

Original Research Article

Effects of Fertilization on Biomass and MacroNutrient contents of *Eucalyptus urophylla* S.T. Blake in Arenized Soil onf Pampa Biome: Macronutrients

ABSTRACT

The objective of this study was to quantify the biomass and the macronutrient stock in an experiment of fertilization with *Eucalyptus urophylla*, ~~im~~planted in arenized soil at 12 months old, in Rio Grande do Sul, Brazil. The experiment had a completely randomized design with five treatments (T1, T2, T3, T4 and T5) with three replications. For the determination of the biomass, fifteen trees were felled and separated in the following components: leaves, branches, stem_bark, stem_wood and roots. Samples of the components were collected and ~~forwarded-transported~~ to the laboratory for biomass determination and chemical analysis. The total biomass ~~have~~-varied between the treatments, ~~being the~~with highest biomass accumulation of 6.83 Mg ha^{-1} ~~occurring in biomass was verified in T5 with~~ 6.83 Mg ha^{-1} . The T1 presented the highest biomass ~~in the~~for roots ~~representing~~: 33.4% of the total biomass. The biomass distribution among the different components ~~was~~in the decreasing order ~~was~~: roots > stem_wood > leaves > branches > stem_bark, for all the treatments. The treatment with higher doses of fertilizers (T5) presented the highest amount of nutrients accumulation~~ioned~~ in the total biomass ($131.26 \text{ kg ha}^{-1}$). The concentration and accumulation of nutrients presented the following trend $\text{K} > \text{N} > \text{Ca} > \text{Mg} > \text{P} > \text{S}$. Analyzing the different components of biomass, the highest amounts of nutrients followed the order: leaves > roots > stem_wood > branches > stem_bark. Fertilization influenced the biomass production of *E. ucalyptus urophylla* in arenized soil in the Pampa biome, but without significant differences to date (12 months). The leaves ~~present had~~ the highest concentration of macronutrients, with the exception of Ca, which ~~has a was~~ higher ~~concentration~~ in the bark. The K was the element that presented highest accumulation. The ~~implantation of eucalyptus with~~ fertilization management may be an alternative for the economic use of arenized soil.

Keywords: forest nutrition, forest production, sandy soil, nutrient doses

1. INTRODUCTION

The Pampa biome has an area of approximately 700 thousand km², present in Brazil, Argentina and Uruguay [1]. In Brazil, the Pampa is restricted to the state of Rio Grande do Sul, where it occupies an area of 176,496 km², corresponding to 63% of the state territory and 2.07% of the Brazilian territory [2].

Comment [R1]: Generally, abstract is studied more than the full article. Therefore, mention what these five treatments were for the benefit of the readers.

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In the west of Rio Grande do Sul, there are areas with intense degradation caused by the arenization process [3]. Arenization, a morphogenic process of arenized soil formation, can be one of the most intense environmental degradation scenarios in the Pampa biome region [4].

The first works to recover the arenized soils started from the Department of Agriculture of the State of Rio Grande do Sul, through a pilot project installed in the city of Alegrete, with which it was possible to identify that eucalyptus was the species that best suited the arenized soils [5]. However, the arenized soils present very low natural fertility and require chemical supplementation, through fertilization, to enable the implantation of forest stands.

Fertilization should maximize productivity with minimal investment and no negative impacts on the environment [6]. For this, the quantification of biomass and the allocation of nutrients in the different tree components of forest stands are essential for understanding the nutritional balance of the site [7] [8], especially for definitions of sustainable management.

During the different stages of tree growth, due to changes in physiological and growth processes, there are changes in the demand, storage and distribution of nutrients in the trees [9]. After planting, there is an intense period of growth, mainly for the formation of the canopy and root system, after the canopy closure, tree growth is directed to the stem [8]. The canopy presents high concentrations of nutrients and low biochemical cycling (senescence) during the initial growth period, thus absorbing large amounts of nutrients from the soil during this period, which may restrict tree growth if the soil has a limited supply of nutrients [9].

The nutrient requirement of the species and the soil properties are useful information to adjust the fertilization regimes specific to the site, especially when it aims to maintain the nutrient stock in the soil along the rotations [10]. Silva et al. [6] ~~mentions showed~~ how difficult it is to establish fertilization regimes in sandy soils with low nutrient retention and high hydraulic conductivity, since they are highly susceptible to nutrient leaching and present risks of nutrient loss through deep drainage in this type of soil.

