Water Air Soil Pollut (2016) 227: 435
DOI 10.1007/s11270-016-3124-4

Retention of Atmospheric Particulate by Three Woody Ornamental Species in Santiago, Chile

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Received: 6 July 2016 / Accepted: 18 October 2016 / Published online: 8 November 2016

Abstract It is traditionally accepted that urban vegetation contributes to improve air quality by intercepting and retaining the particulate matter. Although the mitigating role of plants has been recognized by several studies, the role of individual species is still poorly understood. This is particularly important in cities like Santiago (Chile), which has high levels of atmospheric particulate and also has high plant species diversity. In this study, we evaluated the retention of atmospheric particles by three widely distributed ornamental species (*Nerium oleander*, *Pittosporum tobira*, and *Ligustrum lucidum*) in Santiago. For this proposal, we took leaf samples in different sampling points across the city which vary in their concentration of atmospheric particulate. Samples were taken 12 and 16 days after a rainfall episode that washed the leaves of plants in the sampling sites. In the laboratory, leaves were washed to recover the surface retained particles that were collected to determine its mass gravimetrically. With this information, we estimated the foliar retention (mass of particulate matter retained in the foliar surface) and daily retention efficiency (mass of particulate matter retained in the foliar surface per day). We found that foliar retention and daily retention efficiency varied significantly between the studied species. The leaves of *N. oleander* retained 8.2 g m^{-2} of particulate matter on average, those of *P. tobira* 6.1 g m^{-2}, and those of *L. lucidum* 3.9 g m^{-2}; meanwhile, the daily retention efficiencies of particulate matter were 0.6, 0.4, and 0.3 g m^{-2} day^{-1} for *N. oleander*, *P. tobira*, and *L. lucidum*, respectively. These results suggest that the studied species retain atmospheric particulate matter differentially in Santiago. These results can be attributed to differences on leaf surface characteristics. The recognition of the most efficient species in the retention of the atmospheric particulate matter can help to decide which species can be used to improve the air quality in the city.

Keywords Atmospheric particulate · Daily retention efficiency · Foliar retention · Mitigation · PM_{10} · Urban trees

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1 Introduction

Particle emission into the atmosphere is one of the main problems faced by urban development (Gurjar et al.

2008). Home heating, vehicular traffic, and industrial activities (Hertel and Goodsite 2009) produce suspended particles that end up circulating in the cities. Among them, particles with diameters <10 μm (PM_{10}) and <2.5 μm ($PM_{2.5}$) have attracted special attention because, regardless of their chemical nature, they can enter into the respiratory system and cause harmful effects to human health (Bernstein et al. 2004; Jimoda 2012).

Although it is traditionally accepted that urban vegetation contributes to mitigate the air pollution by intercepting atmospheric particulate matter (e.g., Yang et al. 2005; Nowak et al. 2014), few studies have advanced in understanding how different plant species contribute to retain these particles (e.g., Prusty et al. 2005; Qiu et al. 2009; Wang 2011; Wang et al. 2013). Some studies have shown that the diversity and complexity of the canopy (Beckett et al. 2000), as well as the characteristics of the leaves surface (e.g., trichomes, rugosities, and secretions; Wang et al. 2011; Liu et al. 2012; Saebo et al. 2012), favor the interruption of air flow, leading to greater retention of particles at the foliar level (Leung et al. 2011). Therefore, it is estimated that urban trees can be capable of retaining between 100 and 61,500 t year^{-1} of atmospheric particles (Yang et al. 2005; Nowak et al. 2014).

Santiago City, the capital of Chile, is one of the cities with the highest concentration of atmospheric particulate in America (WHO 2016), including the PM_{10} and $PM_{2.5}$ fractions, which can reach average annual concentrations of 64 and 29 μg m^{-3} day^{-1}, respectively (WHO 2016). The weather and geographic characteristics of Santiago prevent adequate atmospheric ventilation, causing the emissions produced in the city to be retained at low altitude and to recirculate as particulate matter (Garreaud and Rutllant 2006). The Chilean environmental agency "Ministerio del Medio Ambiente" has implemented a Plan for Prevention and Atmospheric Decontamination (see SINIA 2010), which includes ten air quality monitoring stations in the urban area of Santiago; the information acquired by those stations is reported through the National System of Air Quality Information (Sistema de Información Nacional de Calidad del Aire, SINCA). These stations are located in different sites within the city recording real-time atmospheric concentration of PM_{10} (SINCA 2014).

