Eucalyptus Growth in Silvopastoral System under Different Crown Diameters[1]

Crescimento de Eucalipto em Sistema Silvipastoril sob Diferentes Diâmetros de Coroamento

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ABSTRACT - *The aim of this study was to evaluate the effect of different crown diameters on the early growth of eucalyptus intercropped with* ***Brachiaria decumbens*** *in a silvopastoral system. The experiment was conducted in a* ***B. decumbens*** *established pasture, where hybrid eucalyptus urograndis (clone GG100) was planted, spaced 8 x 3 m. A randomized block design was used, with six replicates. Treatments consisted of five crown diameters (0.0, 1.0, 1.5, 2.0, and 3.0 m) surrounding the eucalyptus plants. Five weeding hoes were performed throughout the experiment, according to the different crown diameters, aiming to maintain the eucalyptus plants free from B. decumbens interference. At 90, 180, 270, and 360 DAP, the height and the diameter of the eucalyptus plants were evaluated, and at 360 DAP, surface biomass and leaf area were evaluated. At 90 DAP, it was verified that the non-weeded plants had lower growth, compared to those submitted to crowns. Crown diameters of 2.51 and 2.64 m allowed greater growth in height and diameter at ground level of eucalyptus plants, respectively, in all periods evaluated. Biomass production and leaf area per plant at 360 DAP were also influenced by the different crown diameters. It was concluded that crown diameter around 2 meters provided favorable conditions for early growth of eucalyptus and less involvement in the area occupied by forage.*

Keywords: agroforestry systems, weed competition, control ranges.

RESUMO **-** Objetivou-se neste trabalho avaliar o efeito de diferentes diâmetros de coroamento sobre o crescimento inicial de plantas de eucalipto em sistema silvipastoril com *Brachiaria decumbens*. O experimento foi realizado em área de pastagem estabelecida de *B. decumbens*, na qual foi plantado o eucalipto híbrido urograndis (clone GG100), no espaçamento de 8 x 3 m. Utilizou-se o delineamento de blocos ao acaso com seis repetições. Os tratamentos consistiram de cinco diâmetros de coroamento (0,0, 1,0, 1,5, 2,0 e 3,0 m) no entorno das plantas de eucalipto. Ao longo do experimento foram realizadas cinco capinas com enxada, conforme os diferentes diâmetros de coroamento, visando manter as plantas de eucalipto livres da interferência de *B. decumbens*. Aos 90, 180, 270 e 360 dias após o plantio (DAP), foram avaliados a altura e o diâmetro nas plantas de eucalipto e, aos 360 DAP, a biomassa da parte aérea e a área foliar. Aos 90 DAP, verificou-se que as plantas não capinadas tiveram menor crescimento, quando comparadas às submetidas aos coroamentos. Diâmetros de coroamento de 2,51 e 2,64 m permitiram maior crescimento em altura e em diâmetro ao nível do solo das plantas de eucalipto, respectivamente, em todas as épocas avaliadas. A produção da biomassa e a área foliar por planta, aos 360 DAP, também foram influenciadas pelos diâmetros de coroamento. O coroamento em torno de 2 m proporcionou condições favoráveis ao crescimento inicial das plantas de eucalipto e menor comprometimento na área ocupada pela forrageira.

Palavras-chave: sistemas agroflorestais, matocompetição, faixas de controle.

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INTRODUCTION

The forest plantations in different regions of the world are needed to ensure the wood supply to the varied needs of the growing world population, generating business opportunities on an industrial scale, as well as at level of rural properties, especially when idle areas are used for forest plantations (Oliveira Neto et al., 2007). In this regard, the interest in fast growing species and high wood production, such as of the genus *Eucalyptus*, has increased in recent years, as it is a profitable activity and it contributes to the reduction of impacts on native forest remnants (Fontan, 2007).