The objective of this study was to verify the effect of fertilization on the production of biomass and stock of macronutrients of *Eucalyptus urophylla*, at 12 months old, established in arenized soil in the Pampa biome.

2. MATERIAL AND METHODS

2.1 Characterization of the experimental area

The experiment was conducted in the municipality of Maçambará, western region of Rio Grande do Sul, Brazil, with geographic coordinates 29° 02' 32.67" S and 55° 19' 40.44" W.

According to Köppen classification the climate in the municipality of Maçambará - RS is of the type Cfa (humid temperate climate). The average annual rainfall is 1628 mm, the average annual temperature is 20.7 °C, while the average of the coldest month is 15.5 °C and the average of the hottest month is 26.3 °C. In winter, negative temperatures and frost formation occur [11].

The soil of the experimental area is characterized as sandy (composed of more than 80% of coarse sand), of low natural fertility, with very low organic matter content and levels below that recommended for all elements analyzed (Table 1). The soil profile presented

homogeneity of the attributes analyzed between the different depths and did not present any active biological activity in the soil, nor was to the presence of roots (live or dead).

Table 1. Physical-chemical attributes of the soil in the ~~area of the experimental site~~ planted with *Eucalyptus urophylla* in ~~the~~ arenized ~~nucleus in the~~ Pampa biome

Attribute	Unit	Depth (cm)									
		0	20	40	60	80	100	120	140	160	180
		20	40	60	80	100	120	140	160	180	200
SD	g cm ⁻³	2.1	2.3	1.9	1.8	1.7	1.8	1.9	1.7	1.6	1.6
CS		88.0	88.3	86.0	81.3	82.3	84.0	77.6	81.0	84.0	82.0
FS		3.0	3.5	3.0	4.0	1.6	2.7	4.3	5.4	3.3	3.4
Silt	%	1.0	1.6	1.0	3.0	4.7	2.6	6.0	2.3	1.4	3.3
Clay		8.0	6.6	10.0	11.6	11.3	10.6	12.0	11.3	11.3	11.3
O.M.		0.2	0.2	0.3	0.3	0.2	0.2	0.2	0.2	0.1	0.1
pH	1:2.5 H ₂ O	4.8	4.7	4.6	4.6	4.6	4.6	4.6	4.7	4.7	4.6
Al		0.7	0.6	0.8	0.8	0.9	0.9	0.9	0.8	0.9	1.0
Ca	cmol _c dm ⁻³	0.2	0.1	0.1	<0.1	0.2	0.2	0.1	<0.1	0.1	<0.1
Mg		0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1
P ^a	mg dm ⁻³	4.6	3.4	2.3	2.9	3.5	4.3	5.0	6.9	7.3	6.9
K ^a		13.3	12.7	14.8	13.8	14.1	14.0	13.3	14.5	13.5	13.3
CECef	cmol _c dm ⁻³	0.9	0.7	0.9	0.9	1.1	1.1	1.0	1.0	0.9	1.1
CECpH ₇		2.6	2.9	3.6	3.7	3.8	3.9	3.8	3.7	3.8	3.7
V	%	7.7	4.6	4.6	3.2	4.9	5.1	3.7	2.6	2.9	2.5
m		77.2	82.1	81.7	87.0	82.9	82.3	86.1	90.4	88.6	91.3
S		3.9	10.1	13.9	15.6	15.9	14.4	14.6	7.0	8.9	7.7
B	mg dm ⁻³	0.3	0.3	0.4	0.4	0.3	0.3	0.2	0.2	0.2	0.3
Cu		0.4	0.4	0.5	0.5	0.6	0.5	0.6	0.5	0.5	0.4
Zn		0.2	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1

Where: SD = soil density; CS = coarse sand; FS = fine sand; O.M = organic matter; ^aExtraction method Melich I. CECef = cation exchange capacity effective; CECpH₇ = cation exchange capacity pH 7.0; V = base saturation; m = aluminum saturation.

For the installation of the experiment realized the ant control activities in the areas surrounding the arenized soil, subsoiling, planting and replanting. The subsoiling was performed using subsoiler with a shank 30 cm deep. The planting was done manually, using clonal seedlings of *Eucalyptus urophylla*, spacing 3.0 m x 2.0 m.

The experiment was conducted in completely randomized design with five treatments, containing three replicates for each treatment. Each plot has 60 m x 30 m, with 300 trees, and the effective plot (excluding double border) is composed of 143 trees.

