

Urban airborne pollen in a semiarid environment

Maribel Moreno-Sarmiento  · M. Cristina Peñalba · Jordina Belmonte ·
Irma Rosas · M. Magdalena Ortega-Nieblas · Martín Villa-Ibarra ·
Fernando Lares-Villa · L. Julián Pizano-Nazara

Received: 13 February 2015 / Accepted: 19 August 2015
© Springer Science+Business Media Dordrecht 2015

Abstract The present investigation was conducted to determine the pollen types and their quantities in the atmosphere of Obregón City (a semiarid region) and establish the relationship with meteorological parameters in 2008 and 2011. A bimodal pattern with peaks in dry warm (spring) and late rainy (autumn) seasons was observed. The highest monthly pollen indexes were observed in October 2008 and September 2011. Precipitation in 2008 was 2.6 times higher than in

2011, beginning in June in both years, and ending in November (2008) and September (2011). Main pollen types were Poaceae, Chenopodiaceae/Amaranthaceae, Asteraceae and *Parkinsonia* (the latter was dominant in the dry warm season). Statistical correlations (Spearman's rank-order correlation $p < 0.05$) with meteorological parameters were performed. In both sampling years, relative humidity caused adverse effects on the atmospheric pollen content, while temperature, solar radiation and wind speed in the

M. Moreno-Sarmiento (✉) · M. C. Peñalba ·
M. M. Ortega-Nieblas
Departamento de Investigaciones Científicas y
Tecnológicas, de la Universidad de Sonora, Edificio 7-G,
Luis Donaldo Colosio s/n, entre Sahuaripa y Reforma
Colonia Centro, 83000 Hermosillo, Sonora, Mexico
e-mail: maribelmorenosarmiento@gmail.com

J. Belmonte
Institut de Ciència i Tecnologia Ambientals (ICTA),
Edifici Z, Carrer de les Columnes s/n, Universitat
Autònoma de Barcelona, Campus de Bellaterra,
08193 Bellaterra, Cerdanyola del Vallès, Barcelona, Spain

J. Belmonte
Departament de Biologia Animal, Biologia Vegetal i
Ecologia, Universitat Autònoma de Barcelona,
Bellaterra, Cerdanyola del Vallès, Barcelona, Spain

I. Rosas
Centro de Ciencias de la Atmósfera, Universidad
Nacional Autónoma de México, circuito exterior s/n,
04510, Ciudad Universitaria, Del. Coyoacán, Mexico,
D.F., Mexico

M. Villa-Ibarra
División de Ingeniería Ambiental, Instituto Tecnológico
Superior de Cajeme, carretera Internacional a Nogales
Km. 2 s/n, 85000 Ciudad Obregón, Sonora, Mexico

F. Lares-Villa
Departamento de Biotecnología y Ciencias Alimentarias,
Instituto Tecnológico de Sonora, 5 de febrero #818 Sur,
85000 Ciudad Obregón, Sonora, Mexico

L. J. Pizano-Nazara
Departamento de Inmunología Clínica y Alergia, Clínica
Hospital San José, No Reelección #100,
85000 Ciudad Obregón, Sonora, Mexico

dry season were associated with increased pollen indexes. Compared to other studies of semiarid areas, the pollen index at Obregón is low, which is attributed to a relatively high humidity and to the large area of grain crops surrounding the city.

Keywords Aerobiology · Semiarid region · Airborne pollen · Obregón City · Sonora · Mexico

