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Original article

The wood density of 3 *Eucalyptus saligna* Smith clones in relation to age *

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Summary — The evaluation of the basic density of wood of *Eucalyptus* spp, cultivated extensively in Brazil, has become of fundamental importance in various types of projects, due to the fact that density is the principal index of wood quality. Through periodic collections of wood samples from 3 clones of *E saligna* between the ages of 9 and 42 months, the interclonal and intraclonal variations at various ages as well as temporal behaviour were determined. The analysis of the results led to the following conclusions: i) the mean basic density of the wood of the 3 clones all together can be estimated in function of age by the cubic model: $BD = -0.018510 + 0.53200.A - 0.001920{*}A^2 + 0.000023{*}A^3$ (R^2 = 0.832 and F = 260.89); ii) at the level of the clone, the basic density for each individual can be calculated by the following equations: $BD_1 = 0.015179 + 0.052466{*}A - 0.001966 * A^2 + 0.000024{*}A^3$; $BD_2 = -0.070743 + 0.057755{*}A - 0.002030{*}A^2 + 0.000024{*}A^3$; and $BD_3 = 0.000867 + 0.049257{*}A - 0.001767{*}A^2 + 0.000021{*}A^3$; and iii) the intraclonal variation in relation to basic density is relatively low at the ages studied.

wood density / clone / *Eucalyptus saligna*

Résumé — Évolution de la densité du bois selon l'âge de 3 clones d'*Eucalyptus saligna* Smith. *Étant donné l'importance économique d'*Eucalyptus *spp dans la production forestière brésilienne, ce bois est de plus en plus étudié vis-à-vis de l'amélioration de sa qualité. On connaît le rôle important joué par la densité sur la qualité du bois. C'est pourquoi on a évalué l'évolution de l'infradensité (DB) du bois de 3 clones d'*E saligna *entre 9 et 42 mois. Les évaluations ont porté sur les variations inter et intra-clonales pendant cette période. Les analyses effectuées conduisent aux résultats suivants : i) la variation de l'infradensité moyenne (DBm) en fonction de l'âge du bois peut être estimée par l'équation* $DB = 0{,}018\,510 + 0{,}053\,200.A - 0{,}001\,920 * A^2 + 0{,}000\,023 * A^3$ *(*$R^2 = 0{,}832$ *et F = 260,89) ; ii) l'infradensité de chaque clone peut être correctement évaluée par l'intermédiaire des équations* $DB_1 = 0{,}015\,179 + 0{,}052\,466 * A - 0{,}001\,966 * A^2 + 0{,}000\,024{*}A^3$; $DB_2 = -0{,}070\,743 + 0{,}057\,755 * A - 0{,}002\,030 * A^2 + 0{,}000\,024 * A^3$ *et* $DB_3 = 0{,}000\,867 + 0{,}049\,257 * A - 0{,}001\,767 * A^2 + 0{,}000\,021 * A^3$; *iii) la variabilité intra-clonale de l'infradensité n'est pas significative statistiquement.*

***densité du bois / clone /* Eucalyptus saligna**

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INTRODUCTION

The forest species most extensively cultivated in Brazil belong to the genus *Eucalyptus*. The principal end uses of *Eucalyptus* are the production of charcoal (for smelting iron ore), paper pulp and fiberboard. The quality of the product obtained bears a close relationship with the quality of wood used as raw material. In considering various characteristics of wood, density is the principal parameter used to express its quality because it is strongly correlated with other properties of wood, and moreover, it can be easily determined.

Previous studies have shown that the wood density of *Eucalyptus* increases with the age of the trees (Ferreira, 1972; Foelkel *et al*, 1983). The effect of the age on the density of the wood produced by *E grandis* was well described by a linear regression model (Vital *et al*, 1984).

