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Mineral contents in leaves of *Morus alba* L. (Moraceae) and *Platanus hispanica* Miller (Platanaceae) from the urban forests of central-western area of Argentina.

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ABSTRACT

The returning of mineral contents and organic matter to the soil as litterfall is one of the most essential ecological process that contributes to the nutrient cycles and provides enough nutrients to plants for a healthy growth. The fallen leaves from urban forests of the cities of San Juan and Mendoza, Argentina are frequently collected especially during the autumn season with a loss of great quantity of litterfall every year. High amounts of nutrients and organic matter are exported from the urban ecosystem without completing the mineral nutrient cycle. The aim of this work is to evaluate the variation in foliar mineral and organic matter contents along seasons (spring, summer and autumn) for the two most abundant non-native species: *Morus alba* and *Platanus hispanica* located in the urban forests of the central-western part of Argentina, and the effect of the periodical leaf removal in urban areas. Differences in mineral and organic matter contents were found along the seasons. Foliar concentration losses follow the order of magnitude: N > Mg > P>K > Na. This research is a contribution to a more adequate understanding of the urban ecosystem patterns and dynamics, and it means to be helpful in the management and conservation practices of urban ecosystems.

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Urban forests; mineral; seasons; management practices

Introduction

The annual returning of mineral contents and organic matter to the soil as litterfall is the principal source of fertility of soils (McHargue and Roy 1932) and the main way of nutrient recycling in the forest ecosystems (Santa Regina and Gallardo 1985). This natural feedback is one of the most essential ecological process that contributes to the nutrient cycles (Laskowski and Berg 1993; Santa Regina and Gallardo 1985), and provides enough nutrients to plants for a healthy growth keeping the equilibrium among soil, vegetation and the environment (Hobbie and Vitousek 2000; Kavvadias et al. 2001).

Urban trees are one of the main components of urban ecosystems and provide benefits that improve the quality of life in cities (Konijnendijk 2008; McPherson et al. 1997; Nowak, Crane, and Stevens 2006;Peckham, Duinker, and Ordóñez 2013; Reyes Avilés and Gutiérrez Chaparro 2010), helping to moderate seasonal temperatures (Solecki et al. 2005) especially in arid or semi-arid areas. Most of the information about trees, their biology and environmental interactions, comes from the study of these plants in non-urban environments (Högberg et al. 2001; Lal 2005; Pandey et al. 2007), but the interactions between urban development patterns and ecosystem dynamic are still poorly understood (Alberti 2005; Byrne 2007). Macro-elements and trace elements are essential for the plant life, and deficiencies affect the structure and functions of plants (Clarkson and Hanson 1980; Killingbeck 1996; Schulze, Beck and Müller-Hohenstein 2002). Nitrogen is the nutrient required in the largest quantity after carbohydrates, being essential in amino acids and nucleic acid composition (Hoch 2015; Millard and Grelet 2010; Palacio et al. 2014; Schulze, Beck and Müller-Hohenstein 2002). Magnesium is the central component of the chlorophyll molecule, and fluctuations in its levels in the chloroplast regulate the activity of key photosynthetic enzymes (Shaul 2002). Potassium is another essential element involved in inorganic plant nutrition as an enzyme activator in the photosynthesis and respiration processes (Bhandal and Malik 1988). Sodium has a very specific function in the concentration of carbon dioxide and it can replace potassium when deficiency is evidenced (Brownell 1980; Subbarao et al. 2003). Phosphorus is essential in supplying phosphate in several physiological processes, being the main component of the ATP-ADP molecules (Clarkson and Hanson 1980). A detailed study about mineral and nitrogen contents in more than twenty species of trees along the growing season was conducted several decades ago by McHargue and Roy (1932). Watkins (1998) conducted

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Figure 1. Map showing the location of the city of San Juan and Mendoza in the central-western part of Argentina.

a research about nutrition and fertilization in species from the urban forestry. Nevertheless, information about leaf mineral contents and organic matter dynamic in urban ecosystems is still scarce, and a better knowledge of the biogeochemical process in urban green areas will improve the understanding of the urban ecosystem dynamic (Pataki et al. 2011).

