Original Research Article

Effects of Soil Type in Amount of Nutrient in *Eucalyptus urograndis*: Macronutrients

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ABSTRACT

The present study had the objective of quantifying the macornutrient stock in the hybrid *Eucalyptus urograndis*, in different soil types, for the Telemaco Borba, Parana, Brazil. The soils selected for the study were the sandy texture (Cambisols Inceptisols), and the second had soil with a clayey texture (Ferralsols Oxisols). Based on the diameter at breast height (DBH) survey of all the constituent trees of each plot, 12 trees were selected per soil type for biomass sampling. The trees were sectioned at the soil level and separated in the components: leaves, branches, stem bark, stem wood, roots and tree tops, and a representative sample of each component was collected and ground in a Wiley-type mill for analytical determination of the macronutrients. The concentrations of the macronutrients in the different biomass components were significantly different in both types of soil. With the exception of calcium, which was more present in the stem bark component in the sandy soil and calcium and magnesium in the clayey soil, the other components had the highest concentration values in the leaves component. In addition, the lowest concentration values of the macronutrients, both for the sandy soil and for the clay soil, were found in the stem wood and roots component. The total nutrient stock found in the biomass, in the sandy soil was 1.65 Mg ha^{-1}, distributed in the following order of magnitude: stem wood > root > stem bark > leaves > branches > Tree tops. For the clayey soil there was an inversion in the quantities in the following order: stem wood > stem bark > root > branches > leaves > tree tops, presenting a total stock of 2.41 Mg ha^{-1}. The highest amount of macronutrients in the biomass was found in soil with a clayey texture.

Keywords: forest nutrition, forest soils, sandy soil, clayey soil.

1. INTRODUCTION

Because of the growing demand for products of forest origin, plantations with exotic species of fast growth and high productivity, make Brazilian forestry a prominent factor in the world scenario, due to its economic, social and environmental benefits to the country. The plantations in the tropical region provide a growing share of timber for global supply and competition with other land uses will require sustainable production of these stands to meet market demand [1]. Among the forest species *Eucalyptus urograndis*, a hybrid of *Eucalyptus urophylla* S.T. In this study, Blake and *Eucalyptus grandis* Hill ex Maiden developed good adaptation to several regions of the country, as well as good productivity and better characteristics of wood for several industrial purposes [2].

The quantification of the nutrients in the different components of biomass is of fundamental importance for the nutrition of the trees, especially when it is desired to raise the productivity of a certain species under the edaphoclimatic conditions of the evaluated site. In addition to enabling the prediction of situations critical to the stand and chemical characteristics of the soil and analysis of the effects caused by the forest harvest, with the evaluation of the export of nutrients from the site [3] [4].

The concentration and amount of nutrients stored in the trees vary according to the species, age, soil and climatic conditions of the site and the management practices adopted in the stand, and within the same biomass component there may be variations due to internal translocations [5]. Thus, evaluations of the nutritional requirement of the species and the soil properties at different sites are useful for adjusting the fertilization regimes in order to maintain the nutrient stock in the soil along successive rotations [1]. Silva et al. [6] also emphasized out that it is necessary to consider the relationship between the amount of nutrients in the biomass components and the soil's climatic and climatic conditions to suit the nutritional need of the species.

Forest plantations established in gleissolos and podzols tend to be more affected in the nutrient stock of the soil, by the biomass harvest, than stands growing in acrosols and cambisolos [7]. Sandy soils with low nutrient retention and high hydraulic conductivity are highly susceptible to nutrient leaching, hindering the fertilization regime to be adopted [6]. The objective of the present work was to quantify the stock of macronutrients in *Eucalyptus urograndis* stands established in sandy and clayey soils.

2. MATERIAL AND METHODS

2.1 Characterization of the area and experimental design

The present study was carried out in a plantation with the hybrid Eucalyptus urograndis, in the municipality of Telemaco Borba, Paraná - Brazil. The climate of the region, according to the classification of Köppen, is of the type Cfb (Humid subtropical climate), with rains well distributed during the year and mild summers, without dry season. Average annual temperatures fluctuate around 19 ºC and rainfall reaches about 1,184 mm annually with the average of the hottest month at around 27 °C and the coldest month around 13 °C [8].

