SELECTION OF FOREST SPECIES FOR USE IN URBAN ENVIRONMENT IN RELATION TO THEIR POTENTIAL CONCENTRATION TO HEAVY METALS

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ABSTRACT

The aim of this research is to study the behavior of different forest species in accordance with their ability to retain heavy metals on their leaves in order to select the most suitable species for urban and peri-urban use, which will contribute to the reduction of the continuously growing atmospheric pollution in the cities. Five species were studied: *Cupressus arizonica*, *Albizia julibrissin*, *Platanus orientalis*, *Celtis australis* and *Ligustrum japonicum*. 360 leaf samples were collected and two treatments (non-washed and washed sheets) were applied on them. The heavy metals that were measured are: copper (Cu), lead (Pb), chromium (Cr), nickel (Ni), cadmium (Cd), manganese (Mn) and zinc (Zn). The determinative estimation of the concentration of metals in the clear filtrate was carried out with the use of ICP-OES inductively coupled plasma optical emission spectrometry. In order to correlate the concentration of heavy metals in leaves with the silvicultural characteristics of species, the following characteristics were measured in 20 individuals per species: breast diameter, total height of tree, crown beginning height and crown's diameters. Statistically significant differences between the studied species were found for all metals. In addition, not a single species
was found to retain the highest concentration of all. Metal concentration on leaves' surface in declining order was: manganese (Mn) > copper (Cu) > zinc (Zn) > lead (Pb) > chromium (Cr) > nickel (Ni) > cadmium (Cd). All species had higher metal concentration at their lower crown part except from *Albizia julibrissin*. In conclusion, it can be stated that the leaves of *Cupressus arizonica* concentrated the higher quantities of copper (Cu), lead (Pb), cadmium (Cd) chromium (Cr) and nickel (Ni) while *Albizia jullibrissin* concentrated the higher quantities of manganese (Mn) and zinc (Zn). The effect (influence) of the height in relation to the concentration of heavy metals, which was studied for the first time, was found statistically significant. The factor of height is significant both in the upper and lower layer of the crown. All species had higher concentration of metals at their lower crown part except from *Albizia jullibrissin.*

Keywords
urban green, silvicultural characteristics, air pollution, concentration, leaf morphology, crown surface.
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INTRODUCTION

Quality of the environment is a matter of serious concern; especially today as the consequences of human intervention have already been evident. Although the environment is extremely valuable for every living organism, it is continuously destroyed by human activities (Davis *et al*., 2006). Roadsides in urban areas are usually polluted with heavy metals mostly derived from traffic: motor vehicle emissions, abrasion of tyres, brake linings as well as road surface, turbulence of dust due to vehicular movement, dispersion of construction material, etc. (Petrovsky and Ellwood, 1999; Gautam *et al*., 2004).

Plants not only have an ornamental function in urban areas, but they also may improve the quality of urban life (Akbari, 2002; Brack, 2002). Moreover, plants can absorb and accumulate pollutants through their roots and leaves (Sawidis *et al*., 1995). Heavy metals can be dry deposited on plant surfaces and accumulated through sedimentation under the influence of gravity (Nowak, 2004). They can also be accumulated internal and/or be retention on leaves's surface (Gratani *et al*., 2000).
Nowadays heavy metals are of high environmental concern. They are harmful to humans and animals and tend to bio-accumulate in the food chain (Yoon *et al*., 2006). The majority of plants can absorb metals and reach higher accumulation levels than those found in the air (Onder and Dursun, 2006). Urban vegetation can improve air quality in several ways. Trees can intercept atmospheric particles and absorb various gaseous pollutants. Various tree characteristics can alter wind profile or create local inversions in order to trap pollutants. As a consequence pollutant's removal is enhanced in local scale (Khan and Abbasi, 2001). During hot periods, trees can reduce the use of energy in buildings by shading them and altering air flows and thereby indirectly reduce pollutants emissions from power plants (Nowak, 1994).

In urban areas woody species are mostly suitable for monitoring metal pollution since lichens and mosses are often missing (Al-Alawi and Mandiwana, 2007).
The aim of the present study is to look into the pollution levels of copper (Cu), lead (Pb), chromium (Cr), nickel (Ni), cadmium (Cd), manganese (Mn) and zinc (Zn) using leaves from five forest species in Thessaloniki.

