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Performance and quality of wood in a clone of *Eucalyptus* in monoculture and silvipastoral system

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ABSTRACT: This work was carried out with the purpose to evaluate and compare the performance and the variations in the quality of the wood of eucalyptus trees planted in silvopastoral system and in monoculture. Data were collected from 13 trees sampled at the age of 36 months, selected according to confidence interval of the mean diameter at breast height (DBH) and according to the position of the trees in the planting strip in the silvopastoral system, with south, north and central-facing exposure slopes. The variables DBH, total height and commercial height, volume and conicity of the trunk, basic density and displacement of the pith were evaluated. Results led to the conclusion that trees in the silvopastoral system had higher DBH, lower overall height and increased conicity of the trunk than in monocultures. DBH did not vary according to the position in the planting strip, but trees with north-facing exposure were lower and more conic. Basic density and displacement of the pith were not influenced by cropping system.

Keywords: hybrid clone *Eucalyptus grandis* x *Eucalyptus urophylla*, integrated production systems, Mato Grosso.

Desempenho e qualidade da madeira de um clone de eucalipto em monocultivo e sistema silvipastoril

RESUMO: Este trabalho foi desenvolvido com o objetivo de avaliar e comparar o desempenho e as variações na qualidade da madeirade árvores de eucalipto implantadas em sistema silvipastoril e em monocultivo. Os dados foram coletados em 13 árvores amostras aos 36 meses de idade, selecionadas em função do intervalo de confiança da média dos diâmetros a altura do peito (DAP), e da posição das árvores na faixa de plantio no sistema silvipastoril, com face de exposição sul, norte e central. Foram avaliadas as variáveis DAP, altura total e altura comercial, volume e conicidade do tronco, densidade básica e deslocamento da medula. Concluiu-se que no sistema silvipastoril as árvores apresentaram maior DAP, menor altura total e maior conicidade do tronco que no monocultivo. O DAP não diferiu em relação à posição na faixa de plantio, porém as árvores com face de exposição norte foram mais baixas e cônicas. A densidade básica e o deslocamento da medula não foram influenciados pelo sistema de cultivo.

Palavras-chave: clone de híbrido *Eucalyptus grandis* x *Eucalyptus urophylla*, sistemas integrados de produção, Mato Grosso.

1. INTRODUCTION

One of the great national challenges today is to turn degraded land into productive areas with the introduction of trees in agricultural systems such as integrated crop livestock forest (iCLF) or agrosilvopastoral systems. The presence of trees in agricultural systems can add several benefits such as improved thermal comfort indices, increased forage supply throughout the year, reduced erosion, optimized use of solar energy and optimized nutrient cycling (SALTON, 2015).

The integration of production systems has been adopted in Brazil and currently totals approximately 2 million hectares. The expectation is that in the next 20 years these are implemented in more than 20 million hectares (BEHLING et al., 2013). In Mato Grosso, the area with integration systems has increased and currently encompasses 500,000 hectares distributed in 41 municipalities. However, in only 11% of this area, the forest component is present (GIL, 2013).

The low utilization of the forest component in integration systems is due in large part to the lack of information on the environmental benefits and profitability brought about by the inclusion of trees in agricultural systems. It is still necessary to generate technologies and information in order to enable the handling, quantification, assess and prediction of forest production and its environmental benefits in integrated crop livestock forest (iCLF).

There is still little information in relation to growth variations and quality of the wood of trees produced in integration systems, which are key data to access the sawnwood market, that provides greater added value and higher rates of return to producers.

Higher growth rates and probably increased tension in the wood caused by higher exposure to wind action, asymmetric competition and changes in the sun's position in the terrestrial vault (sun exposure) are expected in trees planted in integration systems.

As it is known, the sun has two apparent movements around the earth, one in the east-west direction due to the rotation of the planet, and one in the north-south direction due to translational motion. The solar declination is related to the apparent motion of the star in the North-South direction throughout the year and it influences the direct radiation incident on the plants.