At the same time, the Plan for Prevention and Atmospheric Decontamination promotes the creation and maintenance of green areas in Santiago with the purpose of reducing the amount of breathable particles (SINIA 2010). Although recent modeling-based estimations suggest that the plant cover in Santiago may retain between 1.0 and 2.7% of atmospheric particulates (Escobedo et al. 2008; Escobedo and Nowak 2009), there are no empirical studies that have assessed the particle retention by different plant species. Therefore, in the present study, we evaluated particle retention by leaves in three woody species in Santiago (*Nerium oleander* L., *Pittosporum tobira* (Thunb.) W.T. Aiton, and *Ligustrum lucidum* W.T. Aiton). These species are abundant and widely distributed as ornamental plants in the city (Figueroa et al. 2016). Thus, foliar particulate matter retention (g m^{-2}) and daily retention efficiency (g m^{-2} day^{-1}) of atmospheric particulate matter were measured in the field for the three species. For this proposal, we implemented a sampling design around SINCA stations in order to control the spatial heterogeneity of the concentration of breathable atmospheric particles (i.e., PM_{10}).

2 Methodology

2.1 Study Area

Santiago (33° 26′ 16″ S–70° 39′ 01″ W; Fig. 1) covers an area of 827 km^2, with 6.4 million inhabitants (INE 2015). The city is located in a longitudinal valley between two mountain ranges (the Andes and the Coastal Range), at an average altitude of 520 m above sea level. The climate is Mediterranean, characterized by an extended warm and dry season, and a colder and rainy winter, with an average annual temperature of 14 °C and precipitation of 356 mm year^{-1} on average (Luebert and Pliscoff 2006).

Administratively, Santiago is divided into 37 districts. Ten districts in Santiago are included into the SINCA (Sistema de Información Nacional de Calidad del Aire) network because they have monitoring stations recording the air quality. Here, we named the stations according to the district in which the monitoring point is located (Fig. 1). The SINCA stations are located mainly (but not exclusively) in residential neighborhoods (see Fig. 1), both in the center (2 stations: Parque O'Higgins and Independencia) and in the urban periphery (8 stations: Quilicura, Cerro Navia, Pudahuel, Cerrillos, El Bosque, Puente Alto, La Florida, and Las Condes). The stations record atmospheric concentration of PM_{10} data, whose emission source comes mainly from traffic flow and industrial processes. Thus, the

