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NUTRITIONAL EVALUATION IN NATIVE FOREST SPECIES USED IN AFFORESTATION ON CAMPUS OF THE UNIVERSIDADE FEDERAL DE SANTA MARIA, RS

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ABSTRACT

Mineral nutrition of urban trees should be considered in the implantation and preservation of afforestation projects. This study aimed to provide parameters for this practice, evaluating nutrient content in leaves of five woody species on campus of the Universidade Federal de Santa Maria – Rio Grande do Sul state – Brazil. Leaf samples were collected from young branches, in the middle portion of the crown, facing north, prepared and analyzed for contents of macro and micronutrients. *Eugenia uniflora* presented N and P deficiency. *Parapiptadenia rigida* showed very low level for P, even thought there was good P content available in the soil. All species showed adequate contents of K and Ca, attributed to good supply from the soil and low Al contents. *Cedrella fissilis* presented adequate supplied of Mg while *Caesalpinia pluviosa* showed deficiency. *Eugenia uniflora* presented S deficiency. *Cedrella fissilis* and *Peltophorum dubium* showed B deficiency. All species showed adequate Cu contents. *Peltophorum dubium* presented low Fe content, but not deficient. *Parapiptadenia rigida* showed Fe toxicity. *Cedrella fissilis*, *Eugenia uniflora* and *Caesalpinia pluviosa* showed Mn deficiency. *Eugenia uniflora*, *Parapiptadenia rigida* and *Caesalpinia pluviosa* showed Zn deficiency.

Keywords: tree forest mineral nutrition, urban trees, leaf analysis.

AVALIAÇÃO NUTRICIONAL DE ESPÉCIES NATIVAS UTILIZADAS NA ARBORIZAÇÃO DO CAMPUS DA UNIVERSIDADE FEDERAL DE SANTA MARIA-RS

RESUMO

A nutrição mineral de árvores urbanas deve ser considerada na implantação e condução de projetos de arborização. Objetivou-se fornecer parâmetros para essa prática, avaliando-se o teor de nutrientes nas folhas de cinco espécies florestais nativas presentes na arborização do Câmpus da Universidade Federal de Santa Maria/Rio Grande do Sul. Amostras foliares foram coletadas de ramos jovens, na porção média da copa, em exposição norte, preparadas e analisadas quanto aos teores de macro e micronutrientes. *Eugenia uniflora* apresentou deficiência de N e P. *Parapiptadenia rigida* apresentou teor muito baixo para P, mesmo com bom teor disponível no solo. Todas as espécies apresentaram teores adequados de K e Ca, pelo bom suprimento via solo e teores baixos de Al no mesmo. *Cedrella fissilis* apresentou-se adequadamente suprida de Mg, porém *Caesalpinia pluviosa* mostrou deficiência. *Eugenia uniflora* apresentou-se deficiente de S. *Cedrella fissilis* e *Peltophorum dubium* apresentaram deficiência de B. Todas as espécies mostraram teores entre adequados e altos de Cu. *Peltophorum dubium* apresentou teor abaixo do adequado para o Fe, mesmo assim sem deficiência. *Parapiptadenia rigida* apresentou toxicidade de Fe. *Cedrella fissilis, Eugenia uniflora* e *Caesalpinia pluviosa* apresentaram deficiência de Mn. *Eugenia uniflora*, *Parapiptadenia rigida* e *Caesalpinia pluviosa* apresentaram teores deficientes de Zn.

Palavras-chave: nutrição mineral de espécies arbóreas, arborização urbana, análise foliar.

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INTRODUCTION

Urban trees should have the capacity to, besides grow adequately in inhospitable conditions, express a range of landscape features and provide environmental benefits to the site where they are planted, because only then, they will be able to express their multiple benefits often reported in the literature (SILVA FILHO and TOSSETTI, 2010; TEIXEIRA and SANTOS, 2001; BRUN, 2008).

Trees offer recreational benefits, directly or indirectly, to life quality to users through adequate formation and growth, which are obtained by the correct use of tree species planted.

This management process, as well as implementation activities, should take into account the conditions of the planting sites in terms of physical, chemical and biological conditions of the soil, such as the nutrient supply to the plant.

In most cases, urban soils have low natural fertility, with inadequate physical features containing toxic elements coming from construction sites and deposition of several materials foreign to the natural conditions of the soil, among others.

This condition requires stakeholders of urban afforestation to place special attention to the mineral nutrition of the tree species planted, even if it is not frequently applied by most entities in charge of implementing afforestation projects, mainly road afforestation.

Thus, assessing and/or monitoring of the nutritional condition of trees have been studied for decades, since the nutritional diagnosis has proven to be a good indicator of nutritional stress of trees (MALAVOLTA, 1987). In urban conditions, several species may show problems with growth and expression of their scenic beauty, besides problems with the numerous benefits that they offer to the population. These problems may be related to nutritional deficiency of soil nutrients or to the tree's inability to absorb them because the soil may not offer adequate conditions, mainly physical (soil compaction and impermeability), but also chemical and biological.

