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EARLY SELECTION OF FAST - GROWING EUCALYPTUS CLONES AND SPECIES

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ABSTRACT - Morphological and physiological parameters which correlate with growth rate were sought as early indicators of field performance. Seedlings of **Eucalyptus grandis** W. Hill ex Maiden, **E. urophylla**, S.T. Blake and **E. cloeziana** F. Muell., as well as tall and short groups of rooted cuttings of three **E. grandis** clones, were measured at four months of age (i.e., prior to out planting) and at 6 and 15 months after they were transplanted to the field. Size differences at the time of planting proved to be poor indicators of growth performance, as the smaller species and clones had caught up in size by 15 months. After 15 months of growth in the field, rooted cuttings as a group were similar in size to the seedlings. Seedlings of **E. grandis** had the greatest total dry weight, the lowest total leaf area, the lowest leaf area/root dry weight ratio and the lowest plant moisture stress of any stock type. Of the rooted cuttings, cv. 93 exhibited the greatest total dry weight, and had lower transpiration rates and plant moisture stress. Larger root systems and the ability to limit water loss and plant moisture stress appeared to be correlated with total dry matter production. Species and clones which maintained lower plant moisture stress while under drought grew faster after planting. These plants were characterized by higher xylem pressure potentials under drought and lower leaf area/root dry weight ratios both before and after planting.

RESUMO - A correlação de parâmetros morfológicos e fisiológicos com a taxa de crescimento era vista como um indicador precoce da performance no campo. Mudanças de semente de **Eucalyptus grandis** w. Hill (ex-Maiden), **E. urophylla** S.T. Blake e **E. cloeziana** F. Muell., bem como mudas de estacas de três clones de **E. grandis** separadas em grupos de mudas grandes e pequenas foram medidas aos quatro meses de idade (antes do plantio) e aos seis e quinze meses após o plantio. As diferenças em tamanho existentes por ocasião do plantio revelaram-se um indicador pobre da performance de crescimento na medida em que as espécies e os clones pequenos não apresentavam diferenças aos quinze meses. Após quinze meses, as mudas de estacas apresentavam crescimento em tamanho semelhante às mudas de semente. As mudas de semente de **E. grandis** apresentaram o maior peso seco total, a menor área foliar total, a menor taxa de área foliar/peso seco de raiz e o mais alto potencial hídrico, considerando-se todos os demais tratamentos. O clone

93 mostrou o maior peso seco total, as mais baixas taxas transpiratórias e o mais alto potencial hídrico, dentre os clones. O sistema radicular desenvolvido bem como a capacidade de limitar a perda de água e o estresse hídrico parecem estar correlacionados com a produção de matéria seca total. Espécies e clones que mantiveram altos potenciais hídricos sob condições de déficit hídrico, cresceram mais rapidamente após o plantio. Essas plantas caracterizavam-se ainda por apresentar baixas taxas de área foliar/peso seco de raiz antes e após o plantio.

INTRODUCTION

The development of a large number of new eucalypt clones and seedling provenances points to the need to identify criteria for early selection of fast-growing genotypes at an early age. The physiological basis of vigorous growth is poorly understood. More vigorous growth of faster-growing genotypes has been correlated with gibberellin levels (BATE; ROOD & BLAKE, 1988), water use efficiency (BLAKE & YEATMAN, 1989) and, in some studies, net photosynthesis (i.e., photosynthesis minus respiration)(SINHA & KHANNA, 1975). However, correlations between morphological and physiological parameters and growth in the field are often poor (CEULEMANS; IMPENS & STEENACKERS, 1988).

The influence of plant water status and growth rate appears to have received little study. However, BLAKE; TSCHPLINSKI & EASTHAM, 1984, showed that faster-growing hybrids had a greater ability to limit transpirational water loss compared with slower-growing clones, resulting in a higher water use efficiency - i.e., they fixed more carbon in photosynthesis per unit of water transpired.

This paper considers the relationship between morphological and physiological characteristics in four-month-old **Eucalyptus** planting stock at the time of planting and growth rates 6 and 15 months after planting. Stock types compared were seedlings of **Eucalyptus grandis** W. Hill ex Maid., **E. urophylla** S.T. Blake and **E. cloeziana** F. Muell. and, also, tall (T) and short (S) rooted cuttings of **E. grandis** of the same age: cv.33 , cv.79 and cv.93.

MATERIALS AND METHODS

On March 19, 1987, 15 seedlings of each species and 15 rooted cuttings of each cultivar, by size class, were analyzed for initial root, shoot (leaf plus stem) and whole plant dry weight. Leaf areas were determined before drying using a Li-3000 planimeter (Li-Cor Inc., Lincoln, Nebraska). Provenances of seedlings and the methods of raising rooted cuttings are as described previously (BLAKE & SUITER FILHO, 1988). Seedlings and cuttings, 288 per treatment, were planted in the field in May 1987.

