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Leaf content of macronutrients in *Tabebuia aurea* seedlings grown on different substrates and luminosities

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Taking into consideration that species react differently to the substrate and luminance variations, this study aimed to evaluate the leaf content of some macronutrients and dry matter in *Tabebuia aurea* seedlings through the hypothesis that the growth environment can alter the concentration of chemical elements in the species. The study was conducted in a greenhouse, in randomized blocks, factorial 2 × 3 (two light intensities and three types of substrates). The first greenhouse was covered with shade cloth, with maximum flow of 950 µmol m^{-2} s^{-1} radiation, and the second was 750 µmol m^{-2} s^{-1}. The substrates were: 1) Cerr. Savannah soil, 2) Ca-Mg – Savannah soil with calcium carbonate and magnesium and, 3) OM – Savannah soil with organic matter (2/1), with samples taken after 230 days of experiment. The data obtained indicated that *T. aurea* species has better development when grown in brighter locations in OM soils, which would be expected due to its higher nutritional content. However, when the seedlings were placed in soils with low nutrient content (Ca-Mg and Cerr.) and similar levels of potassium, plants maintained in soils with higher amounts of calcium and magnesium obtained higher growth, with greater accumulation of dry matter in leaves and total. This could indicate that the difference in growth should be related to increased amount of these Ca-Mg elements of treatment and the calcicole characteristic of the species tested.

Key words: Greenhouse, seedling formation, dry matter, ipê.

INTRODUCTION

The species *Tabebuia aurea* (Silva Manso) Benth. & Hook.f ex. S. Moore is found in areas of the Amazon region, Northeast, Midwest and Southeast, in different environments. The species is popularly known as "ipê", "paratudo", "caraíba", "ipê-do-cerrado", and "ipê-amarelo", among other regional names and often found in the Pantanal (floodplain) and Cerrado (savannah) areas in the state of Mato Grosso do Sul (Lorenzi and Matos, 2008; Soares and Oliveira, 2009). Its wood is used for making tools, furniture and civil construction, among other uses and may be employed in landscaping; also it has use in popular medicine, to combat influenza, diabetes, malaria and inflammation in general, amongst other activities (Lorenzi and Matos, 2008). It is a species that has great potential for use, including Agroforestry Systems (AFS), in grazing associations to forest and non-forest species, in order to increase the production per unit area, with higher productive diversity in ownership (Rodrigues et al., 2007). Currently, there is a search for native tree species that can be used in these systems, with a significant number of plants of Cerrado and Pantanal region which may be used for this purpose.

However, for its use, the production of seedlings is necessary, using different environmental conditions such as luminosities and substrates. Regarding substrates, the correct choice of the appropriate material is important for producing high quality seedlings, as it directly affects the quality of plants due to the variation of physical, chemical and biological properties, and should have good porosity, water retention capacity, cationic change and uniform composition.

Furthermore, the diversity of plant responses regarding its growth associated with light is a factor which can affect the initial growth. According to Larcher (2003) and Lambers et al. (2008) the study of the behavior of the species in different light regimes assists in the study of its feasibility for use in reforestation or cultivation, among other actions. Light and its intensity and wavelength, among other characteristics, has great effect on plant growth, and the modification of these parameters may change plant growth (Larcher, 2003; Lambers et al., 2008; Taiz et al., 2014).

Due to its great potential for use, there are studies relating to some of the growth characteristics of the species *Tabebuia aurea* in different types of substrates and luminosities (Oliveira and Gualtieri, 2011, 2012; Oliveira and Perez, 2012), but none is related to accumulation of nutrients in their leaves with different environmental factors. According to Mengel and Kirkby (2001) and Marschner (2012), the concentration of foliar nutrients may vary, among other factors, in accordance with the light available and the type of soil used for seedling growth. It is also necessary that the foliar nutrient content be appropriate, allowing the seedlings a better rate of survival and adaptation to the environment, and allows the chemical profiling of leaves, important for the diagnosis of the nutritional status of plants.

Given the importance of knowledge about the processes of growth of native species, the objective was to evaluate the leaf content of some macronutrients and dry matter of seedlings grown on different substrates and luminosities, identify the factor that most interfered in development and correlate the data obtained with the calcicole characteristics of the species.