The treatments received different sources and doses of fertilization (Table 2). The treatments T2, T3, T4 and T5, received increasing doses of triple superphosphate, ranging from 112.5 - 225 kg ha⁻¹. On the other hand, the T1 treatment was the only one to receive natural phosphate in planting. The dosages of triple superphosphate and natural phosphate were application in planting for all treatments.

Fertilizers were used in a varied way among treatments, the only equal dosages were for dolomitic limestone, where all received 2 Mg ha⁻¹, and a fertilization with 150 kg ha⁻¹ of K₂O, for all treatments, in the form of potassium chloride 30 days after planting.

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Table 2. ~~Description of the~~Concentration of nutrients used in the experiment with *Eucalyptus urophylla*, in arenized soil ~~in-of~~ the Pampa biome.

Fertilization	Days after planting	Fertilizer	Amount of fertilizer applied (g plant ⁻¹)				
			T 1	T 2	T 3	T 4	T 5
Planting	0	Superphosphate	-	150	200	250	300
		Natural phosphate	250	-	-	-	-
1 st After Planting	30	NPK 06-30-06	60	65	72	85	96
		Potassium chloride	165	165	165	165	165
2 nd After Planting	75	NPK 22-00-18	66	72	84	96	108
3 rd After Planting	120	NPK 22-00-18	66	72	84	96	108
		NPK 10-25-25	-	-	-	-	137
4 th After Planting	180	NPK 06-30-06	-	66	-	-	-
		FTE BR ^a	-	48	66	84	102
5 th After Planting	300	NPK 06-30-06	-	30	36	42	48
		NPK 22-00-18	-	30	36	42	48
		FTE BR ^a	-	30	36	42	48
6 th After Planting	420	NPK 06-30-06	-	30	36	42	48
		NPK 22-00-18	-	30	36	42	48
		FTE BR ^a	-	30	36	42	48

^aFTE BR = constituted by Calcium (7.1%), Sulfur (5.7%), Boron (1.8%), Copper (0.8%), Manganese (2.0%), Molybdenum (1.0%) and Zinc (9.0%).

2.2 Biomass

Through the inventory data, the average tree diameter of each of the plots for biomass determination was selected. The selected tree was separated in the following components: leaves; branches; stem_bark and stem_wood. The root system of the trees was removed by manual excavation of the useful area of each tree (6 m²), up to 1 meter deep.

All components were weighed individually on a table scale to obtain the total wet mass in the field. Afterwards, 150 g wet mass sample was collected from each component, was placed in paper packaging, duly identified and sent to the laboratory. The samples were ~~submitted to drying~~ ~~dried~~ in a circulation oven and air renewal at 70 °C for 72 hours to determine the biomass.

2.3 Nutrients

After weighing, the samples were ground in a Wiley ~~type~~-mill with 20 mesh sieve and ~~sent to the laboratory used~~ for chemical analysis, where the macronutrients (N, P, K, Ca, Mg and S) were determined. Nitrogen was determined by the Kjeldahl method (sulfur digestion = H₂SO₄ + H₂O₂). Phosphorus and boron by spectrophotometry (P by nitric-perchloric digestion and B by dry digestion). Potassium by flame photometry, sulfur by turbidimetry and calcium, magnesium, copper, iron, manganese and zinc by atomic absorption spectrometry (all by nitric-perchloric digestion), following the methodology described by Tedesco et al. [12] and Miyazawa et al. [13].

The amount of nutrients in each of the components of the trees was obtained through the product between the biomass and the concentration of nutrients. The estimate of the nutrient

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stock in the biomass per hectare was performed by extrapolating the stock of nutrients based on the area sampled.

2.4 Statistical analysis

The results were statistically analyzed through the SAS for Windows [14] package, using the Tukey test at the 0.05 error probability level, considering the completely randomized design, where each sampled tree corresponded to one repetition, for each component of the biomass studied.

3. RESULTS AND DISCUSSION

3.1 Biomass

The biomass components do not ~~present statistical difference~~ differ significantly for the ~~different various~~ treatments evaluated (Table 3). However, evaluating the management of fertilizers in eucalyptus plantations in sandy soil in Brazil, Silva et al. [6] concluded that eucalyptus responds positively to increased fertilizer doses, resulting in higher productivity.

