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Eucalyptus/Leucaena MIXTURE EXPERIMENT - GROWTH AND YIELD

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ABSTRACT - The growth and yield of **Eucalyptus urophylla** Blake and two varieties of **Leocaena leucocephalla** (Lam) de Wit[Brewbaker's vars K8 and K72] in pure stands and two-species mixtures were assessed over a seven year rotation. A randomized complete block design was used with 3 replications and 5 treatments with 64-tree block plots established at 2.73m x 2.73m spacing. Mixtures consisted of alternate rows of **Eucalyptus** and **Leucaena**. The experiment was established on moderately fertile soil in the humid/subhumid tropical climate of coastal Espírito Santo, Brazil. Complete site preparation, fertilizer application and weed control further improved the site conditions for both species. At the age of 7 years, the **Eucalyptus** were all single-stemmed with an average height of about 20m and dbh_{ob} of 19cm, while the **Leucaena** were multi-stemmed (2-2 stems/tree), with an average height of 13m and dbh_{ob} of 19cm per stem. **Leucaena** survival ranged from 95 to 100%, while **Eucalyptus** survival was 75%, when grown pure, and only 50 to 65%, when grown in mixture with **Leucaena**. Yields varied between 31 and 46 m^3/ha/yr, with maximum yield in the pure **Eucalyptus** treatment, intermediate yields in the two species mixtures and lowest yields in the pure **Leucaena** treatments. Tables are presented of stacked and solid volume yields, dry matter biomass and charcoal production. It is suggested that under good soil fertility conditions, there is no advantage in growing **Leucaena** and **Eucalyptus** in mixture.

RESUMO - Foram avaliados, numa rotação de sete anos, o crescimento e a produção de **Eucalyptus urophylla** Blake e duas variedades de **Leucaena leucocephalla** (Lam) de Wit [vars K8 e K72 de Brewbaker] em plantios puros e em consórcios. Foi utilizado um delineamento de blocos completos ao acaso com 3 repetições, 5 tratamentos e com 64 árvores por parcela no espaçamento de 2,73m x 2,73m. O consórcio consiste em linhas alternadas de **Eucalyptus** e de **Leucaena**. Aos sete anos de idade, o **Eucalyptus** apresentava-se com fuste simples e uma altura média aproximada de 20m e DAP de 19cm, enquanto a **Leucaena** apresentava vários fustes por planta (2-3 fustes/planta) com uma média de altura de 13m e DAP de 9cm por fuste. A sobrevivência da **Leucaena** ficou entre 95 e 100%, enquanto a sobrevivência do **Eucalyptus** foi de 75% em plantio puro e somente 50 a 65% quando em consórcio com **Leucaena**. A produtividade variou entre 31 a 46 m^3/ha/ano máxima no tratamento com **Eucalyptus** puro, produção intermediária nos consórcios e menor nos tratamentos com **Leucaena** pura. São apresentadas tabelas de

produção para volume empilhado e sólido, matéria seca e produção de carvão. Por tratamento também são apresentados gráficos comparando determinadas características edáficas na época da implantação do ensaio com a situação no momento do corte. Teores de alumínio, fósforo, potássio, cálcio, magnésio, matéria orgânica e pH são os parâmetros edáficos comparados.

INTRODUCTION

Eucalyptus urophylla S. T. Blake grows well in tropical or subtropical regions with over 1000 mm of rainfall (NATIONAL ACADEMY OF SCIENCES, 1983). It is well known in Espírito Santo, Brazil, since it is one of the parents of a high yielding hybrid which is widely planted for pulp and charcoal. **Eucalyptus urophylla** has also been planted in the Canga, both as apure species and in hybrid combination (DELWAULLE, 1985; CORBASSON, 1986). **Leucaena leucacephalla** (Lam) de Wit has been widely acclaimed as a multipurpose tree for lowland tropical regions (NATIONAL ACADEMY OF SCIENCES, 1984). It has been particularly popular because of its nitrogen fixing abilities and multiple uses. Hawaiian giant types of **Leucaena leucocephalla** varieties K8 and K72 were introduced to the Companhia Vale do Rio Doce (CVRD*) forest reserve of Linhares in the late 1970's.

An experiment comparing artificial inoculation of **Leucaena** var K72 with natural rhizobial infection and with growth under nitrogen fertilization was performed at the CVRD forest reserve FARIA et alii (1985). This showed that although artificially inoculated plants grew taller at all stages, differences in height growth response tended to decrease with time until no significant differences were detectable after 325 days in the field. Natural inoculation was assumed to have occurred on the **Leucaena** plants used for this experiment. In an attempt to determine the possible effects of Leucaena on the growth of other trees in polyculture, a replicated experiment was established in 1978.