Human activities are increasingly influencing biogeochemical cycles at a global scale (Vitousek et al. 1997; Wright 2005) including the nutrient cycles in urban ecosystems (Kaye et al. 2006). The litterfall breakdown releases nutrients that make the organic matter available to plants and microorganisms, thereby completing the nutrient cycles in natural forest ecosystems (Gessner and Chauvet 2002; Vitousek and Sanford 1986). However, this natural process is quite different in urban ecosystems where the mineral and organic elements accumulated in the fallen leaves are periodically removed from the cities, and high amounts of nutrients and organic matter are exported from the urban ecosystem every year without completing the cycle (Lorenz and LAL 2009). Trees in urban ecosystems are often adversely impacted by leaf removal, which results in a loss of primary storage site for organic matter and nutrients in the soil profile (Mader and Cook 1982). In the cities of San Juan and Mendoza, the litterfall removal is a frequent activity because of the daily leaf collection by sweeping, together with the uncontrolled pruning performed every year in the winter season that contributes to the loss of a considerable amount of litterfall. This fact supports the idea that the mineral, nitrogen and carbon contents in trees located along the streets of urban forests of central-western Argentina will have lower values compared to urban parks forested with the same species and where litterfall is occasionally removed. *Morus alba* and *Platanus hispanica* are two of the most abundant species in urban forests of central-western Argentina. Various studies about these arboreal species have been published over the last two decades (Adams et al. 1990; Dávila et al. 2006; Ercisli and Orhan 2007; Kandylis, Hadjigeorgiou, and Harizanis 2009; Moreno et al. 2008; Perry and Hickman 2001; Velázquez-Martí, Sajdak, and López-Cortés 2013) but there is still a lack of information about seasonal variation in mineral content and management practices in urban ecosystems, and more research is needed.

The aim of this work is to evaluate and evidence the variation in foliar mineral and organic matter contents along the seasons (spring, summer and autumn) for the most abundant non-native species: *M. alba* and *P. hispanica* located in the urban forests of the central-western part of Argentina and to study the effect of the periodical litterfall removal in the urban ecosystem. We expect to find seasonal differences specially between spring and autumn when the leaves are ready to fall and be part of the litter.

Material and methods

Study site

The central-west part of Argentina includes both the cities of Mendoza and San Juan (Figure 1). The area is a semi-desert where urban forests are constituted almost exclusively by non-native trees located along the sidewalks together with trees located in urban parks near to the cities. Urban trees are watered through artificial irrigation systems (ditches) with approximately 10–12 trees per block. The most abundant species present in these cities are *Morus alba* and *Platanus hispanica*. *Morus alba* is a monoecious and deciduous species with leaves alternate, serrated or lobate with laticifers and milky sap. *Platanus hispanica* is a monoecious and deciduous species with alternate and simple leaves (Judd et al. 2002).

The urban studied area is an inter-mountain valley surrounded by high mountains. The climate is arid to semi-arid, and daily mean maximum temperatures ranges from 43° C in the summer to -9° C in the winter, and the average relative humidity is around 43% (Norte 2000). Rainfall ranges from 100 to 200 mm yearly (in the summer season) and dry west wind occurs in the winter and spring seasons (Servicio Meteorológico Nacional

1981). During the development of this project the mean precipitation values recorded for the urban areas was approximately 7.5 mm/monthly (Servicio Meterológico Nacional unpublished data). Urban soils are immature and mainly characterized by silt, clay and a lacking of the organic matter-enriched horizon (INTA (Instituto Nacional de Tecnología Agropecuaria) 1976). Sidewalks are covered with cement except for an area of about a 2–4 m^2 where trees can grow up, and the water table is located approximately at 30 to 50 m depth (INA (Instituto Nacional del Agua), CRAS (Centro Regional de Aguas Subterráneas) 2000).

Leaf sampling

The mean dry matter for each tree was estimated using a non-damage expeditious methodology that was especially developed for the purpose of this work. Fresh leaf samples were collected from urban forests (trees along the sidewalks) and also from trees located in urban parks near to the cities where the soil, watering and climate conditions were similar to the urban forests, but with occasional litter removal. Forty trees of *Morus alba* and 40 trees of *Platanus hispanica* (30–40 years old) were randomly selected and sampled, during the spring, summer and autumn seasons. Leaf samples were taken as follows. A total of four dry matter samples (around 500 to 1000 g of fresh weight) for each tree were hand collected following a perpendicular axis (in reference to the street): two of the samples were collected closer to the trunk (inner) and the other two samples were collected from the peripheral area (outer). During the sampling, a rectangular frame (surface=2.500 cm^2) was used to collect all the leaves from the base up to the mid part of the crown for each tree. This kind of sampling was chosen and performed according to the heterogeneous distribution of the foliage observed in the trees, and this sampling is independent from the distribution of leaves exposed to sun or shadow along the tree. All fruits of *P. hispanica* were also picked up in one quarter of the plants during the spring season when they reached the maturity, and the total fruit harvest was estimated to analyze the mineral and organic element contribution of fruits. *Morus alba* trees do not produce mature fruits, only flower develop and then fall at the beginning of the spring season.