2. MATERIALS AND METHODS

2.1 Study site
The research was carried out in Thessaloniki during August-September 2006. The city of Thessaloniki, is located in Northern Greece, is the second biggest city in Greece. It is a rapidly growing city and its present population is estimated above 1.000.000 citizens. The city has Mediterranean climate with dry hot summers and mild winters. The average annual air temperature is 15.8°C with minimum average monthly temperature 5.9°C (January) and maximum 25.9°C (July). The average annual precipitation is 449.3 mm and relative humidity is 66.7% (Sawidis *et al*., 1995; Batala and Tsitsoni, 2007, 2009).

The three sites which were chosen for this research are K. Karamanlis Avenue, Egnatia Street and M. Alexandrou Avenue. The sites were chosen because they are three major, heavy traffic roads of Thessaloniki according to data by Prefecture of Central Macedonia.

2.2 Sample collection and preparation

Five species of trees and shrubs were selected to investigate the concentration of metal in their leaves. The species that analyzed were *Cupressus arizonica*, *Albizia julibrissin*, *Celtis australis*, *Platanus orientalis* and *Ligustrum japonicum*. The aim of the collection was to cover a good range of species (broadleaves and coniferous, deciduous and evergreen) and it was based on different leaves' morphology (needle-lamina, simple-compound) (Sawidis *et al.*, 1995) and their different silvicultural treatment (*Albizia julibrissin* prunned). They also were chosen because of their presence in both urban and natural ecosystems; they have a widely geographical range and ecological distribution throughout the world; in addition their sampling, identification and cultivation is easy and inexpensive (Celik *et al.*, 2005).

Twenty trees from each species were selected in each of the considered sites (Taylor *et al.*,1990; Pourkhabbaz *et al.*, 2010). From each tree two leaf samples were collected, one at the 1/3 and the other at the 2/3 of the tree crown height. The following silvicultural characteristics were also measured or calculated for each tree: breast diameter, total height, crown length, crown surface areas and crown diameters. The crown diameter measured from their project to the ground and through two vertical directions. Every length was measured with a hypsometer. Crown surface area (Ca) was calculated assuming the crown as a solid geometrical object. The regular geometrical objects were: conoid for *Cupressus arizonica*, hemisphere for *Albizia jullibrissin* and paraboloidal for *Celtis australis* and *Platanus orientalis*.

The leaf samples were divided into two sub-samples. The one was thoroughly washed with running distilled water to remove superficial leaf deposit, and the other remained untreated. Both washed and unwashed leaf samples were oven-dried at 80 ^{0}C for 24 h, milled in a micro-hammer cutter and fed through a 0.2 mm sieve. Contamination from the micro-hammer cutter was negligible, since it was washed with distilled water after each use.

2.3 Chemical analysis

About 0.2 gr of dried and milled plant material was ashed in furnace at 600° C for 5 hours. The capsule was removed from the furnace and was released reintroducing the sample to environmental temperature. Ten milliliters of concentrated HNO_3 (2N) were added and the sample was heated at 80 ^{o}C. The solution was cooled and was filtered through Whatman No. 42 diameter 125mm. The filtrate was diluted to 50 ml of distilled water. Each final solution was analyzed for copper (Cu), lead (Pb), chromium (Cr), nickel (Ni), cadmium (Cd), manganese (Mn) and zinc (Zn).
In order to ascertain the accuracy of the method employed and calibrate for any slight contamination, three reference materials were used with every batch (Culture Labatory Proficiency-ALP program operated by Collaborative Testing Services Inc.).

The three reference materials were: corn stalk from Connecticut, potato leaves from California and citrus leaves from California. Heavy metals concentrations were measured on inductively coupled plasma optical emission spectrometry ICP-OES (PS-1000 AT-Seqential Axial Transmittion Model with Autosampler of Leeman Labs).

2.4 Statistical analysis

The values were statistically evaluated with three-way analyses of variance (ANOVA), in the methodological frame of General Linear Models (GLM) (Zar, 1996; Rencher, 2000). Specifically, the data were assessed using linear model that included a factor between the experimental units (Factor "Species" with 5levels: *Cupressus arizonica*, *Albizia julibrissin*, *Platanus orientalis*, *Celtis australis* and *Ligustrum japonicum* and two factors inside the experimental units (Factor "Height with 2 levels: upper and lower, Factor "Treatment" with 2 levels: unwashed and washed). The experimental plan was considered as completely randomized factorial.

