Ciência Rural, Santa Maria, v.42, n.10, p.1818-1825, out, 2012
ISSN 0103-8478

Mixed and monospecific stands of eucalyptus and black-wattle. I – Fine root length density

Plantios monoespecíficos e mistos de eucalipto e acácia-negra. I – Densidade do comprimento de raízes finas

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ABSTRACT

Fine root length density (FRLD) was evaluated in mixed and monospecific stands of ***Eucalyptus grandis*** *x* ***E. urophylla*** *and* ***Acacia mearnsii*** *in Southern Brazil. FRLD (≤2,0mm) at 8 and 18 months after planting in the treatments: 100E (100% of eucalyptus); 100A (100% of* ***Acacia mearnsii****); 50E:50A (50% of eucalyptus + 50% of* ***Acacia mearnsii****). The findings demonstrated that the FRLD at 8 months of age have the same distribution, in the two different species, in the distribution of the different soil layers, reaching the maximum projection of 125cm from the tree trunk. For the age of 18 months after planting, it was verified that the FRLD in the monospecific stand of* ***Acacia mearnsii*** *was higher than in the monoculture and mixed stand of* ***Eucalyptus grandis*** *x* ***E. urophylla****. Therefore, no interaction, neither positive nor negative, between the root systems of* ***Eucalyptus grandis*** *x* ***E. urophylla*** *and* ***Acacia mearnsii*** *during the 18 months after planting was found. The higher FRLD is found at the soil layers surface, next to the tree trunk and in the planting line, followed by the diagonal and planting rows. The initial growth in length of the root system of* ***Acacia mearnsii*** *is more dynamic with higher density than the eucalyptus, but without interfering directly in the global growth of fine roots in mixed stands.*

Key words: *fine root length density,* ***Eucalyptus grandis*** *x* ***E. urophylla****,* ***Acacia mearnsii****, mixed-species* ***Eucalyptus*** *plantations, interactions.*

RESUMO

Avaliou-se a densidade do comprimento de raízes finas (DCRF) de plantios monoespecíficos e misto de ***Eucalyptus grandis*** *x* ***E. urophylla*** *e de* ***Acacia mearnsii*** *na região sul do Brasil. A DCRF (≤2,0mm) foi determinada aos 8 e 18 meses após o plantio nos tratamentos: 100E (100% de eucalipto); 100A (100% de* ***Acacia mearnsii****); 50E:50A (50% de eucalipto + 50% de* ***Acacia mearnsii****). A DCRF aos oito meses de idade possui o mesmo comportamento para a ocupação das diferentes camadas do solo, atingindo uma projeção máxima de 125cm de distância em relação ao tronco da árvore. Já, aos 18 meses após o plantio, verificou-se que, no cultivo monoespecífico de* ***Acacia mearnsii,*** *a DCRF foi superior em relação ao monocultivo e plantio misto de* ***Eucalyptus grandis*** *x* ***E. urophylla****. Não ocorreram interações positivas ou negativas entre os sistemas radiculares do eucalipto e da acácia-negra durante os primeiros 18 meses após o plantio. A maior DCRF encontra-se nas camadas superficiais do solo, nas proximidades do tronco da árvore e na linha de plantio, seguida pela diagonal e entrelinha de plantio. O crescimento inicial em comprimento do sistema radicular da* ***Acacia mearnsii*** *é mais dinâmico e maior do que a do eucalipto, mas sem interferir diretamente no crescimento global das raízes finas no cultivo misto.*

Palavras-chave: *densidade do comprimento de raízes finas,* ***Eucalyptus grandis*** *x* ***E. urophylla****,* ***Acacia mearnsii****, plantio misto de eucalipto, interações.*

INTRODUCTION

Competition between root systems in planting systems that involve more than one species may be significant (DHYANI & TRIPATHI, 2000). Although studies about the biomass quantification and the fine root length in the soil have already been carried

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Received 05.17.11 Approved 04.10.12 Returned by the author 07.18.12
CR-5374

out or, are presently under development (HAUSER, 1993; TORQUEBIAU & KWESIGA, 1996), little is known about their soil occupation profile (DHYANI & TRIPATHI, 2000) and, the possibility of interspecies competition (SCHMID, 2002) between species in mixed planting. For this reason, the knowledge about root distribution in the soil profile is necessary to understand the ecological niche of tree species and, to realize the possible silviculture interferences in the systems (SCHROTH, 1995; DHYANI & TRIPATHI, 2000).

