MICRONUTRIENTS AND BIOMASS IN *Eucalyptus dunnii* Maiden STAND[1]

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ABSTRACT – The expansion of silviculture in Brazil, and the consequent intensive practices for soil preparation with high demand for fertilizers require sustainable nutrient management of forest sites. The objective of this study was to quantify the biomass and the micronutrient stocks of a 60-month-old *Eucalyptus dunnii* stand established in Alegrete, Rio Grande do Sul. The stand was established in a Rhodic Paleudult soil with low fertility and texture varying between sandy loam and sandy-clay loam. For the sampling of stand biomass, twelve trees were harvested, sectioned at ground level, and subsequently fractionated into the components roots, leaves, branches, stembark and stemwood to determine the dry mass and micronutrient content. The total biomass of the stand was 67.49 Mg ha^{-1}, with mass allocation in descending order from: stem wood > root > bark > branches > leaves. Total micronutrient stocks for boron (B), copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn) were 562.57, 401.46, 9913.28, 31877.82, and 766.96 g ha^{-1}, respectively. In addition, we found greater accumulation of Zn in the wood, high Mn accumulation especially in the bark, and high Fe content in the roots. Therefore, based on these micronutrient levels and their allocation between biomass fractions, we emphasize that the practice of retaining forest residues on-site after harvest is essential for forest nutrition through nutrient cycling and for soil conservation and fertility.

Keywords: Forest nutrition; Nutrients cycling; Manganese

MICRONUTRIENTES E BIOMASSA EM POVOAMENTO DE Eucalyptus dunnii Maiden

RESUMO – A expansão da silvicultura no Brasil e as consequentes práticas intensivas para o preparo do solo, com elevada demanda por fertilizantes, requerem ações de manejo nutricional sustentável dos sítios florestais. O objetivo do presente trabalho foi quantificar a biomassa e o estoque de micronutrientes, em um povoamento de **Eucalyptus dunnii***, aos 60 meses de idade, estabelecido em Alegrete, Rio Grande do Sul. O povoamento foi implantado em solo do tipo Argissolo Vermelho Distrófico típico, com baixa fertilidade natural e textura variando entre franco-arenosa e franco-argilo-arenosa. Para a amostragem da biomassa, doze árvores foram abatidas e seccionadas ao nível do solo, onde posteriormente houve o fracionamento nos componentes: raízes, folhas, galhos, casca do tronco e madeira do tronco, com determinação de massa seca e teores de micronutrientes. Verificou-se que a biomassa total do povoamento foi de 67,49 Mg ha^{-1}, com sequência decrescente de alocação de massa na ordem de: madeira do tronco > raízes > casca do tronco > galhos > folhas. O estoque total de micronutrientes B, Cu, Fe, Mn e Zn na biomassa foi de 562,57; 401,46; 9.913,28; 31.877,82 e 766,96 g ha^{-1} respectivamente. Constatou-se maior acúmulo de zinco na madeira do tronco, elevado acúmulo de manganês especialmente na casca do tronco e de ferro nas raízes. Em função*

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dos níveis de micronutrientes alocados na biomassa, enfatiza-se à prática de manutenção dos resíduos florestais no sítio após a colheita, indispensáveis para a nutrição florestal, que através da ciclagem de nutrientes propiciam a conservação da fertilidade.

Palavras-chave: Nutrição Florestal; Ciclagem de nutrientes; Manganês.

1. INTRODUCTION

Forest stand establishment in Brazil, mainly that of eucalyptus species, has been occurring since the beginning of the last century, resulting in approximately 51 million hectares of total forests, of which seven million hectares are occupied with planted forest stands (ABRAF, 2013). Along with this promising scenario, there is a concern with sustainability, and the production must be achieved and avoiding to the maximum nutritional exhaustion of the site, also reducing fertilization expenditure.

To ensure rational use of mineral elements, Lopes and Abreu (2000) suggested that micronutrient fertilization in particular should be based not only on soil analyses, but also on vegetation responses and use efficiency of those nutrients. Micronutrients (i.e., trace minerals) are essential elements required in smaller amounts for the development of vegetation (Gupta, 2001). These, however, have recently been used commonly for fertilization in several regions and in diverse soil conditions, climates, and cultures of Brazil (Lopes and Abreu, 2000).