Leaf diagnosis is a method that consists of assessing the soil using the tree as an extractor and it has proven to be one of the best ways for assessments on nutritional contents, once the leaves are organs that best reflect the nutritional condition of plants (MALAVOLTA, 1989), reflecting nutrients translocation in the nutritional concentrations (BELLOTE and SILVA, 2004).

Plant nutrition involves the absorption of several chemical elements, all or most of which are found in the lithosphere, necessary or not for the biochemical processes essential for plants (LARCHER, 2004); their distribution within the plant and the use of essential elements in metabolism and plant growth (RAVEN et al., 2001; LARCHER, 2004). Deficiency of nutrients considered essential limits plants growth and hinders their development (LARCHER, 2004, BEGON et al., 2007). Furthermore, there are some plant species that have special requirements and may deplete distinct mineral resources at different quantities (BEGON et al., 2007).

According to Epstein and Bloom (2004), only approximately 1.5% of fresh matter of plants is represented by mineral elements, formed by macro and microelements that are absorbed in the environment, mainly in the soil.

Data on nutritional requirements of native forest species are scarce in the literature (SORREANO et al., 2008), and the few existing studies are restricted to only some plant formations. There is need to build a database for native species, establishing standard thresholds that indicate their nutritional condition, involving the most varied types of ecosystems, which will allow further comparisons. Therefore, we will be able to assess features of species planted in environments of poor fertility or modified, such as degraded areas and urban forests, aiming to promote ideal nutritional conditions for their natural environments. In urban afforestation, stress factors are high and, in many cases, are compared to those found in degraded areas.

In this context, this study aimed to assess the content of nutrients found in leaf tissues of some native forest species, sampled on the campus of the Universidade Federal de Santa Maria, in the municipality of Santa Maria, Rio Grande do Sul state – Brazil –, to obtain data on possible deficiencies or excesses of macro and micronutrients analyzed.

MATERIALS AND METHODS

The study was carried out on the campus of the Universidade Federal de Santa Maria (UFSM) in the municipality of Santa Maria, Rio Grande do Sul state – Brazil. The UFSM is situated in the central lowland of Rio Grande do Sul state at 29°42’24” S and 53°48’42” W at 95 m above sea level. The predominant climate in the region is the Cfa type (Köppen classification) (MORENO, 1961) – rainy temperate with rains well distributed along the year. The annual precipitation reaches circa 1,770 mm. The average annual temperature is 18.8°C and the average temperature of the hottest month (January) is 24.6°C and in the coldest (June), 12.0°C.

The soil is classified as sandy dystrophic Oxisol (STRECK et al., 2008). To determine the main soil features, we collected four samples on the campus of UFSM, near trees that were sampled for their leaves. The soil samples were collected at 10 cm, with an auger screw, by collecting three simple samples, after cleaning the soil surface. The chemical analyses were performed at the Laboratory of Ecology at UFSM, using the methodology described in Tedesco et al. (1995). The results presented in Table 1 were used as basis for interpretation of the results found in the leaf fractions of the studied species. We noted that, although the soil classification of the site at the third level is dystrophic, the V value remained above 50%, which characterizes the soil as eutrophic at this level. However, this higher value is attributed to a factor typically found in urban soils affected by the urbanization process, such as the presence of construction debris, mix of horizons, amongst other factors, increasing the concentrations in the soil of some chemical elements that integrate the sum of bases (e.g., Ca), therefore, elevating the V value.

Table 1: Chemical characteristics and soil clay on the campus of UFSM, Santa Maria, Rio Grande do Sul state - Brazil.

	pH (H_2O 1:1)	C g kg^{-1}	OM	V	M	K*	P*	Ca	Mg	Al	H+Al
			-------- (%) --------			- ($mg.dm^{-3}$) -		----- ($cmol.\ dm^{-3}$) -------			
Average	5.17	240.0	2.09	61.47	2.78	70.75	13.69	5.47	1.62	0.18	5.11
CV%	8.1	14.6	14.4	19.8	110.1	39.9	27.0	16.5	11.1	116.7	53.4

C =Clay; MO = organic matter; V=Saturation of bases; m=Saturation by aluminum; * Extractor Mehlich-1; CV = Coefficient of variation

According to the Brazilian Society of Soil Science/Committee for Chemistry and Soil Fertility (SBCS-CQFS, 2004), the soil pH had low values, which may hinder plant development due to chemical restrictions to the absorption of some nutrients, such as phosphorous. The clay content, at a layer where P content was available, is considered medium and high (SBCS-CQFS, 2004). Potash, for CTC_{pH7} of this soil is equal to 12.4 $cmol_c.dm^{-3}$ (considered medium) and has a content considered high (SBCS-CQFS, 2004). The Ca and Mg contents are also considered high while the organic matter content of the soil is low (SBCS-CQFS, 2004). The Al saturation is considered low, less than 3% of the CTC (value m%), leading to the predomination of bases saturation in the CTC in the soil (SBCS-CQFS, 2004).