The planting site is located near Bom Despacho, Brazil, at an altitude of 703 m, where the mean annual precipitation is 1375 mm. The site is flat to undulating in topography, comprising of a dark red latosol soil with high clay content, typical for this humid, sub-tropical region.

The field trial was laid out as a replicated block design. Each of the 16 blocks consisted of 18 rows of plants, two rows per treatment, with nine plants per row. Thus, there were 18 plants per treatment per block, providing 288 plants per treatment, for a total of 2592 plants: The material was planted at a conventional spacing of 3m x 1.5m. Three

rows of edge trees surrounded each block. The experimental plots were established by the Companhia Agricola e Florestal Santa Bárbara, Minas Gerais.

For growth analysis, the height and diameter of every tree from each block were recorded at 6 and 15 months after planting. In addition, 72 plants per treatment from four blocks were harvested at 6 months for dry weight determination, while another 18 trees per treatment from two blocks being destructively sampled at 15 months; Root and shoot dry weights were recorded for each tree at 6 months, however, root dry weights at 15 months were collected for only one-third of the harvested trees due to the amount of work involved with the root excavation. Shoots were separated into leaves, branches and main stem for dry weight determination.

Stomatal conductance (g_{wv}), transpiration rate (T_1), net photosynthesis (P_n) and xylem pressure potential (Ψ_x) were measured for detached branches from six plants per stock type: 9 and T_1 were measured with a Li-Cor Li-1600 Steady State Porometer (Li-Cor Inc., Lincoln, Nebraska), P_n with a Li-Cor Li-6200 Portable Photosynthesis System, and Ψ_x with a Scholander-type pressure bomb (PMS Instruments, Corvallis, Oregon). It was first established that physiological parameters were not affected, in the short term, by detachment of the branch.

Plants measured were 22-months-old, 18 months after planting. Two leaves per tree, 3 and 4 nodes from the end of the branches were sampled. The branches were collected half-way up the stem, i.e., at 2 m above the ground. Prior study (TSCHAPLINSKI & BLAKE, 1989) had established that photosynthetic differences between faster- and slower-growing poplar clones were more evident on the middle and lower leaves, compared with those on the upper crown. Physiological readings were made within 0.5 minutes of detaching branches from the tree.

Readings were taken every few hours over the course of the day for 3 consecutive days. Physiological readings were taken in the open, 1 m above the ground, on bright, sunny days. Photosynthetically active radiation (PAR) at midday on the measurement days (i.e., 07 to 09 September 1988) ranged from 832 to 1880 $\mu\text{mol m}^{-2} \text{s}^{-1}$, air temperature from 31.0 to 41.6°C, leaf temperature from 32.0 to 45.8°C, and relative humidity from 7.4 to 31.5%. The plants were experiencing drought at the time of physiological measurements due to the absence of rain on the planting site for the preceding 100 days.

Tissue water parameters, including the turgor loss point (TLP), were measured for 4 plants per stock type by pressure-volume (P-V) curve analysis techniques involving simultaneous measurement of x and water loss. The TLP was calculated from the inflection point in the curve generated by regression analysis, when the reciprocal of Ψ_x is plotted against relative water content. Techniques are as previously described (BLAKE & SUITER FILHO, 1988).

Statistical analysis was by analysis of variance (ANOVA) using SAS/PC, and a Student's 't' test was used to calculate least significant difference (LSD) among means. The level of statistical probability used for determining significant differences was $P=0.05$, unless otherwise stated.

RESULTS AND DISCUSSION

Growth parameters

At the time of planting the short rooted cuttings were the smallest in terms of height, diameter, and shoot, root and total plant dry weight (Fig. 1a and b). The tall rooted cuttings, although having the same height as the seedlings, were intermediate in dry weight, while the seedlings were the largest as regards height and dry weight of shoots, roots and total plant (Fig. 1a and b).

During the first six months of field growth, the clones grew faster than the seedlings. The tall clones grew the fastest, averaging 1.55 g day^{-1} , and had largely caught-up to the seedlings in most dry matter parameters. The short clones were still significantly smaller than the tall clones, although the relative differences in their sizes had decreased.

After 15 months of field growth seedlings were growing at a faster rate than the rooted cuttings, averaging 12.75 g day^{-1} in total dry weight, compared to 10.37 g day^{-1} for the clones. There were no significant differences between tall and short clones in any of the growth parameters (Fig. 1a and b), demonstrating that initial size differences at the time of planting are poor indicators of field performance.

The tallest plants at 15 months were **E. urophylla** seedlings. Although **E. cloeziana** was significantly shorter than the other treatments, there were no significant differences between any of the stock types in terms of above-ground dry weight (Fig. 1a and c). **E. grandis** seedlings were the heaviest with respect to root and total plant dry weight (Fig. 1b and c), and had the fastest growth of all the treatments during the first 15 months, averaging 15.80 g day^{-1} .

E. grandis had the greatest specific leaf area (i.e., the largest leaf surface area per unit leaf dry weight), yet had the smallest and light-test leaves, and the lowest total leaf area per tree, of all the treatments. **E. cloeziana** had the greatest leaf area per tree, with the seedlings as a group having more leaf area than the rooted cuttings after 15 months of field growth (Fig. 1d).