MATERIALS AND METHODS

The climate in the region near the CVRD forest (18° 50'S & 39° 50'W) has been described by (GOLFARI et alii,1978)as tropical, humid to subhumid, with a mean annual temperature between 23° and 27°C, no frost, a mean annual precipitation of 1000 to 1700 mm with periodic summer rainfall and moderate winter water deficits. The experimental site was located on a recent clearing in the Atlantic high forest.

All the planting stock was seedling material. A randomized complete block design was used with 3 replications and 5 treatments with 64-tree block plots established at 2.73 x 2.73 m spacing. The study consisted of the following single-species and mixed plots: pure **Eucalyptus** (E); pure **Leucaena** variety K8(K8), pure **Leucaena** variety K72 (K72), and the two possible **Eucalyptus-Leucaena** mixture (E + K8 and E+ K72). Mixtures consisted of al ternate rows of Eucalyptus and **Leucaena**. The site was ploughed, broadcast limed at the rate of 2 tons of dolomitic limestone per hectare, fertilized at the rate of 20 grams of ammonium sulphate, 110 grams of single superphosphate and 20 grams of potassium chloride per planting hole at the time of planting, and kept free of weeds and epiphytes

* CVRD = Companhia Vale do Rio Doce is the parent mining company to Florestas Rio Doce S.A. (FRD/S.A.) a forestry subsidiary.

manually for the first 1:5 years. This silvicultural treatment was similar to operational techniques used in CVRD'S commercial Eucalyptus plantations. Initial soil analyses indicated that the site was moderately fertile, and fertilizer amendments can be assumed to have reduced any potential impact of nitrogen fixation by the **Leucaena**.

The experiment was measured annually. Survival, over-bark diameter at breast height (dbh), and total tree height were recorded. Survival was calculated on the basis of averages over the three blocks with 64 trees per plot. The **Leucaena** trees were mostly multi-stemmed, with up to 6 stems per tree, 50 the dbh and height of each stem were measured and recorded separately. Cylindrical volumes were calculated from these periodic measurements, Average diameters and heights are given on a per-stem basis, while cylindrical volumes are on a per-stem basis for the single stemmed **Eucalyptus** and summed over all stems for the multi-stemmed **Leucaena** trees.

The experiment was clear felled at age 7 years. The stems were cross cut into billets with an upper diameter limit of 7 cm overbark. All stem wood was stacked, and the volume of stacked wood measured in steres (1 stere = a stack of dimensions 1 m x 1 m x 1m). Subsamples of stacked wood were measured for volume and weight of green wood, 50 that factors could be calculated for conversion of stacked to solid overbark volume. The central four trees of each species from each plot were sub-sampled for determination of basic density and charcoal conversion percentage on a dry weight basis. Standard procedures were used for determination of basic density and charcoal conversion using wood from wedges taken from breast-height discs of the four central trees in each plot. Basic density was determined by the water displacement method using a hydrostatic balance and saturated and oven-dry weights. Charcoal conversion was determined on small samples of known oven-dry weight placed in a small-scale laboratory kiln. These two factors were used to calculate woody dry matter biomass and charcoal productivity per plot.

Briefly, stacked volume in steres was measured directly, solid volume was obtained by multi-plying stacked volumes by conversion factors (calculated ar each block and species), solid volume was multiplied by basic density (different for the two species) to give biomass production in metric tons of oven-dry wood. Charcoal production was obtained by multiplying dry matter biomass by charcoal conversion rates calculated for each species. All plot productivity values were standardized to a per hectare per year basis by scaling for plot size and dividing by age in years.

Standard analysis of variance (ANOVA) procedures were used to partition total variance into effects due to blocks and treatments. In this experiment with five treatments it is possible to construct four orthogonal contrasts to test differences between treatments. The F-test for treatments in the analysis of variance averages the contributions of the four single degree of freedom contrast sums of square and could thus obscure significant treatment differences. CHEW (1977) pointed out that when meaningful contrasts among treatment effects can be constructed, then testing each contrast separately is preferable to pooling them together and possibly declaring treatment5 non-significant. As this experiment was designed to evaluate the relative performance of pure species versus mixture treatments, the following orthogonal contrasts were constructed:

CONTRAST	E	E+K72	E+K8	K72	K8
Pure **Eucalyptus** versus others	4	-1	-1	-1	-1
Mixture versus pure **Leucaena**	0	1	1	-1	-1
Between mixture treatments	0	1	-1	0	0
Between **Leucaena** varieties	0	0	0	1	-1

Similar ANOVA's and partitions of treatment sums of squares into orthogonal contrasts were carried out using as dependent variable the following measures of production: stacked volume, solid volume over-bark, dry matter and charcoal biomass.