Root systems in soils with low availability of water and nutrients tend to produce longer root while if the nutritional and water conditions of the soil are adequate, the root system tends to be more branchy, with many short root and so, it can considerably change from one year to another (GONÇALVES & MELLO, 2004; LACLAU et al., 2004). To evaluate the root system distribution at the soil profile, it was taken into account the fine root biomass (parameter indicated to evaluate the effects of environmental conditions on the root growth) and root growth (parameter indicated to evaluate water and nutrient absorption) (GONÇALVES & MELLO, 2004).

Analyzing the fine root in pure and mixed stands of ***Eucalyptus globulus*** and ***Acacia mearnsii***, BAUHUS et al. (2000) did not find any synergism to biomass and fine root length between the two species in the intercropping, indicating that the ***Acacia mearnsii*** may develop a strong competition for soil resources with the other species in intercropping. But, according to COELHO et al. (2007), it cannot be established if the increase in fine root density of one or both intercropping species is the result of a better competitive capacity of one of them or, if it is the result of the decrease in the availability of one resource. This study evaluated the soil occupation by fine root length density from ***Eucalyptus grandis*** x ***E. urophylla*** and ***Acacia mearnsii*** in monospecific and mixed stands.

MATERIAL AND METHODS

The study was carried out at an experimental area located at the city of Bagé in the State of Rio Grande do Sul, Brazil. The area location is determined by the central geographic coordinates of 31°14’43” S and 54°04’55” W and, an average altitude of 242m height in relation to sea level. According to Köppen climate classification, the fundamental predominant climate is Cfa (subtropical wet), the average annual rainfall is 1,364mm. Average annual temperatures of 17.5°C, where the mean maximum temperature is 23.5°C and mean lower temperature is of 12.3°C. The soil in the experimental area is classified as Eutric Nitosols (FAO classification), characterized by a natural low fertility, strong acidity and high aluminium saturation, and a sandy-loamy texture (Table 1).

Statistical design chosen was random blocks with 3 treatments and 3 repetitions. Total area of each repetition was 1224m^2 (25.5m x 48.8m) with 17 rows x 12 interrows. Ignored for measurement are the two ends of the trees were ignored for measurement. The treatments used were as follows: **-** 100E (100% of eucalyptus); **-** 100A (100% of ***Acacia mearnsii***); **-** 50E:50A (50% of eucalyptus + 50% of ***Acacia mearnsii***, in alternate rows), in the last tree of each species evaluated. The species planting was made (november 2007) with a 4.0m x 1.5m

Table 1 - Soil chemical proprieties at the experiment area.

Depth (cm)	O.M. (%)	pH (H_2O)	Al	H + Al	CEC_{effect}	$CEC_{pH 7}$	P	K	Ca	Mg	m	v
			------------------cmol$_c$ dm^{-3}------------------				-----mg dm^{-3}-----		----cmol$_c$ dm^{-3}----		----------(%)----------	
0-5	2.0	4.8	0.9	6.5	2.8	8.4	6.7	80.3	1.0	0.7	32.5	22.4
5-10	1.8	4.8	1.0	7.8	2.9	9.6	3.6	54.6	1.0	0.7	37.6	19.4
10-20	1.4	4.7	1.3	7.8	2.7	9.3	2.0	36.6	0.8	0.6	47.6	16.4
20-30	1.1	4.7	1.5	8.5	3.0	10.0	1.2	31.0	0.8	0.6	52.8	15.0

Depth (cm)	----------------------------Sand (%)----------------------------		Silt (%)	Clay (%)	Density g cm^{-3}
	(2-0.2mm)[a]	(0.2-0.05mm)[b]	(0.05-0.002mm)	(<0.002mm)	
0-5	25	53	5	18	1.38
5-10	25	52	6	18	1.50
10-20	26	51	4	20	1.49
20-30	24	52	4	21	1.49

P and K: Mehlich-1 Extractor; Al, Ca and Mg: KCL 1 mol l^{-1} Extractor; H + Al: $Ca(OAc)_2$ 0.5 mol l^{-1} pH 7.0 Extractor; O.M. = Organic matter; CEC = Cation Exchange capacity; m = Aluminium saturation percentage; v = Base saturation percentage. [a] Coarse sand; [b] Fine sand.

spacing, after subsoiling, at a mean depth of 50 cm, in the planting row. Concomitantly to this operation, the soil received a chemical fertilizer, at the planting row, with the following formulation: 06:30:06 of the formula N - $P_2O_5 – K_2O$ + 7% of Ca + 6% of S + 0.1% of B + 0.5% of Cu, applied at the rate of 300 kg/ha.