Of the clonal stocks, cv. 33 was significantly taller than cv. 93 and cv. 79, which did not differ significantly from each other (Fig. 1a). However, cv. 93 was significantly heavier and had a larger root system than the other rooted cuttings (Fig. 1c). This cultivar also had a faster growth rate-over the 15 month period, producing 11.64 g day^{-1} of total dry mass.

Physiological parameters

The seedlings had significantly lower g_{wv} , T_1 and P_n relative to the rooted cuttings for the three measurement days, while there was no significant difference between species (Fig. 2a, b, and c). Since no rainfall had fallen for 100 days, plants were exhibiting signs of water stress, and average Ψ_x differed markedly between species. **E. cloeziana** had the lowest (i.e., most negative) pressure potentials, with values averaging less than -3.0 MPa (Fig. 2d), i.e., well below its TLP.

In fact, **E. cloeziana** showed evidence of water stress by the loss of its lower leaves and by having wavy leaf margins. In addition, there was a yellowing or chlorosis of the leaves around the main vein, which could indicate that water stress was limiting nitrogen and magnesium uptake (BONNER & GALSTON, 1952). **E. grandis** seedlings had a significantly greater Ψ_x compared to the other species and clones, indicating it suffered less water stress.

Clonal differences were observed in physiological parameters, with cv. 79 and cv. 33 having significantly higher g_{wv} , T_1 and Pn compared to cv. 93. The same two clones also had significantly lower Ψ_x relative to cv. 93 (Fig. 2d).

Tissue water parameters showed that seedlings lost turgor at lower water potentials, i.e., they had a lower TLP, ranging from -2.2 to -2.7 MPa in the seedlings and from -2.1 to -2.3 MPa in the rooted cuttings.

Comparisons of growth and physiological parameters at 15 months

E. grandis, which had the greatest total dry mass at planting, was still the heaviest at 15 months. This seedling stock had the fastest growth of the three **Eucalyptus** spp., despite having the smallest leaf area per tree (Fig. 3a). By comparison, **E. urophylla** had approximately the same leaf area per tree as **E. cloeziana**, yet had the slowest growth of the three species. A lower leaf area per tree in **E. grandis** was compensated for by a higher net photosynthesis per unit leaf area.

This indicates a higher photosynthetic efficiency in the **E. grandis** leaves compared to the other species. Fig. 3b illustrates this point by the observed relationship between the mean net photosynthetic rate taken over three days and the average daily total dry mass growth over the past 15 months. A beneficial effect of the relatively low leaf area and T_1 that water loss is kept to a minimum, thereby reducing plant moisture stress.

This association between Pn and growth was not evident in the rooted cuttings. In fact, there appeared to be an inverse relationship between the two variables (Fig. 4b). Cv. 79 had the slowest growth, despite having the greatest leaf area and highest Pn (Fig. 4a and b). One reason for its poor growth performance may have been that it was more moisture stressed than the other cuttings, as evidenced by a lower Ψ_x observed over 2 days (Fig. 2d).

In a previous study (BLAKE & SUITER FILHO, 1988), it was reported that eucalypt rooted cuttings were smaller and were more moisture stressed than seedlings when droughted at the time of planting, due partly to a greater leaf area relative to root dry weight and an inability of stomata to control water loss in transpiration. Fig. 5a and b demonstrate that a lower leaf area/root dry weight (L/R) ratio may be of importance in eucalypt growth.

For both seedlings and cuttings, the planting stock with the lowest L/R ratio grew the fastest. In addition, the faster-growing type in each category, **E. grandis** and cv. 93, respectively, were less water-stressed, as shown by the higher Ψ_x (Fig. 2d). **E. grandis** seedlings also had the lowest L/R ratio and were the least stressed when droughted at the time of planting (BLAKE & SUITER FILHO, 1988).

E. cloeziana, which was the smallest species at the time of planting, had caught up to **E. urophylla** in shoot, root and total dry mass at 15 months, despite very low Ψ_x values when measured under drought conditions at the time of planting (BLAKE & SUITER FILHO, 1988) and after 18 months growth in the field (Fig. 2a). The low Ψ_x may be a result of a large L/R ratio, as the root systems were not able to supply sufficient moisture to compensate for the large transpiring surface.

This species had the largest absolute leaf mass and leaf area, and visual symptoms suggested this species may have reached the wilting point under the drought conditions pertaining at the time of measurement. A greater water stress in this species would explain the slower growth in height and diameter, compared with **E. grandis**.

It is now generally accepted that a reduction in growth is one of the first signs of water deficits. It has been hypothesized (KRAMER, 1986) that water stress may limit growth more than the rates of physiological processes, such as photosynthesis. The control of leaf area and, hence, water transpiring surface, may be one of the more powerful means a mesophytic plant has of influencing its growth rate when subject to longer-term water stress in the field (BEGG, 1980, HALE & ORCUTT, 1987). This occurs due to changes in leaf morphology, leaf senescence, and L/R ratio. All of these were found to differ between faster- and slower-growing clones and seedlings. Criteria such as these influence growth and could be used as selection criteria to identify faster-growing, drought-adapted clones, species and provenances.