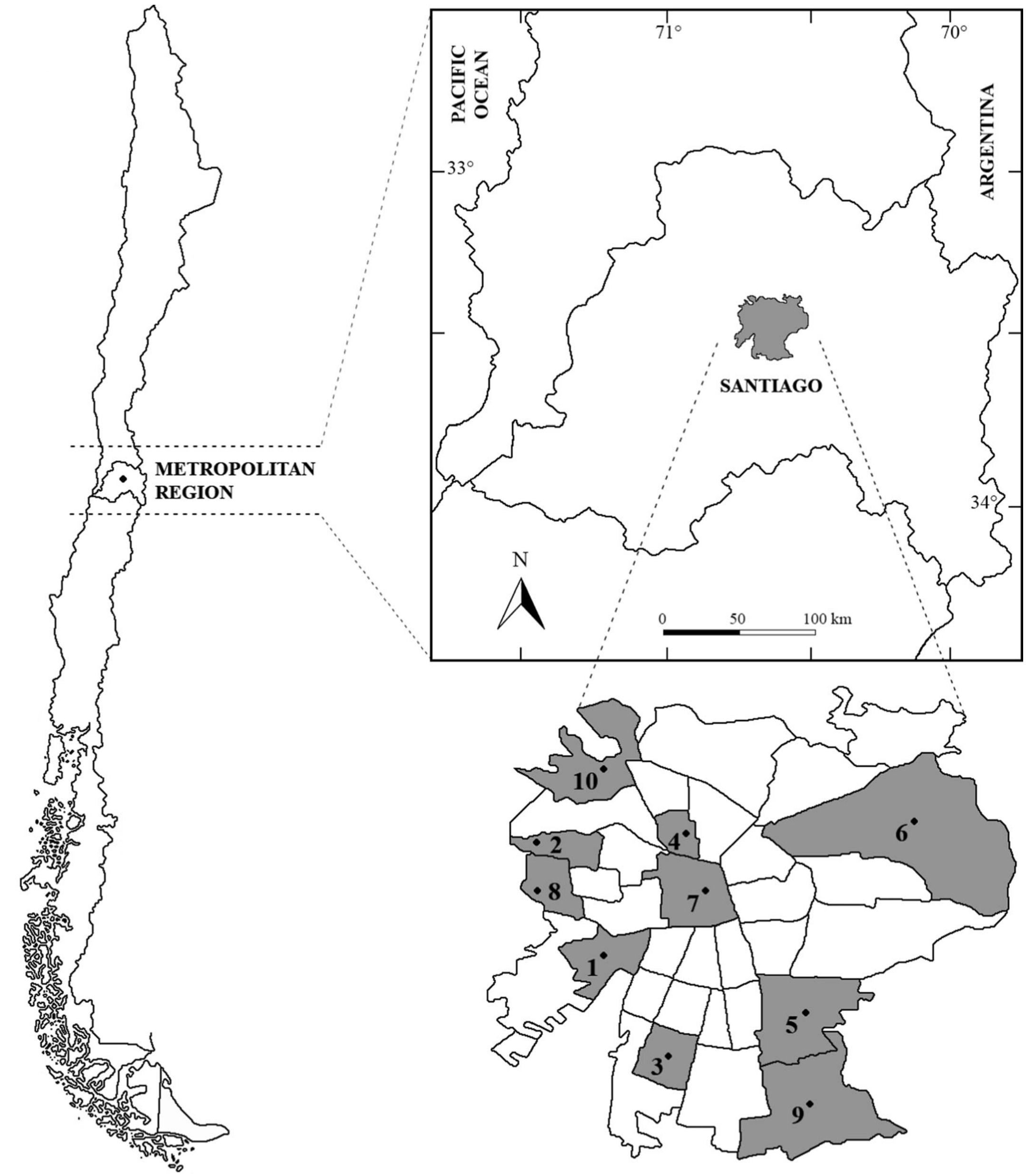

Fig. 1 Geographical location of the city of Santiago and of the air quality monitoring stations (SINCA network) in the city. The stations have been numbered in alphabetical order. 1 Cerrillos, 2 Cerro Navia, 3 El Bosque, 4 Independencia, 5 La Florida, 6 Las Condes, 7 Parque O'Higgins, 8 Pudahuel, 9 Puente Alto, 10 Quilicura

atmospheric particulate may diffuse across the air and then be deposited on the foliar surface of plants.

2.2 The Species

We studied three woody species in Santiago: *N. oleander* (Apocynaceae), *P. tobira* (Pittosporaceae), and *L. lucidum* (Oleaceae high plant species diversity); all chosen species are widely distributed in Santiago as exotic ornamental plants (Figueroa et al. 2016). Nevertheless, none of these species has been recorded as escaped or naturalized in Chile (Figueroa et al. 2016). The native range for the three species includes Asia, although *N. oleander* is also distributed in Europe (Polunin 1991). In Santiago, *N. oleander*, *P. tobira*, and *L. lucidum* have been planted in public spaces such as streets, avenues, squares, and parks for urban ornamentation purposes (Figueroa et al. 2016). Species are woody plants, which can grow as shrubs and/or trees. However, in the present study, the analyzed individuals were shrubs, except for *L. lucidum* which were trees. Interestingly, these plant species differ in their foliar characteristics because *N. oleander* has a rough leaves surface with microfolds, crypts, and furrows (Pal et al. 2002), *L. lucidum* has smooth leaves (Wang et al. 2015), whereas *P. tobira* has leaves with small folds in the surface (Wang et al. 2011).

