborne pollen analysis conducted in the survey area. In Philadelphia, PA and Cherry Hill, NJ, similar 3-year average measurements included 75.0 and 74.2% tree pollen, 14.8 and 17.5% weed pollen, and 10.2 and 8.3% grass pollen, respectively. Eight prominent taxa were identified at both locations. Listed in descending rank order, these airborne pollen taxa were *Acer*, *Quercus*, Poaceae, *Betula*, *Ambrosia*, *Pinus*, *Rumex*, and Cupressaceae in Philadelphia and *Acer*, *Quercus*, *Pinus*, Poaceae, *Rumex*, *Ambrosia*, *Betula*, and Cupressaceae in Cherry Hill.

Although pollen levels varied considerably from year to year, late April to early May and early September consistently represented significant spring and fall periods of airborne pollen prevalence, respectively. Similar qualitative patterns of pollen onset, duration, peak week, and year-to-year variability were observed between sampling stations. Slight quantitative differences were attributable to local vegetation. *Pinus* and *Rumex* pollen concentrations were consistently greater in Cherry Hill whereas *Betula* pollen concentrations were largely more abundant in Philadelphia. Of particular note, *Rumex*, not *Ambrosia* as generally believed, represents the most abundant airborne weed pollen in Cherry Hill, NJ.

Airborne pollen levels were examined in relation to single meteorologic conditions. Daily Poaceae levels were directly influenced by same-day warm temperature; daily *Ambrosia* levels were inversely influenced by same-day total precipitation; and daily variations in tree levels were not significantly correlated with any variable studied. Examination of the complex interaction of multiple weather parameters would perhaps more fully elucidate the relationship between meteorology and aerobiology and provide the clinician with information necessary to forecast pollen prevalence. An awareness of the ever changing, local aeroallergen patterns requires regular monitoring. Such awareness serves as a useful guide in the effective testing and treatment of atopic patients.

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REFERENCES

1. Blackley CH. Experimental researches on the cause and nature of *Catarrhus aestivus*. London: Balliere, Tindall, & Cox, 1873.
2. Durham OC. The contribution of air analysis to the study of allergy: comparative ragweed records for nine large cities. J Lab Clin Med 1928;13: 967–976.
3. Fairmount Park Commission. Philadelphia, PA. http://www.phila.gov/summary/fairpark/index.shtml.
4. Weber RW. Aeroallergens and Hymenoptera: Geographic distribution and cross-reactivity. Immunol Allergy Clin N Amer 2000;20:479–501.
5. Sutton A, Sutton M. Eastern Forests. New York: Alfred A. Knopf, Inc,1985.
6. Lewis W, Vinay P, Zenger V. Airborne and Allergenic Pollen of North America. Baltimore: Johns Hopkins University Press, 1983.
7. Rhoads AF, Block TA. The Plants of Pennsylvania: An Illustrated Manual. Philadelphia: University of Pennsylvania Press, 2000.
8. Boyd HP. A Field Guide to the Pine Barrens of New Jersey: Its Flora, Fauna, Ecology, and Historic Sites. Medford, NJ: Plexus Publishing, Inc, 1991.
9. Local Climatological Data, Philadelphia International Airport, Philadelphia, PA. National Oceanic and Atmospheric Administration, Washington, D.C., National Climatic Data Center, Asheville, NC, Regional Climatic Data Center, Ithaca, NY, National Weather Service Forecast Office, Mt. Holly, NJ.
10. Rantio-Lehtimaki A, Koivikko A, Kupias R, et al. Significance of sampling height of airborne particles for aerobiological information. Allergy 1991; 46:68–76.
11. Lewis WH, Dixit AB, Ward WA. Distribution and incidence of North American pollen aeroallergens. Am J Otolaryngol 1991;12:205–226.
12. Kosisky SE, Carpenter GB. Predominant tree aeroallergens of the Washington, DC area: a six year survey (1989–1994). Ann Allergy Asthma Immunol 1997:78:381–392.
13. McLean AC, Parker L, von Reis J, von Reis J. Airborne pollen and fungal spore sampling on the central California Coast: the San Luis Obispo pollen project. Ann Allergy 1991;67: 441–447.
14. Reddi CS. A comparative survey of atmospheric pollen and fungus spores at two places twenty miles apart. Acta Allergol 1970;25:189–215.
15. Fairley D, Batchelder GL. A study of oak-pollen production and phenology in northern California: prediction of annual variation in pollen counts based on geographic and meteorologic factors. J Allergy Clin Immunol 1986;78: 300–307.
16. Buck P, Levetin E. Weather patterns and ragweed pollen production in Tulsa, Oklahoma. Ann Allergy 1982;