1 Introduction

The presence of some biological particles in the air is a serious problem due to the harmful effects on the environment and on human health such as rhinitis and asthma (Bousquet and Khaltayev 2007; Mao et al. 2012). As a result, in recent decades, there has been an increasing interest in aerobiological research (Nayar and Jothish 2013). It focuses on determining various aspects of the pollen content in the atmosphere (Lorenzoni-Chiesura et al. 2000; Nitui et al. 2003; Latorre and Belmonte 2004; Izquierdo et al. 2011; Ianovici et al. 2013), in order to establish pollen calendars for the diagnosis and prevention of pollinosis (hay fever) (Rizzi-Longo et al. 2007). Investigations have also been focused on identifying factors that enable the release of bioparticles and their dispersion in the atmosphere, establishing correlations between the pattern of distribution of the airborne particles and the meteorological parameters (Moreno-Grau et al. 2000; Bowers and Turner 2002; Burch and Levett 2002), which affect both the production of these allergens and their spread in the atmosphere. However, these investigations have been conducted mostly in temperate zones and the tropics and subtropics have been poorly analyzed in aeropalynology, although a significant portion of the world population lives in these regions. In Mexico, there are few such studies, and they are mainly focused on Mexico City and Monterrey (Bronillett 1996; Rocha-Estrada et al. 2009; González-Díaz et al. 2010; Calderón-Ezquerro et al. 2015), with a single study in the northwest for Mexicali (Ahumada-Valdez et al. 2009); these three cities are located at 1600, 1000 and 800 km distance, respectively, from Obregón City (Fig. 1), at different elevations, under different temperature and precipitation regimes, and surrounded by different vegetation types.

The present research shows the first study of airborne pollen of Obregón City, a city of more than 400,000 inhabitants (INEGI 2010) in the semiarid region of northwestern Mexico.

2 Materials and methods

Concerning the study site, Obregón City is located in northwestern Mexico, in the south of Sonora (27° 29'N, 109° 56'W, 40-m elevation) (Fig. 1). It has a BWh climate (very warm, with summer temperatures above 40 °C and winter arid) according to the Köppen classification (García 1973), with an average relative humidity of about 60 % (Agrosón 2013). The annual average rainfall is 350 mm, mainly falling during the monsoon season (late June to late October). As a result, the major vegetation type around the city is thornscrub; this is an ecosystem composed of plants that are controlled by summer monsoon precipitations, they are frost sensitive, and there are few winter ephemerals many of which respond to rainfall at any season (Felger et al. 2001).

For pollen collection, a Burkard Manufacturing Co. Ltd. volumetric spore trap collector for 7 days was installed at 10 m height on the roof of the building number 500 at Instituto Tecnológico de Sonora, which is located in the city center. The airborne pollen records were obtained from January 1 to December 31, 2008, and from January 1 to December 31, 2011. They were analyzed following the guidelines of the guidebook for the management and quality of Spanish Aerobiology Network (Galán et al. 2007); counts were made under an optical microscope, along four horizontal sweeps at 400× for each slide. Pollen counts were converted into pollen concentrations (P/m^3). To summarize data, the daily pollen concentrations thus obtained were summed up per monthly periods to be expressed as monthly pollen index (MPI: sum of the daily values for each month) as in Fig. 2, and per 10-day periods to obtain a 10-day cumulative pollen index graph (Fig. 3).

Daily meteorological data of precipitation, temperature, relative humidity, wind speed and solar radiation were obtained from the meteorological databases of the Web sites Weather Underground (The Weather Channel, LLC, 2014) and the Sonoran State Meteorological Stations Network (Agrosón 2013).

For statistical analysis, a normality test was performed on daily pollen data, and then statistical correlations (Spearman's rank-order correlation at 95 % reliability) were performed using the statistical package Sigma Plot 11.0, between daily concentration of pollen grains/m³ of air of the most representative taxa and the meteorological parameters (average temperature, maximum temperature, minimum temperature, average relative humidity, maximum relative humidity, minimum relative humidity, precipitation, wind speed, maximum wind speed, average solar radiation and maximum solar radiation). A second correlation analysis was made considering two seasons (dry season from January to May and rainy season from June to December) within which correlations were established between the monthly averages of the above-mentioned climatic parameters and the MPI.

3 Results

A bimodal pattern is observed in the atmospheric pollen counts of year 2008, peaking in October and April and with a minimum in August, while year 2011 shows a three-body pattern, peaking in September, May and February–March and with minima in December and April (Fig. 2). The total accumulated annual pollen was 514 pollen grains in 2008 and 538 in 2011. For 2008, the pollen types Poaceae, Chenopodiaceae/Amaranthaceae, Asteraceae, Fabaceae, *Parkinsonia*,