Sampled the fine root ($\leq$ 2.0mm) at 8 (July 2008) and 18 (May 2009) months after planting of the monospecific and mixed ***Eucalyptus grandis*** x ***E. urophylla*** and ***Acacia mearnsii*** stands. The definition of the trees to sample the root was based on the diameter at ground height to 8 months (100E = 4.43cm; 100A = 3.58cm; 50E:50A(E) = 4.41cm and 50E:50A(A) = 3.42cm) and diameter at breast height to 18 months (100E = 7.61cm; 100A = 7.52cm; 50E:50A(E) = 7.56cm and 50E:50A(A) = 7.61cm). It was evaluated three trees by treatment in monoculture and six trees for mixed treatment, three for each species. The sampling points around each tree were identified with ordinal numbers (1 to 38). The distribution of these sampling points was sistematically done through the allocation of eight transects (2 at the inter-row, 2 at the line and, 4 at the diagonal), from the tree trunk center in relation to mean soil level. Considering 25cm from the tree trunk and radially at an equidistant form, marked the collecting points (clockwise) reaching all the useful area of each considered tree (4.0mx1.5m). This collecting methodology was adapted from BÖHM (1979) (Figure 1). The sampling at each collecting point was fractionated in sample subpoints originated at each different considered depth (0-5; 5.1-10; 10.1-20 and 20.1-30cm). The collecting was made using a cylindrical steel extractor tube with 7.0cm of inside diameter.

A set of sieves was used (2.0 and 0.34mm meshes), and using water jets, fine root were separated from the soil. All the fine root, living or dead were put into plastic receivers with a solution of distilled water + 12% of alcohol and stored in refrigerated environments thus allowing the fine root original characteristic to be kept. After that withdrew the fine root from the receivers were placed on an absorbent paper to remove the excess of moisture. Following that, living root were separated from the dead root, living root of other plants and from the impurity (organic fragments) using pinchers. Separation of living and dead root was performed visually, based on the morphological characteristics, color and flexibility. In mixed planting, to facilitate ***Eucalyptus grandis*** x ***E. urophylla*** fine root separation from ***Acacia mearnsii*** fine root, root collected in monospecific plantings were used as reference. Besides that, the root color was different: the eucalyptus root had a light-brown color while the ***Acacia mearnsii*** roots were light-yellow. After that, the root were placed on a white surface (A4 paper sheets) and photographed using a digital camera (7.0 Mega pixels), supported by a metallic structure with a fixed height of 0.5m. Each image got from the digital camera was analyzed using the UTHSCSA *software*, Image Tool for Windows version 3.00© (2002) that determines the root length.

Based on fine root values, it is possible to elaborate cartograms to demonstrate fine root length density occupation of the soil. The cartograms show the fine root distribution in the planting row spacing, line and diagonal. Bartlett test of homogeneity of variance and the Lilliefors test of error normality were applied to the results to verify their validation by the variance analysis presupposes. Results that did not meet the assumption, were transformed by applying the square root and/or the square root inverse, in the next step to that proceeded with the analysis. The statistic analysis was performed using the ASSISTAT version 7.5 beta (SILVA, 2008) at a 5% of error probability, considering a random blocks design, where the species corresponded to the treatments and blocks the repetitions. To separate the average contrast, it was used the Tukey test.