The soils selected for the study were the Cambisols Inceptisols and the Ferralsols Oxisols, denominated as sandy and clayey soil, respectively. The Cambisols has a moderate A horizon of clay of low activity and light average texture (sandy loam) with the occurrence of rocks in the soil mass. On the other hand, the Ferralsols is characterized by a moderate A horizon with a clayey and very clayey texture. The clayey soil naturally presents a higher cation exchange capacity (2.95 $cmol_c$ dm^{-3}) when compared to the sandy soil (2.39 $cmol_c$ dm^{-3}), especially in the first layer of 0 to 20 cm of depth where they present higher levels of organic matter (Table 1).

Table 1. Chemical and physical attributes of distinct soils planted with *E. urograndis* in the region of Telemaco Borba, Paraná, Brazil

Atribute	Sandy			Clayey		
	0-20 cm	20-40 cm	40-60 cm	0-20 cm	20-40 cm	40-60 cm

O.M.* (%)	1.79	1.32	1.42	3.39	2.45	1.72
pH (H_2O)	3.97	3.97	3.95	3.98	4.19	4.41
P* (mg dm^{-3})	1.61	1.12	0.89	0.86	0.68	0.68
K* (mg dm^{-3})	30.92	20.08	35.11	45.04	32.59	27.63
S (mg dm^{-3})	9.08	10.28	13.03	26.13	23.36	11.26
B (mg dm^{-3})	0.55	0.63	0.67	0.61	0.61	0.56
Cu (mg dm^{-3})	1.25	1.22	1.19	2.65	2.06	1.40
Zn (mg dm^{-3})	0.54	0.48	0.43	0.58	0.25	0.19
Ca ($cmol_c$ dm^{-3})	0.09	0.06	0.06	0.18	0.05	0.03
Mg ($cmol_c$ dm^{-3})	0.07	0.05	0.05	0.45	0.11	0.03
ECEC ($cmol_c$ dm^{-3})	2.30	2.41	2.47	3.72	2.85	2.29
V (%)	2.54	1.53	2.68	2.89	1.00	0.75
m (%)	89.92	96.19	93.36	80.02	91.76	94.25
Coarse sand (%)	39.89	40.33	40.72	14.68	16.51	16.18
Fine sand (%)	40.36	40.50	37.05	6.87	5.79	6.73
Silt (%)	4.19	2.11	3.67	28.23	31.48	26.87
Clay (%)	15.56	17.06	18.56	50.22	46.22	50.22

Where: O.M. = organic matter; P = Phosphorus; K = Potassium; S = Sulfur; B = Boron; Cu = Copper; Zn = Zinc; Ca = Calcium; Mg = Magnesium; ECEC = Effective Cation Exchange Capacity; V = saturation per exchangeable base; m = exchangeable aluminum saturation; *Determination of nutrients using the $Mehlich^{-1}$ extractor.

For each soil type, 4 sample plots with an area of 2,550 m^2 and composed of 340 plants were demarcated. The planting was done manually, with spacing of 3.0 m x 2.5 m and initial density of 1,333 plants per hectare. For the planting, a soil subsoiling was carried out in the planting line, with a depth of 45 cm, where a dosage of 200 kg ha^{-1} of natural rock phosphate was incorporated. After the planting, two other fertilizations were carried out, the first being a basic fertilization of 15 kg ha^{-1} of N, 35 kg ha^{-1} of P, 15 kg ha^{-1} of K, and the second one was a cover fertilization with 40 kg ha^{-1} of N, 5 kg ha^{-1} of P, 65 kg ha^{-1} of K + 1,5 kg ha^{-1} of B.

2.2 Measurements of biomass and nutrients

Based on the diameter at breast height (DBH) survey of all the constituent trees of each plot (disregarding dead trees and faults), 12 trees were selected per soil type for above-ground biomass sampling (the tree mean diameter minus one standard deviation, tree of mean diameter and tree mean diameter plus standard deviation of each plot).

The selected trees were sectioned at soil level and separated in the following components above-ground: leaves, branches, stem bark and stem wood, tree tops (shaft diameter below 8 cm). Root biomass was estimated by digging in the useful area (7.5 m²), to the depth of one meter, of the four medium DAP trees, in each soil type.

All samples were sent to the laboratory, dried at 70 °C in a circulating greenhouse and air renewal, until reaching constant mass, and after they were weighed again to determine the biomass, through the humidity of the samples of each component. The total biomass per hectare was extrapolated per hectare based on the biomass of each tree and number of trees per hectare. A detailed description of the methodology adopted for biomass determination can also be found in Salvador et al. [9].

