Influence of Fertilizer Management on Sanded Soil and Its Response on Spatial Distribution of fine Roots

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Abstract

The fine root component, although it represents the lowest proportional biomass in a tree, has an important function in obtaining water and nutrients. In addition, it is an indicator of the physiological quality and growth of a tree. Thus, the objective of the study was to evaluate the spatial distribution of biomass and the density of fine roots in five different fertilizer treatments. The five treatments received increasing amounts of fertilizers. The collections were made between trees in the planting line and between the planting lines. Soil layers of 25 cm x 25 cm x 20 cm (length x width x depth) were collected until reaching a depth of 1 meter. Treatments that had less nutrient input via fertilization showed higher production of fine roots. In general, the line position in the superficial layers showed a higher density of fine roots. There was significant difference between the positions of the land monoliths and between the different layers. Strategically, the lower supply of nutrients via fertilization provided greater investment in the production of fine roots by trees in order to increase the area of absorption and exploration of the soil.

Keywords: nutrient cycling, sanded soil, *Eucalyptus urophylla*, arenization, forestry

1. Introduction

Currently, the Brazilian forestry sector represents about 1.3% of the national GDP and 6.9% of the industrial GDP. Analyzing the balance of trade, difference between what is exported for what matters, in 2012 it was US $ 5.7 billion, increasing to US $ 11.4 billion in 2018. With more than 7.83 million hectares planted with trees, the genus *Eucalyptus* sp. is the most cultivated, representing 72.4% of (IBÁ, 2019).

Despite the expansion of cultivation in regions of low agricultural aptitude, it is observed that investments in research and technology have increased the average productivity from 20 m³ha⁻¹ to 36 m³ha⁻¹. Advances have been observed with the selection of materials suitable for edaphic and climatic conditions. However, since these are soils with low natural fertility, chemical fertilization has provided high productivity (Gonçalves et al., 2013).

The correct application of fertilizers takes into account the type, quantity, time and place of application on the plant (Barros et al., 2005). Studies that evaluate the production of fine roots and their spatial distribution in the soil can provide information for techniques of soil management, forest nutrition and fertilization. (Laclau et al., 2010).

Although root production is not the goal of the production chain, studying its behavior is fundamental. According to Gonçalves and Mello (2005), the roots can be classified as supports (thick roots) or absorption (fine roots). Usually, fine roots are classified with diameter (<2 mm) (Freschet et al., 2017). From a nutritional point of view, they have the

function of absorbing and transporting water and nutrients to the plant (Pregitzer et al., 2002; Fort et al., 2017).

Typically, the spatial distribution of fine roots occurs most abundantly in topsoil (Laclau et al., 2013; Pinheiro et al., 2016.). However, Christina et al. (2011) in a study developed in Itatinga, Brazil, with the species *Eucalyptus grandis* at 3.5 years of age, reported the presence of fine roots up to 17 meters deep.

The biomass of fine roots in *Eucalyptus* sp. generally vary as 2.3%, 4.1%, and 6.3% of the total biomass for seedlings from seeds, upper clones and lower clones, respectively (Mello et al., 1998). For Reis et al. (1985), the aerial part / roots ratio is also affected by the quality of the site. In soils with high fertility, the ratio varies between 4 and 6, while in soils with low fertility the ratio decreases to an average of 2.

For many researchers, fine roots are important tools for capturing and increasing water availability to trees, especially during the dry season (Christina et al., 2017; Fan et al., 2017). Even so, several physiological aspects are still incomprehensible (Maeght et al., 2013).

The present study aims to quantify fine roots production under different fertilization treatments in sanded cores.

2. Method

2.1 Characterization of the Experiment

The study was carried out in a sanded core, with exposed soil, without vegetation cover. The total sandy area covers 80 ha and is located in the municipality of Maçambará - RS, within the geographical coordinates 29º 02 .32.67. S and 55º 19 .40.44. W, at an average altitude of 191 m in relation to sea level.

The soil of the experimental area is classified as Entisols (Quartzipsamments), predominantly sandy texture with an average of 85.2%, 3.0%, 2.3% and 9.5% for coarse sand, fine sand, silt and clay, respectively. Regarding chemical attributes, the average organic matter content (0.24%) up to 1 m deep was very low. Base saturation (V) of 5.0% indicates that it is a dystrophic soil with low natural fertility SBCS-CQFS (2016). 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 presents the physical and chemical attributes of the soil.