Due to the investments required for the implementation of these forests and the long time to obtain a financial return, several alternatives to amortize this cost have been sought, and the use of silvopastoral system with eucalyptus has been one of them (Bernardino & Garcia, 2009). This system allows the obtaining of forest products while maintaining the pastoral activity and respecting the principles of sustainable management (Oliveira Neto et al., 2007).

Despite showing fast early growth and good competitiveness for its establishment in field, eucalyptus is sensitive to interference caused by Brachiaria, resulting in decreases in production (Tuffi Santos et al., 2005). In this regard, the management of mixed species is essential for the silvopastoral system to be successful.

The interference imposed by Brachiaria species is more severe in the early growth phase, that is, the first two years of implementation of eucalyptus cultivation (Toledo et al., 2003). Silva et al. (2000) observed that, regardless the water level in the soil, *B. brizantha* was more competitive in the early stage of development than the *Eucalyptus citriodora* and *E. grandis* species.

Toledo et al. (2000), evaluating control ranges of *B. decumbens* in the formation of *Eucalyptus urograndis* forests (*E. grandis* x *E. urophylla*), 3 x 3 m spaced, verified that the weeds begin to significantly reduce the growth of eucalyptus from 14-28 days of coexistence and that a period of 140 days of control is necessary to ensure the full development of culture in the first year of its development cycle. These authors concluded that to promote increased growth rate of eucalyptus it would require a minimum control range of 1 m from each side of the planting row.

In wider spacing of plantings, as adopted in silvopastoral and agroforestry systems, the interactions between intercropped species are different when compared to the forest monocultures, and there may be more available water in soil (Leite et al., 1997) and, especially, greater input of solar radiation in the canopy system. This greater amount of radiation available, necessary for the proper growth of Brachiaria species with C4 metabolism, becomes an important factor in these systems (Oliveira Neto et al., 2007), increasing the competitiveness of this species. Andrade et al. (2003), evaluating the performance of forage grasses in a silvopastoral system with eucalyptus (10 x 4 m), concluded that even in shaded environments *B. brizantha*, *B. decumbens* and *Panicum maximum* species showed good production capacity. Campos et al. (2007) and Fernandes et al. (2008) state that these species are highly competitive with eucalyptus.

Because it is a consortium between species, the silvopastoral system is more complex, making cultural practices also complex (Ferreira et al., 2010; Oliveira Neto & Paiva, 2010). To promote a good growth of eucalyptus, spaced 3 x 3 m, it requires a control range of Brachiaria equal to 2.0 m wide (Toledo et al., 2000). However, in silvopastoral system, the lower the control range, the greater the area occupied by brachiaria and consequently the greater the area available for grazing. In this case, it is essential to determine the diameter of the brachiaria crown that provides good conditions for the establishment of eucalyptus plantation without compromising the pasture area, in order thus to obtain better use of the system. However, there is limited scientific information on specific cultivation techniques of such intercropping systems.

Given the above, the aim of this study was to evaluate the effect of different crown diameters on the initial growth of eucalyptus trees in silvopastoral system with *B. decumbens*.

MATERIAL AND METHODS

The experiment was established in Viçosa, Minas Gerais, in a pasture formed with *B. decumbens*, in which hybrid eucalyptus urograndis was planted, (clone GG100), spaced 8 x 3 m (416 plants ha^{-1}). Before planting eucalyptus, soil sampling for chemical analysis was performed (Table 1). Subsequently, the existing vegetation was dried out through the application of glyphosate (1.080 g e.a. ha^{-1}) in 2 m ranges, in which holes of 0.3 x 0.3 x 0.3 m were dig. The planting of eucalyptus seedlings was conducted in December 2009, when 130 g of commercial NPK formulation (06-30-06) + 1% boron, per hole, and in coverage (90 days after planting), with 150 g of NPK formulation per plant (5/20/20) + 1% boron + magnesium were applied.