MATERIALS AND METHODS

Fruit collection

Tabebuia aurea fruits were harvested from 10 matrices located in Passo do Lontra, sub-basin of the river Miranda (Upper Paraguay River Basin), Municipality of Corumbá, Mato Grosso do Sul, and transported to the city of São Carlos, State São Paulo. After opening the fruits by natural dehiscence, the seeds were chosen with no apparent signs of attack by insects and equivalent size. Later, they were placed to germinate in plastic boxes containing filter paper moistened with Captan fungicide solution (0.2%) and kept on laboratory shelves under environmental temperatures in Plant Physiology laboratory of the Federal University of São Carlos (UFSCar). After issuing the primary root, the seedlings were placed in aluminium trays containing vermiculite, irrigated daily with distilled water and, after reaching a height of 7 cm above the substrate, transplanted to planting bags (black bags of 28 × 40 cm - width × height - with of 8 L capacity containing substrate, each recipient received single plantlet), and transported to greenhouses.

Study area and climate

The region where the experiment was developed has a Cwb type climate (dry-winter highland climate), according to Köppen classification, with well-defined seasons, with a dry, from April to September, and a rainy season, from December to February (tropical region). The climate is characterized as tropical, due to the seasonal rhythm of rainfall, under hot (with an average annual temperature below 22°C and at least one month with an average temperature below 18°C) and humid (short dry season in winter), with annual rainfall averages between 1,200 and 1,500 mm. Taking into account a sunny day without clouds, the first batch of plants had been kept in the house of vegetation covered with shade cloth (shading), with maximum passage of 950 µmol m^{-2} s^{-1} radiation (79.2%) and the second, in a greenhouse with maximum flow of 750 µmol m^{-2} s^{-1} luminosity (62.5%). The brightness values were obtained using a portable infrared gas analyzer (ADC-LCA-2).

Substrate

The substrate utilized, typic hapludox, sandy texture (68.3% sand, 5.1% silt and 26.6% clay), was collected on campus UFSCar, in Cerrado area (savannah), at a depth of 0 to 20 cm, sieved and placed on plastic canvas to dry outdoor. Based on collected soil, three types of substrate were prepared: 1) OM - Savannah soil with added organic fertilizer (manure) in the ratio 2: 1; 2) Ca-Mg -

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Table 1. Soil and chemical composition (Cerr. savannah soil; Ca-Mg - savannah with calcium carbonate and magnesium; OM – savannah with organic matter).

Substrate	OM	pH	P resin	K^+	Ca^{2+}	Mg^{2+}	H + Al	Al^{3+}	SB	V%
	(g kg^{-1})		(mg dm^{-3})	cmol$_c$ dm^{-3}						
Cerr.	20.7	4.33	02	0.09	0.72	0.56	3.4	0.35	1.37	29
Ca-Mg	27.1	5.91	03	0.10	2.68	2.32	2.2	0.03	5.1	70
OM	36.5	4.89	22	0.58	1.24	1.08	2.6	0.14	2.9	53

(OM - organic matter, pH in $CaCl_2$, P - phosphorus, K^+ - potassium, Ca^{2+} - calcium, Mg^{2+} - magnesium, H + Al – potential acidity, Al^{3+} - aluminium, SB – sum of bases, V - saturation of bases).

Savannah soil with added calcium carbonate (500 g) and magnesium (10 g) and 3) Cerr. - Savannah soil. After homogenization, the substrates were sent for analysis in the Chemical Analysis Laboratory of Soil and Plant, Department of Natural Resources, Agricultural Science Center - UFSCar, *Campus* Araras (Table 1). Phosphorus, potassium, calcium and magnesium extraction was performed with ionic exchange resin, and for determination of aluminium and potential acidity (H + Al) extraction was performed with KCl 1 mol L^{-1}, as described in EMBRAPA (2009).

Collection of samples and delimitations

After 37 days of growth in polyethylene bags commenced the beginning of the monthly collections of the experiment, and this process ended after growth of 230 days in a greenhouse. The experiment was conducted in a randomized block design in a factorial design 2 × 3 (two light intensities and three types of substrate) and each treatment (six) consisted of four plants, analysed monthly.

Mass determination and chemical analysis

The material was collected, packed in paper bags, and then placed in drying ovens with forced air circulation at 80 ± 5°C until constant weight and evaluated on analytical balance in order to determine the dry mass (leaves and total). Subsequently, the material was ground in a knife mill and subjected to chemical analysis, according to EMBRAPA (2009).

Interactions

In the unfolding of the interactions, growth days were considered within each luminous intensity for each substrate by adjusting the linear regression models in relation to growth time and analysing the angular coefficients of the adjusted linear equation as the rate of increase in the studied period.

Principal component analysis and statistics

The analysis of components is a multivariate statistical technique, based on the 1st main component (MC1) and 2nd main component (MC2); MC1 is defined as the maximum variability of the data explained and MC2, the maximum unexplained variability. It can also be said that MC1 and MC2 performs the analysis of the variables with the explained variability, placing them within grouping. Statistical analysis was performed using procedures PROC GLM, PROC REG and PROC PRINCOMP using SAS package (version 8.2).

