



**Characterization of visual symptoms and growth of australian cedar seedlings under nutritional deficiencies**

*Caracterização de sintomas visuais e crescimento de mudas de cedro australiano sob deficiências nutricionais*

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**Abstract.** Australian cedar is an exotic species adapted to soil and climatic conditions of Brazil. This study aimed to characterize the symptoms of nutritional deficiencies and their effect on cloned australian cedar seedling growth via the missing element technique. We used seedlings of two clones of australian cedar (MB and XB) and the experimental design was completely randomized with eight treatments consisting of: a complete nutrient solution, omitting the joint solution of macronutrients (multiple deficiency - MD) and solutions with omission of N, P, K, Ca, Mg and S. Nutrient deficiency symptoms were described and photographed. Characteristics were evaluated: height, stem diameter, aerial part dry mass (APDM), root dry mass (RDM), and RDM/APDM ratio. In summary, with omission of N, the plants showed reduced growth and chlorosis of older leaves, with later evolution to younger leaves. These symptoms were similar to those presented by the plants that did not receive nutrients (DM). Moreover, plants with S deficiency showed chlorosis on younger leaves. With the omission of P, was observed only a slight coloration of leaves to blue-green, in the absence of K, chlorosis followed by necrosis with particularities for each clone, and interveinal chlorosis on deficient Mg plants. In general, the N, Ca and S omissions limited the growth of the specie. The decreases in dry matter production yield due to nutrient omissions occur in the following order: Ca > K > Mg > S > N for clone MB and K > Mg > Ca > S > N for clone XB.

**Keywords:** *Toona ciliata*, mineral nutrition of plants, visual diagnosis, missing element

**Resumo.** O cedro australiano é uma espécie exótica adaptada às condições edafoclimáticas do Brasil. Este trabalho teve como objetivo caracterizar os sintomas de deficiências nutricionais e seu efeito no crescimento de mudas clonadas de cedro australiano, sob a técnica do elemento faltante. Foram utilizadas mudas de dois clones de cedro australiano (MB e XB) e o delineamento experimental foi inteiramente casualizado, com 8 tratamentos constituídos de: solução nutritiva completa, solução com omissão conjunta de macronutrientes e soluções com omissões de N, P, K, Ca, Mg e S. Os sintomas de deficiência dos nutrientes foram descritos e fotografados. Foram avaliadas as características: altura, diâmetro do caule, massa seca da parte aérea (MSPA), massa seca da raiz (MSR), relação MSR/MSPA. Em síntese, na omissão de N, as plantas apresentaram crescimento reduzido e clorose nas folhas mais velhas com posterior evolução para folhas mais novas. Estes sintomas foram similares aos apresentados pelas plantas que não receberam os nutrientes (DM). Por outro lado, as plantas com deficiência de S manifestaram a clorose nas folhas novas. Com a omissão de P, observou-se apenas uma leve coloração das folhas para verde-azulada, na ausência de K, clorose seguida de necrose com particularidades para cada clone, e clorose internerval nas plantas deficientes em Mg. De maneira geral, as omissões de N, Ca e S são as que mais limitaram o crescimento da espécie. Os decréscimos das produções de MSPA, devido à omissão de nutrientes, ocorrem na seguinte ordem: Ca > K > Mg > S > N para o clone MB e K > Mg > Ca > S > N para o clone XB.

**Palavras-chave.** *Toona ciliata*, nutrição mineral de plantas, diagnose visual, elemento faltante



## Introduction

The tropical forests hold most of the biodiversity of the planet and they are being degraded quickly by antropic action, such as the predatory logging exploration and the substitution of the forests by agriculture and livestock. In function of the degradation reality, measures have been adopted to lessen these effects, be them in the correct application and enforcement of the environmental legislation, in the adoption of different conservation strategies and in reforestation programs.

Now there is a need of reforestation plans that provide the environmental balance inserting the producer in this context (social aspect). An alternative to timber extraction is in the cultivation of australian cedar. This is an exotic species that has adapted to the edaphoclimatic conditions of Brazil by the fact of presenting an attractive annual average increase and a good valorization of the wood. Lorenzi et al. (2003) emphasize that its wood possesses quality similar to that of the native cedar (*Cedrela odorata e Cedrela fissilis*) and, it is destined for noble uses, such as furniture production and construction industry finishings.

The australian cedar is a large tree that belongs to the Meliaceae family and can reach 20 m of height and 40 cm diameter at breast height. In Brazil, this species grows better in areas with annual precipitation of 1,100 mm, with good drainage and absence of frost. It presents specific nutritional demands and low tolerance to soil acidity (Lorenzi et al., 2003; Souza, 2010).