Morphometric information such as total height, timber height (breast height), timber diameter, and crown diameter was recorded for all the plants and the mean values were calculated for the determination of a mean tree. Crown volume for each tree was estimated using the recorded morphometric measurements and the ellipsoidal shape formula for *M. alba*, and the truncate cone shape formula for *P. hispanica* (Vento 2003).

The allometric relationship (p=0.01) between crown volume and each morphometric measure was obtained using a linear regression model to select the best foliage volume estimator. Crown height was the best estimator used for calculation of crown volume values. The combination of mean crown volume values and mean dry matter volumes obtained from the four leaves samples per tree allowed us to estimate the mean dry matter for each tree and later, to calculate the mean tree volume of dry matter of a typical urban tree.

Chemical determinations and statistical analysis

Urban trees were randomly selected in four sections of the cities (North, South, East and West sections), and trees located in urban parks were also sampled. Ten leaf samples (around 250–300 g fresh weight) of *Morus alba* and *Platanus hispanica* were hand collected from September 2001 to April 2002. Two samples were closer to the trunk and the other eight samples were collected from the peripheral area of the crown to compensate the heterogeneous foliage distribution. The leaves were collected at three different moments throughout the year: spring (September–December), summer (December–March) and autumn (March–June). Fruits from *P. hispanica* were collected, but not from *M. alba* because all trees are clones. Leaves and fruits were dried in a drying oven at 80 °C until reaching constant weight and after that they were milled. Additionally, ten homogenized random soil samples were collected to identify the soil condition. The extraction procedure consisted of making a pit of approximately 80 cm deep using a shovel and taking a soil sample of around 1.5 to 2 kg. Areas with residual water elimination systems were selected and samplings were made away from seasonal rains to prevent the influence of mineral contents on the samples.

Chemical determinations for leaves, fruits and soils were made according to the official methods of analysis (A.O.A.C 1975) as follow: ash (by calcination method using a muffle furnace), potassium (Pratt 1965), phosphorus by UV-visible spectrophotometry, sodium by wavelength spectrophotometry, magnesium by atomic absorption spectrophotometry (AAS), total nitrogen by digestion and distillation using Kjeldahl method (Kjeldahl 1883), organic matter, according to Walkley-Black (1934) and carbon (by using a constant factor from the organic matter).

The statistical analysis was performed using a statistical package (StataCorp 2003). The relationship between the mean dry matter for each tree and the seasonal contents of mineral elements such as Potassium (K), Sodium (Na), Mg (Magnesium) together with C (Carbon) and N (Nitrogen) values was analyzed using MANOVA ($p<0.01$). Homogeneity of variance (Sokal and Rohlf 1979) was verified ($p<0.05$) using Levene's test and the normality on data distribution was tested using the Kolmogorov-Smirnov and Square Chi tests. The data that had not a normal distribution were transformed as follows: in *M. alba*, for K using the Log_{10} function, for K using the arc function, and for Na using the Log_{10}

Table 1. *Morus alba*: mean seasonal contents and variance values in leaf dry matter samples (mg/kg DM) using MANOVA (p<0.01). Same letters (a, b, and c) in a row show no statistical differences according to Tukey's test.

	Spring	Summer	Autumn
Ash	165.9 ± 42.2 **a**	223 ± 40.4 **b**	254.8 ± 25.9 **c**
Organic matter	834.1 ± 42.2 **a**	776.9 ± 40.4 **b**	745.1 ± 25.9 **c**
C	483.8 ± 2.4 **a**	450.6 ± 2.3 **b**	432.2 ± 15 **b**
N	21 ± 6,1 **a**	18 ± 3.9 **b**	13.6 ± 3.4 **b**
K	0.4 ± 0.16 **a**	0.6 ± 0.19 *ab*	0.67 ± 0.49 **b**
Na	0.02 ± 0.006 **a**	0.02 ± 0.008 **a**	0.04 ± 0.018 **b**
Mg	4.8 ± 4.86 **a**	4.4 ± 8.2 **a**	4.4 ± 9.1 **a**

function. In *P. hispanica*, for K using the Log$_{10}$ function, for Na by Log$_{10}$, for Na using Log$_{10}$, for Mg by means of Log$_{10}$, and for organic matter using the arc-sin function. Mean were compared by Tukey's test (p<0.01).