RESULTS AND DISCUSSION

The substrates, light intensity and time of cultivation had a significant effect ($p<0.01$), either individually or through interactions, nutrient accumulation, dry matter in leaves and total dry matter (Tables 2, 3 and 4), indicating that the species *T. aurea* responded positively to different treatments and showed different patterns of development, depending on the assessed factor. According to Larcher (2003) and Lambers et al. (2008) it is expected that different environmental conditions will result in differentiated plant growth. In nutrient accumulation in the leaves (Table 2), all adjusted models were significant, with the exception of magnesium and potassium in the substrate Cerr., with luminous intensity of 950 µmol m^{-2} s^{-1}, indicating that the species had a different growth pattern, depending on the type of substrate or light intensity. Thus, their behaviour during growth is associated with the environmental parameter to which it is subjected. Since there exist different results for these two elements, substrate Cerr., could be related to its low availability in the soil (Table 1) and a greater need for absorption of these elements by the plant in the presence of higher brightness.

In relation to the intensity absorption of nutrients, the Ca-Mg and Cerr. substrates showed few elements being affected by a greater or lesser amount of light present (Ca-Mg substrate, nitrogen; Cerr. substrate, calcium). In relation to the OM substrate, a larger number of elements have its absorption intensity increased, such as sulfur, phosphorus and potassium, most probably related to the factor of availability of some elements of the substrate and their interaction when in the presence of intense light.

It is noteworthy that although almost all the elements have had their absorption intensity increased when the plants were kept in 950 µmol m^{-2} s^{-1}, magnesium reduces the intensity. Castro et al. (2001), working with six species of tropical forage grasses (*Andropogon gayanus*, *Brachiaria brizantha*, *B. decumbens*, *Melinis minutiflora*, *Panicum maximum* and *Setaria sphacelata*) indicated

Table 2. Nutrients accumulation (mg kg^{-1}) in *Tabebuia aurea* leaves in two light intensities (750 and 950 µmol m^{-2} s^{-1}) and three types of soil (Cerr. savannah soil; Ca-Mg - savannah with calcium carbonate and magnesium; OM – savannah with organic matter).

Parameter	Days	Ca		S		Mg		N		P		K	
		750	950	750	950	750	950	750	950	750	950	750	950
Ca-Mg	30	28.1	18.7	0.9	0.4	9.1	8.5	8.6	5.7	0.7	0.4	5.6	3.1
	60	28.9	12.3	2.7	1.4	6.5	4.8	28.2	13.1	2.0	0.7	17.0	7.9
	90	29.6	25.2	5.3	5.3	8.2	8.6	24.1	24.3	3.8	1.7	38.6	22.0
	120	57.9	55.5	9.4	15.9	16.5	26.0	46.8	85.9	6.9	4.3	41.9	62.3
	150	57.3	55.0	13.3	19.0	16.0	23.5	45.2	79.0	7.8	4.5	41.2	64.5
	180	104.2	83.3	21.2	28.9	24.4	27.6	67.0	94.1	10.4	5.7	57.1	70.6
	210	138.4	114.0	21.8	33.3	26.8	31.6	66.1	88.9	11.2	5.9	48.6	52.6
	230	124.5	140.9	23.7	36.9	26.1	33.6	69.7	110.1	11.6	7.4	48.4	47.7
Ac		0.54^{a}	0.50^{a}	0.54^{a}	0.5^{a}	0.12^{a}	0.15^{a}	0.33^{b}	0.48^{a}	0.05^{a}	0.03^{a}	0.27^{a}	0.30^{a}
R^2		0.86**	0.90**	0.87**	0.87**	0.88**	0.86**	0.92**	0.85**	0.97**	0.92**	0.75*	0.58*
Cerr.	30	5.0	11.1	0.4	0.5	2.0	5.6	5.0	8.4	0.3	0.6	2.4	4.5
	60	15.5	19.5	1.2	1.1	4.4	5.9	14.8	12.7	0.9	0.9	7.8	9.8
	90	26.7	22.0	2.6	4.1	6.9	3.4	19.1	17.2	1.2	1.4	11.8	12.9
	120	27.0	57.6	4.6	6.1	7.1	6.6	21.3	28.7	0.7	2.5	9.9	15.5
	150	35.9	51.5	8.2	7.3	12.6	6.3	37.5	33.2	1.7	2.9	22.0	19.7
	180	35.3	79.5	10.5	9.2	12.6	6.5	39.3	37.5	2.0	3.1	22.7	20.4
	210	35.5	105.4	10.7	9.5	11.5	8.5	32.8	41.8	2.1	2.8	17.5	16.4
	230	56.1	111.3	14.1	11.1	15.2	10.1	49.0	46.7	2.9	3.2	22.7	13.8
Ac		0.22^{b}	0.45^{a}	0.05^{a}	0.05^{a}	0.07^{a}	0.04^{a}	0.20^{a}	0.21^{a}	0.22^{a}	0.20^{a}	0.11a	0.10^{a}
R^2		0.90**	0.80**	0.99**	0.96**	0.90**	ns	0.86**	0.80**	0.86**	0.85**	0.78**	ns
OM	30	12.1	25.6	0.5	0.9	5.3	8.8	7.2	8.6	0.5	0.8	3.6	7.5
	60	46.7	54.1	2.5	4.9	8.2	11.2	31.2	36.1	1.8	4.7	18.9	35.0
	90	105.1	80.0	12.5	13.4	19.4	22.5	68.7	56.5	5.7	8.7	51.0	71.0
	120	190.7	307.0	23.4	50.5	27.4	71.2	123.5	196.9	9.7	31.1	68.1	226.7
	150	428.0	326.9	38.2	46.3	51.8	74.9	184.9	224.1	14.5	31.4	66.1	150.0
	180	403.2	388.5	50.5	78.3	57.3	100.5	150.2	205.1	17.8	41.9	73.6	157.4
	210	404.1	450.6	52.8	86.0	52.9	125.5	175.2	224.0	12.5	42.3	79.3	203.0
Ac		2.26^{a}	2.24^{a}	0.25^{b}	0.39^{a}	2.27^{a}	0.51^{b}	0.88^{a}	1.18^{a}	0.07^{b}	0.22^{a}	0.37^{b}	0.88^{a}
R^2		0.84**	0.89**	0.90**	0.88**	0.84*	0.90**	0.88**	0.86**	0.80**	0.89**	0.62*	0.54*