RESULTS AND DISCUSSION

When the stands were 8 months old, fine root length density (cm dm^{-3}), differed only at the superficial soil layer (0 to 5cm depth), at 25cm from the tree trunk, being higher for the mixed planting of ***Eucalyptus grandis*** x ***E. urophylla*** in relation to the monoculture and mixed planting of ***Acacia mearnsii*** (Figure 2). At that age there was no apparent competition in water and nutrient uptake between the root systems of the species because the fine root systems of the eucalyptus and of the ***Acacia mearnsii*** reached, at most, a distance of 125cm from the trunk. Therewith, the initial development (until the 8 months of age) of the fine root of the ***Eucalyptus grandis*** and of the ***Acacia mearnsii*** have the same behavior to the occupation of the different soil layers. SILVA et al. (2009) highlight that, in very young stands, it would be premature any assertion about differences between species regarding their root development, because the necessary resources (water, nutrients and solar energy) for the trees development would not yet be scarce due to the presence of a competitor species.

Nevertheless, after the 18 months of the stand age, there was a considerable increase in the fine root length density (cm dm^{-3}) in all the considered soil layers. Monospecific planting of ***Acacia mearnsii*** presented the higher FRLD, especially at the 20cm

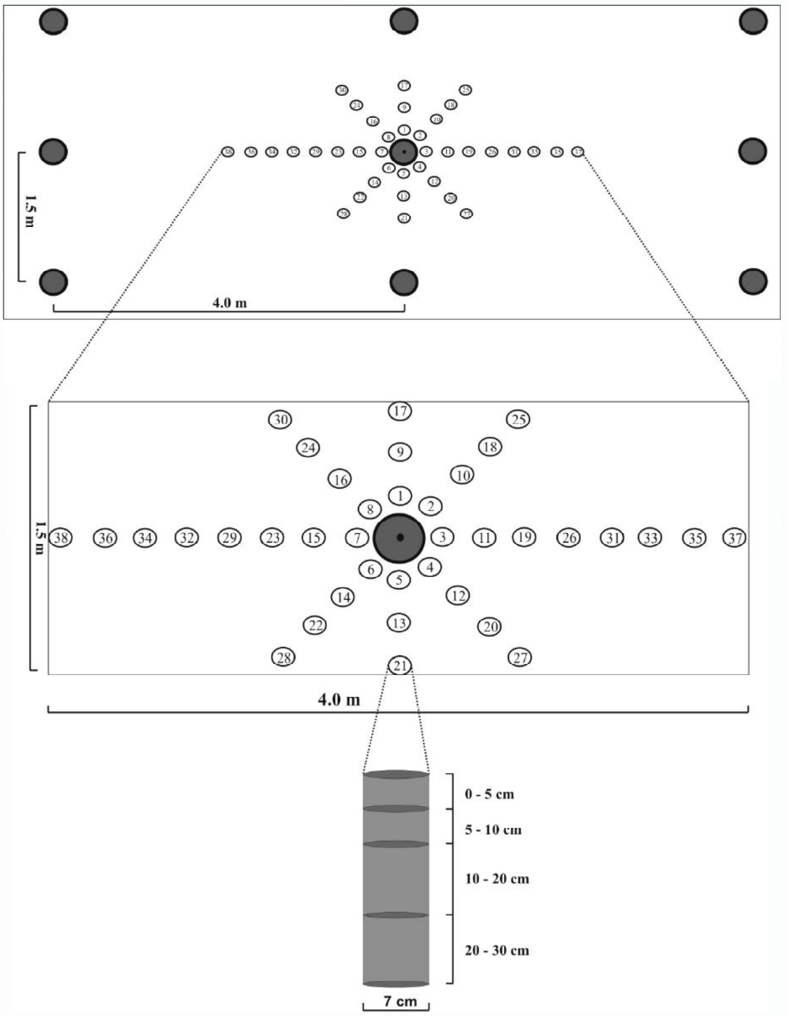

Figure 1 - Distribution of fine root length density sample points.

depth, being higher than the monospecific and mixed stand of ***Eucalyptus grandis*** x ***E. urophylla*** until a distance of 125cm for the first 10cm of depth and 100 cm at the layer of 10 to 20cm of depth and, at the distance of 100cm for the layers of 20 to 30cm in relation to the tree trunk. Between the monoculture and the mixed planting of ***Acacia mearnsii*** there were differences only at 75 and 100cm of distance from the trees trunk at the first ten centimeters of depth. In relation to the monoculture and mixed planting of ***Eucalyptus grandis*** x ***E. urophylla*** there was no significant differences at any depth for the different distances from the trees trunk.