2.3 Sampling

The sampling was carried out during August 2014 (southern winter), one of the months in which atmospheric particulates reach the highest concentrations of the year in Santiago (Garreaud and Rutllant 2006). Samples were obtained from *N. oleander*, *L. lucidum*, and *P. tobira* specimens found within a radius of 500 m around the monitoring stations of the SINCA network; thus, these sites were named according to the nearest monitoring station (Table 1). The sampled sites were sidewalks of streets located in residential neighborhoods. *N. oleander* and *L. lucidum* were present in all the sites, whereas *P. tobira* was present around only seven stations (Table 1). The sampling was implemented between 12 and 16 days after a rainfall that washed the leaves (Qiu et al. 2009).

At each sampling site, five leaves were collected from each plant. We sampled three individuals per species, totaling 150 leaves of *N. oleander* (5 leaves × 3 plants × 10 sites), 150 leaves of *L. lucidum* (5 leaves × 3 plants × 10 sites), and 105 leaves of *P. tobira* (5 leaves × 3 plants × 7 sites). Only nonsenescent and completely extended leaves were gathered, all of them sampled between 1.5 and 2.0 m above the ground. Once collected, leaves were stored separately in hermetic polyethylene bags (9 × 18 cm), which were duly labeled and taken to the laboratory.

2.4 Evaluation of Particulate Retained by the Leaves

The mass of the particulate present on the surface of each leaf was determined by the gravimetric method. For this purpose, leaves were removed carefully from the bags and immersed in 50 mL of deionized water in Petri dishes covered with aluminum foil of known weight. The particles adhered to the surface of leaves were removed mechanically brushing the surface of the leaves for 5 min. Remnant matter in the bags was also retrieved by washing and then collected in a Petri dish. The water on each dish was then evaporated in an oven at 60 °C for 48 h, and the aluminum foil with the retrieved particles was weighed on analytical balance (precision ± 0.1 mg). Finally, the area of the washed leaves was measured with a scanner (cm), using the ImageJ program (version 1.48, National Institutes of Health, USA). The obtained values were converted to gram (g) and square meters (m^2) to make them comparable with the results of others studies.

Table 1 Foliar retention ($\overline{X}$ ± S.D.; g m^{-2}) and daily retention efficiency ($\overline{X}$ ± S.D.; g m^{-2} day^{-1}) for *N. oleander*, *P. tobira*, and *L. lucidum*. Additionally, it indicated the atmospheric concentration of PM_{10} ($\overline{X}$ ± S.D.; μg m^{-3}) in the SINCA stations

Site	Atmospheric (PM_{10})[a]	Mass of particulates retained			Daily retention efficiency		
		N. oleander	*P. tobira*	*L. lucidum*	*N. oleander*	*P. tobira*	*L. lucidum*
Cerrillos	75.6 ± 27	8.4 ± 4	3.4 ± 1	5.0 ± 3	0.6 ± 0.3	0.2 ± 0.1	0.4 ± 0.2
Cerro Navia	95.2 ± 34	9.8 ± 4	–	3.1 ± 1	0.8 ± 0.3	–	0.2 ± 0.1
El Bosque	83.4 ± 29	8.3 ± 3	5.8 ± 1	4.1 ± 1	0.6 ± 0.2	0.4 ± 0.1	0.3 ± 0.1
Independencia	79.9 ± 19	5.0 ± 4	–	3.5 ± 1	0.4 ± 0.3	–	0.3 ± 0.1
La Florida	80.9 ± 20	8.4 ± 6	–	4.9 ± 2	0.6 ± 0.4	–	0.3 ± 0.1
La Condes	54.8 ± 12	4.2 ± 1	7.8 ± 7	3.3 ± 1	0.3 ± 0.1	0.5 ± 0.4	0.2 ± 0.1
Parque O'Higgins	93.9 ± 34	7.8 ± 5	6.6 ± 5	2.0 ± 0.4	0.7 ± 0.4	0.5 ± 0.4	0.2 ± 0.03
Pudahuel	100.7 ± 41	13.4 ± 5	5.5 ± 4	4.4 ± 2	1.0 ± 0.4	0.4 ± 0.3	0.3 ± 0.1
Puente Alto	76.3 ± 19	6.8 ± 3	6.4 ± 6	3.1 ± 1	0.5 ± 0.2	0.4 ± 0.4	0.2 ± 0.1
Quilicura	113.6 ± 53	9.9 ± 4	7.4 ± 8	5.9 ± 2	0.7 ± 0.3	0.5 ± 0.6	0.4 ± 0.2