49:272–275.
17. Singh AB, Babu CR. Survey of atmospheric pollen allergens in Delhi: seasonal periodicity. Ann Allergy 1982; 48:115–122.
18. Solomon WR. Aerobiology of pollinosis. J Allergy Clin Immunol 1984;74: 449–461.
19. Andersen ST. Influence of climatic variation on pollen season severity in wind-pollinated trees and herbs. Grana 1980;19:47–52.
20. Caiaffa MF, Macchia L, Strada S, et al. Airborne Cupressaceae pollen in southern Italy. Ann Allergy 1993;71: 45–50.
21. Davies RR, Smith LP. Weather and the grass pollen content of the air. Clin Allergy 1974;4:95–108.
22. Al-Doory Y, Domson JE, Howard WA, et al. Airborne fungi and pollens of the Washington DC metropolitan area. Ann Allergy 1980;45:360–367.
23. Pereira MR, Ferrand EF. Assessing levels of airborne bioallergens in New York City. Environ Health Perspect 1981;37:171–178.
24. Salvaggio J, Zaslow L, Greer J, Seabury J. New Orleans asthma. 3. Semiquantitative aerometric pollen sampling, 1967 and 1968. Ann Allergy 1971;29:305–317.
25. Anderson EF, Dorsett CS, Fleming EO. The airborne pollens of Walla Walla, Washington. Ann Allergy 1978;41:232–235.
26. Raynor GS, Ogden EC, Hayes JV. Spatial variability in airborne pollen concentrations. J Allergy Clin Immunol 1975;55:195–202.
27. Frenz DA. Interpreting atmospheric pollen counts for use in clinical allergy: spatial variability. Ann Allergy 2000;84:481–491.
28. Decco ML, Wendland BI, O'Connell EJ. Volumetric assessment of airborne pollen and spore levels in Rochester, Minnesota, 1992 through 1995. Mayo Clin Proc 1998;73:225–229.
29. Solomon WR. Volumetric studies of aeroallergen prevalence I. Pollens of weedy forbs at a midwestern station. J Allergy Clin Immunol 1976;57: 318–327.
30. Niering WA, Olmstead NC. The Audubon Society Field Guide to North American Wildflowers. New York: Alfred A. Knopf, 1979.
31. Harris RM, German DF. The incidence of pine pollen reactivity in an allergic atopic population. Ann Allergy 1985; 55:678–679.
32. Freeman GL. Pine pollen allergy in northern Arizona. Ann Allergy 1993; 70:491–494.
33. Armentia A, Quintero A, Fernandez-Garcia A, et al. Allergy to pine pollen and pinion nuts: a review of three cases. Ann Allergy 1990;64:49–53.
34. Newmark FM, Itkin IH. Asthma due to pine pollen. Ann Allergy 1967;25: 251–252.
35. Davies RR. Climate and topography in relation to aero-allergens at Davos and London. Acta Allergol 1969;24: 396–409.
36. Glassheim JW, Ledoux RA, Vaughn TR, et al. Analysis of meteorologic variables and seasonal aeroallergen pollen counts in Denver, Colorado. Ann Allergy 1995;75:149–156.

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