The large increase in fine root for both the ***Eucalyptus grandis*** x ***E. urophylla*** and ***Acacia mearnsii*** in monospecific and mixed planting, from 8 to 18 months of age, due in part, beyond the natural grow of the species, to the low rainfall in the period. Especially during the months before the last data collection, considerably reducing soil moisture and making the species fine root reach greater distances and depths in search of water, due to a possible water stress. The influence of soil moisture in the development of the root system was verified by COELHO et al. (2007) in monospecific and mixed planting of ***Eucalyptus grandis*** and leguminous trees. According to NAMBIAR (1983), the root growth is closely related to water content in soil.

Fine roots grow until the 8th month of age, both for the monospecific and for mixed planting, reachinged an occupation of about 125cm far from the tree trunk (Figure 3). Considering that planting row spacing is 400cm, it results in a spacing of 150cm between one tree in a planting line and the other line.

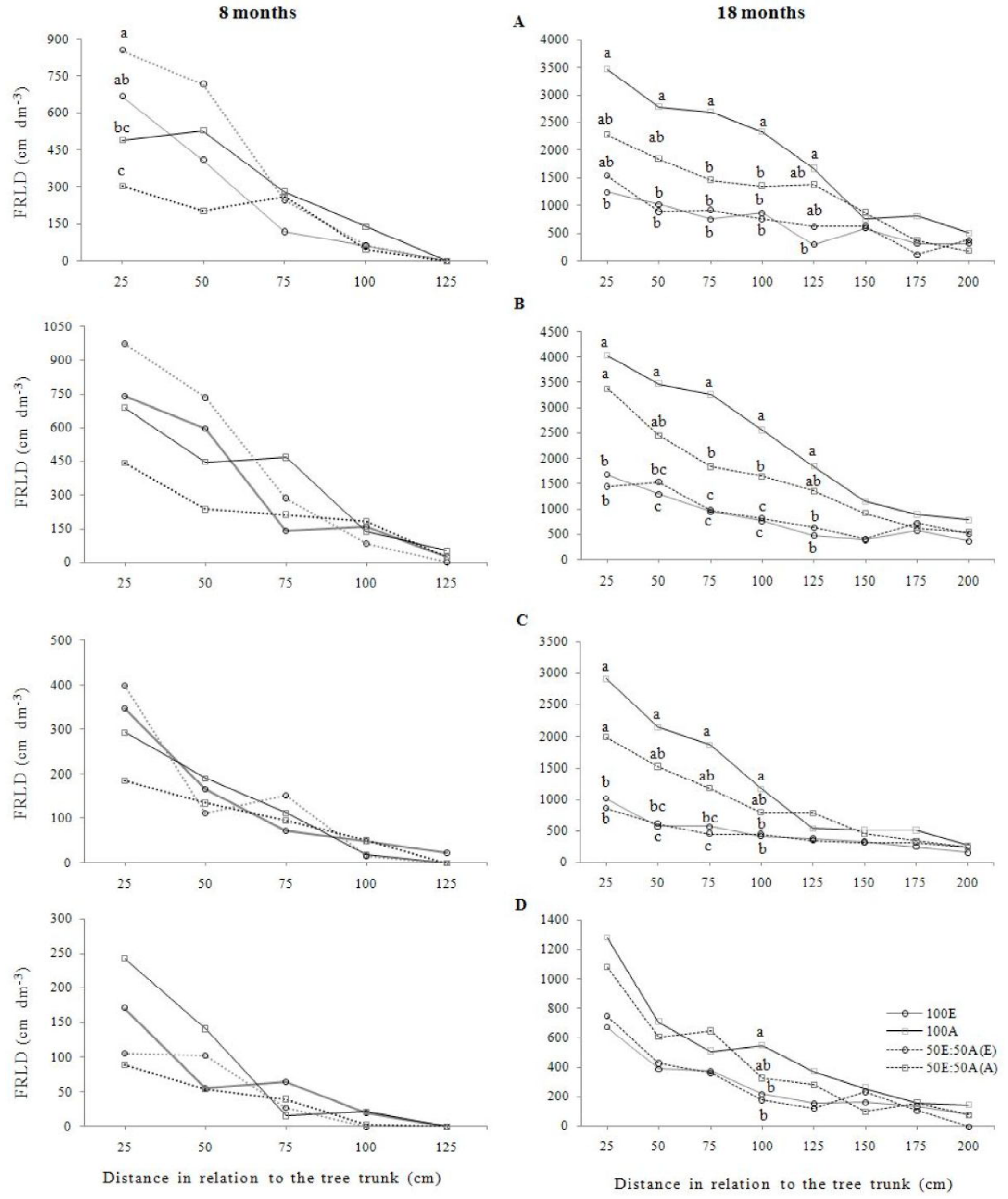

Figure 2 - Fine root length density (FRLD - cm dm^{-3}) at 8 and 18 months in monospecific and mixed planting of ***Eucalyptus grandis*** x ***E. urophylla*** and ***Acacia mearnsii***, in the different depths (A. 0-5; B. 5-10; C. 10-20 and D. 20-30 cm), considering the distance in relation to the tree trunk. (The existence of letters indicates that there are significant differences between the treatments by the Tukey Test, at a significance level of 0.05).

At the age of 8 months, the trees presented a higher concentration of fine root next to the trunk (0 to 50cm distance), while in an approximate distance of 75cm there is the occurrence of a not significant root density (10cm dm^{-3}). At 18 months of age, the fine root of forest species occupied all the system useful area and, the density of the root length in the row spacing direction reached more than 3.900cm dm^{-3} near to the trunk in the monospecific stand of ***Acacia mearnsii***. This density was greater than the one verified in the stands at the age of 8 months when they reached not more than 600cm dm^{-3} in the mixed planting of ***Eucalyptus grandis*** x ***E. urophylla***, for example. In this 10 month interval between the collections, it was