All samples were milled in a Wiley-type mill for analytical determination of the macronutrients N, P, K, Ca, Mg and S according to the methodology described by Tedesco et al. [10] and Miyazawa et al. [11]. For the estimation of the total nutrient stock, the product was calculated between the mean nutrient concentration and the biomass of each component.

2.3 Statistical analysis

Statistical analyzes were performed with the aid of the statistical program SAS [12], at the level of 5% probability of error. Tukey's test was used to separate the contrasts of averages, considering a completely randomized design, where each tree analyzed corresponds to one repetition in each type of soil.

3. RESULTS AND DISCUSSION

The concentration of macronutrients in the different biomass components were significantly different (p=.05) in both types of soil (Table 2). With the exception of calcium, which presented higher values in the stem bark component in sandy soil and calcium and magnesium in the clay soil, the other components had the highest concentration in the leaves component, in both types of soil. In addition, the lowest concentrations of macronutrients, both for sandy soil and clayey soil, were found in the stem wood and root component. Boulliet et al. [13] analyzing the concentration of Nitrogen in the different components of *E. grandis* found concentrations similar to the present study: leaves (17.7 g kg^{-1}) > stem bark (3.4 g kg^{-1}) > branches (3.3 g kg^{-1}) > stem wood (1.5 g kg^{-1}).

Table 2. Concentration of nutrients in biomass components in a *Eucalyptus urograndis* stands at 7 years-old in different soil types

Soil	Component	N	P	K	Ca	Mg	S
		g kg^{-1}					
Sandy	Leaves	21.28 *±2.34** a*	1.38 *±0.21* a	11.75 *±2.32* a	4.58 *±0.56* b	3.30 *±0.38* a	1.17 *±0.18* a
	Branches	3.20 *±0.85* bcd	0.32 *±0.13* c	5.30 *±1.03* b	2.89 *±0.98* c	0.85 *±0.41* b	0.39 *±0.03* b
	Stem bark	3.92 *±0.35* b	0.51 *±0.11* b	9.83 *±1.91* a	8.16 *±1.75* a	2.23 *±0.21* a	0.40 *±0.04* b
	Stem wood	1.25 *±0.12* d	0.09 *±0.01* d	1.31 *±0.12* cd	0.49 *±0.09* d	0.18 *±0.03* c	0.24 *±0.04* bc
	Roots	3.93 *±0.26* cd	0.19 *±0.05* d	1.54 *±0.34* d	1.59 *±0.98* d	0.59 *±0.14* c	0.42 *±0.03* c
	Tree tops	7.48 *±0.54* bc	0.60 *±0.13* c	6.75 *±1.00* bc	4.14 *±0.42* c	1.68 *±0.27* b	0.46 *±0.05* bc

Clayey	Leaves	22.18 *±1.26* a	1.21 *±0.10* a	12.18 *±1.93* a	6.66 *±1.18* c	2.93 *±0.41* a	1.10 *±0.23* a
	Branches	4.69 *±1.00* c	0.41 *±0.14* c	4.83 *±1.69* c	8.60 *±2.65* b	1.77 *±0.45* b	0.26 *±0.03* c
	Stem bark	3.97 *±0.32* c	0.59 *±0.19* b	7.58 *±1.95* b	11.48 *±1.58* a	2.99 *±0.52* a	0.28 *±0.04* c
	Stem wood	1.09 *±0.12* d	0.07 *±0.02* d	1.10 *±0.16* d	0.65 *±0.17* d	0.19 *±0.04* c	0.25 *±0.06* c
	Roots	3.73 *±0.21* d	0.24 *±0.03* d	4.08 *±0.46* d	2.42 *±0.61* d	1.10 *±0.20* c	0.26 *±0.01* d
	Tree tops	8.18 *±0.34* b	0.65 *±0.11* b	6.15 *±0.74* bc	5.82 *±0.77* c	2.14 *±0.24* b	0.47 *±0.07* b

* Values in italics indicate the standard deviation of each component. Different vertical letters indicate significant differences between the biomass components, at the 0.05 level of significance, by the Tukey test.

The highest concentration of nutrients in leaves was also found by Turner and Lambert [14] and Viera et al. [3]. The nutrients present higher concentration in the leaves due to the greater metabolic activity (photosynthesis and transpiration) of these tissues when compared to the others [3].

Potassium plays a key role in regulating the osmotic potential of plant cells in addition to activating the enzymes of respiration and photosynthesis [15] and is highly mobile in phloem and readily redistributed to new growing organs [16], thus presenting a tendency to concentrate in the leaves, a result obtained in the present study.

