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# Pruning of *Eucalyptus grandis* x *Eucalyptus urophylla* planted at low density in Southeastern Brazil

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**Tree pruning is a silvicultural operation that aims to improve wood quality, but care must be taken regarding the timing and height of the lift to ensure that tree growth is not negatively affected. The objective of this work was to evaluate the effects of different pruning heights on height and diameter growth of *Eucalyptus grandis* × *Eucalyptus urophylla*. The experiment was done in a one year old stand which was planted at 9 × 3 m spacing, managed under a silvopastoral regime, and located in João Pinheiro, Minas Gerais, Brazil. Pruning treatments removed branches carrying the lower green crown as follows: 0% (unpruned), 20, 40, and 60% of total tree height. Diameter at breast height (DBH at 1.3 m) and total height of all trees in the sample plots were measured prior to pruning and one year after pruning. Compared to the unpruned control, pruning significantly reduced mean DBH and total height in the 40 and 60% treatments but not in the 20% treatment. Thus, it was concluded that when pruning operation is done before canopy closure not more than 20% of lower green crow should be removed to avoid tree growth reduction.**

**Key words:** Silvopastoral regime, silvicultural intervention, forest management.

## INTRODUCTION

Brazil houses 7.7 million hectares of planted forests, of which nearly 70% is composed of different *Eucalyptus* species. The main purpose of these plantations is for charcoal, fire wood and cellulose production. A smaller percentage of these eucalypt forests are grown for solid wood products production, a growing activity in the last few years. For instance, eucalypt roundwood consumption for solid wood products (mainly sawnwood, furniture, wood panels and plywood) has risen from about 3 million $m^3$ in 2006 to about 15 million $m^3$ in 2014

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(ABRAF, 2008; IBÁ, 2014).

Considering the silvicultural tools available to forest managers to grow trees for solid wood products, thinning and pruning are among the most important. While thinning allows target trees to grow to large diameters by means of stand competition reduction, pruning is associated with wood quality enhancement through clear wood production. An alternative to thinning is to plant trees at lower densities, such as in the case of silvopastoral regimes. These regimes combine trees, forage and livestock occupying the same plot of land (Cubbage et al., 2012).

Since early thinning operations are unnecessary when trees are planted at silvopastoral regimes, the main silvicultural operation to enhance wood quality is pruning. The ideal timing and severity of pruning should be planned in a way as to minimize the defect log by pruning as early and as high as possible without negatively affecting clear wood production, since wood that is free of defects achieve greater strength properties and yield lumber that earns a high grade (O'hara, 2007).

Pruning yields best results when applied to live green branches. For instance, Smith et al. (2006) found that while branch occlusion rates did not differ between pruned and unpruned dead branches, it was significantly lower for pruned live branches in comparison to unpruned live braches. This implies that pruning interventions must anticipate branch mortality, which occurs early for fast growing shade intolerant species, such as many *Eucalyptus* species. However, pruning should not be done in a way to reduce tree growth.

*Eucalyptus* plantations in Brazil have an important role in providing substitutes for native timber species as solid wood products providers (Teixeira et al., 2009). Changes have been undergoing *Eucalyptus* management for solid wood products, mainly in respect to wider initial spacing to take advantage of high initial diameter growth rates (Maestri, 2003; Nutto et al., 2006). It is important to understand how trees behave in relation to pruning operations when planted under wider initial spacing.

The objective of this work is to evaluate the effects of different pruning heights on diameter and height growth of a *Eucalyptus grandis* × *Eucalyptus urophylla* stand planted at low initial density.

## MATERIALS AND METHODS

The present study was carried out in a *E. grandis* × *E. urophylla* (clone I144) stand (17º 44' 26" S and 46º 10' 27" O), located in the municipality of João Pinheiro, Minas Gerais, Brazil. The regional climate is tropical. The mean annual precipitation is 1,250 mm and rainfall is concentrated from October to March, mean annual temperature is 23.9ºC, mean altitude is 540 m.a.s.l. The soil in the stand is classified as an oxisol with sandy loam texture.