Pinus, *Prosopis*, *Acacia* and *Helianthus* constituted 88 % of the total pollen. The remaining pollen grains were unknown. In 2011, Poaceae, Chenopodiaceae/Amaranthaceae, Asteraceae, Urticaceae, Moraceae, Fabaceae, Euphorbiaceae, *Parkinsonia*, *Prosopis*, *Pinus*, *Acacia*, *Baccharis*, *Artemisia*, *Ambrosia*, *Helianthus*, *Casuarina* and *Plantago*, accounted for 92 % of the total pollen, and 8 % were undetermined. Figure 3 shows the distribution of 10-day cumulative pollen indexes of the main pollen types in the atmosphere: *Parkinsonia*, Poaceae, Asteraceae, Chenopodiaceae–Amaranthaceae, *Prosopis* and *Pinus*, in chronological order in both sampling periods (2008 and 2011); Poaceae (up to 25 pollen grains), Chenopodiaceae/Amaranthaceae (33) and *Parkinsonia* (42) were the best represented taxa. Main differences between both years were the higher scores of *Parkinsonia* in February–March 2011, and those of Poaceae, Chenopodiaceae–Amaranthaceae and Asteraceae in October 2008.

Table 1 shows the results of the Spearman's rank-order correlation between MPI and meteorological parameters. Temperature, solar radiation and wind speed in the dry season are factors which enhance airborne pollen concentrations (significant correlations between 0.8 and 1), whereas relative humidity leads to lower concentrations (negative correlations close to –1) and precipitation shows less significant, mainly negative correlations. The two sampling years showed a contrasting meteorological pattern: a strong

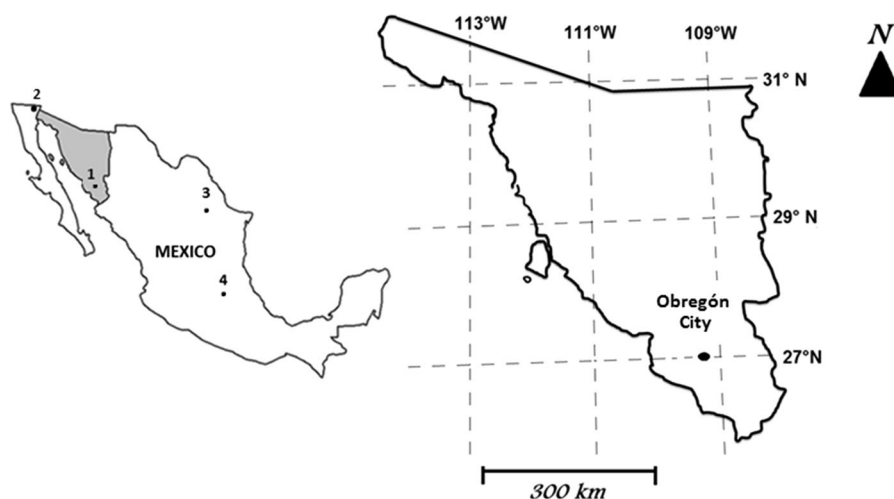


Fig. 1 Location of the study site, Obregón City, in Sonora, Mexico. (1) Obregón City, (2) Mexicali, Baja California, (3) Monterrey, Nuevo León and (4) Mexico City

tropical cyclone, Hurricane Norbert, struck southern Sonora in early October 2008, while no tropical cyclones entered this region in 2011. Additionally, winter precipitations (November–December) were recorded in late 2007, unlike in late 2010.

4 Discussion

The results obtained in this study are different from the already published research from Mexico. In Mexico City (Calderón-Ezquerro et al. 2015), airborne pollen taxa are mainly *Fraxinus*, Cupressaceae, *Alnus* and *Pinus* type. The city is located at more than 2200-m elevation, under a colder climate, and surrounded by oak and conifer forests, contrasting with the thornscrub at 40-m elevation around our site. Results are also different from those of Monterrey (Rocha-Estrada et al. 2009), at 500-m elevation, close to the Sierra Madre Oriental temperate forests, where the dominant taxa are *Fraxinus*, Cupressaceae–Taxodiaceae, *Parietaria* and Poaceae, with concentrations up to 14 000 grains/m³. Only Mexicali shows a closer composition, owing to its location at a similar elevation, also in northwestern Mexico, in the Sonoran Desert. Poaceae and Chenopodiaceae–Amaranthaceae are the most abundant taxa (Ahumada-Valdez et al. 2009), such as in Obregón City; however, no pollen of *Parkinsonia* or *Prosopis* is recorded in Mexicali. Mexico is a large and physiographically complex country, with different climate and vegetation types which provide a diversity

of airborne pollen assemblages which are worth to be studied.