Overall, contents of the main nutrients in the soil are classified in the analyses as medium and high; however, due to factors such as the low OM content (low potential for the availability of nutrients through mineralization) and acidity (making some nutrients unavailable for the roots), many of these nutrients may not be adequately absorbed by plant roots. Moreover, in urban areas, soil compaction may be a barrier for root growth and for better absorption of nutrients by the plant.

To carry out this study, we considered the urban area of the campus, which has streets, sidewalks, electric lines and water supply systems identical to those in any other city. To collect leaf samples, we selected species native to the Atlântica Forest biome that are among the most predominant in the site: cedro *(Cedrela fissilis* Vell.), sibipiruna (*Caesalpinia pluviosa* Benth.), pitangueira (*Eugenia uniflora* L.), angico-vermelho *(Parapipitadenia rigida* (Benth.) Brenan) and canafístula (*Peltophorum dubium* (Spreng.) Taub.).

For each species, we collected leaf samples of four individuals in different sites using a trimmer, and we collected five branches of each individual at the medium part of the crown, facing north, from which we obtained mature leaves in good phytosanitary conditions. Biondi and Reissmann (2002) indicate this procedure as the most adequate.

After each collection, the samples were transported to the Laboratory of Forest Ecology of UFSM, where they were cleaned, dried in an oven of circulating air at 70°C until they reached a constant weight. After drying, the samples were ground and sent for chemical analysis. All of these procedures were adopted in accordance to the standard methodology of the laboratory described in Tedesco et al. (1995).

We determined the contents of macronutrients: N, P, K, Ca, Mg and S, and the micronutrients: Fe, Cu, Mn, B and Zn following the methodology described in Tedesco et al. (1995). To read the extracts, we used an atomic absorption spectrophotometer (Mg, Fe, Cu, Mn and Zn), a flame photometer (K), colorimeter (P, S and B) and a distiller vapodest 5.0 (N). The statistical calculations were performed using the analysis of variance and Tukey test at 5% of probability.

Due to the difficulty to find references for the good nutritional values of native forest species planted in urban areas in the literature, in this study, we performed the interpretation of the nutritional condition of the species in a general way (studies on urban afforestation, on native and cropped forests), given that it is still necessary to expand the studies on urban tree nutrition that offer enough basis for the comparison of consistent data.

RESULTS AND DISCUSSION

Macronutrients

For nitrogen, *Cedrella fissilis* showed the highest average content, which was not significantly different from *Peltophorum dubium.* The lowest value was found in *Eugenia uniflora* (Table 2), a range considered deficient for this element by Silveira et al. (2005), while the contents found for the other species indicated that the trees were well nurtured. However, the reference values found in Epstein and Bloom (2004) show that contents of 15 g kg^{-1} are considered normal for plants, and are commonly found in their dry matter, representing, in this case, an average for the different parts of the plant.

Peltophorum dubium, *Parapipitadenia rigida* and *Caesalpinia pluviosa* showed N contents considered within the adequate range (between medium and high), as compared to other studies, above 18 g kg^{-1} (SILVEIRA et al., 2005), above 21 g kg^{-1} (KOPINGA and VAN DEN BURG, 1995) and between 15-25 g kg^{-1} (LARCHER, 2000). They are leguminous species (Fabaceae), and, therefore, are able to fix N from the atmosphere, which explains the relatively high N contents in the leaf composition of these species, in spite of the low contents of organic matter in the soil.

Table 2: Average of contents of macronutrients obtained for some native forest species used in urban afforestation of the UFSM Campus, Santa Maria city, Rio Grande do Sul state - Brazil.

Species	Macronutrientes					
	N	P	K	Ca	Mg	S
	g kg^{-1}					
Cedrella fissilis	30.04 a* (11.7)**	2.15 a (19.7)	14.43 a (12.6)	10.95 b (5.9)	2.20 a (24.1)	1.52 a (17.1)
Caesalpinia pluviosa	24.77 b (7.1)	1.60 b (6.3)	09.18 b (6.2)	18.31 a b (43.0)	1.20 b (30.7)	1.43 a (11.3)
Eugenia uniflora	15.57 c (12.0)	0.96 c (4.7)	7.15 b c (15.2)	31.06 a (35.3)	1.91 a (23.7)	0.63 b (51.6)
Parapipitadenia rigida	24.94 b (8.1)	0.97 c (9.4)	6.28 c (6.9)	11.58 b (86.9)	1.62 a b (1.3)	1.15 a (5.6)
Peltophorum dubium	27.40 a b (15.8)	1.61 b (10.3)	8.75 b (8.2)	6.34 b (1.6)	1.66 a b (0.9)	1.44 a (15.3)

*Means followed by the same letter in rows do not differ in the Tukey test at 5% probability ($p \leq 0.05$); ** values between brackets represent the coefficient of variation (%) of each mean.