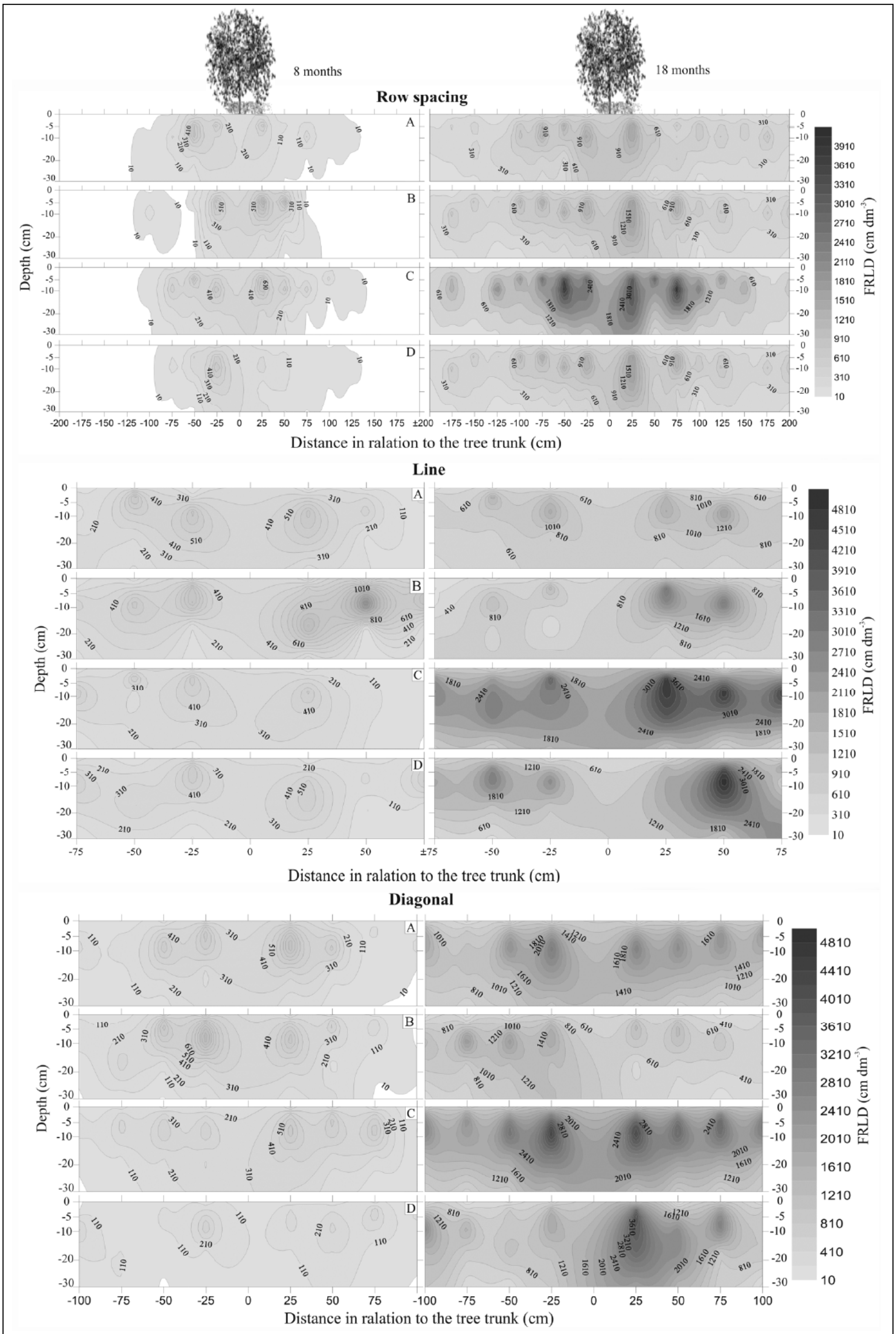

Figure 3 - Spatial distribution of fine root length density (FRLD - cm dm^{-3}) in monospecific and mixed stands of ***Eucalyptus grandis*** x ***E. urophylla*** and ***Acacia mearnsii*** (A=100E; B=50E:50A (E); C=100A and D=50E:50A (A)), at 8 and 18 months of age.

possible to verify that in the age of eight months, the fine root length density grew up to a distance of 75cm from the trunk, reaching at most 10cm dm^{-3} while at the 18th month it changed to more than 600cm dm^{-3}, indicating that in this period there was an intense growth of the species fine root in the monoculture and in the mixed planting stands.

In the planting line, it was verified a higher increase in the fine root density in relation to the density at the planting line spacing. At the age of 8 months, in a distance of 75cm from the tree trunk, the fine root length density in the planting line spacing was about 10cm dm^{-3}, while in the planting line this density became greater than 110cm dm^{-3}. In the diagonal, like for the planting row spacing, the root growth was smaller than in the planting line.

It was also found that it didn't occur any positive or negative interaction between the root systems of eucalyptus and ***Acacia mearnsii*** until the 18th month of age, because the trees in mixed planting did not show significant differences in their fine root growth in relation to their monospecific planting. COELHO et al. (2007) observed a different behavior to the one observed in the present study in consortium planting of ***Eucalyptus grandis*** and leguminous trees, where the fine root density of all leguminous was always smaller in relation to the eucalyptus at the soil superior layers, suggesting a strong interspecific competition at these layers. This author highlights that the differences in root distribution of forest trees may result from the competitiveness between species for the natural soil resources.