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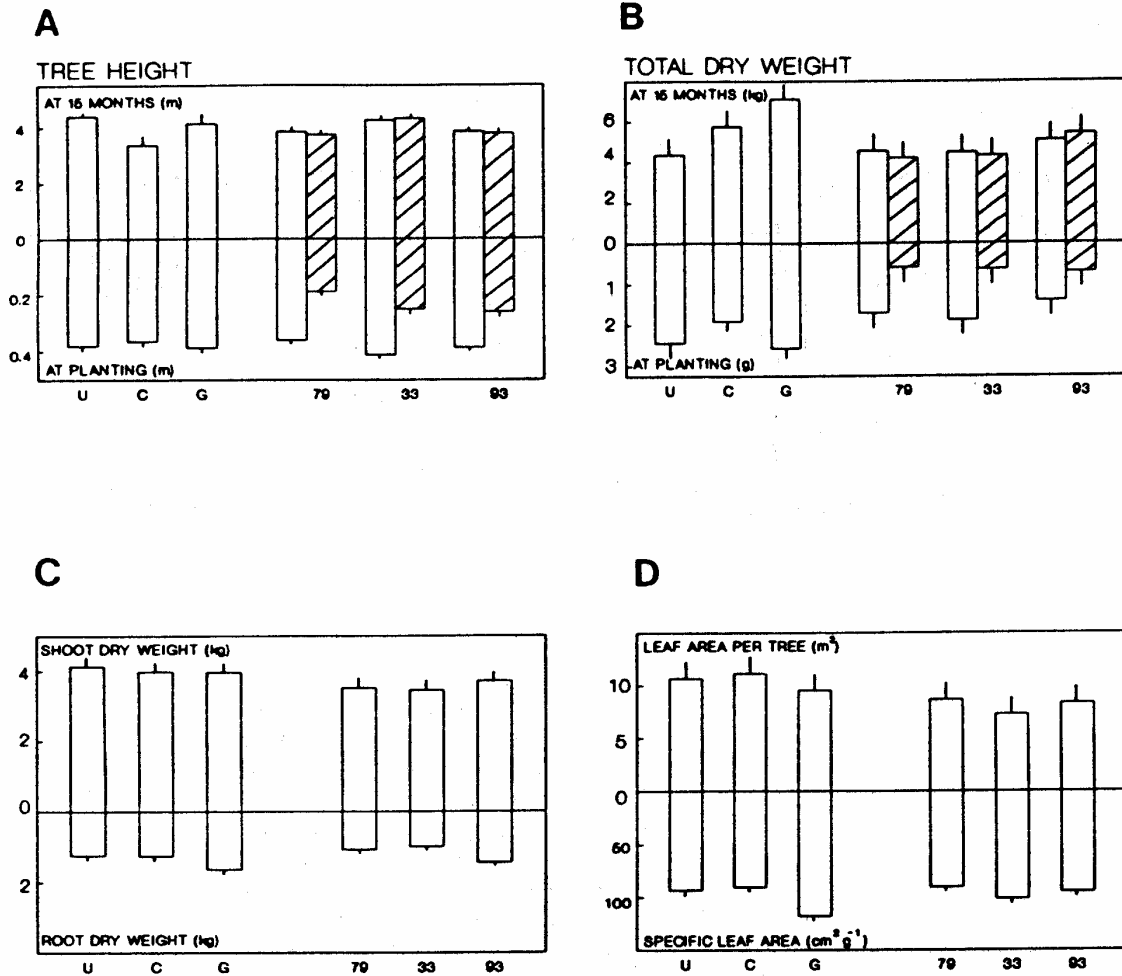
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FIGURE 1 - Comparison of (A) tree height and (B) total dry weight at the time of planting (4 months of age) and at 15 months after planting (19 months of age). Shoot and root dry weights (C) and total area per tree and specific leaf area (D) measure 15 months after planting. Stock types were as follows: Seedlings - *E. urophylla* (U), *E. cloeziana* (C) and *E. grandis* (G); and rooted cuttings of *E. grandis* - clones 79, 33, and 93, separated into tall (□) and short (▨) groups. Vertical line represents standard error of estimate.