In a study was carried out in the neighborhood of Camobi (Santa Maria-RS), Brun et al. (2010) report leaf contents of 22,2 g kg^{-1} for *Caesalpinia pluviosa* and contents in branches of 9.6 g kg^{-1} for the same species. This nutrient, according to Larcher (2000), shows an occurrence range in plants between 15 and 25 g kg^{-1}, which shows that there was no deficiency for this nutrient in the species assessed in this study and only *Eugenia uniflora* had N leaf content near the low limit in the range.

Kopinga and Van den Burg (1995) carried out a review of studies on nutrient contents in 48 tree species used in urban afforestation in cities in the Netherlands, and reported that average N contents lower than 17 g kg^{-1} as very low contents, between 17 and 21 g kg^{-1} as low contents, between 21 and 27 g kg^{-1} as medium and of 27 g kg^{-1} as optimal. This study, due to its vast sampling, in urban conditions and even with European species of trees, provides basis for comparison, showing many similarities in N contents if compared to data found in other studies such as Brun et al. (2010) for *Caesalpinia pluviosa* in the urban area of Santa Maria/RS, Biondi and Reissmann (2002) for *Handroanthus chrysotrichus* in the urban afforestation process of the city of Curitiba, Paraná state, Brazil.

In studies carried out on native species of semideciduous forest in the state of São Paulo – Brazil –, Haddad et al. (2004) reported average leaf contents of N of 13.9 and 8.0 g kg^{-1}, respectively, for *Croton priscus* and *Hymenaea courbaril*, being the experiment conducted in the same soil of natural occurrence of species, which presented medium contents of organic matter at the beginning of the study and very low contents after two years of conducting the experiment. The authors consider that, despite N losses that might have occurred during the experiment (e.g., to the atmosphere), the N released by the mineralization of the organic matter was predominantly absorbed by the plants to build their biomass.

This aspect shows the great need of N by plants, which is not different for tree species used in urban afforestation. These species will certainly need N fertilization, once the organic matter in the soil, found at higher contents on the surface layer, is usually removed or at least mixed with deeper soil in urban areas, where nutrient cycling is also deficient. N fertilization (chemical or organic source) should be carried out not only during planting, but also later, aiming to maintain the tree stable with good structure.

Apply N fertilization in areas subjected to severe air pollution is more important, given that the presence of pollutants may inhibit N absorption, causing chlorosis of plant leaves, as shown in the study conducted by Roberts et al. (1986) with seedlings of four species used in urban afforestation.

For P, according to Silveira et al. (2005), with exception for *Eugenia uniflora* (0.96 g kg^{-1}) and *Parapipitadenia rigida* (0.97 g kg^{-1}), the rest of the species studied showed adequate contents.

According to the classification presented in Kopinga and Van den Burg (1995), the P contents below 1.0 g kg^{-1} are considered very low, between 1 and 1.4 g kg^{-1} low, between 1.4 and 1.9 g kg^{-1} normal and above 1.9 g kg^{-1} very high. According to the data presented by the authors, *Eugenia uniflora* and *Parapiptadenia rigida* showed very low contents, *Peltophorum dubium* and *Caesalpinia pluviosa* showed normal contents and *Cedrella fissilis* had very high P contents.

Fernandes et al. (2007) conducted a study on plant growth and nutrient absorption of seedlings of Freijó (*Cordia goeldiana* Huber) regarding doses of P and Zn and found that the use of P in the soil at 0; 150; 300 and 450 mg dm^{-3} generated a significant linear increase of P content in leaves, stems and roots of the seedlings, as well as a liner reduction of Zn contents in leaves and roots due to its interaction with P.

Despite that, in the current study, the low P contents in leaves of some species may be related to the difficulty of the plant to absorb this nutrient, given that the soil shows good P contents, but the low pH makes part of this P unavailable for plant absorption (Table 1).

In most Brazilian soils, it is reported a general deficiency of P, which compromises good plant growth, therefore, this nutrient is one of the most used in fertilization processes of urban species in Brazil. Because P has low mobility in the soil (SENGIK, 2003), we can expect that in the study area, the P shows great difficulty for absorption by many of the tree species, given that other factors of the soil site contribute to that, such as acidity, and possible poor physical condition, which is very common in urban soils.

Parapiptadenia rigida had the lowest average K content (6.28 g kg^{-1}), significantly differing from the others, even so, the species was not classified as deficient by Silveira et al. (2005).