The total number of measurements of heavy metals concentrations for each species was 80. The comparisons of means were realized by Bonferroni's multiple range test, for a *p*=0.05 confidence level. The Bonferroni's multiple range test was preferred in order to limit Type I Fault (Toothaker, 1993). The statistical analysis was conducted with the statistical software package of SPSS v 15.0 (SPSS Inc., Chicago: IL). The confidence level was predetermined in *p*=0.05.

3. RESULTS

3.1 Silvicultural characteristics

The main silvicultural characteristics of forest species *Cupressus arizonica*, *Albizia julibrissin*, *Platanus orientalis* and *Celtis australis* are represented at Table 1.

TABLE 1. Means and s. deviations of silvicultural characteristics of studied species.

Forest Species	Tree diameter (cm)	Tree height (m)	Crown height (m)	Crown diameter (m)	Crown length (m)	Crown surface (m^2)
Cupressus arizonica	24.03±4.06	12.35±2.23	9.83±2.00	9.73±2.06	4.59±1.27	105.79±33.25
Albizia julibrissin	16.73±5.46	5.98±1.20	3.90±0.94	3.95±1.02	6.5±1.86	26.08±13.35
Celtis australis	17.00±4.87	6.75±1.52	7.38±1.39	4.38±1.39	4.30±0.90	31.83±10.61
Platanus orientalis	59.92±20.32	17.56±5.50	14.50±5.20	13.59±3.47	13.53±2.91	365.65±275.36

Albizia julibrissin is the only of the studied species that is systemically pruning every year.

3.2 Species and heavy metals concentration

The mean concentrations of manganese, zinc, lead, chromium, copper, cadmium and nickel of the tree leaves are given in figures 1a,1b,1c. For *Ligustrum japonicum*, the concentrations were determined only for the leaves from the lower part because it is a shrub.

The concentrations of the heavy metals dependented on the species and the height that leaves were collected. Only in cases of copper, cadmium and nickel the concentration of the heavy metal was dependent on the species, the height and the leaves' treatment that was used (washed-unwashed).
Lead, chromium, copper, cadmium and nickel concentrations were greater in *Cupressus arizonica*, while zinc and lead concentrations were greater in *Albizia julibrissin*.

For all species the height (upper and lower part of the crown) that the leaves were collected is significantly different (ANOVA, p<0.001 and the Bonferroni Test of multiple comparisons). For all studied species, except *Albizia julibrissin*, metal concentration was higher in the leaves that were collected from the upper crown. Higher concentrations were measured at *Cupressus arizonica*. Especially, copper (Cu) 47.810 ppm (not washed leaves), lead (Pb) 27.470 ppm, cadmium (Cd) 1.237 ppm (washed leaves), chromium (Cr) 7.958 ppm and nickel (Ni) 3.296 ppm (washed leaves).

4. DISCUSSION AND CONCLUSIONS

In this research, metals mean concentration in leaves in declining order was: manganese (Mn) > copper (Cu) > zinc (Zn) > lead (Pb) > chromium (Cr) > nickel (Ni) > cadmium (Cd). Respectively, Sawidis *et al.* (1995) for the city of Thessaloniki found the following declining order of metals mean concentration manganese (Mn) > zinc (Zn) > copper (Cu) > cadmium (Cd) for the eight plant species that they have studied. Pyatt (1999) studied the heavy metals concentration in *Pinus nigra* needles in Cyprus. Metals mean concentration in leaves in declining order was: iron (Fe) > manganese (Mn) = zinc (Zn) > copper (Cu). Also, Pyatt (2001) studied, in another research, the heavy metals in leaves of *Acacia retinoides* in Cyprus. The declining order of heavy metals in control area was iron (Fe) > manganese (Mn) > copper (Cu) = lead (Pb) while in the polluted area the order changed in iron (Fe) > lead (Pb) > manganese (Mn) > copper (Cu). The above species were considered that notably retain heavy metals (Pyatt, 1999, 2001).