The experiment was conducted in a randomized block design with six replications. Treatments consisted of five crown diameters (0.0, 1.0, 1.5, 2.0 and 3.0 m) surrounding the eucalyptus trees. Each plot consisted of five plants, three of them being used for data collection in diameter at ground level and height. The plants of *B. decumbens*, as well as other weeds occurring within the proposed crowns were eliminated by mechanical controlling with hoe, during the whole period of experiment evaluation. For this, five weedings at different times were performed (0, 60, 120, 240 and 300 days after planting - DAP).

After the demarcation of plots and before the application of treatments, diameter and height measurements at ground level of each plant in the useful area of the parcels were performed. At the time of initial measurement, the plants showed, an average height of 0.23 m and 0.16 cm in diameter.

Data on plant height and diameter at ground level were analyzed in a split-plot system in time (four evaluation periods: 90, 180, 270 and 360 DAP).

At 360 DAP, we evaluated the dry matter of shoot and leaf area. For this, the total fresh weight of the stem, branches and leaves of the average plant plot were determined separately in the field. Stems with a diameter smaller than 2 cm were considered as branches. Stems samples with approximately 5 cm thick were collected from the basal, middle and top of each stem of the plant sampled. Leaves and twigs samples were randomly collected after the homogenization of the material, for determining the dry mass. These samples were placed in paper bags and kept in an incubator with air circulation at 75 °C until reach constant mass. Leaf samples, before being placed in an incubator, were used for determining the leaf area through a Li-color Instruments area meter (Model LI 3100) (Tomé, 2007).

Data were subjected to analysis of variance and regression. Models were chosen based on the biological phenomenon, in the significance of the regression coefficients by using the t test, adopting 10% of probability level, and in the coefficient of determination (R^2).

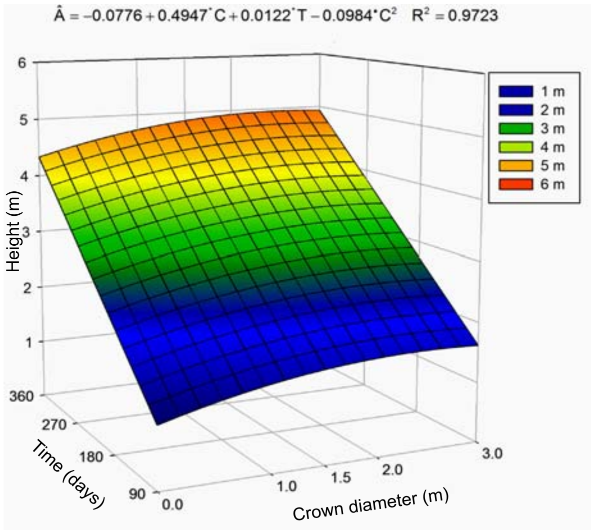
RESULTS AND DISCUSSION

Height and diameter at ground level

At 90 DAP, it was verified that plants that grew under the influence of crowns had higher growth (Figures 1 and 2), when compared with the control without weeding. This behavior was observed in the remaining periods evaluated (180, 270 and 360 DAP), confirming the negative interference that Brachiaria plants play in eucalyptus plants in the first year after planting. Pitelli & Marchi (1991) state that eucalyptus cultivation shows high

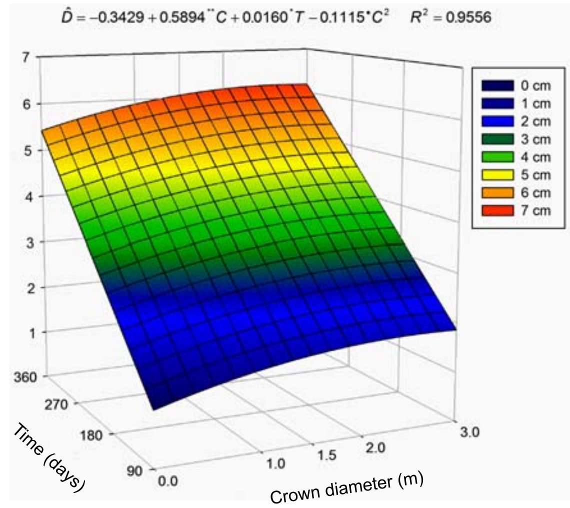
Table 1 - Chemical characteristics of the soil samples collected from 0-20 cm and 20-40 cm in the experiment site