The MPI recorded in the first half of the 2 years studied belongs mainly to trees (note that Poaceae are present all over the year), while in the second half of the year, herbs pollen is mainly found. Although this is similar to other regions (Nitiu et al. 2003), and particularly to temperate regions, the dominant pattern of the tropical trees *Parkinsonia* and *Prosopis* in spring, makes a distinction from those records. This must be considered in the context of pollinosis prevention, since both *Parkinsonia* and *Prosopis* are used as ornamental trees and not only at a local scale, since they have spread to other countries (Barros 2010). Another feature relates to Poaceae, which maintain high levels in October, unlike the situation in other semiarid regions (Belmonte et al. 2010; Alba-Sánchez et al. 2010); this implies a longer period of allergen exposure, which has also been recorded at Monterrey (Rocha-Estrada et al. 2009), Tucson, USA (O'Rourke 1986) and Lucknow, India (Datta et al. 2012). On the other hand, the 2008 and 2011 annual pollen indexes at Obregón City are very similar, but they are very low when compared to other regions (Nitiu et al. 2003; Murray et al. 2008; Ianovici et al. 2013). The city of Mexicali, around 800 km to the northwest, has an annual pollen index considered as low (Ahumada-Valdez et al. 2009), which is four times higher than that observed at Obregón City. The low pollen concentration in the atmosphere of Obregón City is attributed to the fact that the city is surrounded

Fig. 2 Annual dynamics of the monthly pollen index in the atmosphere of Obregón City, Sonora, Mexico; for the years 2008 and 2011