In another research, that was carried out in Denizli (Turkey), metals mean concentration in *Robinia pseudoacacia* leaves in declining order was iron (Fe) > manganese (Mn) > zinc (Zn) > lead (Pb) > copper (Cu) > cadmium (Cd) (Celik *et al*., 2005)
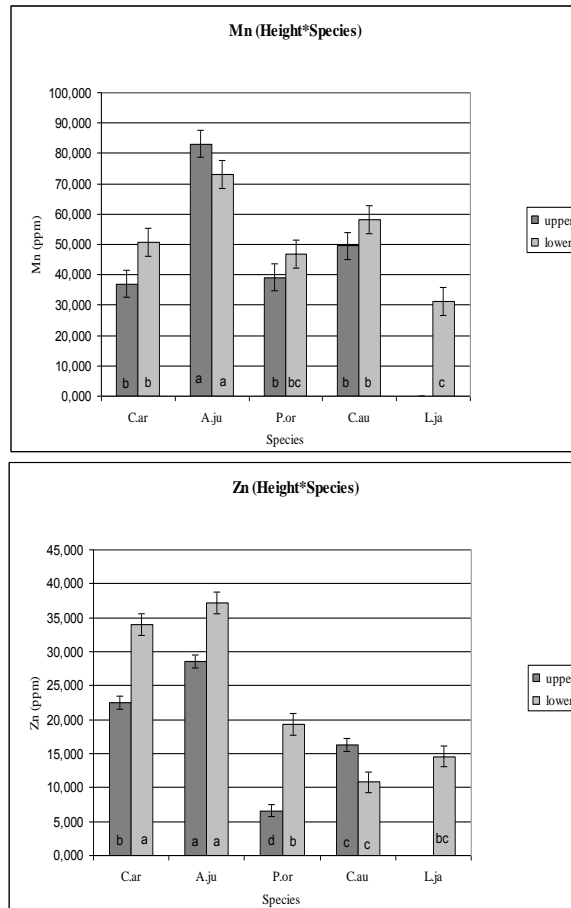