Before planting, the sub-soil was ripped to 50 to 60 cm depth with simultaneous addition of reactive rock phosphate to a depth of 30 cm at a rate of 600 g/plant. Post-planting fertilizer applications consisted of 120 g/plant of NPK (6-30-6) ten days after planting; and 180 g/plant of NPK (10-0-30 + 1% B + 0.5% Zn + 0.5% Cu) 8 and 20 months after planting. The post-planting fertilizer applications were applied at two opposite points about 15 cm away from the seedlings using a hand fertilizer machine.

The stand density at planting was 9 m between and 3 m within rows to meet the requirements of a silvopastoral regime. Four pruning treatments were applied when the stand was one year of age. These resulted in removal of the lower green crown to either 0% (unpruned control), 20%, 40%, or 60% total tree height; the mean pruned heights were 0, 1.2, 2.4, and 3.5 m, respectively. At the time of pruning, there had been no natural pruning or branch mortality, and as such the tested pruning heights represented total live branch removal only. A randomized complete block design was used with five replications. The sample plots consisted of five rows with fourteen trees per row, with a measurement area of 30 trees (ten trees per the three central rows), with a total of 175 measured trees per treatment. All trees of each plot had DBH and height measured prior to treatment installation and one year after pruning. At the time of the pruning intervention, mean stand DBH was 5.5 cm and stand mean height was 5.9 m.

### Statistical analysis

The effects of pruning were assessed at stand and tree level. At stand level, plot means of DBH and height were examined using analysis of variance (ANOVA). Residual properties where checked using the Shapiro-Wilk test for normality and the Bartlett test for homogeneity of variances. The Scott Knott post hoc test (Scott and Knott, 1974) was applied to the separate significant differences between the pruning treatments. This test was chosen since it is considered robust in controlling Type I errors (Borges and Ferreira, 2003).

Linear regression models were used to evaluate pruning effects at tree level. One year DBH and height increments were related to tree size prior to pruning with treatment inserted as a factor variable (Model 1). To account for the lack of independence of trees belonging to the same blocks, linear mixed models were used. A random variable was inserted in the model to account for block variance.

$$ix_{lk} = \beta_0 + \beta_1 * x_{lk} + \beta_2 * T_k + \beta_3 * (x_{lk} * T_k) + u_l + e_{lk} \quad (1)$$

where ix is tree DBH or height increment one year after pruning; x is tree DBH or height at the moment of the pruning intervention; and T is a factor variable to account for treatment variability. Subscripts *l* and *k* refer to block and tree, respectively. $u_l$ and $e_{lk}$ are independent and identically distributed random between-block and between-tree factors with a mean of 0 and constant variances of $\sigma^2_{bl}$, and $\sigma^2_{tr}$, respectively.

All statistical inferences were performed using the program R (R Core Team, 2012) and the following packages: Jelihovschi et al. (2012) and Pinheiro et al. (2012).

## RESULTS

Pruning affected mean stand DBH values ($F(3, 12) = 3.91$, $p = 0.04$, CV = 5.31%) and mean stand height ($F(3, 12) = 3.87$, $p = 0.04$, CV = 5.34%). Residuals were normally distributed with mean zero and there was homogeneity of variances between treatments. Both

**Table 1.** Influence of different pruning heights on mean stand diameter at breast height (DBH) and height (h) values one year after intervention.

| T (%) | DBH (cm)* | h (m) |
|---|---|---|
| 0 | 12.1 (0.4)[a] | 12.4 (0.4)[a] |
| 20 | 11.7 (0.4)[a] | 12.1 (0.6)[a] |
| 40 | 11.2 (0.3)[b] | 11.5 (0.2)[b] |
| 60 | 10.9 (0.3)[b] | 11.2 (0.5)[b] |

*Values followed by the same letter in the same column are statistically equal according to the Scott Knott test (p = 0.05). Numbers in parenthesis represent the standard error.