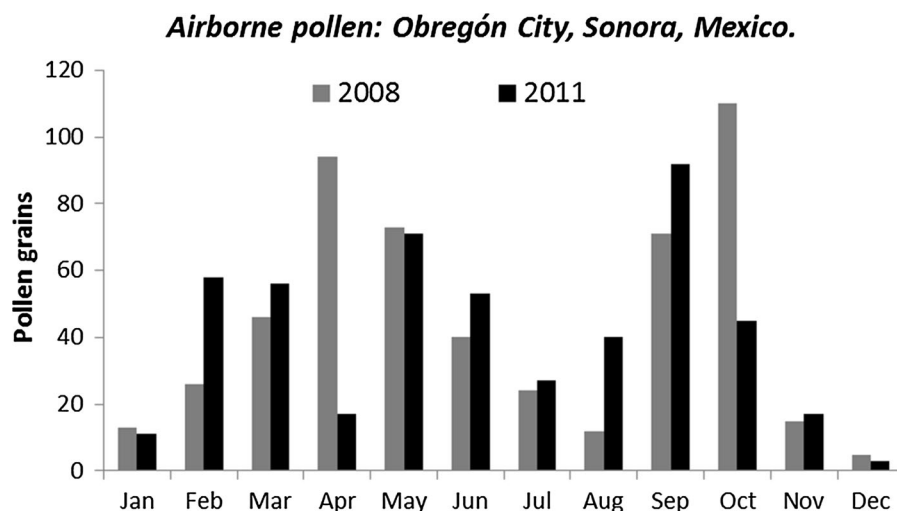
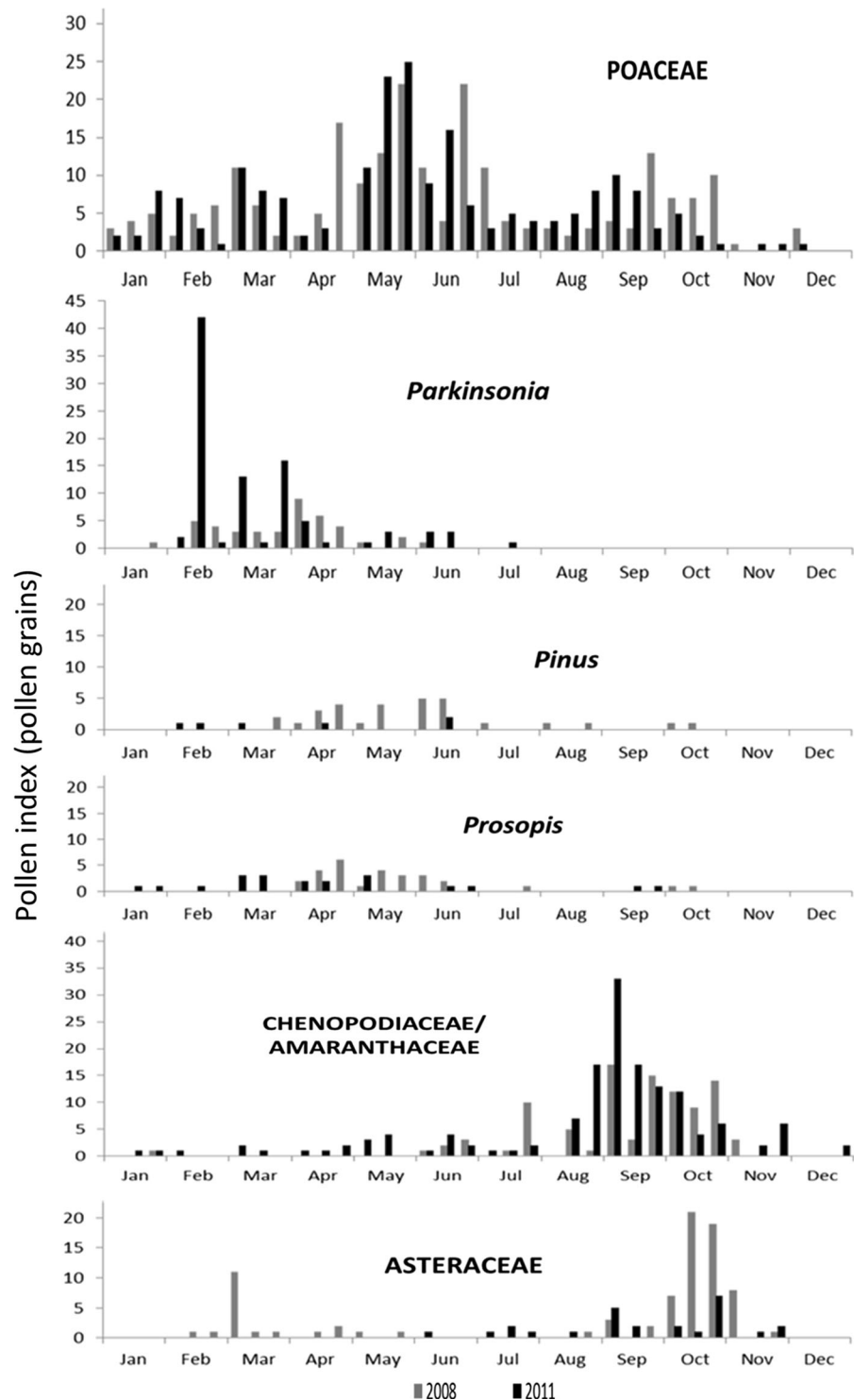


Fig. 3 Main airborne pollen taxa at Obregón City, Sonora, Mexico, 2008 and 2011



by fields, mainly cereal crops. Pollen from these plants does not disperse through the wind, as they are self-pollinated, and therefore, they do not require producing

large amounts of pollen (Damialis and Konstantinou 2011). On the other hand, the fields are surrounded by thornscrub, which in pollen terms is mainly

Table 1 Spearman's rank-order correlation ($*P < 0.05$): correlation between MPI (total pollen and most representative pollen types) and the monthly values of meteorological

parameters in the dry season (a) and rainy season (b) in the atmosphere of Obregón City, Sonora, Mexico, 2008 and 2011