[a] Source: http://sinca.mma.gob.cl/

In order to determine differences in the retaining capacity for the species, we estimated the foliar retention and the daily retention efficiency. The foliar retention was calculated as follows: $(M_f - M_i) \cdot A^{-1}$, where M_f is the mass of the aluminum foil together with the particulate recovered from the leaves (g), M_i is the mass of the clean aluminum foil (g), and A is the area of the leaf surface (m^2); thus, the foliar retention was expressed in grams per square meter. The daily retention efficiency was determined as follows: $(M_f - M_i) \cdot A^{-1} \cdot D^{-1}$, where D is the number of days lapsed between the rainy day and the sampling day (between 12 and 16 days); the efficiency units were expressed as grams per square meter per day.

2.5 Statistical Analysis

To compare foliar retention and daily retention efficiency, two separated bifactorial covariance analyses (ANCOVA) were performed. In the first one, the foliar retention was used as a dependent variable (log-normalized) and the plant species (with three levels: *N. oleander*, *P. tobira*, and *L. lucidum*) and sampling sites (with ten levels: ten SINCA stations) were used as independent factors. In a second ANCOVA, the daily retention efficiency was the dependent variable (log-normalized) and the plant species and the sampling sites were the independent factors, using the same level distribution as in the previous analysis. In order to control the effect of the spatial heterogeneity of the atmospheric particulate concentration on foliar retention and daily retention efficiency, the atmospheric concentration of PM_{10} ($\mu g\ m^{-3}$) at each sampling site (reported by the SINCA network) was included as a covariate in both analyses. Specifically, we used the average concentration for PM_{10} recorded between the rainy day and the sampling day (12 and 16 days). The Tukey post hoc test was used to recognize differences between treatments.

3 Results

The average mass of particulate matter retained by the leaves of *N. oleander* varied between 4.2 and 13.4 $g\ m^{-2}$ (Table 1), whereas the daily retention efficiency ranged between 0.3 and 1.0 $g\ m^{-2}\ day^{-1}$ (Table 1). On the other hand, *P. tobira* showed a foliar retention of particulate matter between 3.4 and 7.8 $g\ m^{-2}$ (Table 1), with daily retention efficiency between 0.2 and 0.5 $g\ m^{-2}\ day^{-1}$ (Table 1). Finally, *L. lucidum* showed a foliar retention of 2.0 and 5.9 $g\ m^{-2}$ and an efficiency of 0.2 and 0.4 $g\ m^{-2}\ day^{-1}$ (Table 1). Overall, the average mass of atmospheric particulate retained by *N. oleander*, *P. tobira*, and *L. lucidum* was 8.2, 6.1, and 3.9 $g\ m^{-2}$, respectively (Fig. 2a), while the daily retention efficiency was 0.6, 0.4, and 0.3 $g\ m^{-2}\ day^{-1}$, respectively (Fig. 2b).