Seedlings of the clone (AEC 0144) of *Eucalyptus urophylla* were used. The soil was subsoiled at a depth of 30 cm. The initial density was 1666 plants ha^{-1} with a spacing of 3 m x 2 m. The plots had dimensions of 60 m x 30 m with 300 individuals in each. The experiment had a completely randomized design with 5 fertilization treatments. Two Mg ha^{-1} of dolomitic limestone were applied for all treatments and a fertilization of 150 kg ha^{-1} of K$_2$O in the form of chloride 30 days after planting.

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

Attribute	Unit	Depth (cm)									
		0 20	20 40	40 60	60 80	80 100	100 120	120 140	140 160	160 180	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	mg dm^{-3}	3.9	10.1	13.9	15.6	15.9	14.4	14.6	7.0	8.9	7.7
B		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; [a]Extraction method Melich I. CECef = cation exchange capacity effective; CECef = cation exchange capacity pH 7.0; V = base saturation; m = aluminum saturation

The treatments received different sources and doses of fertilization. Table 2 shows the total amount applied for each element. Phosphorus dosages were used in the base fertilization. Treatments 2, 3, 4 and 5 received increasing doses of triple superphosphate, varying between 112.5 - 225 kg ha^{-1}. T1 was the only one to receive natural phosphate in the base fertilization.

This application was performed in a single dose. All fertilizations were carried out manually inside pits, incorporating the fertilizer at a depth of 5 to 10 cm and a distance of 20 cm from the seedlings.

Table 2. Total amount of nutrients applied in each treatment

Nutrient	Total of nutrients (kg ha^{-1})				
	T1	T2	T3	T4	T5
N	54.4	94.0	102.4	118.0	156.4
P_2O_5	30.0	96.0	72.0	84.0	153.0
K_2O	45.6	80.4	86.4	99.6	169.8
ST*	-	112.5	149.8	187.2	225.0
FN**	120.6	-	-	-	-
Ca	-	12.8	16.3	19.9	24.9
S	-	10.3	13.1	16.0	20.0
B	-	3.2	4.1	5.0	6.3
Cu	-	1.4	1.8	2.2	2.8
Mn	-	3.6	4.6	5.6	7.0
Mo	-	0.2	0.2	0.3	0.4
Zn	-	16.2	20.7	25.2	31.5

Note: * Triple superphosphate; ** Natural phosphate

The region's climate is classified as humid Subtropical, without dry season and warm summers (Cfa). The average annual rainfall is 1916 mm well distributed over the months of the year. The driest month has an average rainfall > 40 mm. The average temperature of the coldest month is -3 ºC and < 18ºC and the temperature for the warmest month is 22ºC. (Alvares et al., 2013).

2.2 Sampling of Fine Roots

Three monoliths were collected in the planting line and between the planting lines in each