Results

Morus alba

The internal and peripheral dry matter samples, not related to crown volume, showed significant statistical differences. The mean leaf dry matter for the internal versus peripheral samples was 108.47 g DM and 133.6 g DM respectively. The mean tree of *Morus alba* has the following mean values: height 6.5 m, crown volume 119.5 m^3, crown height 4.6 m, minor diameter 6.7 m and major diameter 7.5 m. The relationship between the mean dry matter samples and the mean estimated crown volume for each plant resulted in a total dry matter mean value of 13 kg DM for a typical *M. alba* tree. The height crown was the best estimator (r=0.71) for obtaining the mean crown volume with the following allometric equation: V = -83.78+44.28*h, where V is the estimated volume and h the crown height for each tree.

There were statistical differences in the mineral contents and organic matter between spring-autumn and summer-autumn seasons for the dry leaf samples not related to the volume data. Mean mineral contents, nitrogen and organic matter (mg/kg DM) obtained in the dry matter samples are shown in Table 1. The organic matter and the carbon values decreased along the cycle, the lowest recorded values being in the autumn season, with 745.2 mg/kg DM for the organic matter and 432.2 mg/kg DM for the carbon. Nitrogen contents diminished from 21 mg/kg DM in spring to 13.6 mg/kg DM in autumn. Potassium and sodium contents increased slightly in autumn with values of 0.67 and 0.04 mg/kg DM respectively. Magnesium contents were not statistically different along the three seasons. The recorded value was almost constant (4.4 g/kg DM).

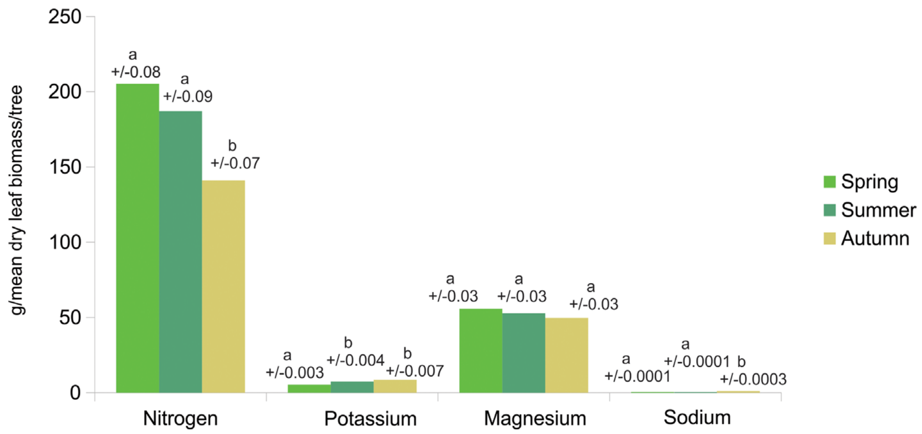

Figure 2. *Morus alba*: mean seasonal nitrogen, potassium, magnesium and sodium contents (g) in relationship to the volume and the mean leaf dry matter per tree. Same letters show no statistical differences according to Tukey's test.

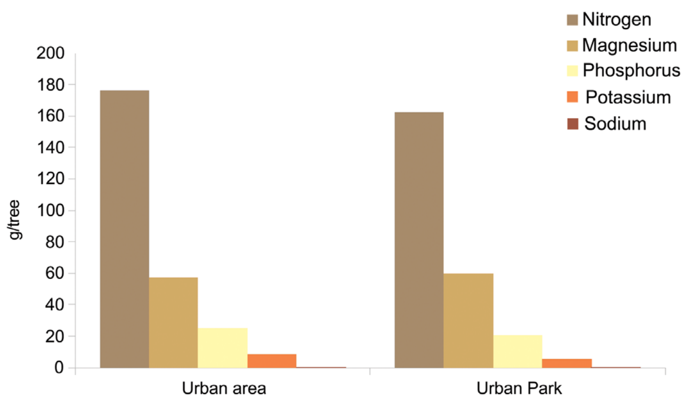

Figure 3. Mineral and nitrogen contents (g) for a typical tree of *Morus alba* with a mean total leaf dry matter of 13 kg DM.

Table 2. *Platanus hispanica*: mean seasonal contents and variance values in leaf dry matter samples of each element analyzed (mg/kgDM) using MANOVA (p<0.01). Same letters (a, b, and c) in a row show no statistical differences according to Tukey's test.