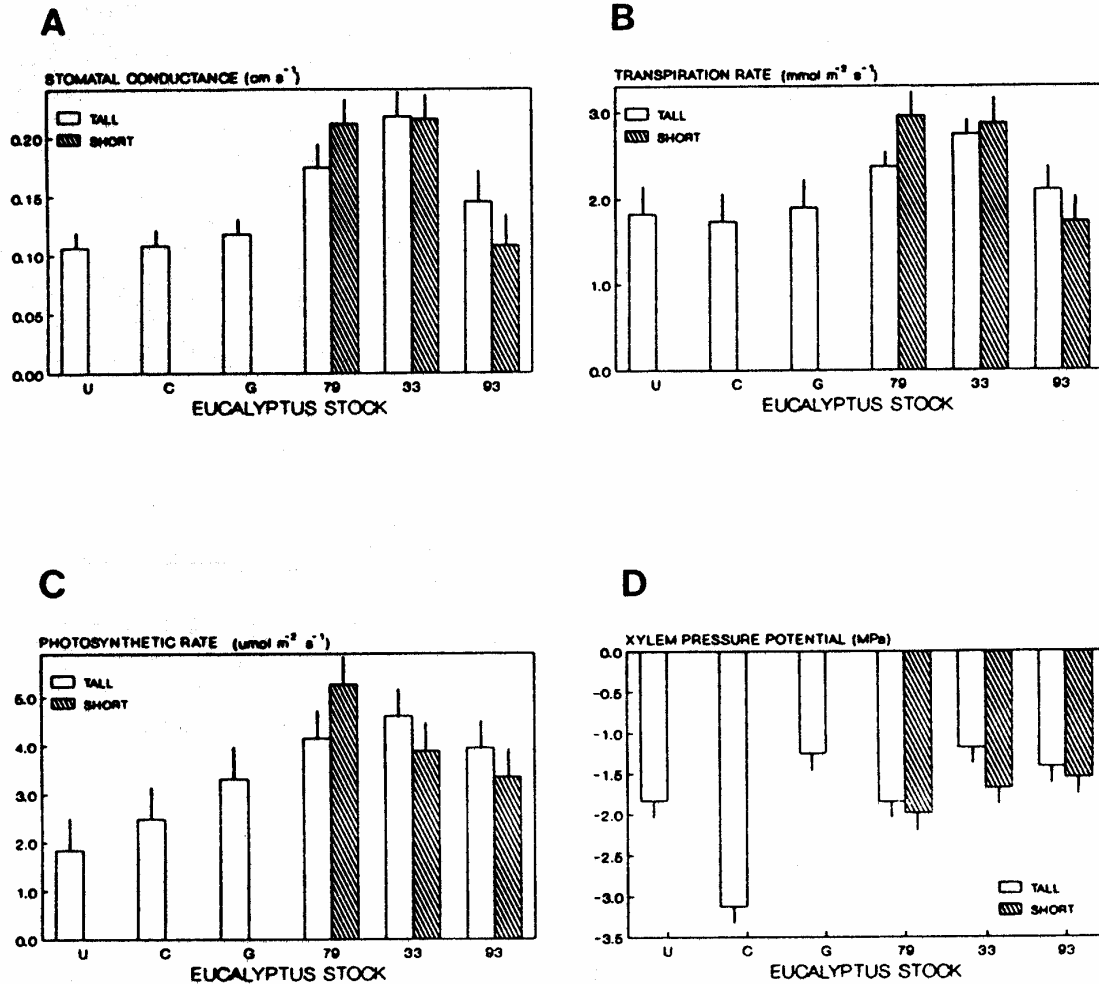


FIGURE 2 - Mean (A) stomatal conductance, g_{wv} (cm s^{-1}), (B) transpiration rate, T_1 ($\text{mmol m}^{-2} \text{s}^{-1}$), (C) net photosynthesis, P_n ($\mu\text{mol m}^{-2} \text{s}^{-1}$), and (D) xylem pressure potential, U_x (Mpa) measure for seedling of 3 *Eucalyptus* spp., and tall and short rooted cuttings of 3 *E. grandis* clones. Stock types were as follows: Seedlings - *E. urophylla* (U), *E. cloeziana* (C) and *E. grandis* (G); and rooted cuttings of *E. grandis* - clones 79, 33, and 93, separated in tall (□) and short (▨) groups. Vertical lines represent standard error of estimate.