Fig. 1a Mean and s.e. of Mn and Zn concentrations of the five studied species. The differences in mean values of the metal concentration with different letters are significantly different (ANOVA, p<0.001 and the Bonferroni Test of multiple comparisons).
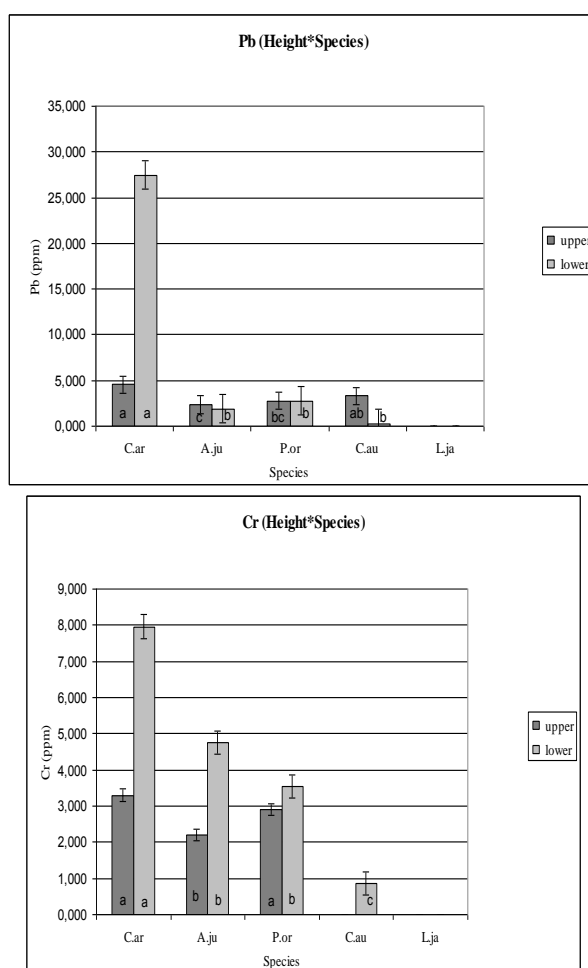
Fig. 1b Mean and s.e. of Pd and Cr concentrations of the five studied species. The differences in mean values of the metal concentration with different letters are significantly different (ANOVA, $p < 0.001$ and the Bonferroni Test of multiple comparisons).
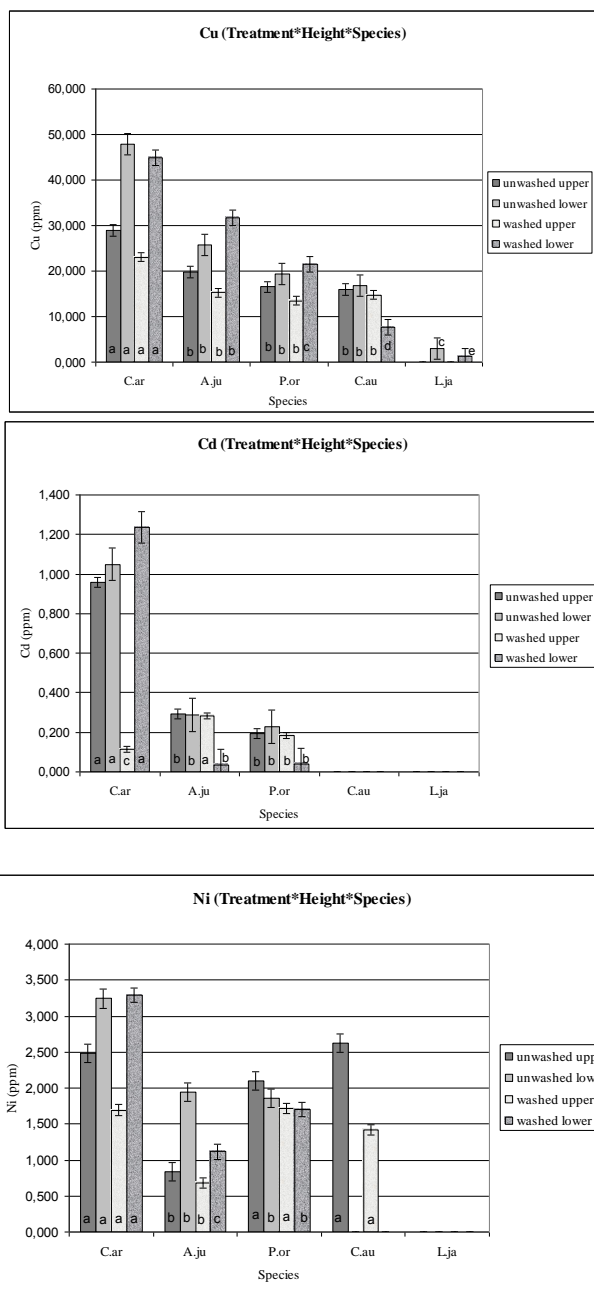
Fig. 1c Mean and s.e. of Cu, Cd and Ni concentrations of the five studied species. The differences in mean values of the metal concentration with different letters are significantly different (ANOVA, $p < 0.001$ and the Bonferroni Test of multiple comparisons).

Sawidis *et al.*, (1995) reported that copper (Cu) was presented with a small deviation among the studied species (*Ligustrum japonicum*, *Nerium oleader*, *Olea europea*, *Pinus brutia*, *Platanus orientalis*, *Populus alba*, *Populus nigra* and *Robinia pseudoacacia*) except from *Neriun oleader* and *Platanus orientalis*. In this research, copper (Cu) presented high deviation between the species. Concretely, the higher mean concentration of copper (Cu) was measured in *Cupressus arizonica* leaves and it was 36.150 ppm, while in *Ligustrum japonicum* was the smallest 1.095 ppm.

Hernandez *et al.* (1987) found that the lead (Pb) concentration in *Nerium oleander* leaves presented no difference between the samples that had been washed or not. The present research confirms the above conclusion since there wasn't found statistically significant difference for the lead (Pb) between leaves that had not been washed and the ones that had, for all the studied species. For the other metals the factor 'treatment' (washed-unwashed) presented statistically significant differences.

As in most conifers, thus in *Cupressus arizonica*, the needles remain on tree from two to five years. These needles are exposed longer at polluted air than the leaves of broadleaves. *Cupressus arizonica*'s needles are microscopic, abundant, blade shape, aquamarine, with obvious gland in ridge and with white resin (Athanasiadis, 1986). Sawidis *et al.* (2001) claims that the rough surface of needles and the presence of resin make surface adhesive contribute to the increase of heavy metals concentration.