Table 3. Distribution of biomass in the different components of *Eucalyptus urophylla*, at 12 months of age, in arenized soil in the Pampa biome

Components	T 1	T 2	T 3	T 4	T 5
	Mg ha ⁻¹				
Leaves	1.02 a	1.13 a	1.14 a	1.45 a	1.58 a
Branches	0.68 a	0.79 a	0.71 a	1.24 a	1.12 a
Stem_bark	0.24 a	0.31 a	0.29 a	0.34 a	0.39 a
Stem_wood	0.96 a	1.45 a	1.39 a	1.59 a	1.81 a
Roots	1.45 a	1.44 a	1.30 a	1.26 a	1.92 a
Total	4.35 a	5.13 a	4.84 a	5.87 a	6.83 a

~~Where: Different horizontal~~ Means in a row followed by the same letters indicate significant differences between the biomass distributions in the different treatments, ~~do not differ significantly~~ at the 0.05 level of significance, by the ~~according to~~ Tukey test.

The highest value of biomass was found in Treatment 5 with 6.832 Mg ha⁻¹ (treatment with higher doses of fertilizers) and the lowest value observed for T1 (treatment with lower dose of fertilizer), with 4.35 Mg ha⁻¹, which represents a 36.8% difference between treatments (Table 3). The production of above-ground biomass found by Schumacher & Caldeira [15] and Gatto et al. [16] for *Eucalyptus globulus* subspecies maidenii and *Eucalyptus urophylla* x *Eucalyptus grandis* was 83.2 Mg ha⁻¹ and 74.5 Mg ha⁻¹, respectively. Both studies were carried out with in stands at 4 years of age.

Eufrade Júnior et al. [17] studying *Eucalyptus grandis* x *E. urophylla*, at 2 years-old, observed that the stands with higher doses of fertilizer resulted in higher stem growth per hectare (difference of 7.3 Mg ha⁻¹) and a very similar growth between treatments for branches and leaves.

The biomass distribution among the different components was in the decreasing order: roots > stem_wood > leaves > branches > stem_bark, for all the different treatments (Figure 1). The higher biomass share of the stem_wood component was observed for T3 with 28.8% of the total biomass. The lowest percentage was observed for T1 with 22.0%, which also presented the highest amount of biomass in the roots, with 33.4% of the total biomass.

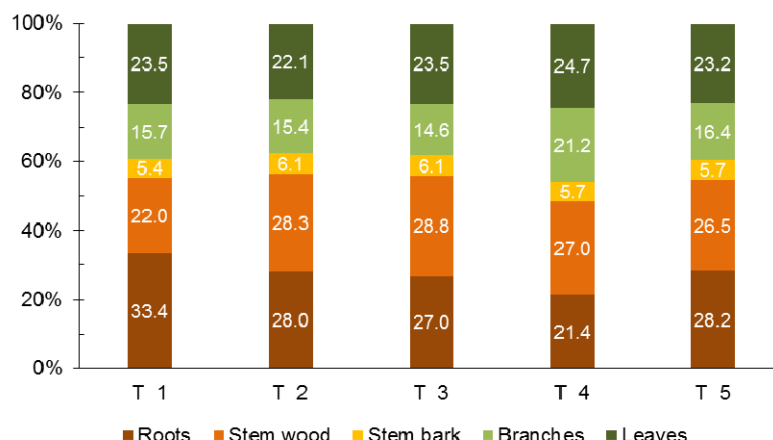


Figure 1. Relative biomass distribution in the different components of *Eucalyptus urophylla*, at 12 months of age, in arenized soil in the Pampa biome

Similar results were observed by Viera et al. [18], when studying a 18 month old stand of *Eucalyptus urograndis*, at 18 months, established in Neosoil, with above-ground biomass of 18.5 Mg ha⁻¹, the wood the component with the highest biomass (37.0%), followed by branches (34.2%), leaves (21.3%) and bark (7.6%).

The order of distribution of the biomass of *Eucalyptus dunnii*, four years old, also in the Pampa biome, presented by Guimarães et al. [19] was of stem_wood (63%) > roots (14%) > branches (11%) > stem_bark (8%) > leaves (4%), with total biomass of 121.9 Mg ha⁻¹. The difference of the results is explained by the stand in study being in an early stage of development (12 months of age) with a tendency of accumulation of biomass in the crown (leaves + branches).

In the Pampa biome, in the same region of the present study, a four years old clonal stand of *Eucalyptus saligna*, four years old, showed above-ground biomass production at of 88.81 Mg ha⁻¹, 76.8% being composed of the wood component, 9.3% bark, 7.9% branches and 6.0% leaves [20]. In *Eucalyptus urophylla* x *Eucalyptus grandis* stands, at 4.5 years of age, Carvalho et al. [21] observed a total biomass production of 74.94 Mg ha⁻¹, distributed in the following decreasing sequence: stem_wood (61.2%) > roots (15.4%) > branches (10.2%) > stem_bark (7.7%) > leaves (5.5%).