According to Abreu et al. (2007), the ability of plants to absorb and use micronutrients is reflected in their biomass nutritional balance. As such, knowledge of the dynamics of micronutrients in the soil is important for the management of fertilization practices and, in turn, the development of the vegetation. The aim of present study was to evaluate the micronutrient stocks of the above- and below-ground biomass of a *Eucalyptus dunnii* stand in the Pampa biome, Rio Grande do Sul state.

2. MATERIAL AND METHODS

2.1 Ecological characterization of the site

This study was conducted in the Campaign region of Rio Grande do Sul state, approximately 76 km from Alegrete city, in the Sesmaria St. Ignatius Farm owned by the company StoraEnso Forest RS Ltd. The central geographical coordinates of the *Eucalyptus dunnii* stand are 29° 47' south and 55° 17' west, at an altitude of 98 m. According to Matzenauer et al. (2011), the region is of a humid climate type, where the summers can show periods of drought, with average annual temperature and precipitation of 18.6 °C and 1,574 mm, respectively. The predominant vegetation in the region is the native fields characterized physiognomically by grasses interspersed by forest capons that occur along the rivers' courses (Boldrini et al., 2010).

Most of the soils of the Campaign region have basalt as their source material, but there are also areas covered by sandstone, with a large dominance of eutrophic Litolics or Regolithic Neosols, generally situated in smooth undulating relief (Streck et al., 2008). In the area where the stand was established, the soil was classified morphologically, and chemical and physical analyses were performed according to Tedesco et al. (1995). It was observed that the soil is of the type Rhodic Paleudult (Embrapa, 2006), with depth varying between intermediate and deep, with good drainage, and sandy texture varying from sandy loam to sandy loam as the depth increases.

According to the interpretation suggested by CQFS (2004), the soil of the experimental area has low organic matter content (SOM) and low pH, low levels of calcium, magnesium, potassium, and phosphorus. In addition, the soil has an effective CTC average (t), and very low base saturation and high aluminum (Al) saturation. Boron (B), Cu, and Zn contents (the latter for the 0-20 cm and 20-100 cm soil layers) are also shown in Table 1.

This condition of low natural soil fertility, a typical soil situation in the Pampa Biome Campaign region, may be related to the predominance of the sand fraction in soil composition, its low organic matter content, and low availability of minerals such as calcium, magnesium, and potassium, which are indispensable for plant nutrition (Dechen and Nachtigall, 2007).

2.2 Silvicultural practices of the stand

The *Eucalyptus dunnii* stand establishment activities began in 2008, on an area that was under

Table 1 – Chemical attributes (mean ± standard deviation) of Rhodic Paleudult soil in the *Eucalyptus dunnii* stand.
Tabela 1 – *Atributos químicos (média ± desvio padrão) do Argissolo Vermelho Distrófico típico em um povoamento de **Eucalyptus dunnii**.*

Attribute	Unit	Soil Layer (cm)				
		0-20	20-40	40-60	60-80	80-100
SOM	%	1,00±0,15	0,91±0,10	0,85±0,07	0,78±0,07	0,72±0,06
pH	(1:2,5H_2O)	4,74±0,06	4,84±0,05	4,96±0,03	4,98±0,01	5,00±0,07
Al^{3+}	$cmol_c\ dm^{-3}$	1,99±0,14	1,95±0,14	1,91±0,32	2,03±0,21	1,75±0,25
Ca^{2+}	$cmol_c\ dm^{-3}$	0,46±0,27	0,79±0,17	1,21±0,12	1,84±0,44	1,88±0,06
Mg^{2+}	$cmol_c\ dm^{-3}$	0,33±0,10	0,24±0,06	0,27±0,02	0,34±0,06	0,40±0,01
P*	mg dm^{-3}	1,87±0,09	1,60±0,16	1,49±0,09	1,49±0,19	1,54±0,19
K*	mg dm^{-3}	20,33±5,5	12,00±3,6	9,67±2,3	8,33±1,53	8,33±1,15
t	$cmol_c\ dm^{-3}$	2,83±0,46	3,01±0,38	3,42±0,45	4,22±0,66	4,04±0,30
T	$cmol_c\ dm^{-3}$	8,96±1,36	9,59±1,23	10,11±2,0	10,78±2,5	10,95±1,7
V	%	9,07±3,11	10,99±1,2	15,15±1,8	20,51±1,9	21,22±2,5
m	%	71,30±9,8	65,04±3,8	55,73±2,0	48,38±3,3	43,17±2,8
B	mg dm^{-3}	0,35±0,07	0,42±0,12	0,47±0,04	0,43±0,07	0,43±0,08
Cu	mg dm^{-3}	2,29±0,40	2,14±0,07	2,20±0,21	2,23±0,14	2,01±0,21
Zn	mg dm^{-3}	0,57±0,09	0,35±0,02	0,24±0,01	0,23±0,11	0,29±0,17