** and * = significant 1 and 5 %, respectively and ns= no significant. Ac = angular coefficient. Equal letters in the angular coefficients on the line for each nutrient, do not differ each other by Tukey test at 5% of probability.

that higher concentrations of magnesium occurred in greater shading, with high values for the leaves. This is due to the higher concentration of chlorophyll in the shaded plants and their constituents such as magnesium. In this manner, a higher luminous intensity could mean a lower uptake rate of this element, which could have occurred to *T. aurea*. Also, some studies indicate that plants in shady environments typically allocate higher amount of biomass in their leaves (Poorter et al., 2012), this could also mean a higher concentration of nutrients, which was not observed for most of the elements evaluated. This is probably related to the fact that their leaves are relatively thin and presence of low leaf mass density (Lambers et al., 2008).

In relation to increasing rates, the element phosphorus, substrate Ca-Mg, sulfur and magnesium elements, substrate Cerr., both luminosities and phosphorus element, substrate OM, 750 µmol m^{-2} s^{-1}, between nutrients studied presented the lowest increase rates, i.e they accumulated lesser amount in the evaluated structures (Table 2). In relation to sulfur, Ca-Mg substrate allowed greater rate of absorption of this element. Sulfur

Table 3. Dry matter accumulation rate (g/plant) in the leaves of *Tabebuia aurea* in two light intensities (750 and 950 µmol m^{-2} s^{-1}) and three types of soil (Cerr. savannah soil; Ca-Mg - savannah with calcium carbonate and magnesium; OM – savannah with organic matter).

Days	Ca-Mg		Cerr.		OM	
	750	950	750	950	750	950
30	0.33	0.38	0.22	0.45	0.49	0.37
60	1.01	0.88	0.69	0.71	2.05	1.88
90	1.52	1.65	0.89	1.00	4.05	3.63
120	2.76	4.83	0.91	1.65	7.82	12.95
150	2.90	5.00	1.91	1.91	11.27	13.61
180	4.35	5.74	2.03	2.04	13.65	16.75
210	4.47	5.85	2.05	2.35	13.91	18.43
230	4.84	6.71	2.53	2.65	14.82	19.00
Ac	0.021^{b}	0.030^{b}	0.011^{c}	0.012^{c}	0.067^{a}	0.086^{a}
R^2	0.96^{**}	0.90^{**}	0.94^{**}	0.97^{**}	0.93^{**}	0.89^{**}

** and * = significant 1% and 5%, respectively. Ac = angular coefficient. Equal letters in the angular coefficients on the line for each nutrient, do not differ each other by Tukey test at 5% of probability.

when in soils rich in organic matter is usually fixed, making it less available to plants. However according to Crusciol et al. (2014), application of plaster doses may cause increase in $S\text{-}SO_4$ content in the soil, which is reflected in the increase in the concentration in leaves, a similar result obtained for *T. aurea*. Thus, soils with the presence of some form of calcium could facilitate the absorption and accumulation of $S\text{-}SO_4$.