A prior knowledge of the density of the wood could result in a considerable saving in time and cost in plant breeding and forest management, as pointed out by Nanson (1976) and demonstrated by Rosado (1982) and Jesus and Vital (1986). Furthermore, the development of successful techniques to propagate *Eucalyptus* vegetatively and the resultant establishment of clonal forests has led to considerable improvement in timber quality due to the low variability in wood density among individuals within clones (Lima *et al*, 1990).

The main objectives of this study were to conduct a preliminary investigation of the basic density of *Eucalyptus saligna*, and to quantify the inter- and intraclonal differences in density at different tree ages.

MATERIALS AND METHODS

Wood samples from 3 *Eucalyptus saligna* Smith clones were obtained from an experimental plot situated in southern Minas Gerais state, Brazil and managed by CAF Florestal, Bom Despacho. The layout of the field experiment is presented in figure 1. The terrain is level to undulating with an altitude of 703 m. Mean annual rainfall is 1 375 mm. The soil is a dark red latosol with a large proportion of clay, typical of this subtropical region. The codes adopted for the clones by CAF Florestal were: clone 01: CAF 2172; clone 02: CAF 2299 and clone 03: CAF 2347.

Six samples trees per clone were taken at the ages of 9, 12, 15, 18, 21, 24, 30, 36 and 42 months, starting at the time of rooting of the cuttings. The sample size was in accordance with the statistical procedure described by Freese (1970). The choice of trees from each clone was based on good form, independent of their dimensions, with borderline trees not included.

The trees were cut, freed of crowns and branches, and the diameter and total height of the trunks were measured. In the case of young trees (until 24 months of age), the entire trunks were taken and debarked manually. In the case of the older trees, samples were taken in the form of trunk disks at intervals of 1 m, starting at the base of the tree.

Wood basic density determinations were carried out in the Department of Forest Science of Escola Superior de Agricultura de Lavras, using the immersion method described by Vital (1984). The xylometer used was specially constructed to measure green volume with a precision of 8.75 cm^3 (VV).

The dry mass (dm) of wood was obtained with the use of an electronic scale. The drying of wood was done in a drying and sterilization oven equipped with a mechanical convection system and capable of maintaining a temperature of 103 $\pm$ 2°C. The values obtained for oven-dry mass and green volume were used to calculate the basic density of the wood.

The following calculations were carried out:

i) the arithmetic mean and the intraclonal coefficient of variation for the basic density for each clone x sampling age;

ii) the arithmetic mean and the interclonal coefficient of variation for the mean basic density of the specimens of each clone at each sampling age.

The values of basic density for each clone (6 values/clone/age) were subjected to regression analysis with the objective to describe the change in density with age. The same analysis was done separately for each clone.

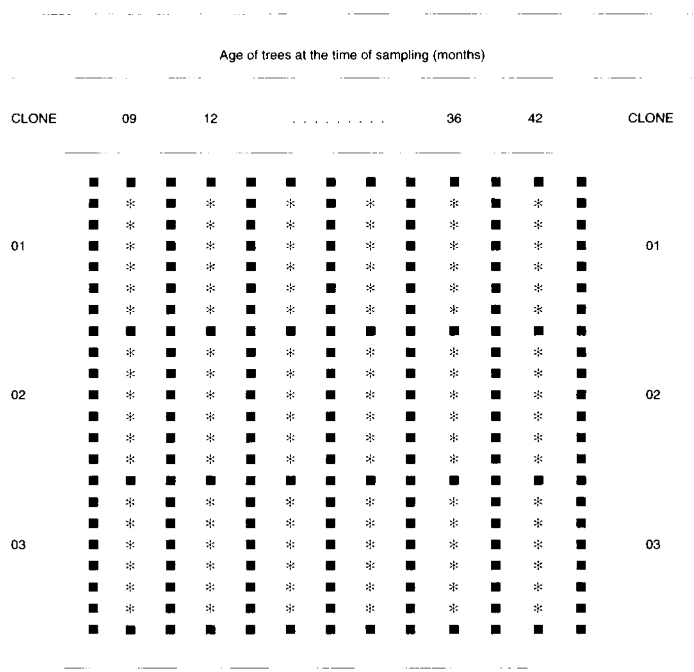

Fig 1. Layout of experimental site (spacing 3.0 m x 1.5 m). ■: borderline trees; ✳: sampled trees.