Phosphorus also has ample mobility within the plant, so it tends to concentrate on the newer organs [17], in the case of this study, on the leaf component. Moreover, the high concentration of phosphorus in the leaves is due to the fact that this element is an integral component of important plant compounds, which are used as energy sources [18].

The high Ca content in the stem bark component was also found in other studies by Guimaraes et al. [19], which can be justified as being a practically immobile element in the plant phloem and being a structural component and part of the middle lamella of the cell membrane.

Component differentiations, besides the physiological importance of each component of the plant, affect nutrient accumulation, and the lowest concentrations of nutrients in this study were found in the wood component. Which is associated with the internal retranslocation of nutrients since the wood presents less intense physiological activity.

Among the factors that cause the variation in nutrient contents in the leaves component, we can mention: length of the day, age of the trees, the effect of pests and diseases, the age of the sampled material, the position of the leaves in the canopy, the collection season, the physiological state of the leaves, soil parameters, species used, site conditions and provenances [20]. In addition, the difference in nutrient concentration between the components and within the plant components is due to the biochemical cycle that involves the retranslocation of a certain element from one organ to another [15].

The total amount of nutrients found in the sandy soil was 1.65 Mg ha^{-1}, in the following order of accumulation: N > K > Ca > Mg > S > P. For the clayey soil there was a inversion in the values presenting the following order: K > Ca > N > Mg > S > P, which represented a total stock of 2.41 Mg ha^{-1} (Table 3). The largest stock of nutrients in the clayey soil is directly related to higher biomass production in this type of soil.

Table 3 - Amount of nutrients in the different components of the biomass in a 7-years-old *Eucalyptus urograndis* stand, in the region of Telêmaco Borba, Parana - Brazil.

Soil	Component	Biomass	N	P	K	Ca	Mg	S
		Mg ha^{-1}	kg ha^{-1}					
Sandy	Leaves	2.61	55.3	3.6	30.6	11.9	8.6	3.0
	Branches	6.95	22.1	2.2	36.6	19.9	5.9	2.7
	Stem bark	13.49	52.9	6.9	132.7	110.2	30.1	5.4
	Stem wood	191.90	239.9	17.3	251.4	94.0	34.5	46.1
	Tree tops	13.06	26.1	2.0	26.7	11.9	5.0	2.2
	Roots	43.05	169.4	8.2	66.4	68.5	25.4	18.1
	Total	271.06	565.7	40.1	544.3	316.5	109.5	77.5
Clayey	Leaves	4.01	90.9	5.0	49.9	27.3	12.0	4.5
	Branches	11.44	53.5	4.7	55.1	98.0	20.2	3.0
	Stem bark	25.08	99.6	14.8	190.3	288.1	75.0	7.0
	Stem wood	223.73	243.8	15.7	246.1	145.4	42.5	55.9
	Tree tops	14.59	41.8	3.1	33.4	36.6	10.1	2.7
	Roots	36.95	137.6	8.9	150.6	89.3	40.6	9.6
	Total	315.79	667.3	52.1	725.9	684.8	200.4	82.7

The magnitude of accumulation, of the different components, of total biomass above ground, found by Viera et al. [3] in *Eucalyptus urophylla* x *E. globulus* stand with 10 years-old was: Ca > N > K > Mg > P > S. This result is similar to the order found by Guimarães et al. [19] com *Eucalyptus dunnii* at 4 years-old: Ca > N > K > Mg > S > P. Already the order found by Santos et al. [21], for *E. urograndis*, 5 years-old, was: N > K > Ca > Mg > P.

The amount of macronutrients in the different components of the biomass presented the following decreasing order of accumulation: stem wood > root > stem bark > leaves > branches > Tree tops. For the clayey soil there was an inversion in the quantities in the following order: stem wood > stem bark > root > branches > leaves > Tree top (Figure 1).