Controlling the effect of the spatial heterogeneity of the atmospheric particulate as a covariate, our analyses showed a significant effect of the "species" factor on the mass of atmospheric particulate retained by the plant leaves (ANCOVA; $F = 81.6$, gl = 2, $P < 0.001$), with significant statistical differences between the three species (Tukey test; $D = 3.3$, $P < 0.001$). Similarly, a significant effect of "species" factor was recognized analyzing the daily retention efficiency among the studied species (ANCOVA; $F = 81.5$, gl = 2, $P < 0.001$; Tukey test, $D = 3.3$, $P < 0.001$).

We compiled values of foliar retention and daily retention efficiency from literature data, for several plant species (Table 2). For comparative proposals, we transformed the original results of foliar retention and daily retention efficiency in units as grams per square meter and grams per square meter per day, respectively. Thus, considering the ranges for foliar retention and daily retention efficiency (i.e., 0.04–4.5 $g\ m^{-2}$ and 0.02–0.9 $g\ m^{-2}\ day^{-1}$, respectively; Table 2), the obtained values for the three species studied in Santiago were in the upper portion of the documented range (see Table 2).

4 Discussion

Our results show significant differences in the foliar retention and daily retention efficiency by leaves of *N. oleander*, *P. tobira*, and *L. lucidum*. Previous studies have shown that the retention of atmospheric particulate varies among species (e.g., Prusty et al. 2005; Wang 2011; Wang et al. 2011, 2013) and that the morphology of the leaf surface is one of the main attributes that explain those differences (e.g., Beckett et al. 2000; Qiu et al. 2009; Liu et al. 2012; Saebo et al. 2012). Our study is not an exception to that pattern, because *N. oleander* (the species with the highest foliar retention and daily retention efficiency) has a rough leaf surface with microfolds, crypts, and furrows (Pal et al. 2002), in contrast with the smooth leaves of *L. lucidum* (the species with the lowest values of foliar retention and

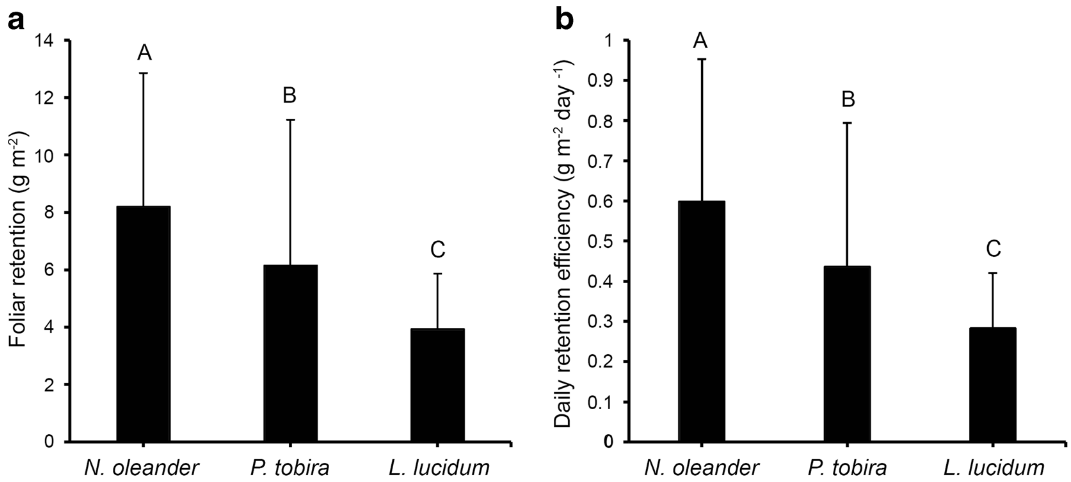

Fig. 2 Retention of atmospheric particulates by the leaves of the plants. **a** Foliar retention ($\overline{X}$ ± S.D.; g m^{-2}). **b** Daily retention efficiency ($\overline{X}$ ± S.D.; g m^{-2} day^{-1}). The *letters* on the bars indicate significant differences between the species (Tukey test; $D = 3.3$)

daily retention efficiency), which do not represent an obstacle for the wind to clean the leaf's lamina (Wang et al. 2015). *P. tobira* has intermediate values of foliar retention and daily retention efficiency due to the existence of small folds in its leaves (Wang et al. 2011).