The proper plant nutrition is an indispensable characteristic for their growth and development, that reflect on yield compatible with the adopted technological level. Advancements have been reached in plant nutrition in works conducted with plants in nutrient solution, which enables better control of the amount of nutrients and eliminates the interference of biotic and abiotic factors, due to heterogeneity and soil complexity (Malavolta et al., 1997).

The missing nutrient technique is widely used in assays of cultivations in nutrient solution, with the objective of determining the nutrient demand of a culture and to characterize the effects in its development. The use of this technique in studies with forest species has been employed by various authors. Among them, Costa et al. (2007) who studied the nutritional limitations on the production, growth and nutrition of the tapir broad bean

(*Dimorphandra mollis*). Wallau et al. (2008a) conducted a study on symptoms of macro and micronutrient deficiencies in mahogany seedlings (*Swietenia macrophylla*), in nutrient solution.

Research's results reveal that different genotypes present available soil nutrient use in a differentiated way, some being more efficient than others. Therefore, studies on the evaluation of the nutritional state of forest species are important to make inferences about the growth limiting nutrients, besides guiding appropriate of the fertilization management.

In that context, the objective of this work was to characterize the visual symptomatology of the macronutrient deficiencies and their effect on the growth of cloned australian cedar seedlings.

## Material and Methods

The work was carried out in a greenhouse located in the Soil Science Department of the Federal University of Lavras, in the city of Lavras, state of Minas Gerais. The municipal district is located in the area of the Campo das Vertentes, at 919 m of altitude, 21°14'S of latitude and 45°00'W of longitude (Dantas, 2007).

Seedlings of two australian cedar clones were used (MB and XB), from the Bela Vista Forest Nursery, located in the municipal district of Bela Vista, MG. The seedlings with approximately 50 days age (after staking) were removed from the tubes and the roots were washed with deionized water to eliminate the substrate residues. Later, the seedlings were placed in trays containing Hoagland & Arnon solution (1950), initially with 25% of the ionic strength, remaining there for seven days. After that period, the ionic strength was increased weekly until reaching 100%. This time corresponds to the adaptation period.

After the initial adaptation, the seedlings were transferred for 5 L vases containing the nutrient solution of the respective treatments. The solutions were renewed daily with deionized water, according to plant demand and renewed fortnightly.

For each clone, the experiment was composed of 8 treatments with four repetitions, with a completely random statistical design. The preparation of the nutrient solutions was based on the missing element technique: 1) complete nutrient solution (CNS); 2) solution with joint omission of macronutrients (multiple deficiency-MD); 3) nitrogen omission (- N); 4) phosphorous omission (- P); 5) potassium omission (- K); 6) calcium



omission (- Ca); 7) magnesium omission (- Mg) and 8) sulfur omission (- S).

The sources necessary for the preparation of the nutrient solutions were obtained from the following reagents, pure for analysis:  $\text{NH}_4\text{H}_2\text{PO}_4$ ,  $\text{KNO}_3$ ,  $\text{Ca}(\text{NO}_2)_3 \cdot 4\text{H}_2\text{O}$ ,  $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ ,  $\text{K}_2\text{SO}_4$ ,  $\text{Ca}(\text{H}_2\text{PO}_4)_2$ ,  $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ ,  $\text{Mg}(\text{NO}_3)_2$  as macronutrient sources and  $\text{Fe-EDTA}$ ,  $\text{H}_2\text{BO}_3$ ,  $\text{MnSO}_4 \cdot \text{H}_2\text{O}$ ,  $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ ,  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$  and  $\text{H}_2\text{MoO}_4 \cdot \text{H}_2\text{O}$  as micronutrient sources.

Over the course of the experiment, the plants were appraised via photographic images and morphometric descriptions, with the intention of accompanying the nutrient deficiency symptoms. Height (H) and stem diameter of the (SD) measurements were taken each 20 days and at the end of the experiment the aerial part dry mass (APDM), root dry mass (RDM), RDM/APDM ratio and the leaf macronutrient contents were determined.

The height of the seedlings was obtained with a millimetric ruler and the stem diameter with a digital caliper. The dry mass of the different parts of the plant was obtained after drying in a forced-air oven at  $65^\circ\text{C}$  until reaching constant mass. The chemical analyses of the plant leaf macronutrient contents were conducted according to the methodology proposed by Silva (2009).