One way to evaluate the effect of environmental variables on the possible formation of growing tensions in the trees is through eccentricity of pith because trunks with eccentric pith are more prone to warping, forming circular cracks, as well as being problematic for the mechanical processing (RANDOMSKI; RIBATZKI, 2010). The basic density is another very useful indicator of the quality of wood and its possibilities of use, because it reflects the amount of woody material per amount of volume or volume of voids in the wood (OLIVEIRA et al., 2005).

In this context, this work was developed aiming to evaluate and compare the growth, wood density and the displacement of the pith along the stem of eucalyptus trees planted in silvopastoral system and in monoculture.

2. MATERIAL AND METHODS

The study was conducted in a crop-livestock-forest integration system under beef cattle management (iCLF-Cattle), cultivated with the hybrid *Eucalyptus grandis x Eucalyptus urophylla* (H13 clone) and located at the agrosilvopastoral EMBRAPA in the municipality of Sinop, Mato Grosso, in the geographical coordinates of 11° 52'23"S, 55°29'54" W and with altitude of 384m. The local climate is Aw - tropical and rainy according to Köppen Climate Classification, characterized by a rainy season and well defined dry season, with an average annual temperature of 24°C and 27°C, respectively (SCHIMITT et al, 2014.). The local soil is of the type Red-Yellow Latosol (Oxisol) (LVA) with clayey texture in flat relief (ARÁUJO, 2008).

iCLF-Cattle was deployed in 3.5x3x30 m planting configuration in triple tracks, integrated with pasture for beef cattle in a livestock forest system (LF). The homogeneous planting, that is, forest (F) was deployed in a spacing of 3,5x3 m. In the latter two systems, subsoiling and application of 350 kg ha^{-1} of simple superphosphate was carried out. In addition, there were three top-dressings, one and two months after planting trees, using NK 20-20 (100 g per plant) and one year after planting with 400 kg ha^{-1} NPK 20-05-20.

Data were collected in January 2014, with the trees aged at 36 months. For selecting sample trees, we used the average of the confidence interval of the diameter at breast height (DBH) based on the continuous inventory of the area.

Nine trees, three per line, located in the center and in the bands with south and north-facing exposure slopes were harvested in the silvopastoral system. In the monocropping, four trees were harvested and all were submitted to volume estimation. Volumes of the sections were obtained through the desmalian method and the method of compartmentalization of biomass per meter along the entire stem. In the volume estimation, commercial (up to 6 cm in diameter with the stem bark) and complete heights were measured with measuring tape and the circumferences with bark in the positions: base, 0.7 m, 1.30 m and each meter in the stem to full height.

For determination of basic density, displacement of the pith, conicity of the trunk and bark volume in percentage, discs approximately 2.5 cm thick were removed from the base of the trunk, at the DBH, and at 25%, 50%, 70% and 90% of the total height. The trunk biomass was obtained by:

$$\text{Trunk biomass}(\text{kg}) = \sum V_i x d_i \qquad (1)$$

where: V_i = Trunk volume in section $_i$ (m^3); d_i = density of wood in section $_i$ (kg m^{-3}).

The trunk volume was obtained by:

$$\text{Trunk volume}(\text{m}^3) = \sum \frac{A_i + A_{i+1}}{2 \times L} \qquad (2)$$

where: A_i = area of the section in position $_i$ (m^2); A_{i+1} = area of the posterior section (m^2); L = length of the section (m).

The average basic density per tree was obtained as the ABCP Norma M 14/70 and calculated by:

$$Db_{mean} = \frac{D_{base} + D_{25h} + D_{50h} + D_{70h} + D_{90h}}{5} \qquad (3)$$

where: Db_{mean} = individual mean basic density (g cm^{-3}); D_{base} = basic density obtained in the base (g cm^{-3}); D_{25h} = basic density obtained at 25% of the total height (g cm^{-3}); D_{50h} = basic density obtained at 50% of the total height (g cm^{-3}); D_{70h} = basic density obtained 70% of the total height (g cm^{-3}); D_{90h} = basic density obtained at 90% of the total height (g cm^{-3}).