Barroso et al. (2005) analyzed deficiencies of macronutrients in *Tectona grandis*, and observed that in the absence of K in nutritional solution, there was reduction of the K content in the shoot. This may explain the adequate nutritional contents in the species studied, because the soil shows good K availability (Table 1).

In forest species, such as species of the genera *Eucalyptus*, *Pinus* and *Araucaria*, sufficient K content, according to SBCS-CQFS (2004), ranges from 6 to 15 g kg^{-1}. All species evaluated in this study are found within this limit. Epstein and Bloom (2004) also present a reference content of 10 g kg^{-1} of K as adequate for plant dry matter in general, regardless of the species.

Brun et al. (2010) carried out a study in the urban area of the Santa Maria city – Rio Grande do Sul state (Brazil) and found a K content in leaves of *Caesalpinia pluviosa* of 6.7 g kg^{-1}, although considered adequate, it is lower than the content we found for K in the trees analyzed on campus of the UFSM in our study. This is explained because the developmental conditions of plants in urban areas are more stressful than on campus. Moreover, sidewalks are narrower, free areas are smaller, pollution levels are higher, etc, that may indicate lower absorption of nutrients, such as K.

Potash, due to its high mobility in plants, as well as to its significant presence in the soil, is absorbed at necessary amounts by plants, in most cases. Potash can be absorbed from the soil by roots in both forms exchangeable and non-exchangeable (MEURER, 2006).

Given that K is absorbed through diffusion and mass flow from soil solutions to roots, it is essential to allow rainwater to reach the soil around the tree in an urban environment by providing plenty free areas and permeable sidewalks.

Eugenia uniflora had the highest Ca content (31.06 g kg^{-1}), similar to *Caesalpinia pluviosa* (18.31 g kg^{-1}). *Peltophorum dubium* showed an average Ca content of 6.34 g kg^{-1}, similar to the content level found by Moraes Neto et al. (2003), who observed contents between 8.7

and 6.5 g kg^{-1} in seedlings of *Peltophorum dubium* in a study to analyze the effect of doses and sources of manure on the growth of seedlings from five native tree species.

Epstein and Bloom (2004) report a reference value of 5 g kg^{-1} for Ca in plant dry matter. Grassi Filho (2007) and Larcher (2004) show a range between 3-15 g kg^{-1} for Ca in plants, in general. For species of *Eucalyptus* sp., a literature review carried out by Silveira et al. (2005) showed leaf values of Ca ranging from 3 to 11 g kg^{-1}, which is considered an adequate range of occurrence.

The Ca content for *Caesalpinia pluviosa* was similar to that found by Brun et al. (2010), for the same species (16.4 g kg^{-1}). *Cedrella fissilis* and *Parapiptadenia rigida* showed adequate contents (SILVEIRA et al., 2005) and similar to those reported by Biondi and Reissmann (2002) for leaves of *Handroanthus chrysotrichus* planted in the city of Curitiba – Paraná state, Brazil, of 10,2 g kg^{-1}.

Furtini Neto et al. (1999) investigated limiting factors to the initial plant growth of four species in acidic soil and observed a reduction in Ca absorption in a treatment with the addition of Al. In the current study, the adequate Ca supply may be related to this fact, given that Al contents in the soil of the study area were low.

Ca contents can also be related to the availability of other nutrients, such as N, P and K, which showed satisfactory contents in the soil and this factor may positively affect Ca absorption by tree species. Knapik and Angelo (2007) studied the effect of fertilization on the growth of seedlings of *Prunus sellowii* (pessegueiro-bravo) and observed an increase of Ca contents in leaf tissues for the treatment with NPK.

Cedrella fissilis showed the highest Mg content (2.20 g kg^{-1}) which was similar to those for *Eugenia uniflora* (1.91 g kg^{-1}), *Parapipitadenia rigida* (1.62 g kg^{-1}) and *Peltophorum dubium* (1.66 g kg^{-1}).

According to Yamada and Roberts (2005), the addition of K to the soil generally implies in decreases of Ca and Mg contents in plants. The authors explain that this may be related to the dilution effect, which leads plants, well supplied with K, to grow more and therefore, reducing Ca and Mg contents in leaf tissues. In our study, this antagonistic relation between K and Mg may have occurred, given that only in *Cedrella fissilis* we noted K content within the range considered adequate and for *Caesalpinia pluviosa*, we observed a content considered deficient, according to interpretations provided by Silveira et al. (2005).

Epstein and Bloom (2004) showed a reference of 2.0 g kg^{-1} for Mg content in plant dry matter, which is similar to reference values presented by SBCS-CQFS (2004) for forest species, with values ranging from 2 to 8 g kg^{-1}.

Regarding S, the lowest content was found in *Eugenia uniflora* (0.62 g kg^{-1}), which is probably nutrient-deficient showing a different content from other species. *Parapiptadenia rigida*, although it did not show contents significantly different from other species, it showed S contents below adequate levels, while other species showed more adequate contents, in accordance to Silveira et al. (2005).