Prof. (cm)	pH	P	K	Ca^{2+}	Mg^{2+}	Al^{3+}	H+Al	SB	CTC (t)	CTC (T)	V	m
	($H_2$0)	(mg dm^{-3})		(cmol$_c$ dm^{-3})							(%)	
0-20	5.5	1.17	29.6	1.43	0.56	1.19	3.73	2.15	2.34	5.88	36.4	9.8
20-40	5.5	0.79	23.0	1.00	0.48	0.32	3.73	1.65	1.97	5.38	30.3	18.2



(*) - Significant at the 5% of probability level; (•) - significant at the 10% of probability level.

Figure 1 **-** Estimate of height of eucalyptus plants subjected to different crown diameters and evaluation periods in silvopastoral system.



(**) - Significant at 1% of probability level (*) - significant at 5% of probability level; (•) - significant at 10% of probability level.

Figure 2 **-** Estimate of diameter at ground level of eucalyptus plants under different crown diameters and evaluation periods in silvopastoral system.

sensitivity to competition with weeds. This competition is most striking in the settlement implementation phase until about a year after planting, particularly when established with fast growing species such as grasses (Silva, 1993).

Because they are species which have different demands for water, light and nutrients and because in most cases these resources or at least one of them are available in insufficient amount, competition is established. In this case, the species that access and use resources more efficiently or continue to grow, even with low levels of resources, will exceed (Machado et al., 2010). In this regard, Silva et al. (2000) state that, by having fast early growth of roots and shoots, *B. brizantha* presents strong competition for growth resources with eucalyptus. Toledo et al. (2001) observed that, from 4 plants m^{-2}, Brachiaria interferes significantly in the early growth of eucalyptus trees, reducing the diameter and height of plants in assessments up to 190 DAP.

The maximum height of eucalyptus plants (4.94 m) was observed at 360 DAP with crown diameter equal to 2.5 m (Figure 1). The crown diameter of about 2.6 m provided the largest diameter at ground level in all periods, the largest value obtained at 360 DAP (6.20 cm) (Figure 2). Under conditions of low infestation, crowns with increasing diameters over time may be more advantageous operational and economically. According to Toledo et al. (2000), growing ranges following the root growth of eucalyptus plants (3 x 3 m) can be applied, taking also into consideration the costs and operational conditions.

In all periods, it was verified that the crown diameter which provided the largest height growth in plants of eucalyptus was 2.5 m eucalyptus (Figure 1) and 2.64 m in diameter at ground level (Figure 2). However, because it is a system that combines two species in the same area, crown diameters which provide maximum eucalyptus growth may not be the most feasible for the system as a whole, since, the larger the area kept clean, the smaller the area available for grazing, and the bigger the cost in making crowns.