The data were submitted to variance analysis, and the averages compared by the Scott Knott test to 5% of probability, with the aid of the Sisvar software (Ferreira, 2011).

## Results and Discussion

### *Description of visual symptoms of deficiency*

The symptoms of nutritional deficiencies observed in the Australian cedar clones were similar for most of the macronutrients (Figures 1 and 2), except for K. The first deficiency symptoms were identified in the MD, - N, - Mg and - S treatments, followed by the - K and - Ca treatments and finally the - P treatment.

In the - N treatment chlorosis (yellowing) was observed initially in the oldest leaves with subsequent evolution to the newest leaves. That deficiency symptom is classic among plants, in function of N mobility and redistribution in the plant (Faquin, 2005). The plants also presented reduced growth and with small leaves, in relation to the plants corresponding to the complete treatment. Those results, as to symptom manifestation, resemble those found by Wallau et al. (2008a) in

assays with mahogany cultures in nutrient solution and Moretti et al. (2011) who observed reduced size and lower number of leaves in Australian cedar under N omission.

In the plants with omission of P only a slight change in the leaf coloration, to a bluish-green shade, was observed (Figures 1 and 2). Possibly, during the seedling adaptation phase in nutrient solution for thirty days (gradual increase of the ionic strength), they absorbed sufficient quantities of P, thus guaranteeing a good reserve of this nutrient in their tissues. A deficiency of this element in the middle induces the plant to use P metabolized present in vacuoles of older leaves, redistributing it to younger leaves and/or organs, manifesting in those early symptoms (Marschner, 1995), in the case of Australian cedar changes occurred in the color of old leaves. This is due to the accumulation of anthocyanins in the vacuoles of epidermal cells (Epstein & Bloom, 2006) due to the limitations of the photochemical reactions of photosynthesis, which induces pigment to protect the leaves of a possible photoinhibition (Trull et al., 1997).

In the cultivation of the Australian cedar in soil, conducted by Moretti et al. (2011), the omission of P reflected directly in lower plant growth. This is due to the fact that the soil used contained a low available P concentration, that was insufficient for the formation of a reserve stock for the plant. P is considered an integral component of important plant cell compounds, such as respiration and photosynthesis intermediates, phosphate-sugars and phospholipids (Taiz & Zeiger, 2012).

In the omission of K (Figure 1), it was verified that the MB clone seedlings presented an initial yellowish-green coloration close to the central rib of the leaves, moving towards the marginal area, and subsequent necrosis. The symptomatology of the deficiency of that nutrient for the XB clone was a reticulated chlorosis followed by necrosis (Figure 2). This last phase of the diagnosis is due to the putrescine accumulation in the leaves (Faquin, 2005). It was also observed that, in the middle third, the borders of the leaves bent upward in the two clones, besides presenting smaller growth, when compared to the seedlings of the complete treatment. K is important in the regulation of the osmotic potential of the plant cells and in the activation of various enzymatic systems (Ernani et al., 2007).

The symptoms of Ca deficiency are characterized by plant growth reduction; marginal chlorosis of the leaves (Figure 1 and 2) that moves