Epstein and Bloom (2004) present 1.0 g kg^{-1} as reference for adequate values of S occurrence in plants and SBCS-CQFS (2004) report a range between 1.0 and 2.0 g kg^{-1}.

Moura et al. (2006) conducted a study on biomass and nutrient distribution in shoots of *Mimosa caesalpiniaefolia* and observed sulfur contents in leaves ranging from 1 to 1.25 g kg^{-1}, values similar to those found in the current study and within the range considered as reference.

Sulfur absorption in environments polluted by NO_2 and SO_2 was tested by Roberts et al. (1986), and the study showed that in presence of atmospheric S pollution, its absorption was facilitated in seedlings of four tree species used in urban afforestation in the United States. In our study, the site is not under severe atmospheric S pollution, which allowed to understand that some species studied showed low S contents.

The general order found for contents of the macronutrient studied showed the following: N>Ca>K>Mg>P>S, being that N, Ca and K had the highest contents for the species studied, according to the relations obtained: N>K>Ca>Mg>P>S (*Cedrella fissilis*); N>Ca>K>P>S>Mg (*Caesalpinia pluviosa*); Ca>N>K>Mg>P>S (*Eugenia uniflora*);

N>Ca>K>Mg>S>P (*Parapipitadenia rigida*) and N>K>Ca>Mg>P>S (*Peltophorum dubium*).

Still, each species with potential use in an urban environment should be studied regarding its nutrition in the initial developmental stages (seedlings), both in natural and urban environments, aiming to identify the real nutrient requirements for the species, given that several species show natural adaptations and survive with low mineral availability in soils, as is the case of *Eugenia uniflora*, which showed higher contents only for Ca and Mg.

Micronutrients

Table 3 shows the average contents of micronutrients for the species analyzed. *Eugenia uniflora* showed the lowest boron content (35.55 mg kg^{-1}), which was similar to those found for *Parapipitadenia rigida* (33.04 mg kg^{-1}) and *Caesalpinia pluviosa* (21.41 mg kg^{-1}).

According to the interpretation parameters of Silveira et al. (2005), the species *Cedrella fissilis* (15.44 mg kg^{-1}), *Peltophorum dubium* (16.89 mg kg^{-1}) and *Caesalpinia pluviosa* (21.41 mg kg^{-1}) showed B deficiency. However, although these species have contents below adequate levels, B greatly varies its leaf content depending on the species and developmental stage of the plant (COELHO and VERLENGIA, 1973).

For Epstein and Bloom (2004), adequate B content in plant tissue remains around 20 mg kg^{-1}, a value corroborated by SBCS-SQFS (2004), who reports a range between 10 and 50 mg kg^{-1} for the leaf tissue of some forest species. However, data mentioned in Dechen and Nachtigall (2006) show that, despite this occurrence range, adequate contents for normal plant growth remains between 30 and 50 mg kg^{-1} and deficiencies are more pronounced when contents are lower than 15 mg kg^{-1}. This corroborates the information in the previous paragraph, showing a B nutrient-deficient condition, at least for *Cedrella fissilis* and *Peltophorum dubium*.

Table 3: Average contents of micronutrients obtained for some native forest species used in the afforestation of the Campus of UFSM, Santa Maria city, Rio Grande do Sul - Brazil.

Species	Micronutrients (mg kg^{-1})				
	B	Cu	Fe	Mn	Zn
Eugenia uniflora	35.55 a*	6.29 b	129.50 b c	30.35 a	19.19 b
	(23.4)**	(39.2)	(19.3)	(5.7)	(5.1)
Parapipitadenia rigida	33.04 a	8.66 b	450.30 a	139.27 a	19.17 b
	(36.4)	(17.8)	(15.0)	(36.8)	(23.9)
Caesalpinia pluviosa	21.41 a b	15.75 a	206.20 b	87.15 a	12.92 b
	(25.8)	(14.5)	(25.9)	(42.2)	(6.0)
Peltophorum dubium	16.89 b	8.34 b	93.02 c	299.22 a	26.65 a
	(21.9)	(3.6)	(12.3)	(91.1)	(20.2)
Cedrella fissilis	15.44 b	10.06 b	164.62 b c	38.72 a	26.74 a
	(22.6)	(26.4)	(32.5)	(45.0)	(8.8)

*Means followed by the same letter in the column do not differ in the Tukey test (5% probability) ($p \leq 0.05$); ** values between brackets represent the coefficient of variation (%) of each mean.

Boron shows low mobility (CAMARGO, 1975) and immobility in plants (RAVEN et al., 2001) which may explain the lower B contents in leaf tissues of *Cedrella fissilis, Peltophorum dubium* and even of *Caesalpinia pluviosa*. The B absorbed by the plant also has positive correlations with OM content in the soil (FERREIRA and CRUZ, 1991) and that the best absorption of B occurs at pH closer to neutral (DECHEN and NACHTIGALL, 2006). Based on that, because the soil in the study area showed low OM content and pH, the adequate contents verified for leaves of *Eugenia uniflora* and *Parapipitadenia rigida* may be related to a higher capacity of absorption and mobility of B in these species.