The statistical analysis used in this project was done with the use of the programme "Sistema para análises estatísticas" (SAEG) version 3.0.

RESULTS AND DISCUSSION

Table I shows the mean basic densities of the wood from each clone at the different sampling ages. It can be observed that the density of each clone increases with age and that this pattern is basically the same for the 3 clones. The sampling procedure adopted, despite having resulted in a great deal of work, considerably reduced the errors due to variation within trunks, confirming observations by Panshin and De Zeeuw (1964).

The dispersion of the density values around the mean, as indicated by the coefficient of variation, was greater in the younger plants, probably because of the relatively greater influence of the environment on these plants. Brown *et al* (1952) suggested that the wood elements gradually increase in size in successive growth rings for a number of years; thereafter, the mean size of the cells is relatively constant, subject to minor fluctuations due to changes in the environment.

The coefficient of variation decreased with increasing age, reaching values much lower than those observed in eucalypts raised from seed; for instance, 6.4% in *E citriodora* (Rosado, 1982) and 6.0% in *E grandis, E tereticornis* and *E camaldulensis* (Lima *et al,* 1991).

Table II presents the mean of the basic densities (mBD) of all sampled trees, regardless of the clone, at the 9 sampling ages. It can be observed that wood density tended to increase with age, although there was a slight decrease around 24 months of age. The variation in density among the trees of all clones reveals a decrease in the coefficients of variation after the age of 12 months. In older trees, the coefficients of variation remained relatively constant irrespective of the age of the clones, confirming that the

Table I. Average wood basic density (aBD) and its coefficient of variation (CV) in each of the 3 clones of *E saligna* at various ages.

Age (month)	*Clone 1*		*Clone 2*		*Clone 3*	
	aBD (g/cm³)	*CV (%)*	*aBD (g/cm³)*	*CV (%)*	*BD (g/cm³)*	*CV (%)*
09	0.333	7.77	0.308	4.55	0.315	4.93
12	0.403	7.05	0.350	2.88	0.356	1.98
15	0.454	2.63	0.438	5.50	0.438	1.85
18	0.478	2.86	0.469	1.82	0.456	0.75
21	0.472	3.10	0.465	1.55	0.439	2.28
24	0.433	4.87	0.443	6.01	0.433	2.87
30	0.467	2.58	0.475	1.11	0.453	2.37
36	0.509	4.17	0.503	4.20	0.489	1.67
42	0.520	1.08	0.525	1.56	0.505	1.90

density of *Eucalyptus* wood tends to stabilize as the age increases.

Figure 2, obtained using the pooled data, illustrates the variation in basic density of all 3 clones as a function of age. The effect of age is described by the cubic model:

mBD = –0.018510 + 0.053200 * A – 0.001920 * A^2 + 0.000023 * A^3, with R^2 = 0.832 F = 260.89 and Sy.x = 0.0256 g/cm³

The tendency for the density value to stabilize itself in the intermediate portion of the curve is ascribed to the seasonal growth of the tree, which interferes with the annual response in density, by the formation of early and late tissues (xylem) (Kollmann and Côte, 1968).

The effect of age on wood basic density in each clone was also best described by a cubic model (table III and fig 3). The fit was even better for clones 2 and 3 in comparison with that observed for the 3 clones together, which is probably due to the fewer values considered, giving rise to less dispersion. Vital (1984) verified that the mean basic density of *E grandis* varies linearly with the age of the trees in accordance with the equations mBD = 389 + 25.4*A with R^2 = 0.71 and Sy.x = 36.34 kg/m³, when the ages varied from 1–7 years. Therefore, the continuity of this study will probably reveal a behaviour different from that found thus far.