Comparing our data with previous studies on *P. tobira* and *L. lucidum* in the city of Xi'an (information for *N. oleander* is not available), we concluded that in Santiago the retention efficiency of both species was lesser than the one informed in the Xi'an study: 0.3 (Santiago) versus 0.8 (Xi'an) g m^{-2} day^{-1} for *P. tobira* and 0.4 (Santiago) versus 0.9 (Xi'an) g m^{-2} day^{-1} for *L. lucidum* (Wang et al. 2011). This may be related to differences in the concentration of atmospheric particulate between both cities. Indeed, according to WHO (2016), in Santiago, the annual average of atmospheric particulate reaches 64 μg m^{-3} day^{-1} whereas in Xi'an 189 μg m^{-3} day^{-1} (WHO 2016). However, the values for foliar retention and daily retention efficiency recorded in our study were within the range reported for other species (see Prusty et al. 2005; Qiu et al. 2009; Wang 2011; Liu et al. 2012).

To establish the contribution of each species to the mitigation of urban atmospheric pollution in cities is an important challenge. Several factors can affect the retention capacity of atmospheric particles by different plant species. Some of those factors are the foliar structure (Liu et al. 2012; Saebo et al. 2012), the complexity of foliage (Beckett et al. 2000), the rate of leaves turnover (Wang et al. 2013), the plant cover (Nowak et al. 2006, 2014; Bealey et al. 2007; Escobedo and Nowak 2009), and the species composition (Saebo et al. 2012). Using available information for Santiago, we carried out a preliminary approach in order to estimate the contribution of *N. oleander*, *P. tobira*, and *L. lucidum* on the atmospheric particle matter removal. According to Escobedo and Nowak (2009), a woody cover (including tree and shrubs) reaches 463 km^2 as an average; assuming that the cover representation of *N. oleander*, *P. tobira*, and *L. lucidum* reaches 11% per species in Santiago (see Figueroa et al. 2016), our estimations suggest that *N. oleander*, *P. tobira*, and *L. lucidum* might contribute to the atmospheric mitigation retaining 13.2, 8.8, and 6.6 t day^{-1}, respectively. These is a coarse and simplified calculation, because of considerate lacks from a greater number of factors and information, whose role as mitigating agents has not been empirically determined yet in Santiago (emission rates, leaves turnover, rainfall, wind, temperature, etc.). However, this example leads to recognize the potential impact of the studied species on the mitigation of urban atmospheric pollution in Santiago.

Studies attempting to evaluate the role of urban plants in the retention of atmospheric particulate and their effects on the improvement of air quality are methodologically heterogenous (see Beckett et al. 2000; Qiu et al. 2009; Liu et al. 2012; Saebo et al. 2012) and therefore hard to compare to each other. However, the currently available data suggests that woody plants have a reduced effect on atmospheric

Table 2 Foliar retention (g m^{-2}) and daily retention efficiency (g m^{-2} day^{-1}) by species documented for different cities