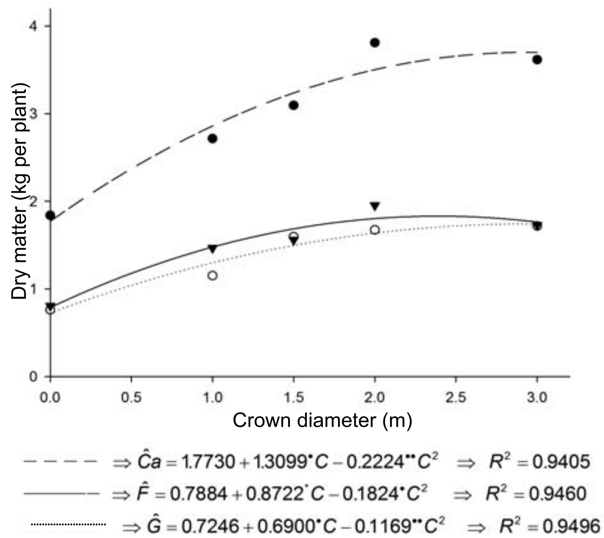
Crown diameters of 2.0 m provided eucalyptus plants with height and diameter of 4.91 m and 6.15 cm (Figures 1 and 2), representing 99.5 and 99.3%, respectively, relative to the crown that provided the maximum growth, noticing that there is no significant gain in the eucalyptus growth when using crowns upper to 2.0 m in diameter. Toledo et al. (2000), assessing the control of weeds in eucalyptus, spaced 3 x 3 m, in the first year of implementation, concluded that to promote a higher growth rate in height and diameter of eucalyptus plants it requires a minimum range control of 1 m from each side of the planting rows, corresponding to the total range of 2 meters in width.

Dry matter and leaf area

The dry matter production per plant at 360 DAP was significantly influenced by the different diameters of crown, being 2.94, 2.39 and 2.95 meters the diameters estimated that promoted greater mass accumulation of stem, leaves and twigs respectively (Figure 3). Comparing the estimated weight of dry stem in different crowns, it is observed that the diameters of 1.0, 1.5, 2.0 and 3.0 meters provided weight gains of 61, 83, 98 and 109%, respectively, when compared to the control without weeding (Figure 3). This fact, combined with estimated values of dry matter of leaves (Figure 3) and leaf area (Figure 4) shows that, due to competition performed by forage, eucalyptus shows lower leaf biomass and leaf area and therefore less accumulation of dry matter of stem, indicating the occurrence of competition with Brachiaria over time.

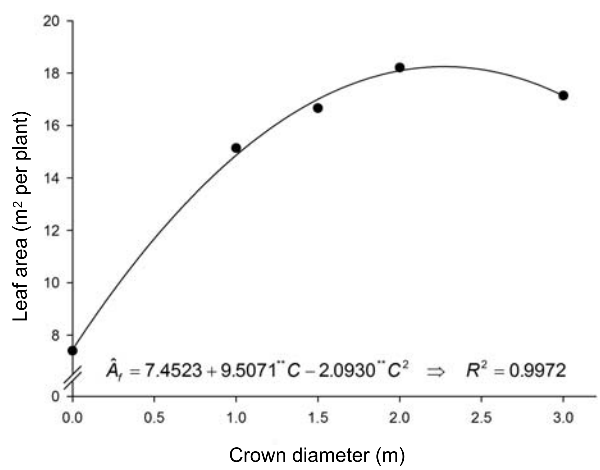
According to Pitelli & Marchi, (1991), plants that invest in photoassimilates in the production of leaves have greater competitive ability, since competition for light restricts the predominant source of energy to the basic processes of recruitment and development of elements of all substances involved in plant growth, causing the plants to be more competitive for water and nutrients (Zanine & Santos, 2004). Walker et al. (1988) emphasize that plants that grow faster in height and leaf area compete more effectively for light. According to Elwinger & Sanderson (2002), the increase of the competitive capacity of plants is related, among other factors, to the speed of leaf expansion, the formation of canopy and plant height.

The leaf area of Eucalyptus plants showed similar results to those of dry matter, which is also affected by crown diameters. For this variable, 2.27 m in diameter was what



(*) - significant at 5% of probability level; (•) - significant at 10% of probability level (••) - significant at 20% of probability level).

Figure 3 - Estimate of dry matter of stem ($\hat{C}a$), leaves ($\hat{F}$) and twigs ($\hat{G}$) of eucalyptus plants in silvopastoral system, at 360 DAP under different crown diameters (C - crown diameter (m).



Af - leaf area (m² per plant), C - crown diameter (m), (**) - significant at 1% of probability level.