Table II. Average wood basic density and its coefficient of variation (CV) in all 3 clones of *E saligna* at various ages.

Age (month)	*Basic density*	
	Average (g/cm³)	*CV (%)*
09	0.319	4.05
12	0.370	7.85
15	0.443	2.08
18	0.468	2.36
21	0.459	3.79
24	0.436	1.32
30	0.465	2.39
36	0.500	2.05
42	0.517	2.01

Bearing in mind the importance of the relations studied and the excellent quality of the results obtained in this study, it would be interesting to continue the sampling and studies with clones until rotation age. Complementary studies on the anatomical and

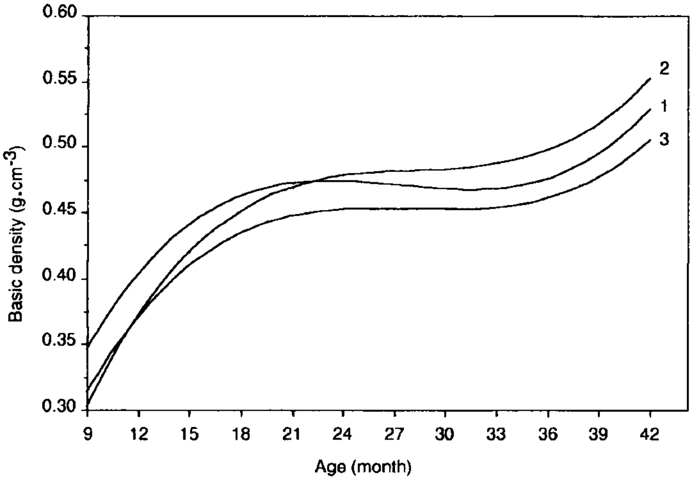

Fig 2. Estimates of the basic density (BD, g/cm^3) in relation to age (months) to clones 1, 2 and 3 of *Eucalyptus saligna*. (The adjusted equations are in table III).

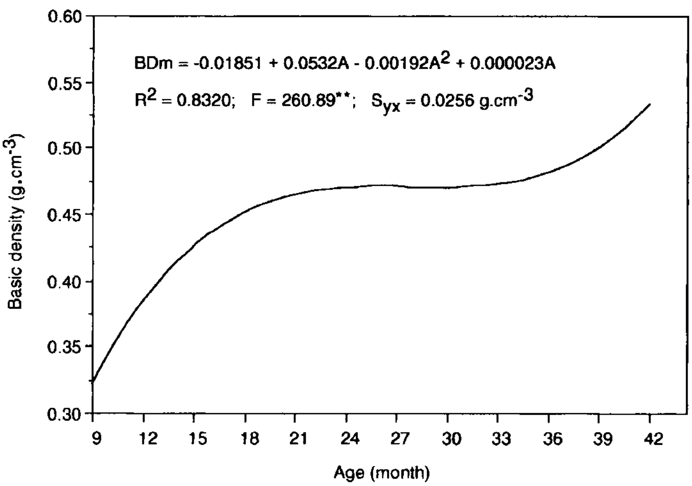

Fig 3. Estimate of the mean basic density (BDm, g/cm^3) in relation to age (months) for 3 clones of *Eucalyptus saligna*.

Table III. Adjusted equations for the estimation of basic density (BD, g/cm^3) in relation to age for each clone of *E saligna*.

Clone	*Equation*	R^2	*Sy.x*	*F* **
1	$BD_1 = 0.0151 + 0.052466 * A - 0.001966 * A^2 + 0.000024 * A^3$	0.789	0.0268	62.45
2	$BD_2 = -0.070743 + 0.057755 * A - 0.002030 * A^2 + 0.000024 * A^3$	0.888	0.0240	132.27
3	$BD_3 = 0.000867 + 0.049257 * A - 0.001767 * A^2 + 0.000021 * A^3$	0.895	0.0190	141.75

** Effects differ significantly ($P < 0.01$) using the F test.

chemical characteristics of the wood from these clones will help to better understand the phenomena observed. A repeat of the experiment would give an indication of climatic impact on the density growth curves.