Species	Foliar retention		Town	Source
	$\overline{X} \pm$ SD	$\overline{X}$ day^{-1}		
Quisqualis indica	0.04 ± 0.05	0.04	Sambalpur	Prusty et al. 2005
Ficus benghalensis	0.1 ± 0.01	0.05	Sambalpur	Prusty et al. 2005
Ficus religiosa	0.1 ± 0.1	0.1	Sambalpur	Prusty et al. 2005
Pongamia pinnata	0.1 ± 0.1	0.1	Sambalpur	Prusty et al. 2005
Tabernaemontana divaricata	0.2 ± 0.1	0.2	Sambalpur	Prusty et al. 2005
Ipomoea carnea	0.2 ± 0.2	0.2	Sambalpur	Prusty et al. 2005
Bauhinia blakeana	0.4 ± 0.1	0.02	Huizhou	Qiu et al. 2009
Ficus microcarpa	0.6 ± 0.2	0.03	Huizhou	Qiu et al. 2009
Ficus virens	0.8 ± 0.3	0.04	Huizhou	Qiu et al. 2009
Ficus altissima	1.0 ± 0.3	0.05	Huizhou	Qiu et al. 2009
Bauhinia blakeana	1.0 ± 1.1	0.04	Guangzhou	Liu et al. 2012
Berberis thunbergii	1.2 ± 0.2	0.2	Xi'an	Wang et al. 2011
Ficus microcarpa	1.4 ± 1.4	0.05	Guangzhou	Liu et al. 2012
Ligustrum quihoui	2.0 ± 0.6	0.4	Xi'an	Wang et al. 2011
Ficus virens	2.2 ± 2.5	0.1	Guangzhou	Liu et al. 2012
Cercis chinensis	2.3 ± 0.3	0.5	Xi'an	Wang et al. 2011
Ginkgo biloba	2.4 ± 0.5	0.5	Xi'an	Wang et al. 2011
Sophora japonica	2.5 ± 0.6	0.5	Xi'an	Wang et al. 2011
Prunus serrulata	2.6 ± 0.5	0.5	Xi'an	Wang et al. 2011
Buxus sinica	3.0 ± 0.8	0.6	Xi'an	Wang et al. 2011
Cedrus deodara	3.9 ± 0.4	0.8	Xi'an	Wang et al. 2011
Ligustrum lucidum	3.9 ± 1.2	0.3	Santiago	Present study
Mangifera indica	4.0 ± 5.8	0.1	Guangzhou	Liu et al. 2012
Viburnum odoratissimum	4.1 ± 0.8	0.8	Xi'an	Wang et al. 2011
Ligustrum lucidum	4.2 ± 1.5	0.8	Xi'an	Wang et al. 2011
Pinus tabuliformis	4.4 ± 0.9	0.9	Xi'an	Wang et al. 2011
Platanus acerifolia	4.5 ± 0.7	0.9	Xi'an	Wang et al. 2011
Pittosporum tobira	4.5 ± 1.4	0.9	Xi'an	Wang et al. 2011
Pittosporum tobira	6.1 ± 1.4	0.4	Santiago	Present study
Nerium oleander	8.2 ± 2.6	0.6	Santiago	Present study

pollution mitigation, which usually does not exceed 1% of the annual particulate emissions (e.g., Nowak et al. 2006; Escobedo and Nowak 2009). Nevertheless, this contribution may be higher depending on the increase of the woody cover and the use of more efficient mitigator plants (Yang et al. 2005; Escobedo et al. 2011; Leung et al. 2011). In fact, Bealey et al. (2007) estimated that in Wolverhampton (UK), the average of annual retention of PM_{10} could reach 8% in areas having 25% of plant cover and up to 22% if 100% of the city's area potentially available for ornamental plantation were planted, while Escobedo and Nowak (2009) estimated that only the trees in Santiago may retain up to 6.1% of the emitted annual atmospheric PM_{10}, considering 100% plant coverage of the available ornamental space. In Santiago City, green areas are scarce (<4 m^2 green area per inhabitant; Reyes and Figueroa 2010), so there is a potential to increase the green coverage of these spaces, in order to reduce the levels of atmospheric particulates (SINIA 2010). Nevertheless, rapid urban spread and population growth has not gone together with the creation of new plant-covered areas (Escobedo et al. 2011).

In summary, our results show the differential contribution of three ornamental species in the reduction of atmospheric particulates in the city of Santiago, Chile. *N. oleander* is the most efficient species, followed by *P. tobira* and *L. lucidum*. Those differences are probably associated with their foliar characteristics. Although the atmospheric mitigating effect of particle matter retention by plants may be currently considered small, an increased plant coverage combined with a program for selecting more efficient species might contribute to significantly improve urban air quality.

Acknowledgments The authors gratefully acknowledge the support of the Center for the Development of Nanoscience and Nanotechnology, CEDENNA FB0807 – Line 6, DICYT 021543CM, USA 1498.04 and CORFO 13IDL2-18665.

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