Cerr. substrate has, among substrates tested, the lowest concentration of Mg, which could explain the lower rate of increase in this substrate. Already phosphorus exists in small quantities in Cerr. and Ca-Mg substrates, but the growth rate was lower only in Ca-Mg substrate. This substrate by adding calcium and magnesium affected the availability of the element for plants of *Tabebuia*, an effect explained by calcium and phosphate reaction to form compounds of low solubility, a process known as precipitation. However according to Tokura et al. (2011), studying the dynamics of phosphorus in soil after the addition of limestone (up to 150 days), in some situations this liming may not cause a reduction in the activity of the element in the soil, a factor related to other existing environmental conditions.

In this study, the period was 230 days, with the use of soluble source of calcium and magnesium. Therefore, there was no time and availability of PO_4^{-3} and Ca^{+2} for the phenomenon known as retrogradation, as discussed in Novais et al. (2007). This process may also be responsible for the reduction in phosphorus accumulation rate, with increasing light intensity, and hence, the greater the soil mass flow by evaporation process. Mengel and Kirkby (2001) and Marschner (2012) noted that calcium movement into the soil is basically through mass flow and phosphorus is by diffusion; thus, the higher the mass flow, the more calcium in the soil solution, and the greater the reaction with phosphorus. Another factor that enhances the interaction between calcium and phosphorus is that at the end of the study period, between chemical elements, calcium was the most accumulated, and phosphorus the least accumulated in the dry mass of leaves, regardless of the substrate and the light intensity. In Cerr. substrate, all the nutrients studied, with the exception of phosphorus, showed lower accumulation rate values, when compared to Ca-Mg and OM, or the two light intensities. These data also show that *T. aurea* species is adapted to environments with low phosphorus availability, with ability to absorb calcium; this also indicates that it is a calcicole species, common in calcareous soil. Crusciol et al. (2014) reported that some plant species develop mechanisms to increase the efficiency in the absorption of calcium by increasing the root system and a high absorption rate of root length unit, thereby achieving high inflow of this nutrient.

According to Soares and Oliveira (2009), *T. aurea* species develops in large areas known as ‘paratudais’, with the predominance of only one tree species dominating the landscape in the Pantanal of Miranda, Mato Grosso do Sul. These areas belong to Miranda River floodplain, whose waters are rich in carbonate compounds, giving the soil of the region high levels of calcium and magnesium.

Light intensity affects the amount of organic matter accumulation in the leaves (Table 3), with increasing light intensity leading to increased nutrient accumulation rate on the dry weight of the leaves. OM substrate, 950 µmol m^{-2} s^{-1}, showed the best performance, followed by Ca-Mg, 950 µmol m^{-2} s^{-1}, indicating that the improved availability of nutrients in OM substrate is essential in expressing the intensity of light as a factor of better development of the plant.

Scalon et al. (2006a), working with *Enterolobium contortisiliqunn* (Vell.) Morong, found higher dry mass in plants with higher brightness, similar to the results found in this study, showing different growth strategies, a factor related to the environment in which species develop. According to Epstein and Bloom (2006) and Lambers et al. (2008), this is a pattern often found in nature. The second best results found for the Ca-Mg substrate, despite differences in concentration of nutrients on substrates (Table 1), also indicates the species studied as calcicole grows even on poor soils, but with a high concentration of calcium and magnesium, allowing its good growth in this environment. The higher pH of this substrate is also a factor that provided better development for the seedlings grown in this environment, because according to Lambers et al. (2008), the growth of calcicole species is better on soils with a high pH.

Table 4. Total dry matter rate (g/plant) of *Tabebuia aurea* in two light intensities (750 and 950 µmol m^{-2} s^{-1}) and three types of substrates (Cerr. pure Cerrado soil; Ca-Mg - Cerrado soil with addition of calcium carbonate and magnesium; OM – Cerrado soil with addition of organic matter).