	Spring	Summer	Autumn
Ash	95 ± 6.8 **a**	116.9 ± 39.2 **a**	160.8 ± 54.7 **b**
Organic matter	905 ± 6.8 **a**	883.1 ± 39.2 **a**	839.2 ± 54.7 **b**
C	524.7 ± 4 **a**	512.2 ± 23 **a**	486.7 ± 32 **b**
N	20.7 ± 20 **a**	18 ± 2.1 **b**	14.4 ± 2.2 **b**
K^+	0.82 ± 0.6 **a**	0.5 ± 0.2 **b**	0.33 ± 0.18 **b**
Na^+	0.01 ± 0.003 **a**	0.01 ± 0.01 **a**	0.02± 0.0 2 *ab*
Mg^{2+}	3.6 ± 8.5 **a**	3.2 ± 7.5 **a**	3.4 ± 7.2 **a**

The results of the foliar mineral and nitrogen contents according to the relationship between the mean leaf dry matter and the crown volume per tree are showed in Figure 2. Foliar nitrogen concentrations showed significant statistical differences between spring-autumn and summer-autumn. The highest value was 205.2 g/tree in spring decreasing down to 141.2 g/tree in autumn. Potassium content was statistically different during the seasons, showing significant differences between spring-summer and spring-autumn. The values increased along the cycle from 5.3 g/tree, reaching the highest value of 8.6 g/tree in autumn. Sodium content showed significant differences between spring–autumn and summer–autumn. During the spring–autumn time the value was 0.3 g/tree and the greatest loss occurred during the senescence process and leaf fall time, with a sodium loss of 0.5 g/tree. Magnesium content did not show significant differences between seasons with values of 55.7 g/tree in spring and 49.7 g/tree in autumn.

The mineral contents in relationship to the mean total dry matter of 13 kg DM for a typical tree of *M. alba* was calculated. The results obtained for urban trees in sidewalks were compared with trees located in urban parks (Figure 3). For urban forest trees the contents were as follows: nitrogen 176.54 g/tree/year; potassium 8.69 g/tree/year; phosphorus 24.7 g/tree/year; sodium 0.45 g/tree/year and magnesium 57.32 g/tree/year. For trees located in urban parks the contents were as follows: nitrogen 162.5 g/tree/year; potassium 5.2 g/tree/year; phosphorus 20,8 g/tree/year; sodium 0.3 g/tree/year and magnesium 59.8 g/tree/year.

Platanus hispanica

The internal and peripheral dry matter samples not related to crown volume showed significant statistical differences. The mean leaf dry matter for the internal and peripheral samples was 114.82 g DM and 134.64 g DM respectively. The mean tree of *Platanus hispanica* has the following mean values: height 7.9 m, crown volume 202 m^3, crown height 5.4 m, minor diameter 6.04 m and

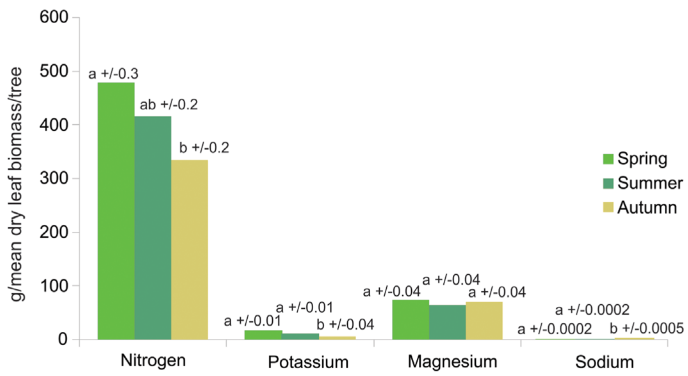

Figure 4. *Platanus hispanica*: mean seasonal nitrogen, potassium, magnesium and sodium contents (g) in relationship to the volume and the mean dry leaf dry matter per tree. Same letters show no statistical differences according to Tukey's test.

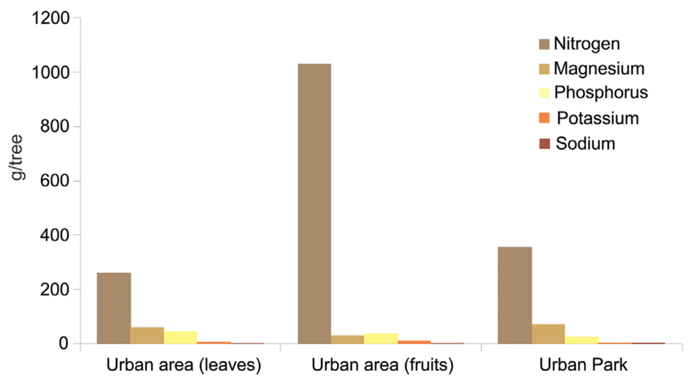

Figure 5. Mineral and nitrogen contents (g) in leaves and fruits for a typical tree of *Platanus hispanica* with a mean total leaf dry matter of 18 kg DM.

major diameter 7 m. The relationship between the mean dry matter samples and the mean estimated crown volume for each plant resulted in a total dry matter mean value of 18 kg DM for a typical *P. hispanica* tree. The height crown was the best estimator (r=0.78) for obtaining the mean crown volume with the following allometric equation: 60.07+22.93*h, for *P. hispanica*; where V is the estimated volume and h the crown height for each tree.