Genetic, environmental and silvicultural factors directly influence the productive capacity of plantations. However, for according to Barros & Comerford [22], soil type and nutritional availability are the main factors influencing production in forest plantations. This stand explains the low biomass production of the present study when compared to the other studies, which is are due to the very low fertility of the arenized soil, as presented in Table 1.

Considering the results obtained in other biomass studies on the genus *Eucalyptus*, it can be seen that the values obtained in the present study are low, but close to those observed in sandy soils in the same region. However, plantations with the genus *Eucalyptus* in the sandstone cores of the Pampa biome, besides presenting biomass accumulation that makes forest production feasible, contributes to the soil cover, helping to soften the erosive processes that accelerate the arenized soil.

3.2 Nutrients

The leaves, the organ with the highest metabolic activity in the tree (photosynthesis and transpiration), ~~present had~~ the highest concentration of macronutrients when compared to the other components, with the exception of Ca ~~having with~~ the highest concentration in the bark (Table 4). This predominance of nutrient concentration in leaves, with the exception of Ca, was also observed by several authors in ~~studies with species of the genus~~ *Eucalyptus* [18] [21] [23].

The P and S were the only elements that presented significant differences ($P = 0.05$) between treatments, ~~being found in treatment 1~~. The lowest concentration of P in leaves ~~was found in treatment 1~~ (compared to T2 and T3) and in stem bark (compared to T5) and S in the stem bark in relation to T4 and T5.

Table 4. Macronutrients concentration in the 12 months old *Eucalyptus urophylla* tree components of the grown in different treatments with *Eucalyptus urophylla*, at 12 fertilizer rates months old, in arenized soil in of the Pampa biome

Treatment	Components	N	P	K	Ca	Mg	S
g kg ⁻¹							
T1	Leaves	15.75 a	0.84 b	8.61 a	5.04 a	1.90 a	1.07 a
	Branches	2.07 a	0.30 a	5.67 a	3.56 a	0.69 a	0.34 a
	Stem bark	2.65 a	0.33 b	7.82 a	8.26 a	1.24 a	0.31 b
	Stem wood	0.69 a	0.21 a	5.30 a	0.60 a	0.39 a	0.35 a
T2	Roots	2.58 a	0.29 a	5.11 a	2.94 a	0.61 a	0.45 a
	Leaves	18.69 a	1.30 a	12.39 a	6.45 a	2.12 a	1.28 a
	Branches	2.61 a	1.02 a	6.27 a	5.10 a	0.77 a	0.39 a
	Stem bark	3.16 a	0.47 ab	11.03 a	6.85 a	1.47 a	0.38 ab
T3	Stem wood	1.17 a	0.57 a	6.89 a	0.79 a	0.48 a	0.16 b
	Roots	1.52 a	0.27 a	5.68 a	4.22 a	1.13 a	0.39 a
	Leaves	18.59 a	1.39 a	9.82 a	6.21 a	2.01 a	1.41 a
	Branches	3.71 a	1.32 a	8.14 a	4.42 a	0.89 a	0.44 a
T4	Stem bark	2.42 a	0.47 ab	8.16 a	6.05 a	1.16 a	0.38 ab
	Stem wood	0.62 a	0.62 a	6.44 a	0.89 a	0.45 a	0.38 a
	Roots	1.81 a	0.31 a	4.67 a	3.64 a	0.75 a	0.43 a
	Leaves	17.10 a	1.02 ab	8.61 a	7.03 a	1.89 a	1.09 a
T5	Branches	2.66 a	0.63 a	4.73 a	2.88 a	0.55 a	0.44 a
	Stem bark	2.97 a	0.51 ab	7.91 a	8.26 a	1.26 a	0.45 a
	Stem wood	0.68 a	0.45 a	6.20 a	0.87 a	0.47 a	0.36 a
	Roots	1.42 a	0.34 a	5.09 a	3.82 a	1.27 a	0.56 a
T5	Leaves	16.44 a	1.19 ab	9.56 a	6.46 a	1.76 a	1.07 a
	Branches	3.70 a	1.20 a	8.02 a	3.41 a	0.72 a	0.44 a
	Stem bark	3.36 a	0.60 a	10.44 a	6.40 a	1.22 a	0.43 a
	Stem wood	1.82 a	0.69 a	7.67 a	0.83 a	0.50 a	0.38 a
T5	Roots	2.45 a	0.36 a	5.01 a	3.30 a	0.70 a	0.49 a

~~Means in a column for a component bearing same~~ Where: Equal vertically letters do not differ statistically between treatments, at the significantly ($P > 0.05$ level) according to ~~of~~ significance, by Tukey's test.