Days	Ca-Mg		Cerr.		OM	
	750	950	750	950	750	950
30	0.71	0.78	0.53	1.05	0.94	0.81
60	2.45	2.12	1.76	1.88	4.26	3.97
90	3.29	4.22	3.01	3.30	8.73	9.22
120	6.61	12.12	3.78	5.23	16.70	30.56
150	7.83	14.65	6.16	7.14	36.98	43.25
180	13.33	26.56	6.97	9.75	48.38	81.10
210	20.16	32.10	9.52	15.79	59.85	101.05
230	22.18	63.28	12.51	21.38	91.95	129.73
Ac	0.079^{d}	0.17^{c}	0.044^{d}	0.068^{d}	0.285^{b}	0.43^{a}
R^2	0.83^{**}	0.67^{*}	0.90^{**}	0.79^{**}	0.78^{**}	0.79^{**}

** e * = significant 1% and 5%, respectively. Ac = angular coefficient. Equal letters in the angular coefficients on the line for each nutrient, do not differ each other by Tukey test at 5% of probability.

According to Soares and Oliveira (2009), *T. aurea* is a specie calcicole or an important tree of areas with soil containing high levels of calcium and magnesium.

In relation to nitrogen, substrate Ca-Mg, calcium element, substrate Cerr. and nutrient potassium, substrate OM, there was an increase of respectively, 58.8, 98 and 155.9% in the quantity of elements on the dry weight of the leaves, after 230 days. This increase in dry weight is associated with increase in light intensity from 750 to 950 µmol m^{-2} s^{-1}. The nutrient uptake by plants occurs by passive and active processes, being active with energy expenditure, i.e, requiring adenosine triphosphate (Larcher, 2003; Lambers et al., 2008; Taiz et al., 2014). Thus, the plant in greater light intensity, therefore, with greater production of photo assimilates, once the nutrients are available, favours higher rate of accumulation of organic matter, as observed in OM and Ca-Mg substrates (Tables 2, 3 and 4), corroborating the data of Aguiar et al. (2011), who worked with the shading effect of the species *Caesalpinia echinata* Lam.

In the dry matter accumulation rate of leaves, OM substrate, there was no effect of intensity (Table 3), despite increase in value of light intensity to 950 µmol m^{-2} s^{-1}. These data indicate that the luminous intensity increases the rate of formation of organic compounds, but not the formation of dry matter, suggesting that the increase was more of an internal than external factor, i.e., balancing the needs of the plant. This fact is reinforced when analysing the total matter, where OM substrate, the rate of total dry matter was influenced by luminosity (Table 4), indicating effect on the formation of organic matter in the shoot and possible accumulation of ions (nutrients) in the roots. The analysis of the dry weight of the root system at the end of period of 230 days indicated that the OM substrate accumulated a larger amount of resources, totaliing 77.84 and 111.3 g pl^{-1} (750 and 950 µmol m^{-2} s^{-1}), while the Ca-Mg substrate, 17.71 and 57.43 g pl^{-1} (750 and 950 µmol m^{-2} s^{-1}) and Cerr., 10.46 and 19.03 g pl^{-1} (750 and 950 µmol m^{-2} s^{-1}) statistical result was well established and discussed, which demonstrates the negative effect of higher shading.

Data from Scalon et al. (2006b), working with seedlings of *Schinus terebinthifolius* Raddi, also found that the shading increased the total dry matter and reduced the specific weight of the leaves. This lighting effect may be related to the transpiration of plants, as found by Dutra et al. (2012), where it was verified that shading reduced perspiration of seedlings of *Copaifera langsdorffii* Desf.

The data obtained for *T. aurea* indicate an increase in mass production of roots due to luminosity, contradicting the data from Cavalcante et al. (2011), who worked with *Hylocereus undatus* [Haw.] specie Britton & Rose, and verified that the increase of the shadowing causes increased dry weight of root. However, this increase in root mass does not reflect significantly in the dry matter of the leaves, suggesting that this species has an ion storage mechanism in the root system. Oliveira and Gualtieri (2011, 2012) and Oliveira and Perez (2012) results indicated that the species has, during the course of its development a tendency of higher photo assimilates accumulation in the root system. According to Oliveira and Gualtieri (2012), the largest accumulation of dry biomass in the root system of *T. aurea* could be a survival strategy during bad times. This allocation provides higher reserves when environmental conditions, such as drought stress, which often occur in the region of origin of species, are adverse. In this manner, the plants grown with more light would be tailored for a possible environmental stress.

With regard to the principal component analysis, this allowed the realization of the analysis variables with the variability explained by placing them within clusters (Figure 1). In the assessment of the chemical element potassium, this was the most varied with the environment. Thus, the reduced availability of nutrients in Cerr. substrate in the luminosity 750 µmol m^{-2} s^{-1}; according to the analysis, the potassium was within the same group of other variables analysed, indicating stressful environment for plants, due to the fact that the plant absorbed what was only necessary for survival.