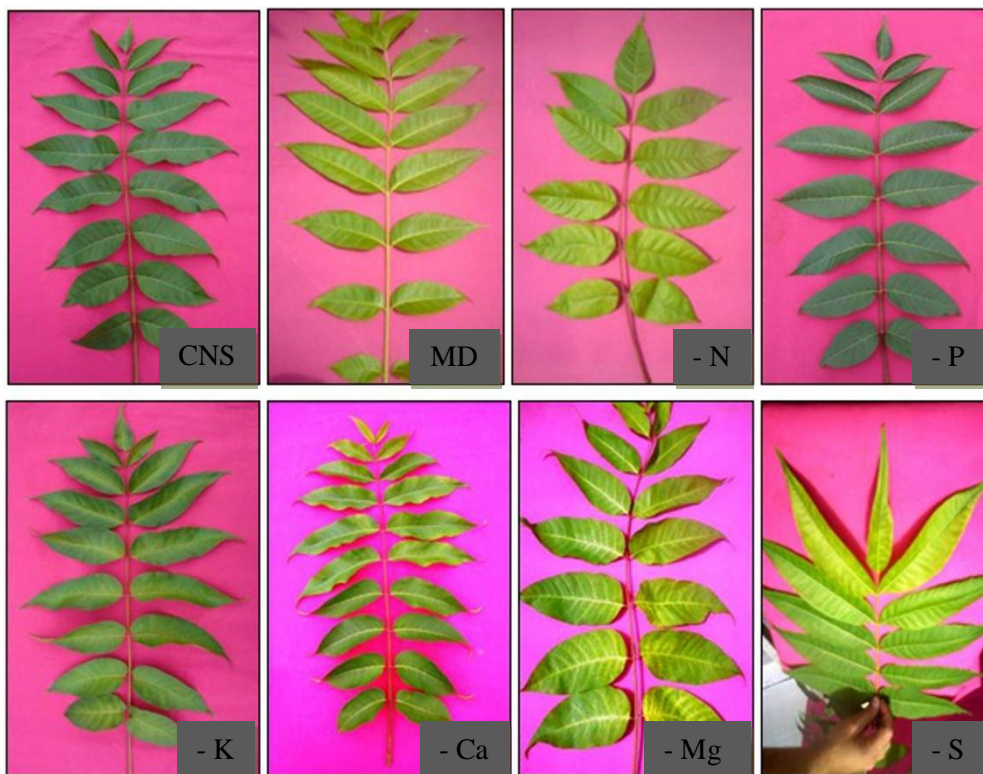
towards the central part (the inverse described for K), followed by random necrotic spots and necrosis of their tips; upward curving of the leaf edges; short internodes; and marked root system reduction with dark coloration. According to Malavolta (2006), due the Ca presenting low translocation in the plant, the nutrient deficiency symptoms occur in the growth points of the aerial and root parts (meristematic growth). That nutrient aids in the synthesis of new cell walls, the middle lamella in particular, reinforcing the plant structure (Taiz & Zeiger, 2012).

In function of the Mg mobility in the plant, as well as N, P and K, the deficiency symptoms initially manifested in the old leaves, later extending to the newest leaves (Figure 1 and 2). The plants cultivated under Mg omission demonstrated internodal chlorosis and subsequently senescence of old leaves. This symptom is in agreement with that

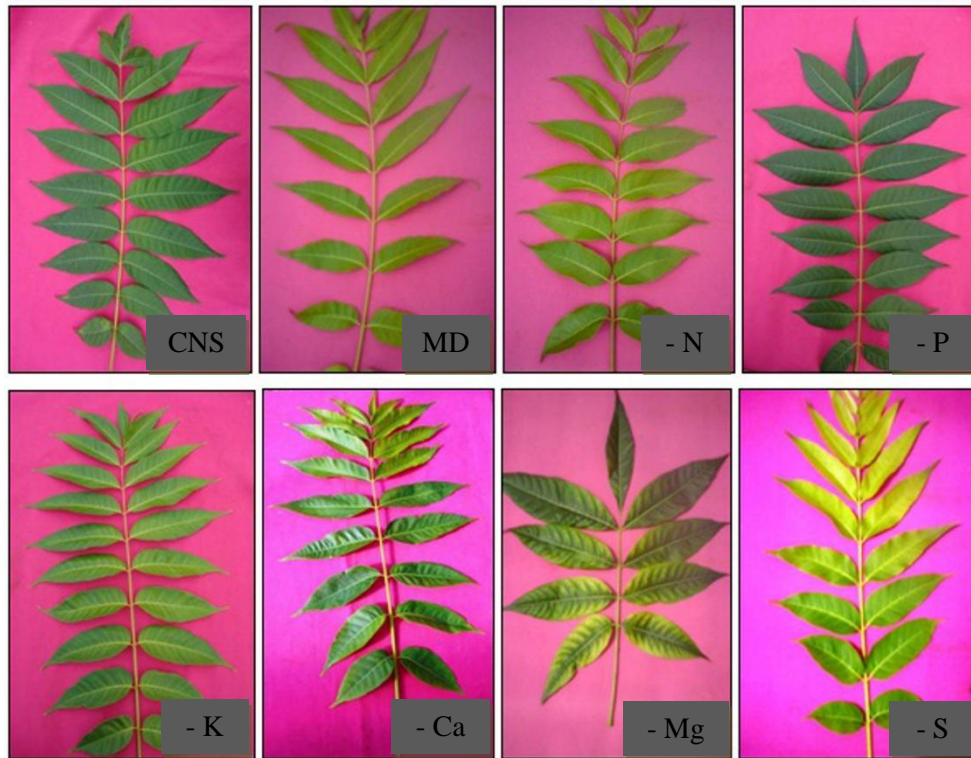
described by Barroso et al. (2005) for Teak (*Tectona grandis*).