2008	Rain	Temp. Max.	Temp. Mean	Temp. Min.	R. H. Max.	R. H. Mean	R. H. Min.	Wind speed	W. S. Max.	S. R.	S. R. Max.
Total pollen											
a	−0.872	0.900	0.900	0.872	−1.000*	−0.900	−0.900	0.462	0.791	1.000*	1.000*
b	0.214	0.867*	0.374	0.164	−0.214	−0.286	−0.357	−0.259	0.074	0.536	0.143
Poaceae											
a	−0.872	1.000*	1.000*	0.975*	−0.900	−1.000*	−1.000*	0.616	0.949*	0.900	0.900
b	0.393	0.867*	0.571	0.346	0.107	0.071	0.071	−0.074	0.281	0.679	0.321
Cheno/Ams											
a	0.725	−0.707	−0.707	−0.544	0.707	0.707	0.707	−0.725	−0.559	−0.707	−0.707
b	0.559	0.656	0.408	0.358	0.414	0.270	0.090	−0.505	−0.085	0.324	0.126
<i>Parkinsonia</i>											
a	−0.564	0.300	0.300	0.154	−0.600	−0.300	−0.300	0.154	0.052	0.600	0.600
b	0.000	0.523	0.523	0.161	0.000	0.158	0.158	0.164	0.497	0.791*	0.316
Asteraceae											
a	−0.289	0.616	0.616	0.553	−0.462	−0.616	−0.616	1.000*	0.703	0.462	0.462
b	−0.177	0.152	−0.337	−0.411	−0.197	−0.374	−0.611	−0.850*	−0.661	−0.256	−0.453
2011	Rain	Temp. Max.	Temp. Mean	Temp. Min.	R. H. Max.	R. H. Mean	R. H. Min.	Wind speed	W. S. Max.	S. R.	S. R. Max.
Total pollen											
a	−0.894	0.600	0.462	0.316	−0.975*	−0.667	−0.600	0.205	0.564	0.600	0.300
b	−0.679	0.837*	0.593	0.450	−0.360	−0.143	−0.126	0.225	0.873*	0.571	0.393
Poaceae											
a	−0.631	0.359	0.368	0.162	−0.763	−0.526	−0.359	−0.526	0.000	0.359	−0.051
b	−0.500	0.855*	0.741*	0.677	−0.108	0.143	0.162	0.430	0.873*	0.857*	0.679
Cheno/Ams											
a	−0.412	0.949*	0.973*	0.917*	−0.649	−0.973*	−0.949*	0.135	0.676	0.949*	0.791
b	−0.127	0.361	0.377	0.239	−0.101	0.000	0.045	−0.219	0.269	−0.018	0.018
<i>Parkinsonia</i>											
a	−0.671	0.000	−0.205	−0.158	−0.359	−0.051	0.000	0.616	0.154	0.000	0.100
b	−0.535	0.476	0.277	0.337	−0.292	−0.089	−0.089	0.420	0.590	0.802*	0.579
Asteraceae											
a	−	−	−	−	−	−	−	−	−	−	−
b	−0.778*	0.604	0.308	0.187	−0.692	−0.482	−0.449	−0.175	0.660	0.296	0.148

Significant correlations in bold

Cheno/Ams Chenopodiaceae–Amaranthaceae, *Temp* temperature, *R.H* relative humidity, *W.S* wind speed, *S. R* solar radiation, *Min.* minimum, *Max.* maximum

represented by Asteraceae, Poaceae and Chenopodiaceae/Amaranthaceae given that the pollen of characteristic tropical taxa, which are zoophilous, are underrepresented in the air (Orvis 1998); this explains the dominance of these taxa in the airborne pollen record (Fig. 3). Moreover, despite having a semiarid

climate, topography gives rise to humid microclimate conditions (Brito-Castillo et al. 2010) that hinder the suspension of pollen in the atmosphere (Table 1). Humidity is a factor that negatively influences the atmospheric pollen concentrations. It may be noted that there is a positive relationship of total pollen and

grasses pollen with average and maximum solar radiation. Temperature is an important parameter since it propitiates the presence of airborne pollen of Poaceae and Chenopodiaceae/Amaranthaceae. *Parkinsonia* does not seem to correlate with any meteorological factor; its high pollen levels may suggest that it blooms in response to other factors; Bowers and Dimmitt (1994) related its flowering to day length and degree-days above 10 °C for northern Sonoran Desert. Indeed, the temperature is not a strong limiting factor at this latitude because the winters are very mild (García, 1973). Precipitation, however, can be decisive for some species. Such is the case of Hurricane Norbert (October 10, 2008) whose rains were followed, a week later, by an increase in pollen concentration of Poaceae, Chenopodiaceae–Amaranthaceae and Asteraceae (Fig. 3), which has implications on the stability of the corresponding pollen seasons (Datta et al. 2012) and therefore, on the seasonal allergies. It is important to continue aerobiological studies in this area to specify these degrees of stability and determine responses of pollen grains dispersion in relation to weather patterns, in order to predict the duration and intensity of pollen seasons. We must consider the fact that at least 20 % of the population in Sonora suffers from some form of allergic reaction (asthma and rhinitis mainly) (Monterverde 2015).