Since environmental stress conditions have decreased due to the increase amount of potassium in the substrate, the element was separated from the other variables, forming another group and does not correlate with other nutrients, dry matter and organic matter, showing a consumption luxury, it would be the ability to absorb more potassium than their needs. This mineral nutrient has no structural function in plant metabolism, but it is the most abundant cation in the cytoplasm and is highly mobile in the plant, which greatly contributes to the maintenance of osmotic potential of cells and tissues, acting as enzyme activator and as neutralizing anionic macromolecules (Epstein and Bloom, 2006; Marschner, 2012).

Another factor to consider is that the species in its habitat, Pantanal of Miranda, grows in soils with high content of calcium and magnesium, which exhibit competitive effect with potassium, thus becoming a species that absorbs little potassium. Another fact to explain the difference in absorption would be the root system, where during initial growth, the species accumulated more dry mass of root, so that an increased demand for calcium and magnesium was seen in pectate formation which composed the middle lamella of the plasma membrane (Taiz and Zeiger, 2010; Taiz et al., 2014). The level of potassium in the leaves have a distinct pattern when compared with calcium, which with the passage of time increases concentrations of leaves and magnesium, which remains; the potassium initially increases its concentration and then, or tend to stabilize or decrease its concentration (Table 2), depending on the treatment. On the other hand, for this element, shaded plants also have higher nutrient levels in leaves. As opposed to the other elements, treatments with OM presented at the end of the experiment, the highest concentrations of potassium in leaves, indicating their importance for the growth of seedlings. This fact should be directly related to the concentration of potassium in the substrate, which was five times more in the treatment OM. To this nutrient, the results obtained seem to indicate that the dry weight has a highest correlated value in the OM treatment with higher potassium concentration, as opposed to magnesium and calcium.

Mengel and Kirkby (2001) and Marschner (2012) wrote that high concentrations of calcium and magnesium reduced the absorption of potassium element. However, this was not observed for the leaves of this species, particularly for the treatment with Ca-Mg. They also underscored that occurring in the lower shaded plants were rates of absorption and dry root weight (the inhibition of absorption of potassium in low light intensities is caused by DNP 2,4- - inhibitor of mitochondrial phosphorylation – formation of ATP). However, to the species *T. aurea,* this process was not observed when subjected to different light intensities, indicating its adaptation to different lighting conditions, with the highest concentration of the element in shaded plants. In accordance with Oliveira and Gualtieri (2012), *T. aurea* has a high phenotypic plasticity to different environmental conditions.

According to Mengel and Kirkby (2001) and Marschner (2012), with the increasing age of the leaves, there is a decrease in the concentration of this element in the leaves of many plant species, this behavior is exhibited by *T. aurea*. The decreasing trend in the concentration of this mineral in the leaves was more rapid when using soil with addition of organic matter and Ca-Mg and less in Cerrado soil probably because in this case the issuance of new leaves is much slower and, consequently, the decrease of potassium in the leaves is smaller, since they take longer time to emerge. In a study, Marschner (2012) cited that older acicula of *Picea abies* (L.) H. Karst. showed lower potassium concentrations, demonstrating that over time, there is a natural reduction in nutrient concentration in leaves.

By comparing the current levels of macronutrients in *T. aurea* leaves with appropriate concentrations found in cultivated species of forest trees (pines, araucaria, eucalyptus and rubber trees), it can be seen that the use of fertilized soils with organic matter afforded average values suitable for the normal development of forest species and probably suitable for the development of this tree species. However, in the soil without fertilization, the foliar values of this element are at the lower limit of what can be considered suitable for adequate growth of those species. Already, the soil with the addition of Ca-Mg propitiated foliar concentration of this nutrient that is below the levels required for the best growth of the mentioned species. Nevertheless, *T. aurea* may properly develop this type of substrate, a factor probably related to the presence of calcium and magnesium.

In potassium deficient plants, significant chemical changes occur because potassium is a constituent or activator of several enzymes, among other actions (Taiz and Zeiger, 2010; Taiz et al., 2014). Photosynthesis is also affected by potassium because an increased concentration of this element stimulates CO_2 fixation (decreasing the diffusive resistance for CO_2 in the mesophyll), and again promotes the synthesis of the enzyme ribulose bisphosphate carboxylase in addition to other effects, as in cell elongation. In this manner, plants with this deficiency experience late growth (Mengel and Kirkby, 2001; Marschner, 2012).