In the plants with S omission generalized chlorosis in the new leaves (Figure 1 and 2) and reduced growth was observed. According to Malavolta et al. (1997) S is considered little mobile in the plant, therefore the deficiency symptoms resemble those presented by the N deficiency, however they are diagnosed in young leaves. The widespread chlorosis was confirmed in the studies conducted by Wallau et al. (2008a) with the cultivation of mahogany seedlings, however their growth was not affected. S plays an important role in the protein structure in the plants (Vitti et al., 2006).

The plants corresponding to the treatment with omission of all the nutrients (multiple deficiency) in the appraised period presented the same symptoms described for the nitrogen (Figure 1 and 2).



**Figure 1.** Australian cedar MB clone leaves submitted to treatments in complete nutrient solution (CNS) and the omission of macronutrients: MD (multiple deficiency), -N, -P, -K, -Ca, -Mg and -S.



**Figure 2.** Australian cedar XB clone leaves submitted to treatments in complete nutrient solution (CNS) and the omission of macronutrients: MD (multiple deficiency), -N, -P, -K, -Ca, -Mg and -S.

### *Vegetative growth*

It was verified that, for both clones, the nutrients N, S and Ca are those that most limited the growth of this tree species (Table 1).

The height growth limitation of the MB clone seedlings caused by the omission of N, Ca and S was observed starting from the first evaluation conducted 20 days after the transplant (DAT). N was the nutrient that most affected the growth in height of the seedlings at 40 DAT. At the end of the experiment, the height of this clone was not affected by the omissions of P and Mg, because their averages did not present significant difference when compared with those of the complete treatment. This can be verified with the visual observation of the symptoms of deficiency of those two nutrients, in the appraised period. The damage caused to the plants by the absence of Mg reached the old leaves, provoking senescence and, with the omission of P, clear symptoms of that nutrient deficiency were not observed. In the final evaluation it was verified that, besides the omissions of N, Ca and S, the absence of K also affected the plant height growth. On the other hand, the limitation to the growth in height of the XB clone was only verified 60 DAT, with the omission of N, Ca and S. This behavior can be

justified by a probable formation of an initial stock of nutrients in the seedlings of this clone, due to intrinsic characteristics of the genetic material. That can be confirmed in Table 1, where one can see that at 40 DAT, the height of the seedlings reached with the omission of all the nutrients (MD-Multiple Deficiency) was not affected significantly ( $p < 0.05$ ) when compared to that of the complete treatment.

It is known that N is a constituent of various plant compounds such as amino acids, nucleic acids, and chlorophyll, being one of the nutrients absorbed in large amounts by plants, because it is required in the participation of key biochemical reactions (Bloom & Epstein, 2006). The S is essential in the proteins production (Vitti et al., 2006) process. The deficiency of these nutrients in plants causes reduced growth, as seen in the results of this study, the absence of N and S affect directly the process that generates indispensable products for the survival of plants, photosynthesis. As a consequence, there is a reduction in chlorophyll content and ribulose - 1, 5 carboxylase / oxigenasse biphosphate (Rubisco), which decreases photosynthesis causing reduced growth of plants (Resurreccion et al., 2001; Taiz & Zeiger, 2012). The reduction in the growth of seedlings of



Australian cedar caused by Ca deficiency is due to the fact of this element actin meristematic plant growth (Malavolta, 2006).

The growth in stem diameter presented significant difference among the treatments starting from the second evaluation (40 DAT) for the appraised clones. In the MB clone, the omission of N caused the highest stem diameter reduction at 60 DAT of the seedlings. It is also observed that, with the omission of P, K, Ca and Mg, in spite of the seedlings presenting diameters inferior to those of the seedlings cultivated in complete solution, they did not differ statistically among themselves. In the

final evaluation, the omissions of P, K and Mg also affected the growth in diameter of the MB clone. In relation to the XB clone, in the second evaluation, we verified that only the lack of N (except the MD) caused reduction of the stem diameter and, in the end of the assay, besides this nutrient, the Ca also affected this morphologic characteristic of the plant.

Various studies indicate that the omission of N and/or Ca is the main responsible factor for the growth reduction of forest species. Such observation was observed in Teak seedlings (*Tectona grandis*) (Barroso et al., 2005).

**Table 1.** Stem diameter (SD) and plant height (H) of australian cedar clonal seedlings (MB clone and XB clone) obtained each 20 days, in response to treatments.