Brun et al. (2010) found the B content in leaves of *Caesalpinia pluviosa* from a neighborhood of Santa Maria city – Rio Grande do Sul state – Brazil –, of 26.6 mg kg^{-1}, which is considered a slight deficiency for the nutrient. Roppa et al., 2005 studied micronutrient contents in *Syagrus romanzoffiana Handroanthus heptaphyllum*, and *Handroanthus chrysotrichum*, and reported a B content of 35.1 mg kg^{-1}; 70.0 mg kg^{-1} and 88.0 mg kg^{-1} respectively, which are high contents when compared to those found in our study, given that the study was also carried out on afforestation on campus of UFSM.

This situation shows a great capacity of some species to supply the needs for certain nutrients, such as boron, even in inadequate conditions for good absorption of the nutrient.

Regarding copper, we observed a higher average content for *Caesalpinia pluviosa* (15.75 mg kg^{-1}), which significantly differed from other species, and had content higher than the levels reported as adequate by Silveira et al. (2005), between 2 and 10 mg kg^{-1}. Still, we can affirm that all species showed adequate Cu contents, considering a range between 5 and 20 mg kg^{-1} cited by Dechen and Nachtigall (2006).

Brun et al. (2010) found that Cu contents in *Caesalpinia pluviosa* were lower, reaching between 7.2 and 6.5 mg kg^{-1}, respectively for leaves and branches, within the expected range for several tree species.

However, plants have the capacity to absorb higher Cu contents, as observed in the study of Medeiros et al. (2005), who studied content changes in leaf nutrients in mango tree crops in Rio Grande do Norte state – Brazil –, with values between 24 and 469 mg kg^{-1}. Studies show that Cu, at high concentrations, shows mobility between new and old leaves and fruits (DECHEN and NACHTIGALL, 2006); however, at low concentrations, this fact does not seem to occur, as shown by Brun et al. (2010) in the previous paragraph, with very similar contents between leaves and branches.

In the study of Roppa et al. (2005), the Cu contents in *Syagrus romanzoffiana* (8.6 mg kg^{-1}), *Handroanthus heptaphyllum* (9.2 mg kg^{-1}) and *Handroanthus chrysotrichum* (20.8 mg kg^{-1}) were adequate and high. High Cu contents may be related to soil contamination caused by construction residues, such as paints and similar materials, not only in original contents in the soil, highlighting that such comparison is not possible to be made in the current study.

The exchangeable Cu in the soil is not significantly adsorbed by organic matter in the soil, where ion is fixed by humus in a more stable than exchangeable way. In an acid pH, with low organic matter content in the soil, (besides the low humus content caused by the anthropogenic actions in urban soils, leading them to higher mineralization), it is expected that the relative proportion of exchangeable Cu predominate and be more readily available to plants, which may explain the adequate contents in all species studied.

Regarding Fe, we identified *Parapiptadenia rigida* with the higher average content (450.30 mg kg^{-1}) which greatly differed from other species. The lowest content was observed in *Peltophorum dubium* (92.02 mg kg^{-1}). The other species showed contents considered normal.

Caldeira et al. (2006) analyzed micronutrient contents of tree species of the Floresta Ombrófila Mista Montana in the municipality of General Carneiro – Paraná state – Brazil –, and found Fe contents in leaves of the species studied above 100.0 mg kg^{-1} for most species. Comparing to the current study, we observe that, except for *Peltophorum dubium*, the studied species also showed Fe contents higher than 100.0 mg kg^{-1}.

The literature prescribes that there is great variability for most nutrients, mainly Fe, among different species. For some species of *Eucalyptus* sp., Silveira et al. (2005) show that, a rage from 63 to 200 mg kg^{-1} of leaf contents is adequate. For Dechen and Nachtigall (2006), the variability of Fe content can occur between 10 and 1500 mg kg^{-1} of DM, considering contents between 50 and 100 mg kg^{-1} as adequate for good plant growth and deficient for plants that show Fe contents lower than10 mg kg^{-1}.

Fe shows low mobility within the plant (DECHEN and NACHTIGALL, 2006), and it usually occurs in the leaf, due to its participation in chlorophyll formation (LARCHER, 2004), which is exemplified in the results obtained by Brun et al. (2010), showing Fe contents in leaves roughly the double found in the shoots for *Caesalpinia pluviosa*.