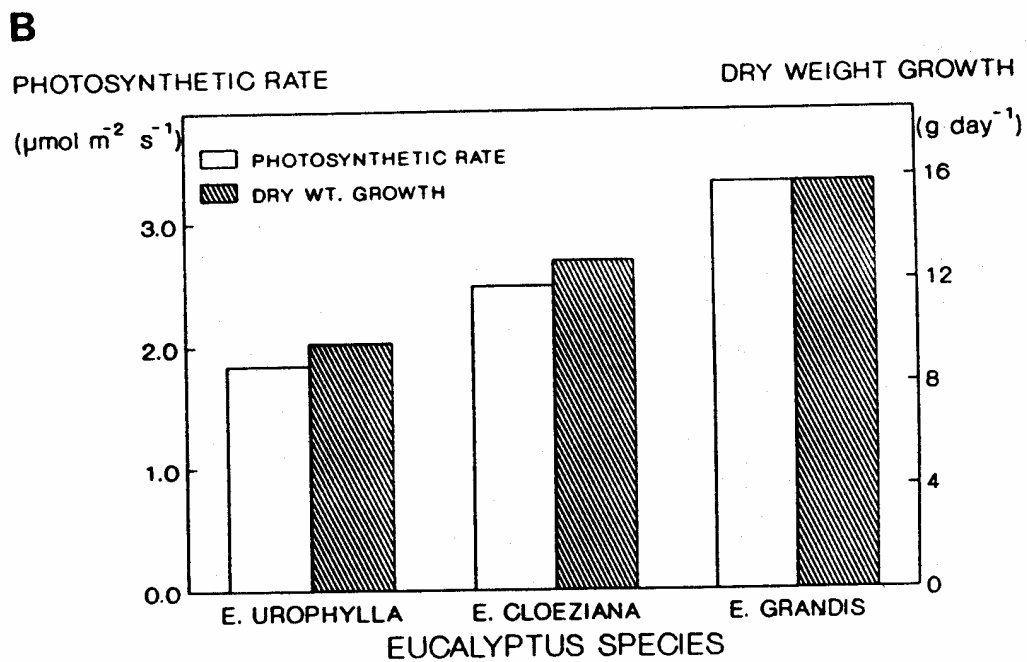
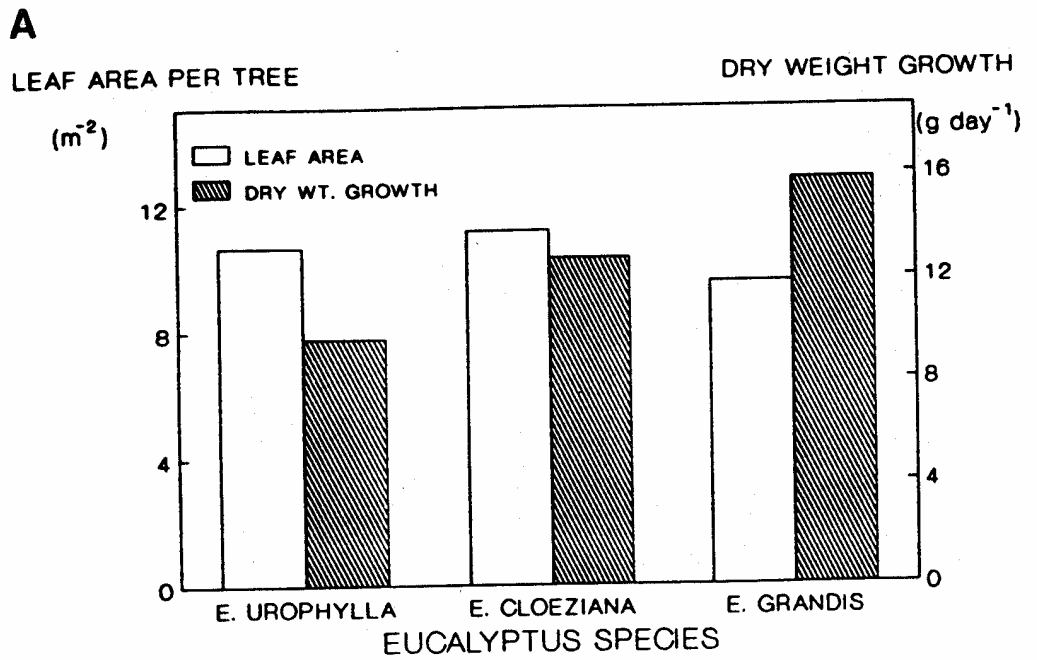
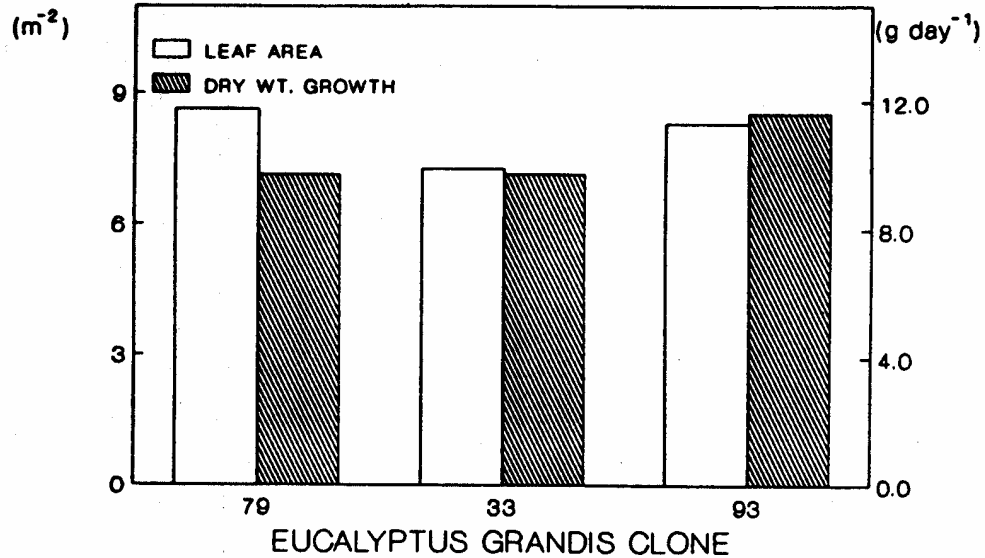


FIGURE 3 - Comparison of dry matter growth, g day⁻¹ (▨) with (A) total leaf area per tree, m² (□) and (B) net photosynthesis (μmol m⁻²s⁻¹), (□). These parameters were measured 15 months after planting for seedlings of 3 *Eucalyptus* spp.