The displacement of the pith was obtained after grinding one face of each disc and marking the north and south cardinal points. The methodology of Lima et al. (2007) was used, measuring four perpendicular radii, and the displacement obtained by:

$$DM = R_M - R_{\bar{m}} \qquad (4)$$

where: DM = displacement of the pith (cm); RM = value of the greater distance between the pith and the periphery of the log; R_m = (Mean disc radius) was obtained by:

$$R_{\bar{m}} = \frac{R_M + R_m + R_{p1} + R_{p2}}{4} \qquad (5)$$

where: R_m = value of the smallest distance between the pith and the periphery of the log; R_{p1} = value of the perpendicular radius at R_M; R_{p2} = value of the perpendicular radius at R_m.

For the analysis of this variable, the position 90% of the total height was not considered due to the small sizes.

Conicity of the stem was obtained by:

$$C = \sum \left(\frac{d_i - d_{i+1}}{L} \right) \quad (6)$$

where: d_i = diameter of the section $_i$ (cm); d_{i+1} = diameter in the posterior section (cm); L = length of the section (m).

The thickness of the bark was measured with a digital caliper and the volume of bark in percentage was calculated by:

$$Vc\% = \frac{v_{cc} - v_{sc}}{v_{cc}} \times 100 \quad (7)$$

where: v_{cc} = total volume of the trunk with bark; v_{sc}= total volume of the trunk without bark.

T-test was used to compare the average of the trees in monoculture and silvopastoral system in the case of variables that followed the normal distribution and showed homogeneous variances among treatments. In order to check the effect of the position of the tree in the planting strip in the silvopastoral system, we used ANOVA for a completely randomized design, where each planting line represented a treatment (south-facing exposure slope lines (PF_{south}), central ($PF_{central}$) and north-facing (PF_{north}), facing with the witness that was the monocropping (F)). Each sampled tree was considered a repetition.

In the case of detecting significant differences between treatments, the Tukey test at a significance level of 5% was applied. The variables that did not meet the assumptions for ANOVA were analyzed using the Kruskal-Wallis test.

3. RESULTS AND DISCUSSION

The variables displacement of the pith and basic density did not have a normal distribution and homogeneity of variance. No significant differences were observed between treatments for the volume of bark in percentage, commercial height and individual total volume with bark on the trunk (Table 1).

The percentage of bark ranged from 15.9% to 21.4% (Table 2) being above the average observed by Alzate (2004) for five clones of *Eucalyptus grandis x Eucalyptus urophylla* (11.9%), ranging from 11.34% to 13.28%.

In the silvopastoral system, the trees had higher DBH, lower overall height and greater conicity compared to the monoculture. With respect to the diameter, trees did not differ according to the position in the planting range (Table 2), but trees with north-facing exposure slopes were lower and conic.

The largest diameter observed in the silvopastoral system did not translate into greater individual volume in the trunk due to lower growth in height. This can be explained by lower

Table 1. The analysis of variance for diameter at breast height (DBH), total height (H), commercial height (Hc), percentage of bark volume (Bark), trunk conicity (C) and total volume of the trunk (v) in clones of *Eucalyptus grandis x Eucalyptus urophylla* in silvopastoral system and monoculture at the age of 36 months.

CV	GL	Average square					
		DBH (cm)	H (m)	Hc (m)	Bark (%)	C	v (m^3)
Treat.	3	0.85*	3.06*	1.48	17.17	0.13*	0.001
Error	9	0.14	0.35	0.62	12.57	0.03	0.01
Total	12						

* At 5% level of significance.

Table 2. Mean values and comparisons of the treatments and analyzed variables.