Considering an average of all the components of the biomass, of the different treatments, the concentration of nutrients presented the following trend $K > N > Ca > Mg > P > S$. ~~This sequence of nutrient is~~ Different from the order obtained by Guimarães et al. [19] in *Eucalyptus dun nii*, at four years old, also in the Pampa biome ($Ca > N > K > Mg > S > P$).

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Verão et al. [24] in 7 years-old *Eucalyptus urograndis* stands, 7 years-old, observed that the mean concentration of macronutrients, in the different biomass components, followed the decreasing order: N > Ca > K > S > Mg > P.

The concentration of nutrients in the different components of the biomass followed a distribution in the order: leaves > stem bark > branches > roots > stem wood for all the treatments. The observed sequence was similar to that found by Guimarães et al. [19] with *Eucalyptus dunnii*, at four years old, and Viera et al. [18] with *Eucalyptus urograndis*, at 18 months old.

Analyzing the amount of macronutrients present in the biomass, K was the element that presented the highest value in all treatments. In the treatment 5, K accumulated 51.68 kg ha⁻¹ and the smallest accumulated amount was observed in T1 with 26.97 kg ha⁻¹ (Table 5).

Table 5. Amount of macronutrients in the components of *Eucalyptus urophylla* trees, at 12 months old, in arenized soil in the Pampa biome

Treatment	Components	N	P	K	Ca	Mg	S
		kg ha ⁻¹					
T1	Leaves	16.06	0.85	8.78	5.14	1.94	1.09
	Branches	1.42	0.20	3.88	2.44	0.47	0.23
	Stembark	0.63	0.08	1.84	1.95	0.29	0.07
	Stemwood	0.66	0.20	5.06	0.58	0.37	0.34
	Roots	3.74	0.42	7.41	4.27	0.88	0.65
	Total	22.51	1.76	26.97	14.36	3.96	2.39
T2	Leaves	21.18	1.47	14.05	7.31	2.41	1.45
	Branches	2.07	0.81	4.95	4.03	0.61	0.31
	Stembark	0.99	0.15	3.46	2.15	0.46	0.12
	Stemwood	1.71	0.83	10.01	1.14	0.70	0.24
	Roots	2.19	0.39	8.17	6.07	1.62	0.56
	Total	28.14	3.65	40.64	20.69	5.79	2.67
T3	Leaves	21.17	1.58	11.18	7.07	2.28	1.61
	Branches	2.62	0.93	5.75	3.12	0.63	0.31
	Stembark	0.71	0.14	2.39	1.77	0.34	0.11
	Stemwood	0.86	0.87	8.98	1.24	0.63	0.53
	Roots	2.37	0.40	6.10	4.75	0.97	0.56
	Total	27.73	3.92	34.40	17.96	4.86	3.12
T4	Leaves	24.78	1.48	12.48	10.19	2.73	1.59
	Branches	3.31	0.79	5.88	3.58	0.69	0.55
	Stembark	1.01	0.17	2.65	2.77	0.42	0.15
	Stemwood	1.08	0.71	9.83	1.37	0.74	0.57
	Roots	1.78	0.43	6.40	4.80	1.60	0.71
	Total	31.96	3.57	37.25	22.71	6.18	3.57
T5	Leaves	26.01	1.88	15.11	10.21	2.78	1.70
	Branches	4.15	1.34	8.98	3.82	0.81	0.50
	Stembark	1.32	0.23	4.09	2.51	0.48	0.17
	Stemwood	3.29	1.24	13.87	1.51	0.91	0.70
	Roots	4.71	0.68	9.63	6.36	1.35	0.94

	Total	39.48	5.38	51.68	24.40	6.32	4.00
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The highest amounts of nutrients among the different components followed the distribution in descending order: leaves > roots > stem_wood > branches > stem_bark. Viera et al. [19] observed that the branches presented highest accumulation of nutrients than the wood, changing the sequence of accumulation for leaves > branches > wood > bark.

In *Eucalyptus urophylla* x *E. grandis* stands, at 5 years-old, Gatto et al. [16] observed that the greatest amount of N, P and S were found in the stem, while K, Mg and Ca presented the highest amount in the branches, leaves and barks, respectively. The same authors presented-reported the following order of amount of nutrients in above-ground biomass: N > K > Ca > S > Mg > P and the order for the amount of nutrients in roots: N > K > Ca > S > Mg > P.