RESULTS AND DISCUSSION

The results will be presented in two groups:

- Those based on the annual measurements of individual stems, including survival, mean diameter, mean height and mean cylindrical volume. These are pre5ented graphically and should provide a basis for the comparison of relative performance over the duration of the experiment.
- Those based on measurements of the final crop after felling, including stacked and solid volume, woody dry matter biomass and charcoal production, enabling the forest manager to evaluate the relative merits of the different treatment alternatives after a full rotation.

1. Annual measurements

Leucaena survival was always over 95% whereas **Eucalyptus** mortality continued over the life of the project, with higher mortality (up to 50%) in the mixed treatments (see Figure 1). **Eucalyptus** mortality was probably due to attack by the **Eucalyptus** canker **Cryphonectria cubensis**. Sporulation and infection in this pathogenic fungus are favoured by humid conditions. It is postulated that the higher **Eucalyptus** mortality in the mixture treatments may have been due to higher humidity caused by the shade cast by the lower and denser **Leucaena** crowns.

Mean height, diameter and cylindrical volume are presented in Figure 2 and 3. Despite the mortality and lower stocking, **Eucalyptus** showed higher biomass productivity. Height and diameter were relatively unaffected by treatment whereas total cylindrical volume was highest for pure Eucalyptus, intermediate for the mixtures and lowest for pure **Leucaena**. The cylindrical volumes are clearly overestimates, but true solid volume (with and without bark) was calculated after the trees were felled and these data are presented in Table 1.

2.Measurements of the final crop

Standardized productivity values are presented in Table 1 below of the production per hectare per year at seven years for the various treatments and measures of production: stacked and solid volume, dry matter and charcoal biomass. Although there were only small differences in productivity between **Eucalyptus** and **Leucaena**, the multi-stemmed **Leucaena** diameters were less than half these of the **Eucalyptus**. Harvesting costs are much higher when dealing with many small stemmed trees and will affect the relative profitability of alternative silvicultural regimes.

TABLE 1 - Productivity per hectare per year expressed as stacked volume, over bark and under bark solid volume, dry matter and charcoal biomass after seven years.

Treatment	Productivity per hectare per year				
	Stacked volume (steres)	Solid m^3_{ob}	Volume m^3_{ub}	Woody dry matter (tons)	Charcoal (tons)
Euc + LK8*	56.0	40,0	33.5	23.3	8.2
L K8	49.2	33,2	29.2	20.8	7.2
Euc	60.1	46.3	36.9	24.9	9.0
Euc + LK72*	60.5	41.9	35.2	24.1	8.6
L K72	57.2	31.0	27.4	19.0	6.5

* The **Eucalyptus** and **Leucaena** contributed approximately equally in both mixture treatments for all productivity traits.

An analysis of variance was conducted on stacked volume as the dependent variable separating the total variance into effects due to blocks and treatments. The treatment sum of squares was further divided into components due to the four contrasts. None of the contrasts were significant at the p = 005 level. Thus no differences in productivity of stacked wood with bark were detectable among the five treatments.

A second ANOVA was calculated using solid volume over-bark as the dependent variable. The results showed that for solid volume, pure **Eucalyptus** is more volumetrically productive than any other treatment and also that treatment including **Eucalyptus** (pure or 50% mixture) is more productive than pure **Leucaena** treatments. No significant differences were found between the two mixture treatments or the two **Leucaena** varieties. The explanation for the differing conclusions when we consider solid volume versus stacked volume can be explained by the different stacking properties of the cut stems of the two species. The straighter stems of Eucalyptus stacked more efficiently (1 stere = 0.770 m^3) than the more crooked **Leucaena** stems (1 stere = 0.614 m^3).

When he same analyses were performed with dry matter index (DMI = volume x wood basic density), the contrasts again showed no significant differences between treatments. This can be explained by the difference in wood density between **Eucalyptus** and **Leucaena.** Although **Eucalyptus** produces more solid volume, its wood is less dense (540 Kg/m^3) than the lower yielding but denser **Leucaena** (620 Kg/m^3).