References

- Agroson. (2013). *Red estatal de estaciones meteorológicas de Sonora*. www.agroson.org.mx. Accessed 02 December 2013.
- Ahumada-Valdez, S., Quintero-Núñez, N., García-Cueto, O. R., & Venegas, R. (2009). Annual study of airborne pollen in Mexicali, Baja California, México. *WIT Transactions on Ecology and the Environment*, 123, 173–182.
- Alba-Sánchez, F., Sabariego-Ruiz, S., Díaz de la Guaria, C., Nieto-Lugilde, D., & De linares, C. (2010). Aerobiological behavior of six anemophilous taxa in semi-arid environments of southern Europe (Almería, SE Spain). *Journal of Arid Environments*, 74, 1382–1391.
- Barros, S. (2010). El género *Prosopis*, valioso recurso forestal de las zonas áridas y semiáridas del América, Asia y África. *Ciencia e Investigación Forestal*, 16(1), 91–128.
- Belmonte, J., Cuevas, E., Poza, P., Gonzáles, R., Roure, J. M., Puigdemunt, R., et al. (2010). *Aerobiología y alergias respiratorias de Tenerife*. Ministerio de Medio Ambiente y Medio Rural y Marino, España: Agencia Estatal de Meteorología.
- Bousquet, J., & Khaltaev, N. (2007). *Global surveillance, prevention and control of chronic respiratory diseases: A comprehensive approach. Global alliance against chronic respiratory diseases*. Geneva: World Health Organization Press.
- Bowers, J. E., & Dimmitt, M. A. (1994). Flowering phenology of six woody plants in the northern Sonoran Desert. *Bulletin of the Torrey Botanical Club*, 121, 215–229.
- Bowers, J. E., & Turner, R. M. (2002). The influence of climatic variability on local population dynamics of *Cercidium microphyllum* (foothill paloverde). *Oecologia*, 130, 105–113.
- Brito-Castillo, L., Crimmins, M. A., & Díaz, S. C. (2010). Clima. In F. E. Molina-Freaner & T. R. Van-Devender (Eds.), *Diversidad biológica de Sonora* (pp. 73–96). México: Universidad Nacional Autónoma de México.
- Bronillet, I. (1996). An annual study of airborne pollen in northern Mexico City. *Aerobiologia*, 12(1), 191–195.
- Burch, M., & Levetin, E. (2002). Effects of meteorological conditions on spore plumes. *International Journal of Biometeorology*, 46, 107–117.
- Calderón-Ezquerro, M. C., Fuentes-Rojas, F., Guerrero-Guerra, C., Téllez-Unzueta, F., Martínez-López, B., Calderón-Segura, M. E., et al. (2015). The first airborne pollen calendar and its relationship with bioclimatic factors in Mexico City. *Aerobiologia*. doi:10.1007/s10453-015-9392-4.
- Damialis, A., & Konstantinou, G. (2011). Cereal pollen sensitisation in pollen allergic patients: To treat or not to treat? *European Annals of Allergy and Clinical Immunology*, 43(2), 36–44.
- Datta, K., Chatterjee, A., Nigam, D., Singh, S. P., & Verma, P. C. (2012). Recent scenario of airborne pollens of Lucknow India with special reference to intra and inter annual, diurnal and vertical variation. *Research and Reports in Biodiversity Studies*, 2, 21–22.
- Felger, R., Johnson, M., & Wilson, F. (2001). *The trees of Sonora, Mexico*. New York: Oxford University Press.
- Galán, C., Cariñanos, P., Alcázar, P., & Domínguez-Vilches, E. (2007). *Spanish aerobiology network: Management and quality manual*. Spain: Universidad de Córdoba Press.
- García, E. (1973). *Modificaciones al sistema de clasificación climática de Köppen (para adaptarlo a las condiciones de la República Mexicana)*. México: Universidad Nacional Autónoma de México.
- González-Díaz, S. N., Rodríguez-Ortiz, P. G., Arias-Cruz, A., Macías-Weinmann, A., Cid-Guerrero, D., & Sedo-Mejía, G. A. (2010). Atmospheric pollen count in Monterrey, Mexico. *Allergy Asthma Proceeding*, 31(4), 341–348.
- Ianovici, N., Panaitescu, C. B., & Brudiu, I. (2013). Analysis of airborne allergenic pollen spectrum for 2009 in Timisoara, Romania. *Aerobiologia*, 29, 95–111.
- INEGI. (2010). *Instituto Nacional de Estadística y Geografía*. México: Censo de población y vivienda del Estado de Sonora.
- Izquierdo, R., Belmonte, J., Ávila, A., Alarcón, M., Cuevas, E., & Alonso-Pérez, S. (2011). Source areas and long-range transport of pollen from continental land to Tenerife (Canary Islands). *International Journal of Biometeorology*, 55, 67–85.