Witschoreck and Schumacher [25], in *Eucalyptus saligna* stands, at 7 years-old, observed that the amount of nutrients decreased among the biomass components in the following order: stem_wood > root > leaves > bark > branches, while the nutrients presented the following order Ca > N > K > Mg > P.

The same tendency of accumulation of nutrients, following the decreasing order of accumulation: K > N > Ca > Mg > P > S, was observed in all treatments. Distinct from the the-sequence observed by Guimarães et al. [19] with *Eucalyptus dunnii* (Ca > N > K > Mg > P > S), Viera et al. [18] and Carvalho et al. [21] with *Eucalyptus urograndis* (Ca > N > K > Mg > P > S and Ca > K > N > Mg > S > P, respectively). As the amount of nutrients is directly related to the biomass, the difference between the studies, mainly for Ca, can be explained by the low biomass of the components that present the highest concentration of this element (bark), compared to other studies.

4. CONCLUSION

Fertilization influenced the biomass production of *Eucalyptus urophylla* in arenized soil in the Pampa biome, but without significant differences with respect to date (12 months).

The biomass production of the stands is below that found in the literature. However considering the soil condition, the implantation of eucalyptus with fertilization management may be an alternative for the economic use of these areas.

The leaves presented the highest concentration of macronutrients, with the exception of Ca, which has a higher concentration in the stem_bark.

The K was the element that presented highest accumulation in the biomass of *Eucalyptus urophylla* in arenized soil in the Pampa biome, independent of the fertilization management.

New studies evaluating the growth and the effect of fertilization on eucalyptus stands in sandy soils should be carried out with a longer period of evaluation to establish the adequate fertilization regime

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. MMA. Ministério do Meio Ambiente. Áreas prioritárias para conservação, uso sustentável e repartição de benefícios da Biodiversidade Brasileira. 1st ed. Brasília: Ministério do Meio Ambiente/Secretaria de Biodiversidade e Florestas; 2007.
2. IBGE. Brazilian Institute of Geography and Statistics. Map of Biomes and Vegetation of Brazil. 2004. Accessed 08 August 2017. Available: <http://www.ibge.gov.br/home/presidencia/noticias/21052004biomashtml.shtm>
3. Souza AC, Pires CAF. Dinâmica da arenização na bacia hidrográfica do Arroio Puitã, oeste do RS, através do mapeamento multitemporal no período de 1984 a 2014. *Revista Brasileira de Geomorfologia*. 2017;18(1):185-196. Portuguese.
4. Bertê AMA. Problemas ambientais no Rio Grande do Sul. In: Verdum R, Basso LA, Suertegaray DMA, editors. Rio Grande do Sul: paisagens e territórios em transformação. Porto Alegre: UFRGS; 2004.
5. Souto JJ. Deserto uma ameaça? Porto Alegre: Secretary of Agriculture; 1984.
6. Silva PHM, Poggiani F, Libardi PL, Gonçalves AN. Fertilizer management of eucalypt plantations on sandy soil in Brazil: Initial growth and nutrient cycling. *Forest Ecology and Management*. 2013; 301 (1): 67-78.
7. Viera M, Schumacher MV, Trüby P, Araújo EF. Implicações nutricionais com base em diferentes intensidades de colheita da biomassa de *Eucalyptus urophylla* x *Eucalyptus globulus*. *Ciência Rural*. 2015;45(3):432-439. Portuguese.
8. Schumacher MV, Witschorek R, Calil FN. Biomassa em povoamentos de *Eucalyptus* spp. de pequenas propriedades rurais em Vera Cruz, RS. *Ciência Florestal*. 2011;21(1):17-22. Portuguese.
9. Leite FP, Silva IR, Novais RF, Barros NF, Neves JCL, Villani EMA. Nutrient relations during an eucalyptus cycle at different population densities. *Revista Brasileira de Ciência do Solo*. 2011;35(3):949-959.
10. Laclau JP, Ranger J, Gonçalves JLM, Maquère V, Krusche, AV, M'Bou AT, et al. Biogeochemical cycles of nutrients in tropical Eucalyptus plantations: main features shown by intensive monitoring in Congo and Brazil. *Forest Ecology and Management*. 2010;259(9): 1771-1785.
11. Matzenauer R, Radin B, Almeida IR. Atlas Climático do Rio Grande do Sul. Porto Alegre. Secretária de Agricultura, Pecuária e Agronegócio; Fundação Estadual de Pesquisa Agropecuária (FEPAGRO); 2011. Portuguese.
12. Tedesco MJ, Ginello C, Bissani CA, Bohnen H, Volkweiss SJ. Análise de solo, plantas e outros materiais. 2nd ed. Porto Alegre: UFRGS; 1995. Portuguese.