There were statistical differences in the mineral and nitrogen foliar contents between spring–autumn and summer–autumn seasons for the dry leaf samples not related to volume. Mean mineral contents, nitrogen and organic matter (mg/kg DM) obtained in the dry matter samples are shown in Table 2. The organic matter and carbon values showed statistical differences between spring–autumn and summer–autumn, and the lowest value was recorded in autumn with 839.2 mg/kg DM for the organic matter and 486.7 mg/kg DM for the carbon. Nitrogen contents decreased from 20.7 mg/kg DM in spring to 14.4 mg/kg DM in autumn. Potassium contents also decreased along the seasons from 0.82 mg/kg DM in spring to 0.33 mg/kg DM in autumn. Sodium content increased slightly with values of 0.01 mg/kg DM in spring and 0.002 mg/kg DM in autumn. Magnesium content did not show significant differences along the three seasons. The value stayed almost constant with a mean value of 3.6 mg/kg DM in spring and 3.4 mg/kg DM in autumn.

The results of the foliar mineral and nitrogen contents according to the relationship between the mean leaf dry matter and the crown volume per tree are showed in Figure 4. Foliar nitrogen concentrations showed significant differences between spring–autumn and summer–autumn. The highest value was 479 g/tree in spring decreasing up to 333 g/tree in autumn. Potassium content was statistically different during the seasons, with significant differences between spring–summer and spring–autumn. The values decreased along the cycle from 16.4 g/tree to 6.3 g/tree in autumn. Sodium content showed significant differences between spring–autumn and summer–autumn. During the spring–autumn time the value was 0.3 g/tree and the major loss occurred during the senescence process and leaf fall time, the sodium value being of 0.5 g/tree. Magnesium content did not show significant differences between seasons with values of 72.9 g/tree in spring and 69.1 g/tree in autumn.

The mineral contents in relationship to the mean total dry matter of 18 kg DM for a typical tree of *P. hispanica* was calculated. The results obtained for urban tress were compared with those of trees located in urban parks (Figure 5). The mineral contents showed similar values between the trees located along the sidewalks of urban forest and the trees located in urban parks, except for the nitrogen values that were higher in trees from urban parks. For the urban forest trees the contents were as follow: nitrogen 259.56 g/tree/year and 1030 g/tree/year in the fruits; potassium 5.93 g/tree/year and 10 g/tree/year in fruits; phosphorus 43.2 g/tree/year in leaves and 36.36 g/tree/year in fruits; sodium: 0.32 g/tree/year for leaves and 0.20 g/tree/year in fruits and magnesium 60.82 g/tree/year in the leaves, and 28.44 g/tree/year in the fruits. For the leaves of trees located in urban parks the contents were as follow: nitrogen 354.6 g/tree/year; potassium 3.6 g/tree/year; phosphorus 23.4 g/tree/year; and sodium 0.4 g/tree/year and magnesium 70.2 g/tree/year.

Table 3. Nutrient (tn) exportation from San Juan and Mendoza cities by leaves of *Morus alba* and *Platanus hispanica* every year.

Species	*M. alba*		*P. hispanica*
City	Mendoza	San Juan	San Juan
Carbon	2443.66	726.88	3002.91
Nitrogen	79.68	23.66	216
Potassium	4.1	1.16	2.67
Sodium	0.24	0.06	0.09
Magnesium	25.77	7.68	14.95
Phosphorus	11.9	3.31	7.24

Table 4. Soil mean mineral contents in the urban and urban park ecosystems.

	Urban	Parks
Organic matter (%)	2.97	3.3
N (g%g)	0.69	0.14
Mg (meq/l)	6.3	9.2
K (ppm)	917	391
Na (meq/l)	20	5
P (ppm)	18.41	8.44
pH.	7.36	5.6
Elec. Cond. (μS/cm)	3680	4950
Relative Humidity (%)	3.54	4.6
Ratio C:N	24/1	13/1

Exportation of mineral contents and soil samples

The total mineral and nitrogen contents exported annually from the studied urban ecosystems was estimated considering the total number of trees recorded in both cities of San Juan and Mendoza (Natural Resources Department unpublished data). In the city of Mendoza, around 480,000 trees of *Morus alba* were recorded; whereas in the city of San Juan was recorded around 134,000 trees of *M. alba* and 167,500 of *Platanus hispanica* (Natural Resources and Forestry Department, unpublished data). The total estimated amount of nutrients exported every year from the two cities because of daily leaf removal is showed in Table 3.