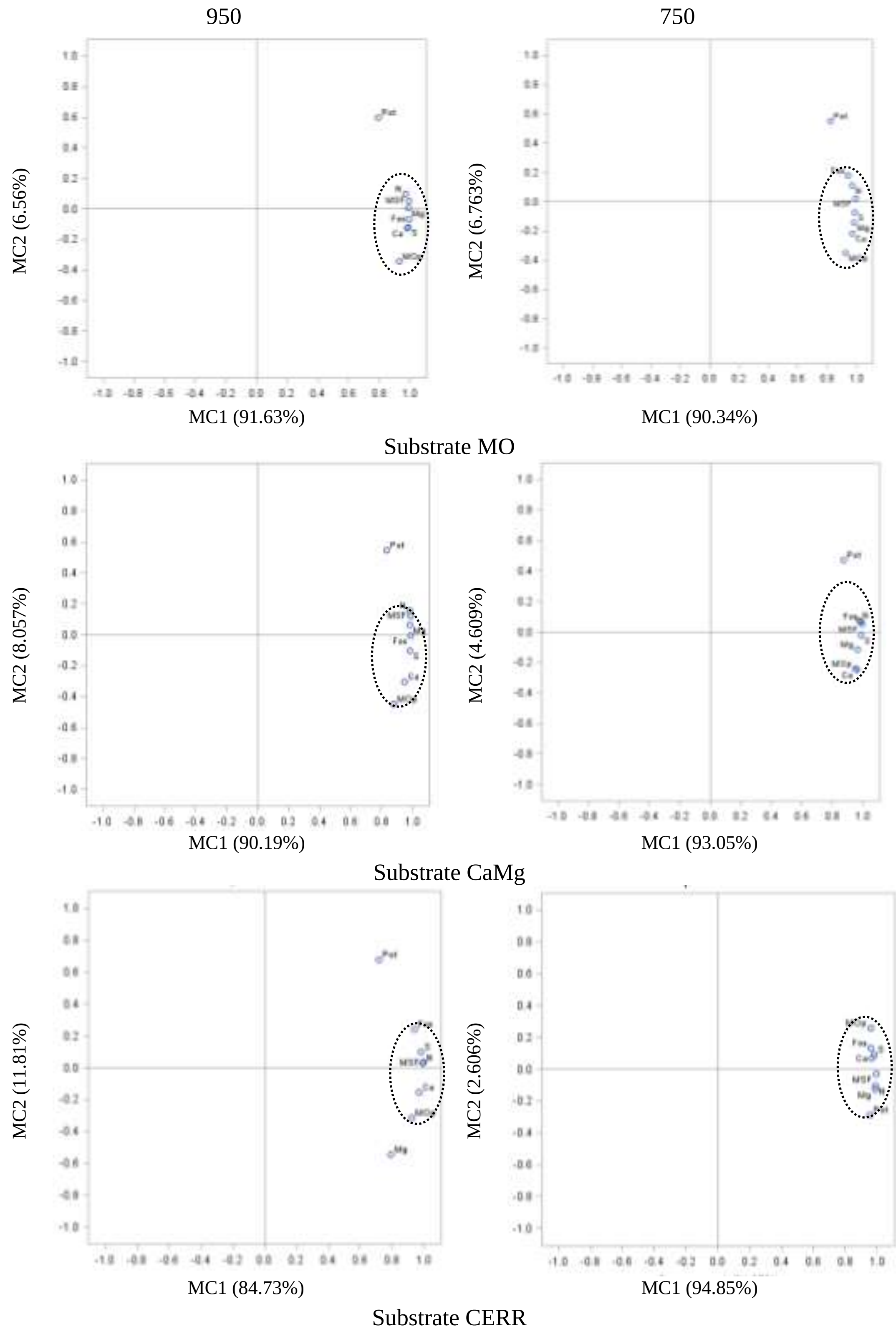

Figure 1. Principal component analysis of macronutrients, dry matter and organic of aerial part, for substrates and luminosity, *Tabebuia aurea*.

Although plants grown in soils with addition of Ca-Mg showed similar potassium values in the substrate, compared to those grown in Cerrado soil, its development was higher with higher dry matter accumulation in leaves and total, indicating that the available soil potassium was suitable for both and the difference in growth should be associated with a higher amount of calcium and magnesium in the treatment with Ca-Mg. Nevertheless, the best performance was observed for plants grown in soil with added organic matter.

Conclusions

The *T. aurea* species has characteristics of calcicoles species and better development when grown in brighter locations. The addition of organic matter provided the best development, a situation related to their higher fertility; but when cultivated in poorer soils, the presence of calcium and magnesium favours its development.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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