- 365 13. Miyazawa M, Pavan MA, Muraoka T, Carmo CAFS, Melo WJ. Análises químicas de
366 tecido vegetal. In: Silva FC, editor. Manual de análises químicas de solos, plantas e
367 fertilizantes. 2nd ed. Brasília: Embrapa; 2009. Portuguese.
- 368
369 14. SAS. Statistical analysis system: Programa de computador, ambiente VM Versão 6.08.
370 Cary; 2003.
- 371
372 15. Schumacher MV, Caldeira MVW. Estimativa da biomassa e do conteúdo de nutrientes
373 de um povoamento de *Eucalyptus globulus* (Labillardière) sub-espécie maidenii. Ciência
374 Florestal. 2001;11(1):45-53. Portuguese.
- 375
376 16. Gatto A, Bussinguer AP, Ribeiro FC, Azevedo GB, Bueno MC, Monteiro MM, et al.
377 Ciclagem e balanço de nutrientes no sistema solo- planta em um plantio de *Eucalyptus* sp.
378 no Distrito Federal. Revista Brasileira de Ciência do Solo. 2014;38(3):879-887. Portuguese.
- 379
380 17. Eufrade Junior HJ, Melo RX, Sartori MMP, Guerra SPS, Ballarin AW. Sustainable use of
381 eucalypt biomass grown on short rotation coppice for bioenergy. Biomass and Bioenergy.
382 2016;90:15-21.
- 383
384 18. Viera MV, Bonacina DM, Schumacher MV, Calil FN, Caldeira MVW, Watzlawick LF.
385 Biomassa e nutrientes em povoamento de *Eucalyptus urograndis* na Serra do Sudeste-RS.
386 Semina: Ciências Agrárias. 2012;33(1): 2481-2490. Portuguese.
- 387
388 19. Guimarães CC, Schumacher MV, Witshoreck R, Souza HP, Santos JC, Vieira FCB.
389 Biomassa e nutrientes em povoamento de *Eucalyptus dunnii* Maiden no Pampa Gaúcho.
390 Revista Árvore. 2015;39(5):873-882. Portuguese.
- 391
392 20. Beulch LS. Biomassa e nutrientes em um povoamento de *Eucalyptus saligna* Smith
393 submetido ao primeiro desbaste [dissertação]. Santa Maria, RS: Universidade Federal de
394 Santa Maria, 2013. Portuguese.
- 395
396 21. Carvalho RR, Guimarães CC, Silva JCM, Momolli DR. Estoque de biomassa e de
397 nutrientes em um povoamento do híbrido *Eucalyptus urophylla* x *Eucalyptus grandis* no
398 Bioma Pampa – RS. Revista Ecologia e Nutrição Florestal. 2016;3(3):71-81.
- 399
400 22. Barros NF, Comerford NB. Sustentabilidade da produção de florestas plantadas na
401 região tropical. In: Alvarez VVH et al. editors. Tópicos em ciência do solo. Viçosa:
402 Sociedade Brasileira de Ciência do Solo; 2002. Portuguese.
- 403
404 23. Frantz BC. Biomassa e estoque de nutrientes em *Eucalyptus urophylla* x *Eucalyptus*
405 *grandis* em área arenizada do bioma Pampa – RS [dissertação]. Santa Maria, RS:
406 Universidade Federal de Santa Maria, 2016. Portuguese.
- 407
408 24. Verão DS, Bleich ME, Martins NP, Bassotto JM, Mortat AF, Santos AFAS. Concentração
409 de nutrientes em *Eucalyptus urograndis* (*Eucalyptus grandis* W. Hill ex Maiden x *Eucalyptus*
410 *urophylla* S. T Blake) com sete anos de idade na borda sul da Amazônia. Biodiversidade.
411 2016;15(3):35-44. Portuguese
- 412
413 25. Witschoreck R, Schumacher MV. Alocação de nutrientes em povoamentos de *Eucalyptus*
414 *saligna* SM. na região de Guaíba - Rio Grande Do Sul. Cerne. 2015;21(4):625-632.
- 415