Treatments	Variables					
	DBH (cm)	H (m)	Hc (m)	V (m^3)	Bark (%)	C
PF	10.5^{*}	10.3^{*}	7.5	0.03517		1.39^{*}
F	9.6^{B*}	11.7^{A*}	8.2	0.03358	21.4	1.07^{C*}
PF_{south}	10.7^{A}	11.0^{A}	7.9	0.03807	19.8	1.33^{B}
$PF_{central}$	10.4^{AB}	10.5^{AB}	7.9	0.03451	19.3	1.31^{B}
PF_{north}	10.5^{A}	9.5^{B}	6.7	0.03229	15.9	1.54^{A}

Where: * Significant at 5% by Tukey test; DBH= diameter at breast height; H = total height; Hc = commercial height; V = total volume of the trunk with bark; Bark = bark volume in percentage; C = conicity.

competition for light that, in the monoculture, stimulated trees to have larger longitudinal growth and larger H/DBH (1,2), indicating that they are growing proportionally more in height than in diameter. In the silvopastoral, the reverse process is still happening, since the H/DBH was less than 1 (0.98).

In the silvopastoral system, trees are lower and conic. Probably, greater tension in the stem caused by the wind makes trees direct their growth toward the lower parts of the stem and toward the roots seeking greater stability. Trees with north-facing exposure slopes showed less growth in height and greater conicity compared to the south-facing trees.

According to Patiño-Valera; Kageyama (1988), even small changes in the environment may be enough to cause significant changes in the phenotypic characters of greater economic interest of trees. In the case of the genus *Eucalyptus*, there is a high correlation between the increase in available usefuls area and the increase in individual dimensions, such as: DBH, stem volume and aboveground and root biomass (REINER et al., 2011). In turn, the effect of the growth in height was not noticeable and depends on the species and may be encouraged, reduced, or not influenced by density (LELES et al., 2001).

No significant differences were observed for basic density (D) of trees (p = 0.883) and in different positions in the same tree trunk (D_{base}, p = 0.525; $D_{1.30}$, p = 0.177; D_{25h}, p = 0.159; D_{50h}, p = 0.106; D_{70h}, p = 0.917; D_{90h}, p = 0.093). This indicates that until the age of 36 months, no significant differences in relation to monocultures or in relation to te effect of sun exposure were observed on this variable.

The mean basic density was 0.444 gcm^{-3} for the silvopastoral and 0.443 gcm^{-3} for monocropping and this did not vary significantly in the longitudinal direction (Table 3 and Figure 1), what was also observed for some species of eucalyptus by Sturion et al. (1987). However, there was a downward trend along the stem length.

In the case of the clones of *E. urograndis*, no pattern in the density variation along the stem length was observed. Carvalho (2000) observed a decrease until the DBH and a growth after this point. Gonçalves (2006) observed increased of density from the base to the top. Padua (2009) observed a decrease up to 25% of commercial height, a increase up to 70% of the commercial height and then a decrease.

It was observed that the density determined in the half of the total height of the tree was the one closest to the mean basic density of the tree trunk (Figure 3). However, since there was no significant difference in relation to$D_{1.30}$ and because this position also allows estimates through non-destructive methods, this can be used to estimate the mean basic density of the trunk under the conditions studied here.

Table 3. Basic density of the tree trunk (gcm^{-3}) of a clone of *Eucalyptus urophylla* in forest monoculture and integrated livestock and forest system.

Statistic	Position in trunk						
PF							
	Base	**1.30**	**25%h**	**50%h**	**70%h**	**90%h**	**Média**
Mean	0.480	0.440	0.434	0.447	0.422	0.438	0.444
Standard deviation	0.016	0.012	0.021	0.020	0.021	0.024	0.012
F							
	Base	**1.30**	**25%h**	**50%h**	**70%h**	**90%h**	**Média**
Mean	0.466	0.434	0.476	0.440	0.421	0.426	0.443
Standard deviation	0.012	0.007	0.026	0.004	0.0025	0.0036	0.0082