treatment, respectively in triplicates. Each monolith had dimensions of 25 cm x 25 cm, that is, a collection area of 0.0625 m². The samples were collected in 20 cm layers until reaching 1 meter of depth. The trees were 12 months old. Figure 1 shows the collection scheme carried out within an experimental unit. Represented in (a), collection positions of fine root samples, in (b), cross section of the monolith with five layers of 20 cm thickness, and in (c), total dimensions of the soil monolith.
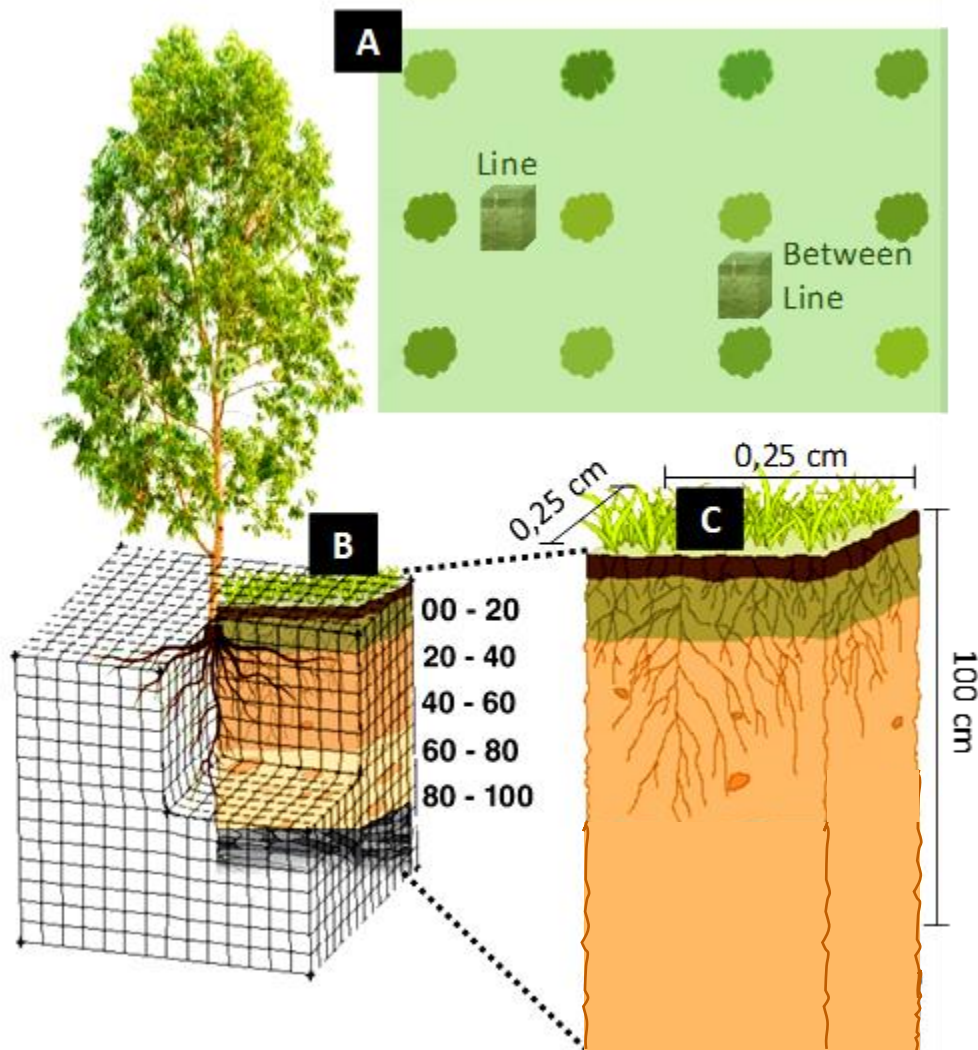

Figure 1. Scheme of collection of fine roots. (A) collection position of each monolith, (B) collection depths and (C) dimensions of each monolith

The 150 samples were packed in plastic bags and transported to the laboratory. The first procedure for separating fine roots from the soil with a sieve. Subsequently, the remaining roots in the mesh were washed carefully and still moist, the diameters were classified with a caliper. Diameters greater than 2 mm were fragmented and their surpluses disregarded in the research. In an oven with renewal and forced air circulation, the samples packed in paper bags, were dried at 70 °C for 72 hours or until they reach constant weight. The weighing of the material was done with a precision scale of 0.001g.

2.3 Date Analysis

The verification of the normal distribution of the data was through the normality test f the residues (Shapiro-Wilk). Analysis of variance (ANOVA) was performed to verify for significant differences: between position of the same Treatment, between different depths of the same position and in the total amount of the fine roots between the different treatments. When the ANOVA was significant, a means test (Tukey) was performed at 5% probability of error to know which variables differed from each other.

3. Results

The amount of fine roots (kg ha^{-1}) for the depth of 0 - 20 cm in the between line position varied from 173 to 240 kg ha^{-1} in Treatments 5 and 1 respectively. For the line position variation was 325 than 600 kg ha^{-1} for Treatments 5 and 2 respectively. In general, as the depth increases, the amount of roots decreases. Table 3 shows the difference in means for treatments, positions and different depths.