Soil samples were taken in the cities and urban park areas as an additional data that characterizes the urban city. The values of the mineral and nitrogen contents found in these two ecosystems are summarized in Table 4. Few thin roots were observed in the soil samples.

Discussion

The leaf mineral contents and organic matter in the species *Morus alba* and *Platanus hispanica* showed seasonal statistical differences between the spring–autumn and summer–autumn seasons as it was expected.

The ash contents, in *M. alba*, increased throughout the vegetative cycle and the highest value was found in autumn. The percentage was around 16% at the beginning of the season, and increased up to over 25% at the end of the vegetative cycle. These percentages are very similar to those reported by Singh, Goel, and Negi (1984) and Kandylis, Hadjigeorgiou, and Harizanis (2009) for trees of *M. alba*. By contrast, organic matter values decreased towards the end of the cycle, reaching the lowest value in autumn. These values indicate that almost 10% is trans-located into the stem at the end of autumn. Ash contents in *P. hispanica* showed variations of 9.5% in spring and 16% in autumn and the organic matter values decreased at the end of the cycle. The organic matter contents are inversely to the ash values and the former is involved in the regulation process of the available nutrients requiring being returned to the soil to complete the mineral nutrient cycle. As it was postulated by Vitousek (1982), decomposition of tree litterfall involves physical and chemical process that reduces litterfall to CO_2, water and mineral nutrients. This process is essential in the nutrient cycle of terrestrial ecosystems for the carbon returning to the atmosphere by decomposition of the organic matter. The growth of mature trees is seldom limited by carbon availability. During certain developmental or phenological stages and under environmental conditions leading to true carbon limitation, a tradeoff between storage and growth may occur (Palacio et al. 2014). The ability of different tree species for compensatory growth and carbon assimilation following defoliation depends upon several aspects of their physiology (Millard and Grelet 2010). It is reported that tree growth is limited by nutrient availability, particularly nitrogen (Rennenberg et al. 2009).

Nitrogen values showed differences among the spring and autumn seasons for both *M. alba* and *P. hispanica* species. The lowest value of nitrogen for both species was observed in autumn, when this mineral element is translocated to the stem and stored. Approximately 50% of nitrogen is exported through litterfall, and the other 50% is translocated to the plant according to the results found herein. Our results showed that the fruits of *P. hispanica* bring a high contribution to nitrogen, more than twice the leaves (Figure 5). Nitrogen storage and remobilization are important processes regulating the growth potential of a tree (Millard and Grelet 2010) and nitrogen is essential for amino acids and protein production (Clarkson and Hanson 1980; Millard and Grelet 2010; Palacio et al. 2014; Schulze, Beck and Müller-Hohenstein 2002). This important element promotes the growth of the plants by the re-translocation of this nutrient before abscission as an important mechanism to keep it available at the beginning of the new vegetative cycle with high nitrogen demand. Interpretable measure of resorption success may well be the level to which nutrients can be reduced in senescent leaves (resorption proficiency) being this process influenced by the environmental conditions (Killingbeck 1996). Values of around 40.9% for carbon and 72.8% for nitrogen were found in senescent leaves of *P. hispanica* (Adams et al. 1990). Nitrogen loss during the autumn is directly related to its abundance in the leaf dry matter and to carbon loss in the coupling N/C (Millard and Grelet 2010). Potassium values in leaf dry matter were different for both species throughout the cycle. Approximately 98% of potassium is lost in *M. alba* and *P. hispanica* when leaves fall down, and only a minimal percentage is translocated. Adams et al. (1990) found a translocation percentage of potassium of 38% for *Platanus occidentalis* during the autumn season. The study conducted by McHargue and Roy (1932) on several species of trees, including *Morus rubra* and *P. occidentalis* showed that the percentage of potassium in the leaves of all the species was greatest in the young leaves and diminished to about 50% of the maximum toward the end of the growing season.

Sodium contents increased for *M. alba* and *P. hispanica* during the autumn season, therefore a great percentage of this mineral is lost during the senescence process and leaf fall time. The sodium content of leaves is very low compared to the other minerals. McHargue and Roy (1932) showed that the sodium content of leaves was low and rather constant in amount, arguing that this mineral does not seem to have an essential function in some plants.