Roppa et al. (2005) found Fe contents in three species ranging from 142.2 mg kg^{-1} in *Syagrus romanzoffiana* to 363.4 mg kg^{-1} in *Handroanthus chrysotrichus*, and for the species *Handroanthus heptaphyllum*, 219.9 mg kg^{-1}, identifying *H. chrysotrichus* as species that accumulated Fe. Biondi and Reissmann (2002) report a similar condition for *Handroanthus chrysotrichus* planted in urban polluted sites in the city of Curitiba (Paraná state – Brazil), with contents near 200 g kg^{-1}.

Even though it is difficult to affirm based on the results of the current study, the Fe contents found in *Parapiptadenia rigida* may also indicate a condition of higher Fe uptake, due to the high Fe content, which is possible for *Caesalpinia pluviosa*.

We identified the greatest manganese average of 299.22 mg kg^{-1} for *Peltophorum dubium*, which did not differ significantly from the other species analyzed. Although it was not observed significant difference between species, *Cedrella fissilis, Eugenia uniflora* and *Caesalpinia pluviosa* showed Mn deficiency. Silveira et al. (2005) reported contents, considered adequate, ranging from 193 and 840 mg kg^{-1} for *Eucalyptus* sp. For the authors, contents lower than 100 mg kg^{-1} are considered deficient.

Reissmann and Carneiro (2004) observed that greater saturation of basis decreased Mn contents in leaf tissue of mate (*Ilex paraguariensis*). This may explain the low Mn contents observed for most species, given that soil in the study site shows elevated basis saturation.

We can also consider, in this case, the effect of low pH as an important factor for the lower capacity of Mn absorption by plants, because low pH favors the reduction of Mn content (DECHEN and NACHTIGALL, 2006).

The higher Zn average content was observed in *Cedrella fissilis* (26.74 mg kg^{-1}), similar to *Peltophorum dubium* (26.65 mg kg^{-1}). These values are similar to those found by Berger (2006) in leaves and stems of mate (24.73 mg kg^{-1}) and are within the range considered adequate for all the species analyzed in this study.

Silveira et al. (2005) studied nutrition of different species of *Eucalyptus* sp. and reported adequate Zn contents in the leaf tissue ranging from 12 to 50 mg kg^{-1}, and all the species analyzed in our study remained within this range. Dechen and Nachtigall (2006) reported occurrence ranges between 3 and 150 mg kg^{-1}, affirming that values lower than 25 mg kg^{-1} in plant leaves are considered deficient.

The good P availability in the soil in the study area may have influenced Zn absorption, given that there is competition between these two nutrients, as seen in experiments conducted by Marschner and Schropp (1977), where high P contents may cause Zn deficiency.

On the other hand, a positive factor for Zn absorption is that it has greater availability in acidic soils (DECHEN and NACHTIGALL, 2006), as in the case of the current study, leading to a good Zn supply to the species studied.

In the study conducted by Brun et al. (2010), the average Zn content in leaves of *Caesalpinia pluviosa* remained within the adequate range for the plant between 10 and 50 mg kg^{-1}, as established by Larcher (2004).

The Zn contents in the leaf fraction found in this study are similar to those reported by Roppa et al. (2005), which remained between 19 and 24.4 mg kg^{-1} for *Handroanthus chrysotrichum, Syagrus romanzoffiana* and *Handroanthus heptaphyllum*, except for *Caesalpinia pluviosa*, which showed a lower content.

In the current study, the general order found for the micronutrient contents was: Fe>Mn>B>Zn>Cu, being that Fe and Mn showed the greatest contents in all species analyzed, as seen in the following relations: Fe>Mn>Zn>B>Cu (*Cedrella fissilis*); Fe>Mn>B>Cu>Zn (*Caesalpinia pluviosa*); Fe>B>Mn>Zn>Cu (*Eugenia uniflora*); Fe>Mn>B>Zn>Cu (*Parapipitadenia rigida*) and Mn>Fe>Zn>B>Cu (*Peltophorum dubium*).

CONCLUSIONS

Regarding macronutrients:

- The leaf N contents were considered normal for all species studied, except for *Eugenia uniflora*, which showed deficiency for the nutrient;
- *Eugenia uniflora* and *Parapiptadenia rigida* showed very low P contents;
- All species studied showed adequate K and Ca contents;
- *Cedrella fissilis* had adequate Mn supply, as opposed to *Caesalpinia pluviosa*, which showed Mn deficiency. The other species showed contents below adequate levels. *Eugenia uniflora* was deficient for S and *Parapiptadenia rígida* had contents below adequate levels;

Regarding micronutrients:

- *Cedrella fissilis* and *Peltophorum dubium* showed B deficiency;
- All species showed contents ranging from adequate to high Cu contents;
- Only *Peltophorum dubium* showed adequate Fe contents;
- *Cedrella fissilis, Eugenia uniflora* and *Caesalpinia pluviosa* showed Mn deficiency;
- *Eugenia uniflora*, *Parapiptadenia rigida* and *Caesalpinia pluviosa* showed Zn deficiency.

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