A

LEAF AREA PER TREE

DRY WEIGHT GROWTH

**B**

PHOTOSYNTHETIC RATE

DRY WEIGHT GROWTH

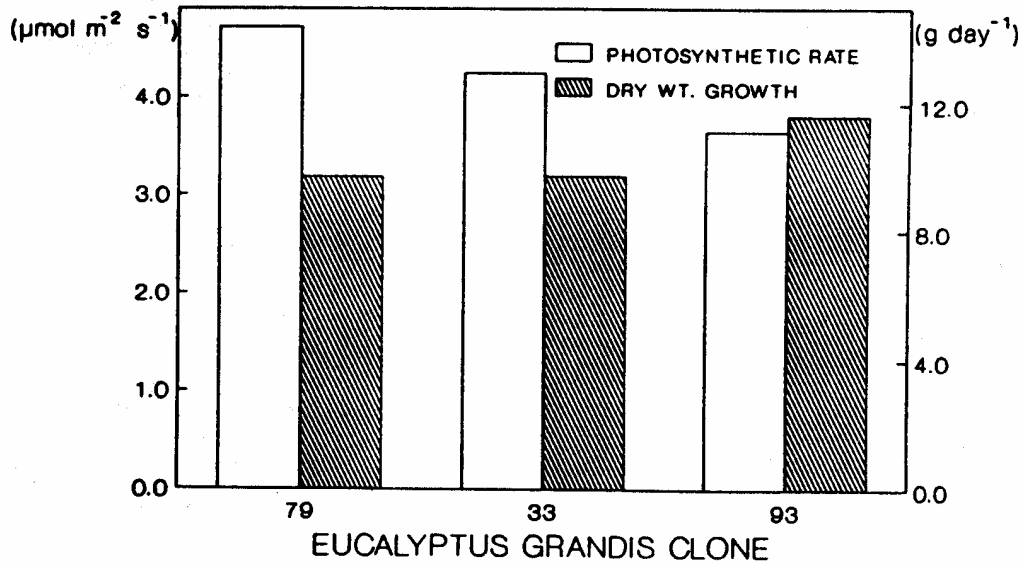


FIGURE 4 - Comparison of dry matter growth, g day^{-1} (\square) with (A) total leaf area per tree, m^2 (\square) and (B) net photosynthesis ($\mu\text{mol m}^{-2}\text{s}^{-1}$), (\square). These parameters were measured 15 months after planting for seedlings of 3 *Eucalyptus grandis*: 79, 33 and 93.