Where: SOM is soil organic matter; t is CTC effective; T is CTC pH7; V is Base Saturation; m is Saturation by aluminum. *Melich I method.

the process of soil degradation. Seedlings were planted from the seeds at a spacing of 2.0 m x 3.5 m between plants.

In the area, soil preparation was performed with a subsoiler, mounted to a tire tractor, at an average depth of 60 cm. Thereafter, phosphatization in line, irrigation, starter and cover fertilization, weeding in the line, and interlining were conducted here 300 kg ha^{-1} of formulation 06-30-06 of $N-P_2O_5-K_2O$ + 0.6% of boron was applied. The second fertilizer addition was at 90 days after planting, where 140 kg ha^{-1} of 22-05-20 of $N-P_2O_5-K_2O$ + 0.2% of boron + 0.4% of zinc was applied. The third fertilization was at 270 days, using 140 kg ha^{-1} of 22-00-18 of $N-P_2O_5-K_2O$ + 1.0% sulfur + 0.3% boron, applied mechanically in the interlinings.

2.3 Quantification of stand biomass and micronutrient stocks

At 60 months of age, in November 2012, samples of biomass above and below the soil were taken in four plots randomly distributed in the area, each with a dimension of 20 m x 21 m. The diameter at breast height (DBH) and total height (h) were measured from all trees in the plots to define four diametric classes, with three trees (lower, middle and upper limit), resulting in 12 repetitions.

The selected trees were accurately cubed according to the Smalian method (Péllico Netto and Brena, 1997), and subsequently fractionated into stemwood, stembark, branches, and leaves and heavy in its entirety, with hook balance of aid, and properly sampled and weighed on a precision scale (1.0 g). For stemwood and stembark, three sampling points distributed along the length of the commercial bole were determined, resulting in the wood fractions being divided into three equal parts. For minimum diameter of the bole (commercial diameter), the measure of eight centimeters was considered.

To estimate the micronutrient stocks, representative samples (150 g) of each biomass component were collected and weighed in the field with a precision scale. These were sent to the laboratory and dried in an air circulation oven at 70 °C for 72 h, after which the dry mass was determined using a precision digital scale (0.01 g) and modeling was applied to estimate the total amount of biomass per hectare.

The below-ground biomass was obtained from four trees, through the excavation of the soil using shovels, hoes, and backhoe, in 7.0 m² area of the central limit tree in each of the tree diameter classes up to a depth of 1 m. In this manner, the biomass produced per hectare was estimated based on the area of each plot.

The analysis of the micronutrients in the leaves and branches was performed by random sampling, considering thin, thick, live, and dead branches located throughout the crown.

Samples of these biomass fractions were used to determine the concentrations of B, Cu, Fe, Mn, and Zn, following the methodology of Tedesco et al. (1995). For the extraction of boron, dry digestion and analysis by spectrophotometry were used. For the other micronutrients, the perchloric nitrate (HNO_3 + $HClO^4$, 3: 1) and the atomic absorption spectrophotometry methods were used. The amounts of micronutrients present in the compartments of *Eucalyptus dunnii* stand were calculated by means of the product of the average concentration of nutrients and the biomass.

2.4 Statistical analyses

For the statistical analysis of the micronutrient contents in the biomass components, the Tukey's test ($\alpha = 5\%$) was performed using the software Assistat version 7.7 (SILVA; AZEVEDO, 2002), considering the completely randomized design with different number of repetition (i.e., twelve samples of each component of the biomass above the soil and four samples for the biomass below the soil were used). Modeling to estimate the biomass of the *Eucalyptus dunnii* stand was performed using the software SAS 13.0 for Windows (1996), considering a 5% level of error probability using the stepwise procedure.