The higher manganese (Mn) and zinc (Zn) mean concentrations were measured in *Albizia julibrissin*'s leaves at the upper crown part. The higher manganese (Mn) mean concentration 83,170 ppm had been measured in the leaves that had been collected in upper crown. Respectively, the higher zinc (Zn) mean concentration 28,627 ppm had been measured in the leaves that had been collected from the upper crown for *Albizia julibrissin*. *Albizia julibrissin* is the only of the species that is systematically pruning. According to Martin and Coughtrey (1982) exterior crown leaves have increased ability to detention elements from atmosphere. Consequently, further research is required on how pruning influences the detention of heavy metals. Sawidis *et al.* (2001) found for *Robinia pseudoacacia* also for *Albizia julibrissin* that the present of aphids make leaves surface more adhesive having as result the easier detention of heavy metals.

Platanus orientalis with its big crown can participate considerably in the improvement of air pollution (Smith and Staskawicz, 1977; Pourkhabbaz *et al.*, 2010). According to Nowak (1994) a big tree with breast diameter 76 cm can remove 70 times more air pollutants from air in Chicago (USA) than a tree with breast diameter 8 cm. Also Yang and Mc Bride (2003) reported that intense pruning decreases the ability of big trees to detention air pollutants. Sawidis *et al.*, (1995) and Beckett *et al.*

(2000 a,b,c) found that the more powerful accumulation of metals presented in species that had rough leaves' surface. In *Platanus orientalis* the dense pilled leaves and the prominent reticulate form of veins trap and retain air pollutants effectively (Smith and Staskawicz, 1977; Martin and Coughtrey, 1982; Dickinson *et al*., 1991; Pourkhabbaz *et al*., 2010). In the present research *Platanus orientalis* detention important heavy metals' concentration, as withheld the fourth higher concentration of manganese (Mn), zinc (Zn) and copper (Cu), the third higher concentration of lead (Pb), cadmium (Cd) and chromium (Cr) and the second higher concentration of nickel (Ni) (1,847 ppm) among the five studied species.

Celtis australis has particularly rough leaves. It withheld the higher manganese (Mn) concentration (31,319 ppm in the leaves that were collected at lower crown), higher even from the conifer that was studied (*Cupressus arizonica*). Kovács (1992 a,b) proposes tree species for their detergent role into urban environment, among them is *Celtis* sp.

The waxy cuticle of *Ligustrum japonicum* which forms a smooth sheet over the epidermal cells enables the fast removal of the particles by the rain (Martin and Coughtrey, 1982; Sawidis *et al*., 1995). This species should be used in places like road axes where the concentrations of heavy metals are higher consequently. According to Sawidis *et al*., (1995) the most important factor for the pollution in local scale from vehicles exhausts, are the places near traffic lights where exists permanent vehicles halt of despite the total circulatory pressure of particular road artery. In fact in the present research higher heavy metal concentration was measured in trees and bushes of studied species that were found near traffic lights. Also, *Ligustrum japonicum* is suitable for such places for an additional reason: it can be pruned in any form so it does not create problems to the optical contact of drivers at traffic lights.

The species *Cupressus arizonica* withhold the largest concentrations of the metals copper (Cu), lead (Pb), cadmium (Cd) chromium (Cr) and nickel (Ni) and the species *Albizia jullibrissin* the higher concentrations of manganese (Mn) and zinc (Zn).

It is the first time, that the effect of crown height -from which leaves samples were collected- was studied. This study gives useful information about how procedures in sample collection should be carried out in future researches. Additional research is required on the effect of trees pruning in metal retention by the leaves. According to Markert (1993) and Witting (1993), the basic criteria for the selection of a species as a biomonitor are: the large number of individuals all over the monitoring area, having a wide geographical range, being easy and inexpensive to sample and presenting no identification problems. The five species in our study satisfy all these criteria and our study fully supports the view that they can be used as biomonitors all around Greece, Europe, Asia, Africa and the U.S.A. Also the methodology is recommended for similar studies because of the significant information that concern the factor: crown height.

The selection of suitable forest species for urban use should depend not only on their ability to retain heavy metals but also by the silvicultural characteristics of trees, the morphological characteristics of leaves, the crown surface and the lifespan of the leaves (deciduous and evergreen species).

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