Table 3. Amount of fine roots at different depths and positions in treatments

Depth (cm)	Treatment (kg ha^{-1})									
	1		2		3		4		5	
	B.L.	L.	B.L.	L.	B.L.	L.	B.L.	L.	B.L.	L.
0-20	240.0Aa	401.6Aa	254.9Ab	600.5Aa	399.7Aa	348.8Aa	220.3Ab	352.0Aa	173.3Ab	325.3Aa
20-40	225.1ABa	174.9Aa	125.6Ab	262.9Ba	125.9ABa	144.8Ba	102.9Aa	85.6Ba	120.0ABb	221.9ABa
40-60	167.5ABa	84.8Ba	130.4Ab	205.3Ba	129.6ABa	107.2Ba	71.5ABa	87.5Ba	123.7Ba	67.2Ba
60-80	69.3ABa	84.8Ba	45.3Ba	59.7Ba	108.3ABa	92.3Ba	36.3Bb	77.9Ba	80.3Ba	56.0Ba
80-100	146.1Ba	72.5Ba	62.4Ba	93.9Ba	70.4Ba	68.8Ba	51.7Ba	56.0Ba	15.5Bb	32.0Ba
Total	848.0	818.7	618.7	1222.4	833.9	761.9	482.7	658.9	512.8	702.4
Average	833.3a		920.5a		797.9ab		570.8b		607.6b	

Note: BL = between line; L = line

The total amount of fine roots varied between Treatments. If we consider the average of the positions in each Treatment, we can conclude that the Treatments in which they received the smallest amounts of nutrients, registered the largest amount of fine roots. Treatments 1 and 2 had an average production of 833 and 920 kg ha⁻¹ while treatments 4 and 5 had an average production of 570 and 607 kg ha⁻¹.

There was a statistical difference between the collection positions within the same Treatment. The Treatments that received the highest amounts of nutrients, differed statistically between their positions, especially in the 0 - 20 cm layer. For treatment 5, this statistical difference can still be seen in the second layer (20 - 40 cm).

Regarding the density of fine roots, Figure 2 shows the variation in g/dm³ for the different treatments between line and line positions. T2 recorded the highest density of fine roots reaching 0.3 g / dm³ for the line position. The opposite behavior was observed in T5, which showed a density of 0.09 g/dm³ in the line position.
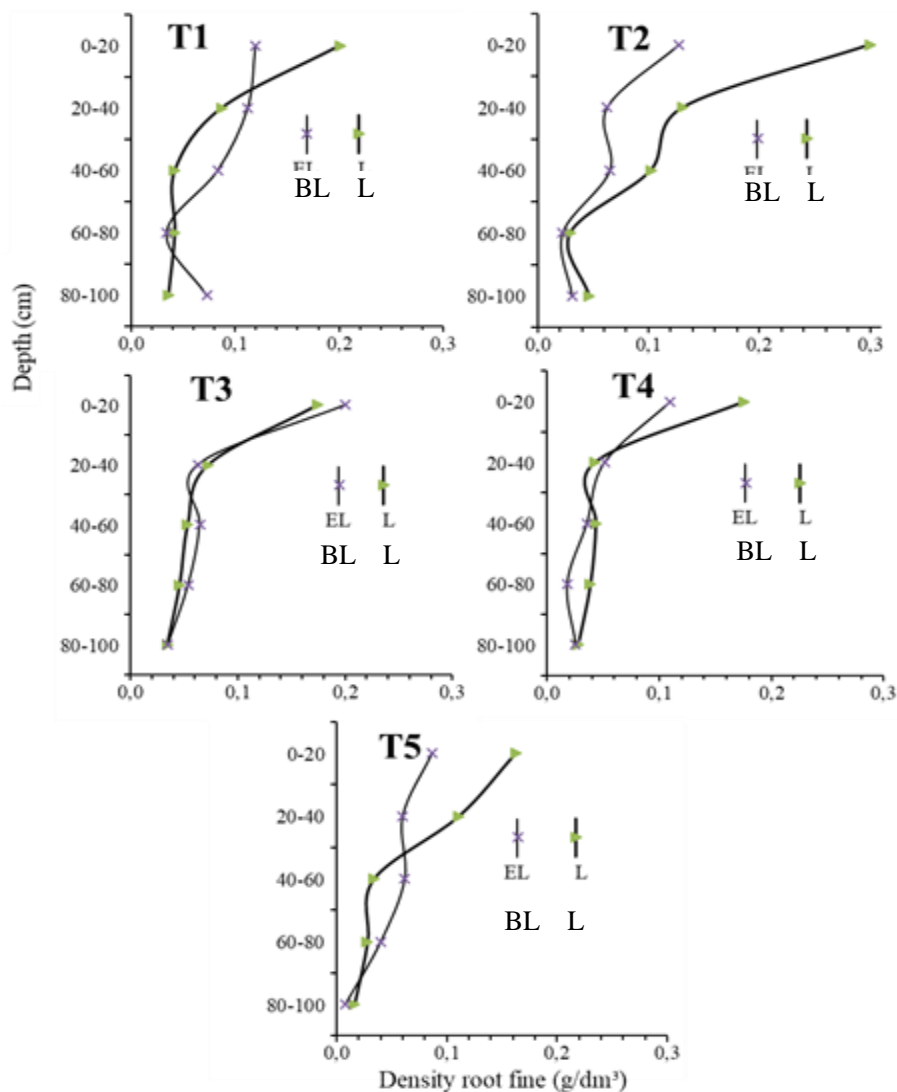