**Table 2.** Parameterization of the DBH and height increment models at tree level.

| | DBH increment | | | Height increment | | |
|---|---|---|---|---|---|---|
| **Parameter** | **Value** | **Std. Error** | ***p*-value** | **Value** | **Std. Error** | ***p*-value** |
| β0 | 9.4269 | 0.523 | 0.000 | 10.8216 | 0.668 | 0.000 |
| β1 | -0.5245 | 0.072 | 0.000 | -0.7317 | 0.078 | 0.000 |
| T20 | -2.3459 | 0.547 | 0.000 | -3.0305 | 0.610 | 0.000 |
| T40 | -2.1910 | 0.487 | 0.000 | -1.7550 | 0.552 | 0.002 |
| T60 | -0.5082 | 0.581 | 0.382 | -1.5752 | 0.664 | 0.018 |
| T20*x | 0.3458 | 0.096 | 0.000 | 0.4636 | 0.102 | 0.000 |
| T40*x | 0.2799 | 0.088 | 0.002 | 0.1653 | 0.094 | 0.079 |
| T60*x | -0.1246 | 0.104 | 0.230 | 0.0555 | 0.111 | 0.617 |
| $\sigma^2_{bl}$ | | 0.556 | | | 1.175 | |
| $\sigma^2_{tr}$ | | 0.696 | | | 0.532 | |

mean diameter and height of trees in the 0 and 20% treatments were greater than those of the 40 and 60% treatments, one year after pruning (Table 1).

Regression analysis confirmed that tree growth loss due to pruning followed the same behavior as mean stand level growth reduction, with higher pruning heights reducing diameter and height increments. Table 2 presents the results of the parameterization of the diameter and height increment models. Visual analysis of residual dispersion of both models did not indicate any undesired trend that could negatively influence model performance.

The parameters of Table 2 where used to illustrate the influence of tree size and pruning height on one year diameter and height growth (Figure 1). The amount of growth reduction caused by the different pruning regimes varied according to initial tree size (Table 2, Figure 1). For instance, a tree with DBH of 5 cm that was pruned up to 40% of tree height would present a DBH increment 11% less than an unpruned tree (6.0 versus 6.8 cm/year). This reduction would be only of 4% if the initial tree size was of 7 cm (5.5 versus 5.8 cm/year). Height growth followed this same behavior.

## DISCUSSION

The present paper relates the effects of pruning prior to canopy closure on growth of clonal *E. grandis* × *E. urophylla* trees planted at a low initial density (370 trees per hectare). Canopy closure can be defined as the moment when the crowns of adjacent trees touch each other. The results obtained from of this experiment come from a young stand, as such it is important to note that the impact of green crown pruning in tree and stand growth may vary as the stand approaches maturity and as successive pruning operations are applied.

The amount of lower green crown that can be removed from *Eucalyptu*s trees in pruning operations without resulting in growth loss have been reported by many authors (e.g. Brendenkamp et al., 1983; Pinkard and Beadle, 2000; Monte et al., 2009). A general consensus is that 40 to 50% of the lower green crown can be removed without affecting tree growth (Pinkard and Beadle, 1998; Alcorn et al., 2008; Forrester et al., 2010). The results found in this study indicated a stronger response of growth loss following pruning than usual, with mean stand attributes suffering reduction with the