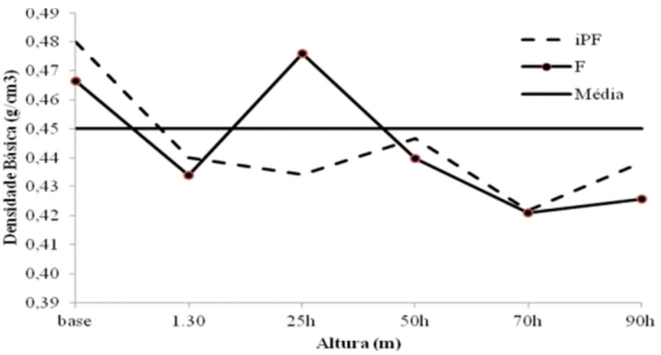

Figure 1. Variations of density of a clone of *Eucalyptus grandis x Eucalyptus urophylla* in silvopastoral system and monoculture.

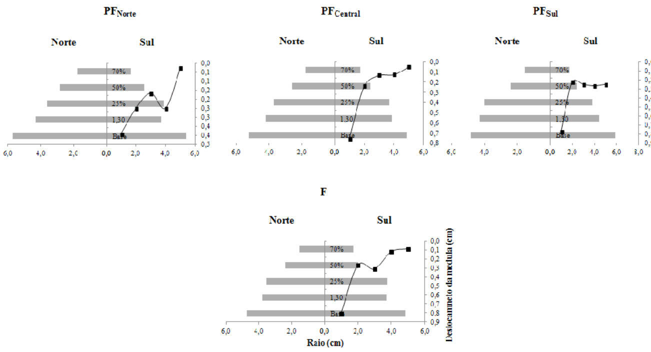

Figure 2. Pith displacement in the stem of a clone of *Eucalyptus grandis x Eucalyptus urophylla*in silvopastoral system and monoculture.

In the comparison with clones and hybrids of *E. urograndis*, values of $D_{1.30}$ observed in this study (0.434 - 0.440 g cm^{-3}) are in the lower range limit (0.439 - 0.51 g cm^{-3}) observed by Gonçalves (2006) and Neves et al., (2013) with ages between 55 and 70 months. The values for Db_{mean} (0.443 - 0.444 g cm^{-3}) are also within the lower limit (0.419 - 0.54 g cm^{-3}) observed by authors such as Carvalho (2000); Gonçalves (2006); Santos; Sansígolo (2007); Neves et al. (2013); Alencar et al. (2014); Protasio et al. (2014), Padua (2009) with ages between 36 and 84 months.

Regarding displacement of the pith, significant differences were observed between the trees (p = 0.320) and in different positions in the same tree trunk (DM_{base}p = 0.428; $DM_{1.30}$p = 0.994; $DM_{25h;}$ p = 0.380; DM_{50h}p = 0.196; DM_{70h}, p = 0.054), indicating that up to the age of 35 months there were no significant differences in relation to monoculture or in relation to the effect of position of the tree in the strip.

Once the trees planted in strips in integration systems are more susceptible to wind and asymmetric competition, what, in turn, can lead to formation of likewise asymmetrical canopy with a higher volume of branches (FERREIRA et al., 2008) larger pith eccentricity is expected. In silvopastoral system, a severe dislocation of the pith was observed in *Corymbia citriodora* by Randomski; Ribaski (2010) on strips of a plant spaced in 30x1,5 m aged at 19 years, and therefore, the lack of significance found in this study probably occurred due to young age.

A decreasing tendency in the displacement of the pith along the stem length was observed indicating that, from the base, the diameter growth became more symmetrical, minimizing the eccentricity of the pith. Regardless of the cropping system and the position of tree in the planting strip, the diameter was greater in the north-facing exposure slopes where the direct sunlight period is longer (Figure 2), resulting in more vigorous and long-lived branches.

4. CONCLUSIONS

The planting system had no influence on the total volume in the trunk with bark, percentage of bark at commercial height. Trees had higher DBH, lower overall height and increased conicity of the trunk in the silvopastoral system than in monoculture. There was no effect of the position of the tree in the planting strip over diameter; however, trees with north-facing exposure slope were lower and conic. The basic density and the displacement of the pith were not influenced by cropping system.

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