Figure 4 - Estimate of leaf area of eucalyptus plants in silvopastoral system, at 360 DAP under different crown diameters.

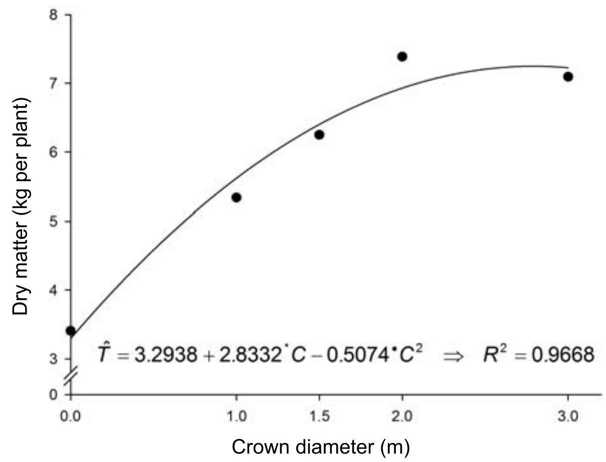
promoted the higher leaf area (18.25 m² per plant) (Figure 4). The higher the investment of the plant to form leaf area, the greater the tendency of biomass gain, since the plant prioritized investment in a producing organ of photoassimilates.

The data of dry matter and shoots of eucalyptus plants (Figure 5) corroborate the height and diameter data (Figures 1 and 2), in the sense that the eucalyptus plants under treatments with larger areas free of infestation stood out with higher average growth. We observed also that the diameter of crown that provided greater dry matter accumulation of shoots was of 2.79 m (Figure 5).

In silvopastoral systems, it is important that the eucalyptus plants to develop faster. In the early phase of the system, one of the most limiting factors to the entry of animals is the low growth in height and diameter of eucalyptus plants, which may confer less resistance to damage caused by animals (Garcia et al., 2010).

The crown diameter of 2.0 m gave dry matter production of shoots estimated at 6.93 kgper plant, or 95.6%, compared to that providing greater gain in biomass (2.79 m) (Figure 5). This shows that the increment of dry shoots provided by diameter of 2.79 m, in relation to 2.0 m, is only 4.4% higher. On the other hand, when using a 2.0 m diameter, in spaced adopted in eucalyptus planting (8 x 3 m) to the silvopastoral system, pasture area gain is of 12% when compared to the crown of 2,79 m (Table 2).

An important aspect related to silvopastoral system studied was the influence exerted by Brachiaria on eucalyptus, according to the diameter of crown. Normally, it is expected that the higher the crown, the greater the growth and development of eucalyptus, at the least interference of Brachiaria. However, in Figures 1 to 5, we observed an optimum crown diameter; above this point, crown becomes harmful to eucalyptus. This result, in a way, shows that Brachiaria can perform positive interactions on eucalyptus. Specific changes in the soil, such as reduction of direct sunlight, humidity maintenance, increased nutrient cycling and increase organic matter, may be the main causes of this interaction (Oliveira et al., 2002; Machado et al., 2010).



T - total dry matter of the plant (kgper plant), (*) - significant at 5% of probability level; (•) - significant at 10% of probability level.

Figure 5 **-** Estimate of the dry biomass of the shoots of eucalyptus plants in silvopastoral system under different crown diameters.

Table 2 **-** Area occupied by crown (m²) and its respective percentage in relation to the total area in silvopastoral system, spaced 8 x 3 m.

Crown diameter (m)	Crown area		
	(m² per plant)	(m² ha^{-1})	% ha
0.0	0.00	0.00	0
1.0	0.79	326.73	3
1.5	1.77	735.13	7
2.0	3.14	1306.90	13
2.79*	6.11	2543.27	25
3.0	7.07	2940.53	29

* Estimate of higher dry matter accumulation of shoots.

We conclude that the crown of about 2 m in diameter provided favorable conditions for the early growth of eucalyptus plants and less involvement in the area occupied by forage.

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