Magnesium did not show significant differences throughout the vegetative cycle, and the results herein were almost constant along the seasons for both species. Around 90% of magnesium is exported every year from the urban soils and merely 10% migrates to the stem. These values indicate that a high proportion of magnesium is lost by senescent leaves, this element being essential in the photosynthesis and many other enzymatic processes (Clarkson and Hanson 1980). According to McHargue and Roy (1932), the magnesium content of the leaves of *M. rubra* and *P. occidentalis* was remarkably constant throughout the growth season, with a slight increase along seasons. Adams et al. (1990) found that 46.9% of magnesium and 53. 2% of phosphorus were lost in senescent leaves of *P. occidentalis*. McHargue and Roy (1932) found phosphorus values of 0.29% for *M. rubra* and 0.26% for *P. occidentalis* during the growing season. By comparing the results from leaves collected from urban areas (sidewalks) and urban parks, we detect that nitrogen values were higher in urban parks for *P. hispanica* and the same occurred with magnesium potassium and sodium (Figure 5). However, the results are quite different in *M. alba* because the values of nitrogen are almost the same in urban forests and urban parks. There are no major differences for the other elements except for potassium with a notoriously higher value in urban areas (Figure 3).

In urban conditions, natural soils generally undergo considerable alteration, their physical and chemical characteristics do not resemble those in natural conditions (Patterson 1990). The soils in the studied urban areas are immature and lack the organic horizon; litterfall is exported out of the city every year and precludes completion of the nutrient cycle. Kostel-Hughes, Young, and Carreiro (1998) worked on a gradient from urban, suburban and rural areas and they concluded that mean litterfall depth, mass and density decreased from rural to the urban forests and postulated that urbanization processes have strong effects on long-term forest regeneration due to environmental changes, including litterfall quality and quantity. Available evidence indicates that trees adapted to conditions of low nutrient availability have lower rates of biomass renewal (Aerts and Berendse 1989; Chapin 1980). The pH value in the soil samples was neutral to alkaline, which is not optimal for most tree species according to Craul (1986). The low C:N ratio indicates that urban soils are generally poor in mineral, nitrogen and organic matter contents. Paul and Clark (1989) suggested that, above a critical C:N ratio, micro-organisms absorb nutrients from the soil, thereby causing net immobilization. Net mineralization occurs when the C:N relationship falls below the critical 20:1 ratio. The C to N ratio is often used to explain turnover rates for early residue decomposition (Cheshire and Chapman 1996). The mean relative humidity percentage for the soil samples in the studied area was low, comprised between 3.54% in urban forests and 4.6% in urban parks (Table 4). The dry climate slows down soil decomposition, as it was documented by Vitousek et al. (1994). The organic matter value found in soil samples from the studied cities was between 2.7% and 3.3% in urban parks, which means a poor organic matter quantity in both soils (Table 4).

In most natural ecosystems, a significant proportion of carbon fixed through photosynthesis is allocated to the production and maintenance of fine roots. Several studies have shown the importance of fine roots for ecosystem functioning, not only for their function in net primary productivity but also in the biogeochemical cycles of forests, because their decomposition contributes to the enrichment of organic horizons due to their swift conversion (Burke and Raynal 1994). In the studied urban areas, fine roots were scarcely observed in the soil samples and therefore they do not contribute to the organic horizon development. These areas are not fertilized at present, and due to the scarce available information about urban nutrition, it is difficult to make conclusions about the healthy conditions of the *M. alba* and *P. hispanica* in the studied urban ecosystems and more research is necessary. Fertilization of urban trees is one cultural practice that lacks substantial research, but the use of fertilizers should always be based on diagnosed deficiencies. These deficiencies should be established and based on the objectives that are appropriate for urban tree uses and values (Watkins 1998).

Conclusions

The nutrient accumulation in the leaf dry matter for *Morus alba* and *Platanus hispanica* indicates that litterfall and leaf removal results in a nutrient loss at the end of the autumn season, following the order of magnitude: N>Mg>P>K>Na.

The foliar concentrations of nitrogen and potassium decreased along the seasons. By contrast, sodium had the highest value at the end of the autumn season and magnesium concentration was the only value that remained almost constant.

According to our study, the litterfall does not constitute the primary pathway for nutrients returning to the soil in the urban ecosystems of the central-western part of Argentina.

By comparing the mineral values from trees located along the sidewalks in urban forests and tress in urban parks we detect important differences in the nitrogen values of *P. hispanica*. The frequent removal of leaves and fruits contributes adversely to nutrient recycling because the biogeochemical are not complete and this does not allow the immature soils to be enriched with mineral and organic elements, and prevents the returning of the essential mineral elements to the trees. A fertilization program is suggested if serious nutrient deficiencies are detected in the future, but it is hard at present to evaluate how it should be conducted until more information will become available. More studies are necessary in urban forests to understand the nutrient cycles in the cities, and differences between urban and parks areas should be clarified by future studies.

This research is a contribution to a more adequate understanding of the urban ecosystem patterns and dynamics and it also means to be useful in the management practices and conservation of urban ecosystems.

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