Finally, the same analysis using charcoal productivity as dependent variable again failed to detect any differences between the treatments. This can be explained by the fact charcoal productivity is the product of dry matter index and charcoal yield on a dry weight basis. There were no significant differences in dry matter index for the five treatments, and charcoal conversion rates are very similar for the two species (35 8% & 34 7% for **Eucalyptus** and **Leucaena** respectively).

CONCLUSIONS

Despite the higher mortality in the **Eucalyptus**, they remained the highest producers, gardless of the measure of production. The differences in productivity were not large however, and only for solid volume could the superiority of **Eucalyptus** over **Leucaena** be demonstrated. **Leucaena** did not appear to have a beneficial effect on **Eucalyptus** growth, and mixed cropping is not recommended. These results were probably affected by the relatively high fertility status of the site and the application of artificial fertilizers. The use of stacked volume measures (steres) should be discouraged since the conversion rates vary with species and stand conditions. Furthermore, differences in quality such as proportion of bark, wood density or moisture content tend to be obscured, making trade in wood products more difficult.

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Figure 1. Plot of Survival with Age

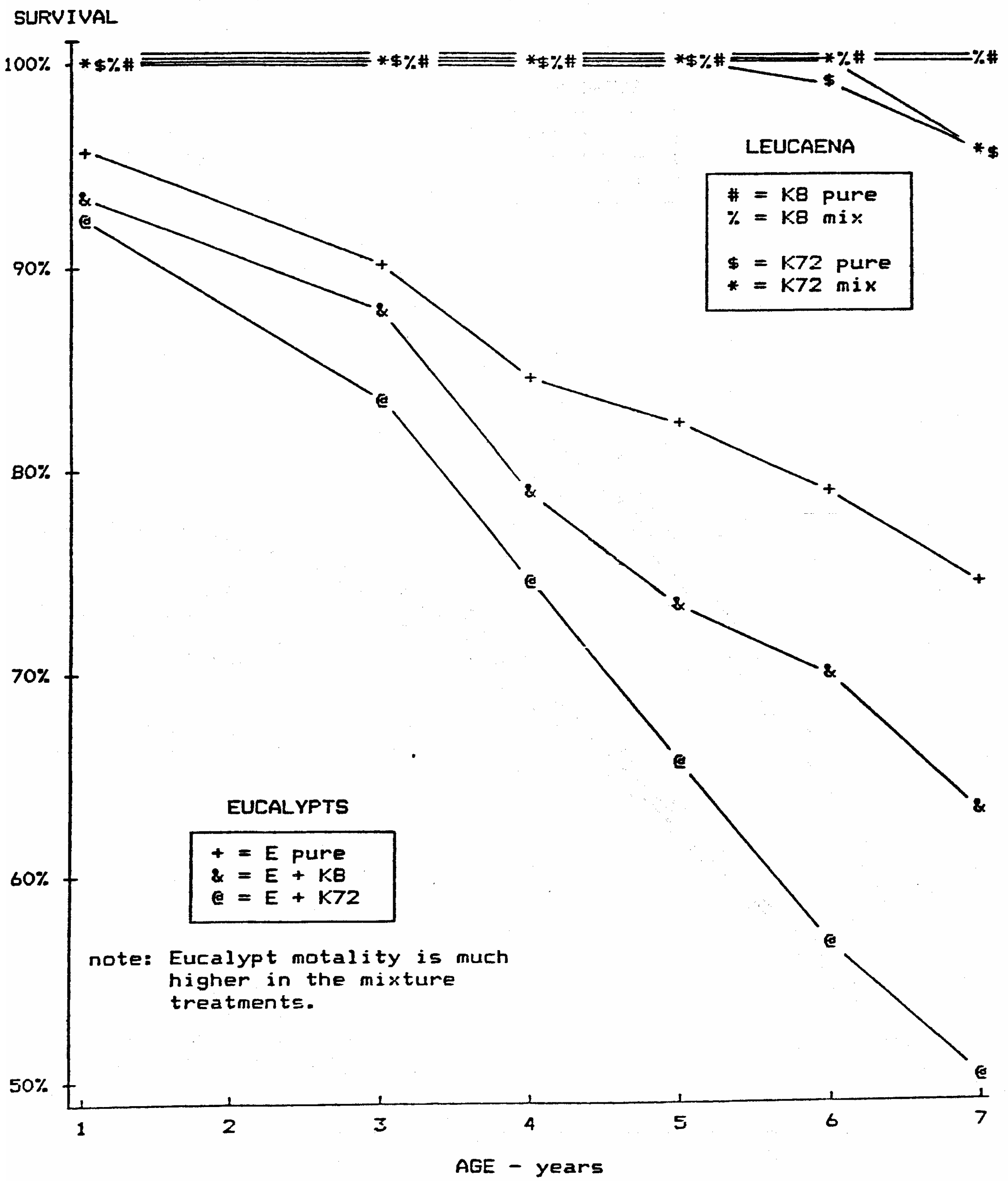

Figure 2. Plot of mean total height against age

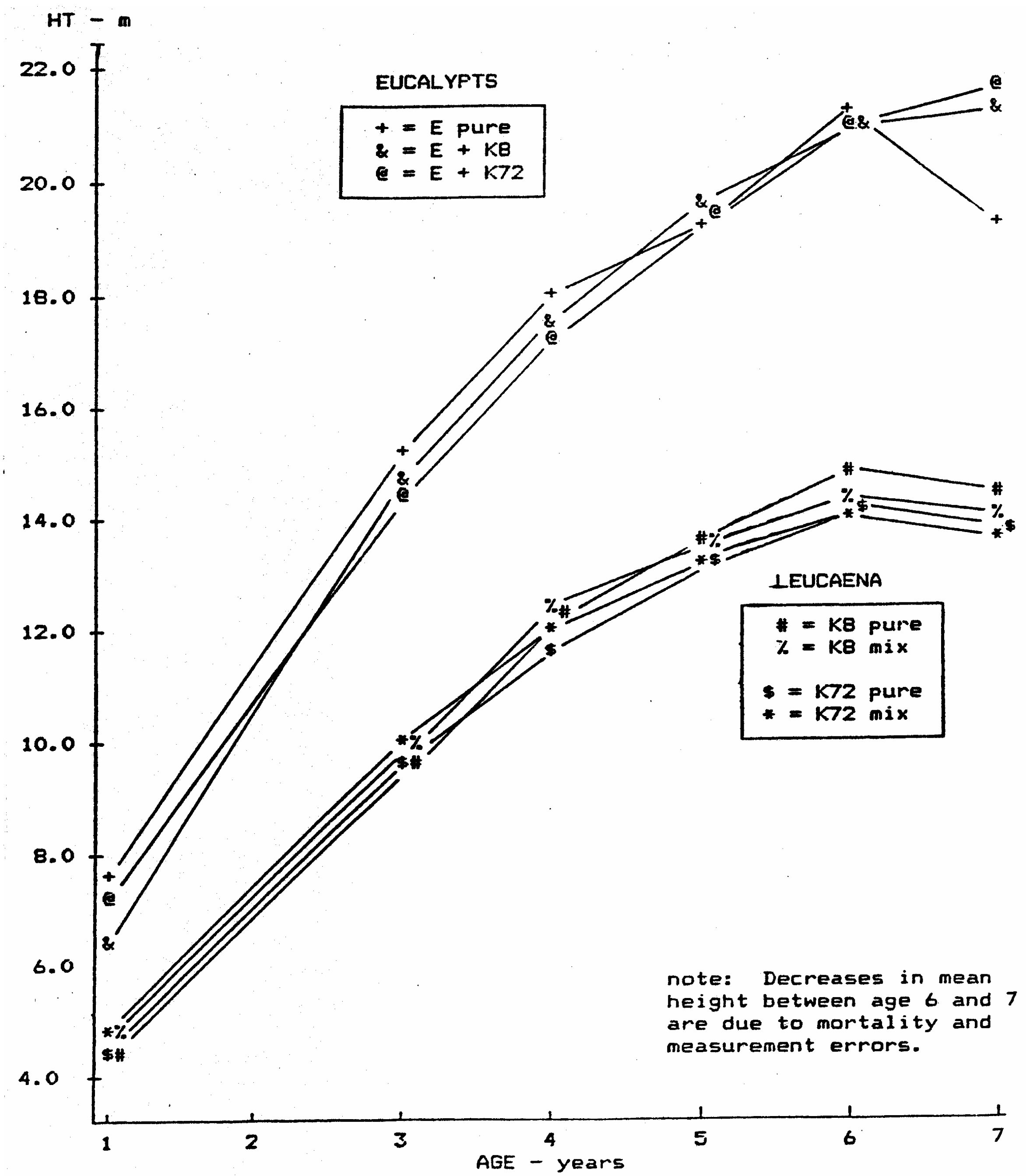

Figure 3. Plot of Cylindrical Over Bark Volume Production against Age.