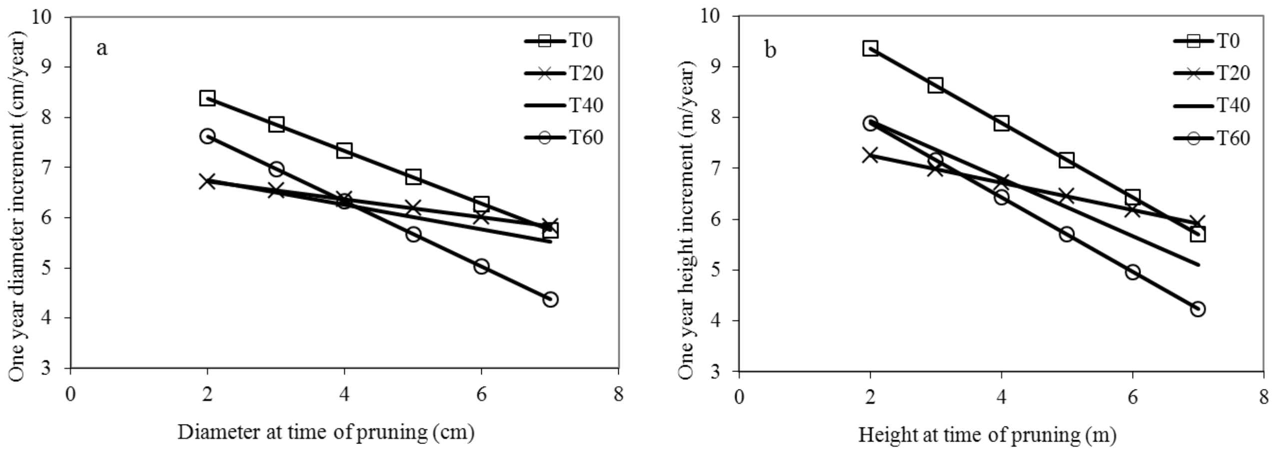


**Figure 1.** Behavior of one year DBH (a) and height (b) increment considering different tree sizes at the moment of the pruning intervention.

removal of 40% of lower green crown onwards. This probably occurred due to the canopy characteristics of the stand at the time of pruning application. The lower tree crowns were not undergoing mortality at the time of pruning. This was due to the early moment of pruning intervention and the wide spacing applied at installation. Thus, the lower crown of the trees was still contributing to tree growth, and its removal affected tree development. The moment of canopy closure is dependent on the planting density and growing conditions (Beadle, 1997; Montagu et al., 2003). For *Eucalyptus* species, canopy closure usually occurs between the ages of 1 and 4 years (Medhurst et al., 1999; Ryan et al., 2004). At the moment of canopy closure, the tree's lower crown does not contribute much in terms of carbon allocation and tree growth (Montagu et al., 2003), allowing high levels of green crown removal (up to 50%) without affecting tree growth.

The results of the present study are in conformity with other pruning trials in *Eucalyptus* species when conducted prior to canopy closure and planted at low density. For instance, Pinkard (2002) found that 20% leaf area removal of pre-canopy closure *Eucalyptus nitens* trees caused stem growth reduction. Fontan et al. (2011) reported diameter growth reduction for a *Eucalyptus camaldulensis* × *E. grandis* clone established in 9.5 × 4.0 m spacing when pruning all trees of the stand, removing 33% of live crown height plus removal of some thick branches above this height in three lifts. To avoid growth reduction in these stands, the aforementioned authors recommended pruning interventions removing 33% of live crown height plus removal of some thick branches above this height in four lifts (beginning at age 9 months with 6 month intervals) only for trees selected for final harvest (60% of the stand).

As for the tree level analysis, smaller trees presented the largest diameter and height increments, regardless of the pruning treatments. The tree level analysis also indicated that, for the two intermediate pruning treatments, growth reduction was mainly concentrated on the smaller trees of the stand, with larger trees presenting growth similar to unpruned trees (Figure 1). Thus, the more intensive treatments, probably removed amounts of leaf area that were too large for the smaller trees to recuperate, this way causing more pronounced growth reduction in these trees. This helps to explain why the 20% pruning treatment presented mean stand attributes statistically equal to the unpruned treatment, since the growth of the larger trees were able to compensate the growth loss of the smaller trees.

From a management perspective, the results found in this study suggests that it should be possible to implement a light pruning prior to canopy closure (e.g. removing up to 20% of lower green crown), and more severe pruning post-canopy closure (e.g. removing up to 50% of lower green crown), without affecting stem growth. However, an economic analysis of such a pruning regime is warranted to check for viability.

## Conclusion

The tested pruning heights reduced eucalypt height and DBH development one year after intervention when more than 20% of the lower live green crown was removed.

## Conflict of Interests

The authors have not declared any conflict of interests.

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