Figure 2. Density of fine roots at different depths and positions in treatments

Figure 2 also shows that considering the layer 0 - 20 cm, only for T3 the density of fine roots in the line position was lower than the line position. For all treatments the biggest differences between the collection positions occur in the 2 most superficial layers. The depths of 60 - 80 and 80 - 100 cm showed similar thin root density within the same treatment.

4. Discussion

The inverse relationship between the number of roots and depth occurs because the topsoil represents the portion with the highest amount of nutrients. This greater nutritional offer is due in part to the chemical fertilization carried out in addition to the decomposition of litter nutrients. Another important function promoted by the litter layer is the reduction of the temperature fluctuation and possible maintenance of humidity in that layer (Macedo et al., 2014).

The amount of fine roots is also influenced, among other factors, by the texture of the soil. As shown by Lambais (2015) in a study carried out in an Oxisol of different textural class, the more sandy the soil, the greater the capacity for development and growth of fine roots. The root length in the 0 - 30 cm layer of 2-year-old *Eucalyptus grandis* trees in 20% clay soil was double that observed in 40% clay soil.

Although the textural class of the soil is an important factor, the fertility of the soil needs to be considered. Assessing the production of fine roots in *Eucalyptus dunnii* stands at 16 months of age, Dick et al. (2019) showed a stock of 727 kg ha^{-1} for layer 0 - 20 cm of soil. This value was much higher than that found in the present study. For line position to the highest value was 600 kg ha^{-1} at T2 and 325 kg ha^{-1} at T5. Dick et al. (2019) found an organic matter of the soil of 1.4% for the respective layer, while for the present study it was only 0.2%. This can explain the lower production of fine roots.

Although the highest density of fine roots g / dm³ is observed in T2, the average for depth 0 - 20 cm in all positions and treatments was 0.16 g / dm³. Assessing the depth 0 - 20 cm in *Eucalyptus dunnii* stands at 16 months, Dick et al. (2019) found an average fine root density of 0.36 g / dm³. Part of the results are due to age of the stand. Another relevant factor is the organic matter content, which in turn allows greater water retention capacity and development of the root system.

Studying the behavior of fine roots in *Eucalyptus grandis* from 2 to 4 years of age, Lambais et al. (2017) found that the greatest growth in length in the topsoil occurred in the warm and wet seasons. These results help to explain the lower density observed in this study when compared to those in the literature. Predominantly sandy soils have low water retention rates (Mezzomo et al., 2018), Sandy soils as in the present study compromise the survival of fine roots during periods of low rainfall.

The density of fine roots in the stand of the hybrid *Eucalyptus urophylla* x *Eucalyptus grandis* at 59 months after planting was evaluated by Macana et al. (2020). The authors concluded that the root density decreases gradually along the soil profile. For depth 0 - 25 cm the density was 0.32 g/dm³ with the clone susceptible to water stress and the addition of gypsum. Germon et al. (2018) found an average density at depth 0 - 50 cm of 0.32 g / dm³ in *Eucalyptus grandis* stands. The findings are above the average of the values found for the

treatments in the present study. The evaluation by the authors was carried out 4 years after the implantation of the stand. This allowed a development of the root system, proportional to the biomass above ground.

5. Conclusion

There was an influence of fertilization on the pattern of development of fine roots. The treatments that received the lowest amounts of fertilizers showed the highest amount and density of fine roots. This behavior is a strategy on the part of the plant in order to explore a greater volume of soil, supplying the plant's physiological demands with water and nutrients.

The statistical analysis also pointed out a significant difference between positions of the same treatment. With that it is concluded that the nutritional contribution in the planting line was positive in the development of the roots and possibly of the aboveground biomass.

An inverse relationship between depth and thin roots was found. Fertility in the superficial layers allowed for greater root development, gradually decreasing with depth.

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