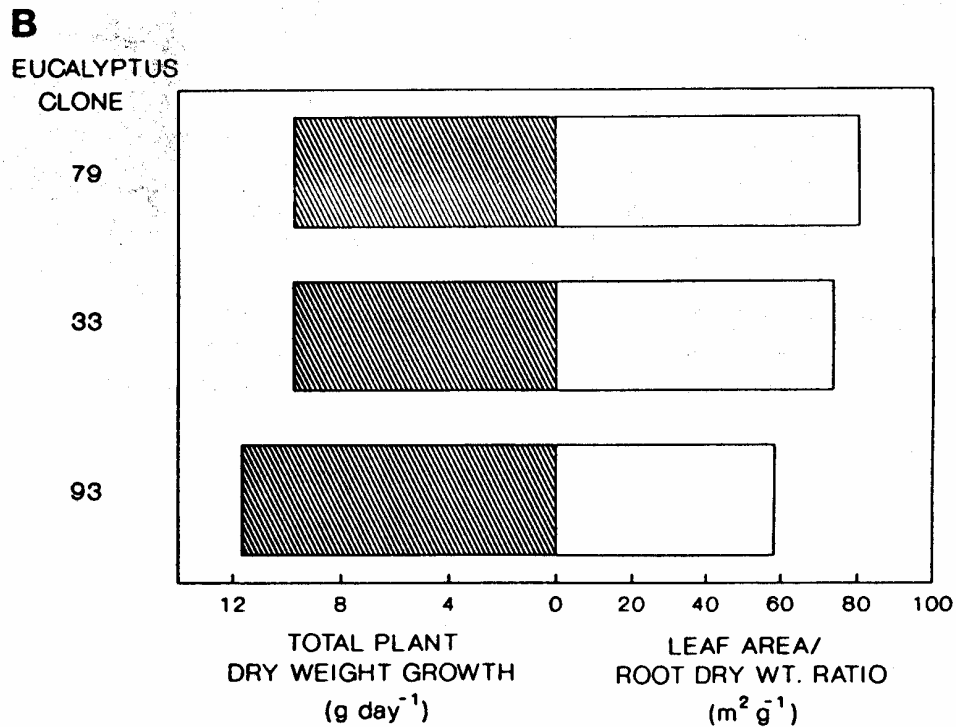
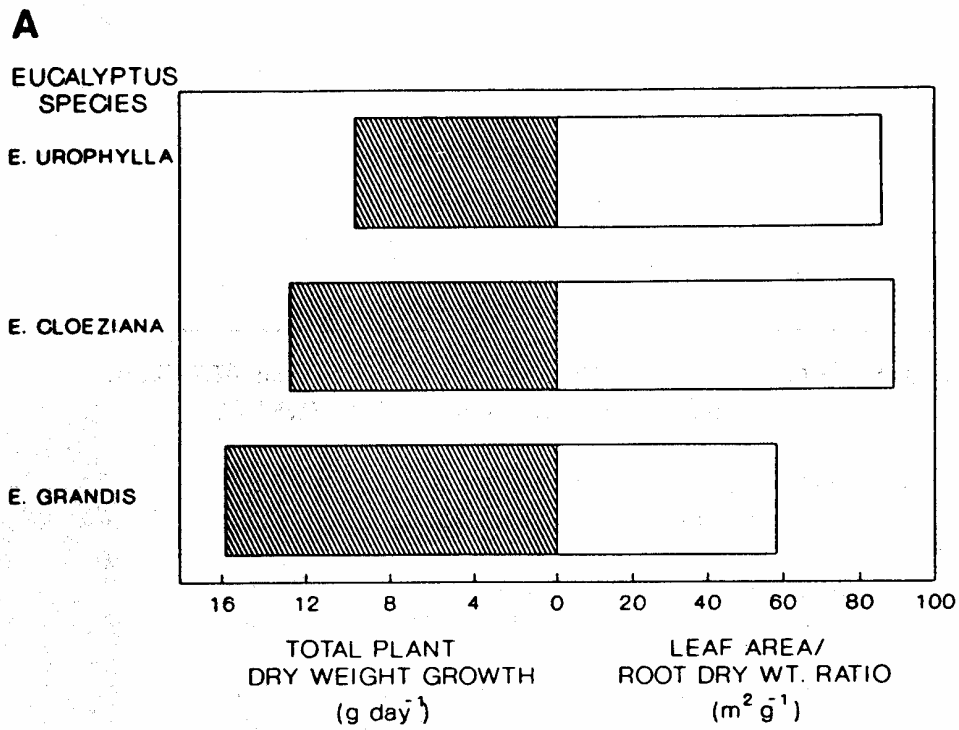


FIGURE 5 - Average total plant dry weight growth (g day⁻¹) compared with the leaf area/root dry weight ratio (m² g⁻¹) for (A) 3 *Eucalyptus* spp., and (B) 3 *Eucalyptus grandis* clones.

CAF – O DESENVOLVIMENTO DE ALTERNATIVAS ENERGÉTICAS A PARTIR DA PRODUÇÃO DE CARVÃO VEGETAL

A CAF; Cia Agrícola e Florestal Santa Bárbara, é a empresa do grupo Belgo-Mineira responsável pelo reflorestamento e a produção de carvão.

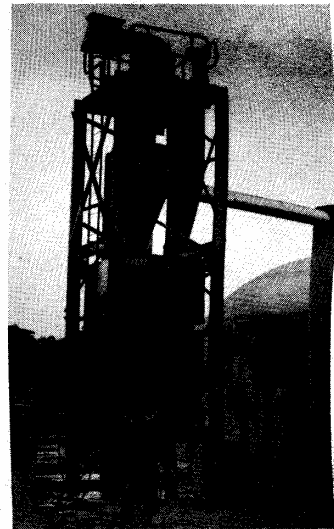
A madeira para a produção de carvão é proveniente das florestas homogêneas de eucalipto de alta produtividade, abrangendo uma extensão superior a 150.000 ha.

O seu modelo de expansão é apoiado na implantação de carvoarias de grande porte, com a recuperação dos combustíveis líquidos da madeira, especialmente o alcatrão e o metano¹. Faz parte deste modelo a implantação de fornos contínuos de carbonização.

Este ano, 9.000 t de alcatrão serão recuperadas; em parte da produção de 310.000 t de carvão vegetal, segundo tecnologia e equipamentos desenvolvidos pela própria empresa.

A CAF integra o homem ao ambiente onde realiza suas atividades, dando-lhe condições adequadas de saúde, educação, habitação e trabalho.

Assim, é uma empresa que reúne o homem, a técnica e a terra para produzir energia de fonte brasileira, renovável e com tecnologia inteiramente nossa contribuindo de maneira significativa para o esforço nacional de desenvolvimento de alternativas energéticas.



Recuperador de alcatrão em fornos de alvenaria