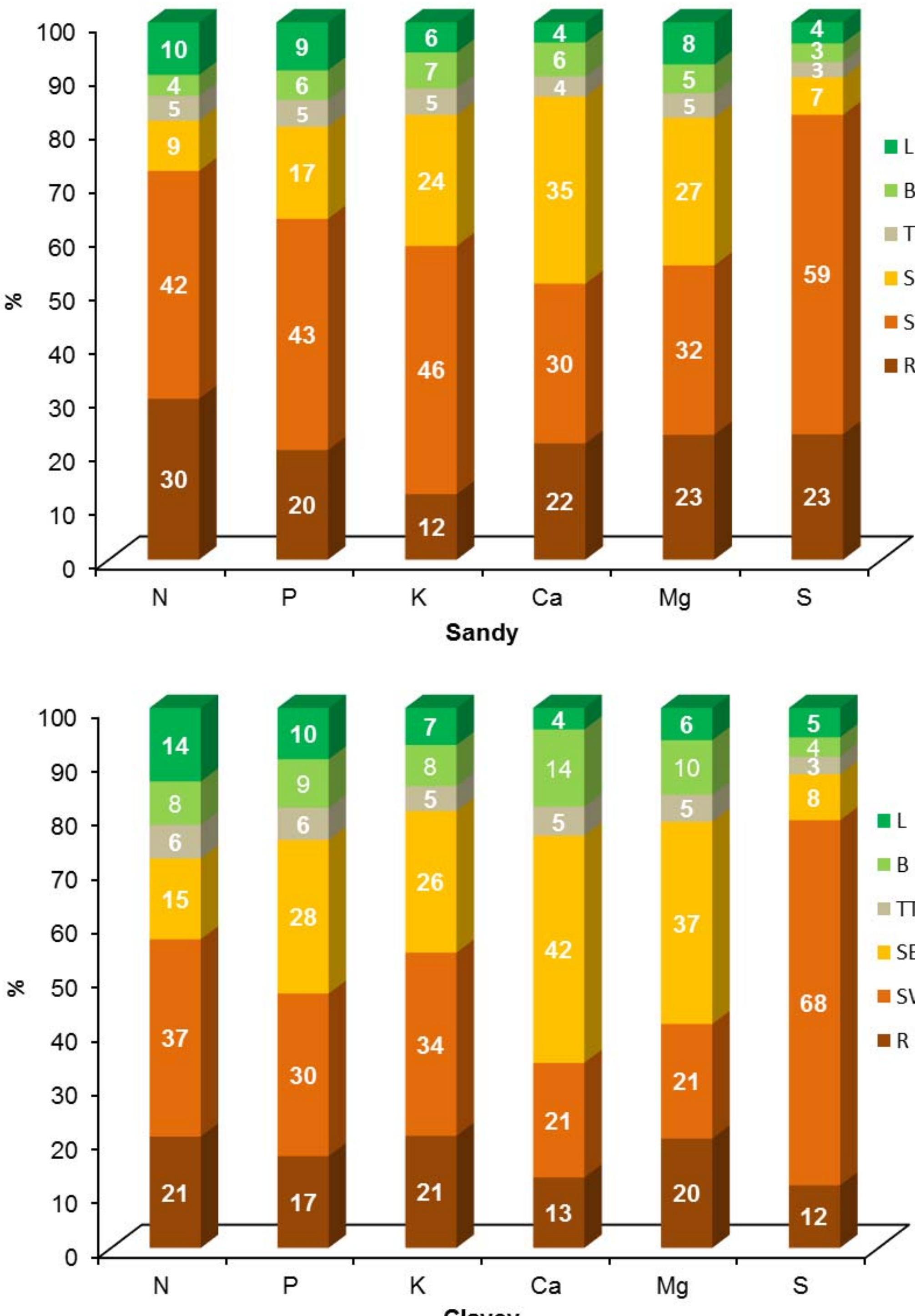

Figure 1. Distribution of nutrients in the different components of the biomass in a 7-years-old *Eucalyptus urograndis* stand, in the region of Telêmaco Borba, Parana - Brazil.

Where: L = Leaves; B = Branches; TT = Tree tops; SB = Stem bark; SW = Stem wood; R = Roots.

Analyzed the distribution of nutrients in the components Viera et al. [3] observed the following order stem wood > stem bark > branches > leaves for *Eucalyptus urophylla* x *E. globulus* stand with 10 years-old. Guimarães et al [19] with 4-year-old *E. dunnii* presented the following order of distribution among the components: stem bark > stem wood > roots > branches > leaves.

Viera et al. [22], reports that the highest concentrations of nutrients in trees are in the tissues of the components that form the crowns. However, the largest amount of biomass is stored in the stem (stem wood + stem bark), which is the part normally harvested, as can be observed in the results found by this study. Changes in nutrient allocation in different plant components are related to the ability of the root system to absorb nutrients and the degree of efficiency that the trees have in the translocation and metabolization of these nutrients [23].

4. CONCLUSION

The highest amount of macronutrients was found in soil with clayey texture, directly related to higher biomass production in this soil.

The leaves present the highest concentration and the wood has the largest amount of macronutrients, regardless of soil type.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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