The highest densities of fine root length are found at the superficial soil layers, near to the trees trunk and at the planting line, followed by the diagonal and the planting row spacing. According to PAULINO et al. (2003), while studying the fine root distribution of three-year-old ***Acacia mearnsii*** trees, the root had a better growth in the planting line where the conditions of density and soil porosity are more adequate. The authors highlight that this better growth of the ***Acacia mearnsii*** fine root is probably due to the fact that the area where the stand was installed, was a native field used for cattle breeding, possibly presenting some soil compression that, at the moment of the tillage through subsoiling allowed the fine root to have a better development at the planting line. This presence of cattle in the area before the establishment of the stand was an identical situation to the one occurred at the present study. In a study conducted by CECONI et al. (2008), where the soil in the planting area had no impediments of compression and, had broadcast fertilization in all area and, not only at the planting line, different growth intensities of fine root were not verified especially at the first centimeters of depth.

CONCLUSION

The initial growth of the root system length of ***Acacia mearnsii*** is more dynamic with higher density than the eucalyptus, but without interfering directly in the global growth of fine roots in mixed stands. In this way, not find any positive nor negative interaction of the fine root of eucalyptus and ***Acacia mearnsii*** during the first 18 months after planting. Highest density of root length can be found in the superficial soil layers, near the tree trunk and, at the planting line followed by the diagonal and the planting row spacing.

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