CONCLUSION

It is possible to conclude, using as a base the experimental conditions, and the results obtained for the 3 clones of *E saligna* studied in the age range 9 months to 42 months, that: i) the wood basic density of the 3 clones grouped together can be estimated in function of age by the following equation:

$aBD = -0.018510 + 0.053200*A -0.001920 * A^2 + 0.000023 * A^3$, with $R^2 = 0.832$ and $F = 260.89$

ii) at the level of the clone, the basic density of each tree can be evaluated efficiently by the following cubic models:

clone 1: $BD_1 = 0.015179 + 0.052466 * A - 0.001966 + A^2 + 0.000024*A^3$

clone 2: $BD_2 = -0.070743 + 0.057755 * A - 0.002030 * A^2 + 0.000024 * A^3$

clone 3: $BD_3 = 0.000867 + 0.049257 * A - 0.01767 * A^2 + 0.000021 * A^3$

iii) the interclonal variation in relation to mean basic density presents small values (inferior to 3%); and in the case of trees of age superior to 15 months, the variation is the same.

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REFERENCES

Brown HP, Panshin AJ, Forsaith CC (1952) *Textbook of wood technology,* vol II, McGraw-Hill, New York, 783 p

Ferreira M (1972) Variação da densidade básica de madeira de povoamentos comerciais de *Eucalyptus grandis* W Hill ex Maiden nas idades de 11, 12, 13, 14 e 16 anos. *IPEF* 4, 85-90

Foelkel CEB, Busnardo CA, Dias C, Schmidt C, Silva RMR, Vezs JBV (1983) Variabilidade radial da madeira de Eucalyptus saligna. *In: Congresso Florestal Brasileiro, IV, Belo Horizonte,* 1982 Proc São Paulo, SBS No 28, 782-791

Freeze F (1970) *Métodos estadisticos elementales para técnicos forestales.* Wisconsin, USA, 104 p

Jesus RM de, Vital BR (1986) Comparação entre densidades de matrizes e de clones de *Eucalyptus grandis. Revista Árvore* 1, 82-90

Kollmann FPP, Côte WA Jr (1968) *Principles of wood science and technology. I. Solid wood.* Springer-Verlag, New York, 592 p

Limat JT, Rosado SCS, Oliveira AD (1990) Évaluation précoce de la densité du bois de clones de *Eucalyptus grandis. In: 19th World Congress/IUFRO,* Montreal, Canada, 1990, Proc, Vol 5, 440

Lima JT, Rosado SCS, Oliveira AD (1991) Variação da densidade da madeira de *Eucalyptus grandis, E tereticornis* e *E camaldulensis* no sentido longitudinal dos caules. *Revista Ciência e Prática* 16, 123-127

Nanson A (1976) Juvenile-mature relationships mainly in provenance and progeny tests. *In: IUFRO, Joint Meet Adv Gener Breed,* Proc, Bordeaux, 99-119

Panshin AJ, De Zeeuw C (1964) *Textbook of wood technology,* vol 1, McGraw-Hill, New York, 705 p

Rosado SCS (1982) Avaliação da densidade básica da madeira com diferentes idades, em *Eucalyptus* spp Viçosa, UFV, 79 p (ms thesis)

Vital BR (1984) Métodos de determinação da densidade da madeira. Viçosa, SIF, 21 p (Tec Bol 1)

Vital BR, Pereira AR, Della Lucia RM, Andrade DC (1984) Efeito da idade da árvore na densidade da madeira de *Eucalyptus grandis* cultivado na região do cerrado de Minas Gerais. Brasília, IBDF, 49-53 (Tec Bol 8)