Treatment	MB CLONE						XB CLONE					
	20 DAT <sup>1</sup>		40 DAT		60 DAT		20 DAT		40 DAT		60 DAT	
	SD	H	SD	H	SD	H	SD	H	SD	H	SD	H
	(mm)	(cm)	(mm)	(cm)	(mm)	(cm)	(mm)	(cm)	(mm)	(cm)	(mm)	(cm)
Complete	7.1 a	41.1 a	12.3 a	72.7 a	18.7 a	87.3 a	6.9 a	38.5 a	12.4 a	58.3 a	16.0 a	69.3 a
M. Def.	6.5 a	38.0 b	9.2 c	42.7 c	12.3 d	59.0 b	6.4 a	35.7 a	9.8 b	42.5 a	12.5 b	47.2 b
- N	6.9 a	36.7 b	9.0 c	39.2 c	11.9 d	61.6 b	6.7 a	35.8 a	9.5 b	37.5 a	11.4 b	46.3 b
- P	6.9 a	41.2 a	10.7 b	57.7 b	15.9 c	88.3 a	7.1 a	37.6 a	11.5 a	55.7 a	16.2 a	76.4 a
- K	7.8 a	44.1 a	11.4 b	58.7 b	16.2 c	68.3 b	7.8 a	40.0 a	11.5 a	48.0 a	15.7 a	67.3 a
- Ca	6.8 a	39.2 b	11.6 b	58.2 b	14.9 c	64.6 b	7.2 a	40.3 a	11.4 a	52.5 a	13.0 b	53.0 b
- Mg	7.5 a	41.2 a	12.8 a	78.5 a	13.4 c	86.2 a	7.6 a	38.4 a	12.8 a	55.7 a	16.1 a	63.0 a
- S	6.6 a	35.0 b	10.9 b	51.3 b	17.1 b	73.6 b	7.4 a	37.6 a	11.3 a	47.8 a	16.1 a	52.3 b
CV	8.9	9.2	7.8	10.2	6.9	10.1	11.4	11.9	10.1	19.1	7.2	12.8

\* Averages followed by the same letter in columns do not differ at 5% probability by the Scott-Knott test.

<sup>1</sup>DAT-Days after transplant.

According to Moretti et al. (2011), the nutrients that limited the initial growth of the australian cedar plants were N, P, K, S and Mg. It is supposed that such differentiated seedling behavior, in comparison with the result obtained in the present work, has a relationship with the genetic material used (seminal seedlings) and the cultivation medium (soil), since the authors conducted the experiment up to 150 days, and in that period, the growth in height of the plants was not significant.

Similar results to those obtained in this work were found by Venturin et al. (1999), *Peltophorum dubium* (SPRENG.) Taub., in which growth in height and stem diameter were prejudiced by the omission of N, Ca and S. In that assay, P was also limiting in the seedling performance. Studies with

different species, such as the pink cedar (Locatelli et al., 2007) and the tapir broad bean (Costa et al., 2007), show that P is one of the nutrients that most limits the growth of those plants. This was not observed for the clones of australian cedar, in that the species did not present susceptibility to the P deficiency.

#### Dry matter production

The results regarding the aerial part dry mass production of the (APDM), root dry mass (RDM) and RDM/APDM ratio for clonal seedlings of australian cedar is presented in Table 2. The results obtained for the treatment with phosphorous omission were not considered in the variance analysis, because the plants of that assay did not



manifest deficiency symptoms at 60 DAT, only being picked 82 DAT.

**Table 2.** Average values of aerial part and root dry mass and the RDM / APDM ratio for clones of Australian cedar (MB and XB), in response to treatments.

Treatment	Clone MB			Clone XB		
	APDM	RDM	RDM/APDM	APDM	RDM	RDM/APDM
Complete	140.8 a	27,5 a	0.19 c	166.5 a	17,5 a	0.11 c
M. Def.	30.3 d	15,1 c	0.49 a	42.7 b	16,6 b	0.42 a
- N	29.3 d	17.1 c	0.59 a	31.5 b	14,5 b	0.45 a
- K	106.4 b	16,8 c	0.16 c	153.5 a	17,1 a	0.15 c
- Ca	118.6 a	20,9 b	0.17 c	76.5 b	12,2 c	0.11 c
- Mg	83.25 b	17.5 c	0.22 c	132.1 a	15,8 b	0.12 c
- S	66.5 c	23.2 b	0.35 b	72.5 b	18,1 a	0.25 b
CV	27.2	32,2	24.9	31.5	27,6	31.6

\* Averages followed by the same letter in columns do not differ at 5% probability by the Scott-Knott test.