To estimate the stand biomass, the modeling used the equation *st and (y)* $= b_0 + b_1$ *x ln (dap)*, which presented the best fit for all compartments (R aj² greater than 0.90), where *ln (y)* represents the natural logarithm of the dry biomass (kg per tree) of the components, *ln (dap)* the natural logarithm of the diameter (DBH cm) and b_0 and b_1 the regression coefficients.

3. RESULTS

3.1 *Eucalyptus dunnii* biomass

The results of the inventory showed that, at 60 months of age, trees of the *Eucalyptus dunnii* stand had a DBH of 12.0 cm, h of 13.0 m, basal area of 14.0 m² ha^{-1}, a total density of 1,143 trees per hectare, and volume with bark of 124.3 m³ ha^{-1}. As such, the stand can be considered of low productivity, likely because of the its genetic composition, establishment of the seedlings from seeds, or the low soil fertility of the area.

The total biomass production in the *Eucalyptus dunnii* stand was 67.49 Mg ha^{-1}, of which the biomass below the ground (i.e., root biomass) was 8.73 Mg ha^{-1} (13 %). For above-ground biomass, there was 3.55 Mg ha^{-1} (5.3 %) of leaves; 6.45 Mg ha^{-1} (9.5 %) of branches; 7.94 Mg ha^{-1} (11.7 %) of stembark; and 40.82 Mg ha^{-1} (60.5 %) of stemwood.

3.2 Nutrient stocks in tree components

With respect to the micronutrient stocks in the stand, significant differences (*P* d" 0.05) in the concentrations of the elements were found among the different tree components (Table 2), with the micronutrients B and Cu being predominant in the leaves. The stemwood, which was the component with highest biomass allocation, showed low accumulation of all the measured elements.

It was observed that there was an expression of manganese, accumulated mainly in the stembark and leaves, which represent 11.7% and 5.3% of the total biomass of the *Eucalyptus dunnii* stand (Table 3), respectively. After Mn, the mostpresent micronutrient was Fe, which was concentrated mainly in the roots.

4. DISCUSSION

4.1 *Eucalyptus dunnii* biomass

The biomass allocation of *Eucalyptus dunnii* species followed the order of: stemwood > roots > branches

Table 2 – Concentrations of micronutrients in the different components of the biomass of *Eucalyptus dunnii.*
Tabela 2** – Concentrações de micronutrientes nos diferentes componentes da biomassa de **Eucalyptus dunnii.

Component	B	Cu	Fe	Mn	Zn
	(mg kg^{-1})				
Leaves	32,19 a(28,0)	8,59 a(29,3)	130,57 b(22,53)	2.061,54 a(33,74)	12,57 a(22,43)
Branches	11,70 b(25,90)	8,75 a(24,23)	42,44 c(56,6)	904,85 b(30,97)	12,71 a(24,97)
Stemwood	2,21 c(45,25)	5,32 b(25,04)	20,31 c(58,93)	142,85 d(18,67)	10,36 b(39,68)
Stembark	14,54 b(14,96)	6,14 b(25,24)	36,52 c(26,27)	1.321,89 b(29,37)	14,23 a(26,21)
Roots	19,15 b(3,14)	5,57 b(2,50)	922,91 a(4,92)	274,47 c(28,6)	11,95 a(17,93)

The averages followed by the same letter in the column within each component do not differ by the Tukey test at 5% probability. Value in parentheses = coefficient of variation between replicates.

Table 3 – Amount of micronutrients in the different components of the biomass of *Eucalyptus dunnii*.
Tabela 3** – Quantidades de micronutrientes nos diferentes componentes da biomassa do povoamento de* ***Eucalyptus dunnii.

Component	B	Cu	Fe	Mn	Zn
			(g ha^{-1})		
Leaves	114,27	30,49	463,52	7.318,47	44,62
Branches	75,46	56,44	273,74	5.836,28	81,98
Stemwood	90,21	217,16	829,05	5.831,14	423,06
Stembark	115,45	48,75	289,97	10.495,81	112,98
Roots	167,18	48,62	8.057,0	2.396,12	104,32
Total	562,57	401,46	9.913,28	31.877,82	766,96

> barkwood > leaves. More than 70% of the stand biomass was above-ground, and the highest proportion of total biomass corresponded to the stemwood. Therefore, for appropriate nutritional management of this soil, it is recommended that only the stemwood be removed from the site during forest harvest, leaving the residues such as leaves, branches, stembark, and roots on-site. Nevertheless, the stemwood also had low concentrations of micronutrient elements (discussed in section 4.2).