- Latorre, F., & Belmonte, J. (2004). Temporal and spatial distribution of atmospheric Poaceae pollen in Catalonia (NE Spain) in 1996–2001. *Grana*, 43, 156–163.
- Lorenzoni-Chiesura, F., Giorato, M., & Marcer, G. (2000). Allergy to pollen of urban cultivated plants. *Aerobiologia*, 16, 313–316.
- Mao, B., Ma, K., Wu, J., Tang, R., Luo, R., Zhang, Y., & Bao, L. (2012). Distribution pattern of allergenic plants in the Beijing metropolitan region. *Aerobiologia*, 29, 217–231.
- Monteverde, A. (2015). Población propensa a alergias en Hermosillo, Sonora. <http://www.uniradionoticias.com/noticias/hermosillo/263464/propenso-a-las-alergias-20-de-la-poblacion-issste.html>. Accessed 27 January 2015.
- Moreno-Grau, S., Angosto, J. M., Elvira-Rendueles, B., Bayo, J., Moreno, J., & Moreno-Clavel, J. (2000). Effects of meteorological parameters and plant distribution on Chenopodiaceae–Amaranthaceae, *Quercus* and *Olea* airborne pollen concentrations in the atmosphere of Cartagena (Spain). *Aerobiologia*, 16(1), 17–20.
- Murray, M. G., Galán, C., & Villamil, C. B. (2008). Aeropalynological research in Salitral de la Vidriera, Buenos Aires province, Argentina. *Aerobiologia*, 24(4), 181–190.
- Nayar, T. S., & Jothish, P. S. (2013). An assessment of the air quality indoor and outdoor air with reference to fungal spores and pollen grains in four working environments in Kerala, India. *Aerobiologia*, 29, 131–152.
- Nitiu, D. S., Mallo, A. C., & Romero, E. J. (2003). Quantitative aeropalynology in the atmosphere of Buenos Aires city, Argentina. *Aerobiologia*, 19, 1–10.
- O'Rourke, M. K. (1986). The implications of atmospheric pollen rain for fossil pollen profiles in the arid southwest. Ph.D. dissertation, University of Arizona, Tucson.
- Orvis, K. H. (1998). Modern surface pollen from three transects across the southern Sonoran Desert margin, northwestern Mexico. *Palynology*, 22, 192–211.
- Rizzi-Longo, L., Pizzulin-Sauli, M., Stravisi, F., & Ganis, P. (2007). Airborne pollen calendar for Trieste (Italy), 1990–2004. *Grana*, 46(2), 98–109.
- Rocha-Estrada, A., Alvarado Vázquez, M. A., Foroughbakhch Pournavab, R., & Hernández Piñero, J. (2009). Polen atmosférico de importancia alergológica en el área metropolitana de Monterrey (Nuevo León, México), durante el periodo marzo 2003: Febrero 2005. *Polibotanica*, 28, 191–212.
- Weather Underground (2014). The Weather Channel, LLC. <http://www.wunderground.com/>. Accessed 14 September 2014.