It was verified that, for both clones (MB and XB), there was significant difference in the evaluated characteristics (Table 2). In the general, observed that the macronutrient omissions caused higher damage to the APDM production. In this case, it was verified that the omission of N, followed by that of S, Mg and K, was that which most affected the APDM production for the MB clone. However for the XB clone, the omissions of N, S and Ca, were the most limiting for its development. The decreases of the APDM productions in clonal seedlings of Australian cedar occurred in the following order: Ca>K>Mg>S>N (clone MB) and K>Mg>Ca>S>N (clone XB).

The interference of N in the APDM production is common in several species, such as mahogany (Wallau et al., 2008a), teak (Barroso et al., 2005), candeia (Venturin et al., 2005) and others. This occurs due to the importance of that nutrient in the plant metabolism, because with its absence there is a reduction of the photosynthetic activity, consequently affecting mass yield.

The root dry mass of Australian cedar seedlings subjected to omissions of macronutrients was significantly affected for the two evaluated clones (Table 2). Absences of all analyzed macronutrients affected the root development of MB Clone. For XB clone, lower yields were obtained with root deficiencies of N, Ca and Mg, being more critical in the absence of Ca, since this nutrient, among other functions, contributes to increase the survival of roots (Taiz & Zeiger, 2012).

Given the changes in the macronutrient availability in nutrient solution, it is observed that the clones obtained a higher RDM/APDM ratio in the treatments with N omission and joint omission of the macronutrients (MD), followed by the absence of S (Table 2). That is due to the reflection of the higher RDM accumulation and APDM reduction. According to Clarkson (1985), the higher RDM/APDM ratio can be considered a plant strategy for absorbing the maximum of nutrients in low fertility soils. In spite of the low RDM/APDM ratio has been observed with the omissions of K, Ca and Mg, they do not have any significant alteration in relation to that determined for the plants of the complete treatment.

It is important to note that, in the present study, the absence of P only caused a slight alteration in the coloration of the oldest leaves to bluish-green, besides presenting APDM values of 186.5 g and 233.4 g, for the clones MB and XB, respectively. That seedling growth is attributed to the fact that the clones, in the adaptation phase, uptake sufficient amounts of P, guaranteeing enough reserves in their tissues. That satisfactory supply of the nutrient to the plants in this phase was also confirmed in research conducted by Sarcinelli et al. (2004) and Wallau et al. (2008a) with *Acacia holosericea* and mahogany, respectively.

In that context, it is suggested the carrying out of new assays with the omission of P in nutrient solution, during a period greater than 82 days, in attempt to characterize the symptoms of deficiency of that nutrient in the Australian cedar.



*Evaluation of plant nutrition*

Since the leaf is considered the plant organ that best reflects its nutritional state (Silveira et al., 2000), where undertook the evaluation of the

australian cedar nutrition through leaf chemistry analysis. The macronutrient contents in the leaves, except for the omission of P, are presented in Table 3.

**Table 3.** Leaf nutrients in australian cedar seedlings (clone MB and clone XB), in response to treatments.

Treatment	CLONE MB						CLONE XB					
	N	P	K	Ca	Mg	S	N	P	K	Ca	Mg	S
	(g kg <sup>-1</sup> )						(g kg <sup>-1</sup> )					
Complete	19.0 b	1.9 c	9.7 a	9.2 c	2.0 c	1.8 a	20.1 b	1.9 d	8.4 b	7.6 c	1.6 c	1.5 b
M. Def.	13.1 c	1.6 c	5.2 b	14.0 b	2.5 b	1.3 b	12.9 c	1.5 e	6.8 c	13.9 b	2.9 b	1.2 b
- N	12.2 c	3.4 a	8.4 a	16.4 a	2.3 c	2.1 a	16.2 c	3.7 a	8.9 b	16.5 a	2.4 c	2.0 a
- K	21.9 a	2.4 b	3.7 b	9.9 c	2.7 b	1.7 a	24.7 a	3.1 b	2.9 d	14.2 b	3.4 b	1.9 a
- Ca	22.9 a	1.9 c	8.6 a	3.1 d	3.7 a	1.7 a	25.2 a	2.6 c	8.9 b	3.6 d	4.2 a	2.0 a
- Mg	23.7 a	2.4 b	5.7 b	9.5 c	1.2 d	1.9 a	19.8 b	1.9 d	10.7 a	8.5 c	0.9 d	1.7 a
- S	17.6 b	2.6 b	8.7 a	16.7 a	2.9 b	1.0 b	21.8 b	2.5 c	6.7 c	12.2 b	2.1 c	1.1 b
CV	13.51	19.7	25.5	13.3	14.6	17.5	12.5	10.8	14.5	10.9	14.2	16.1

\* Averages followed by the same letter in columns do not differ at 5% probability by the Scott-Knott test.