As for the below-ground biomass, roots represented a considerable part of the total biomass, which was within the expected range. For example, according to Foelkel (2014), the roots can constitute 10% to 25% of the total mass of forest biomass, depending on the species of eucalyptus and the quality of the stands. The age of the stand can also be a determining factor for the amount of root biomass. Indeed, Schumacher et al. (2011) in a study with the genus *Eucalyptus* verified that there is a trend of root increase with increasing age. The authors found 5.61 and 25.17 Mg ha^{-1} of root biomass at 4 years and 8 years of age, respectively.

In this study, we found 58.76 Mg ha^{-1} of biomass above the soil. Biomass production in a forest stand may also be linked to the soil type of the site. Hernández et al. (2009) in a study with *Eucalyptus dunnii* at age 9, but established in a soil with high organic matter content, in Algorta, Uruguay, recorded a high biomass production of 236 Mg ha^{-1}. The authors found that the highest biomass proportion was allocated to the stemwood (172 Mg ha^{-1}), followed by stembark (29 Mg ha^{-1}), branches (22 Mg ha^{-1}), and leaves (13 Mg ha^{-1}). In another study in a low fertility site, Gatto et al. (2014) estimated the biomass of a 5-year-old *Eucalyptus urophylla x Eucalyptus grandis* stand and found results similar to the present study, with 57.36 Mg ha^{-1} of stemwood, 8.08 Mg ha^{-1} of branches, 5.03 Mg ha^{-1} of barkwood, totaling 69.19 % of the total biomass in addition to 4.02 Mg ha^{-1} of leaves.

4.2 Nutrient stock in biomass

This study found that there was no deficiency in the nutrient stocks in the biomass, considering the nutritional status of the leaves reported by Alfaia and Uguen (2013). In the stemwood, which was the component with the highest biomass allocation, there was less accumulation of the measured nutrient elements, with the exception of zinc, which suggests little removal of micronutrients from the site due to forest harvesting.

It was also observed micronutrient storage in the biomass compartments followed the descending order of: Mn > Fe > B > Zn > Cu. This result corroborated Viera et al. (2013) who found similar magnitude of concentrations of micronutrients, except boron, in *Eucalyptus urophylla x Eucalyptus globulus* stand. Another study by Guimarães (2014) also found the concentrations of micronutrients of a *Eucalyptus dunnii* stand in the order of Fe > Mn > B > Zn > Cu.

The high concentrations of manganese in all components of the trees indicate the eucalyptus propensity to accumulate this micronutrient. This tendency was also observed by Viera et al. (2013) and Guimarães (2014). On the other hand, manganese is an essential nutrient to the plant, considering that it directly contributes to the process of photosynthesis, forms part of complex of water molecules, and is used in the conversion of light to energy which consequently releases oxygen into the atmosphere (Taiz and Zeiger, 2013). The high accumulation of Mn in the biomass can be explained by the low mobility of this micronutrient (i.e., an element of insufficient redistribution), since the transportation is done unidirectionally through the xylem and after accumulation in the leaves it is not re-mobilized or can be removed by washing (Malavolta et al., 1997; Prado, 2008).

The most important micronutrient is Fe, mainly in the roots, a phenomenon that occurs due to the adsorption of oxide particles on the root surface, which is difficult to remove in the sampling process. However, significant amounts of stemwood indicate the low mobility of this nutrient (Malavolta et al., 1997).

Quantification of micronutrients contained in the biomass is essential for the nutritional management of forest stands, ensuring the rational use of chemical fertilizers. Based on the nutritional status of the *Eucalyptus dunnii* stand observed in the present study, precautions regarding manganese dosages in future fertilization practices are required, since the absence of this micronutrient drastically reduces the productivity of the stand (Marenco and Lopes, 2009). Moreover, according to Leite et al. (2014), high concentration may favor the onset of diseases such as drought of pointers.

5. CONCLUSION

We found low quantities of micronutrients in the stemwood of a *Eucalyptus dunnii* stand, which is generally removed from the forest site at harvest. We recommend that attention be paid to the maintenance of the forest residues on-site, such as leaves, branches, and stembark, which will be crucial for forest nutrition through the cycling of nutrients, improving soil conservation and fertility for the implantation of future stands of *Eucalyptus dunnii* in the area.

6. ACKNOWLEDGMENTS

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