The leaf N content was higher ( $p < 0.05$ ) in the treatments with omissions of K, Ca and Mg in the clone MB and, K and Ca in the XB clone, superior to the content of the nutrient in the complete nutrition treatment. Similarly Wallau et al. (2008b) verified that the omissions of the mentioned nutrients caused an increase in the N contents in the aerial part and in the roots of mahogany. Some authors also observed, in forest species, a higher concentration of N with the Ca omission, such as the aroeira (mastic) (Mendonça et al., 1999) and the teak (Barroso et al., 2005).

This fact can be related to the increased availability of N in the ammonium form in treatments with omissions of K and Ca, because of substitutions of the sources used (calcium and potassium nitrate) for the preparation of these solutions by ammonium nitrate. The absence of the above elements, probably led to the absorption of  $NH_4^{4+}$  by plants. Is important to note that there is an antagonism between K, Ca, Mg and  $NH_4^{4+}$ , with the increase of concentration of one these nutrients in the medium providing a reduced absorption of the other (Malavolta, 1980). According to Marschner (1995), the competition between these elements by exchange sites in the plasma membrane of root cells generally occurs between ions with similar physicochemical properties, such as  $NH_4^{4+}$  which can

cause inhibition of the uptake of  $K^+$  through the roots or  $Mg^{2+}$  which undergoes strong competition for these exchange sites with  $Ca^{2+}$  and  $K^+$ , and vice versa.

For both clones, the highest P content was observed in the treatment with omission of N. In spite of the foliar contents of the nutrients not having been included in the statistical evaluation of the assay with absence of P, contents of that nutrient were determined with average values of 1.3 g kg<sup>-1</sup> and 1.1 g kg<sup>-1</sup>, for the seedlings of the clones MB and XB, respectively. Even in view of those low contents, a plant growth reduction was not observed (Table 1).

The omissions of N, Ca and S caused an increase in the K content in the leaves of the MB clone. For the XB clone, that increase was observed in the absence of Mg. The higher concentration of K in the treatments without Ca and without Mg can be related with decrease interaction by competitive inhibition (Malavolta et al. 1997) between these nutrients, which promotes K uptake by plants. With omission of N, there is no ammonium form of this element, which possibly reduced the competition for exchange sites with K and favored higher accumulation of this nutrient by plants. Similarly, with omission of S, the supply of nitrogen was realized using a source with nitrate in





their composition, thus minimizing the effect of competition by plants for potassium uptake .

The uptake of Ca was favored by the omissions of K and Mg, for both clones. In the MB clone, the Ca contents determined in the plants of the treatments with absence of K and Mg did not present a significant difference when compared with the content of the treatment with complete nutrition. However, for the XB clone, the Ca content with K omission was superior to that determined in plants that received complete fertilization. We also observed that the omission of N favored the Ca absorption. The reduction of the mechanism of competitive inhibition among the nutrients was also observed for Mg, with the omissions of K and Ca, favoring its absorption by the australian cedar plants. The leaf contents in the K and Ca omission assays were superior in relation to the complete treatment. Similar results were found by Wallau et al. (2008b) for mahogany.

The omission of the appraised macronutrients, separately, did not affect the S absorption by the australian cedar. Those results corroborate with those determined Moretti et al. (2011) for this species, except for Mg. We also verified that the S content in the XB clone seedlings, with its omission, did not present significant difference when compared with that of the complete treatment, due to a probable dilution effect of the nutrient facing the higher aerial part dry mass production (Table 2).

In the complete treatment, the foliar contents determined for most of the macronutrients in the australian cedar clones are considered adequate, according to Malavolta et al. (1997), except for K. Only the K content, in all the treatments, was considered below the appropriate range (10 to 15 g kg<sup>-1</sup>). Such as, it is important to emphasize the need of other research on the nutrition of that species, to guarantee the nutritional balance of the plants without compromising their growth and development.

### Conclusions

With exception of P, it was possible to distinctly characterize the macronutrient deficiency symptoms in the australian cedar clones.

In general, the omissions of N, Ca and S is what most limited the growth of the species.

The reductions of the APDM production due to nutrient omission in australian cedar clonal seedlings occur in the following decreasing

sequence: Ca>K>Mg>S>N for the MB clone and K>Mg>Ca>S>N for the XB clone.

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