More wood of better quality through intensive silviculture with rapid-growth improved Brazilian *Eucalyptus*

ABSTRACT

The early forests planted using Brazilian Eucalyptus *seeds produced great variability in the volume of wood. In the specific case of* E. saligna, *the species was unable to adapt itself to the local ecological system. It was obvious that a new silviculture technique should be developed and also that new species and provenances, capable of adapting to the region, should be identified. The objective was to improve wood volume yields as well as to produce better pulp quality. The research and development work has been more successful than anticipated, mainly because a new technique of rooting cuttings which allows propagation of vigorous parent trees, including hybrids, was developed. The production of improved seeds has also been developed. A good genetic base has been established to guarantee continuous improvement for production of seedlings to be used in routine plantings. The first results have already shown good gains in volume, wood density, cellulose content, and resistance to disease.*

KEYWORDS
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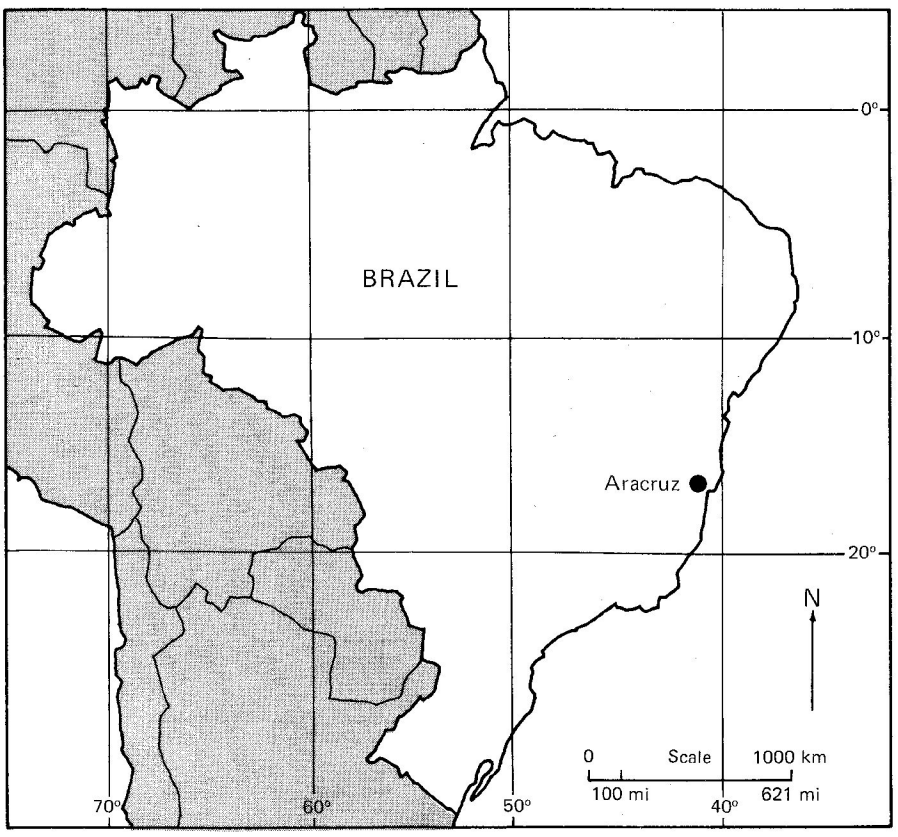
Before 1966, man-made forests were most common in São Paulo, Minas Gerais, and southern Brazil, where there is a larger concentration of forest industries than in other less developed regions in Brazil. With the introduction of the Forest Incentives Law (September 1966), it was possible not only to establish forest acivities in other Brazilian regions but also to increase forest research and development.

Forests planted in Aracruz, São Mateus, and Conceição da Barra between 1967 and 1975 have resulted in a production large enough to supply a 400,000 ton/year bleached kraft pulp mill, even considering that the original species and provenances yielded much less than the improved trees now being used. The present paper describes a project designed to develop a forest of rapid-growth, improved *Eucalyptus* spp. for pulpwood.

Project development

Location and regional characteristics

The project was established in 1967. It is located in two different regions on the coast of Espirito Santo State in Brazil, 150 km apart (see Fig. 1). The first region or block of forest is in Aracruz county with an area of 43,784 ha (4.4×10^8 m^2); the second is in São Mateus and Conceição da Barra counties with an area of 30,633 ha (3.1×10^8 m^2). Of the total gross area of 74,417 ha (7.4×10^8 m^2), 59,100 ha (5.9×10^8 m^2) are planted with *Eucalyptus* spp. Some ecological characteristics are shown in Table I.



1. *Map showing location of Aracruz project.*

I. Ecological characteristics

	Aracruz	S. Mateus/ C. Barra
Latitude	19° 48'S	18° 40'S
Longitude	40° 17'W	39° 45'W
Altitude, m	5-50	5-60
Annual rainfall, mm	1364	1285
Annual average temperature, °C	23.6	24.4
Maximum average temperature, °C	29.2	29.5
Minimum average temperature, °C	19.1	19.5
Annual relative humidity, %	80	85
Topography	Flat land	Flat land
Soil	Oxisol-red-yellow-clayey	Oxisol-red-yellow-clayey

At the beginning of the project the whole area was covered by grass and scrub with no economically significant agricultural or cattle-raising activity. The soils are sediments from the Barreiras formation (Barreira Genesis) and are yellow and clayish with a total predominance of kaolinite.

Forests

The net area of 59,100 ha (5.9×10^8 m²) of forest was planted in 10 years with yearly planting programs starting with 1300 ha/yr (1.3×10^7 m²/year) building up to 15,300 ha/yr (1.5×10^8 m²/year) as a consequence of increased experience and applying correct techniques. The flat topography allows major use of mechanization.

The native vegetation was preserved, especially along the rivers; when suitable, native species with commercial value were planted. Fruit trees were also planted to supply wild animals with food so that they would grow in number and settle in the various regions. The areas of planting other than eucalypts cover about 11,000 ha (1.1×10^8 m²) in both regions.

Wood use

The mill, located in the Aracruz forest region, went on-stream in October 1978. In 1980, it will reach its total capacity (400,000 tons/year), and the consumption of wood with bark is estimated to be 1,680,000 m³. The log length varies from 3.5 to 6.0 m, but most logs are 6.0 m long. They are hauled to the mill over a maximum distance of 190 km.

Branches and small tops are chipped in the forest by mobile chippers and transported to the mill where they are burned in the power boiler, producing 170 tons/hr of high-pressure steam. More than 70% of the fuel for this boiler is wood waste.

Out of 42 MW of energy consumption, 32 MW are self-generated; 7% is generated with fuel oil, and 93% is based on wood (68% black liquor recovery and 25% wood waste).

Silvicultural techniques

Site preparation

The area is divided in compartments of no more than 50 ha (500,000 m²) each, separated by roads. These areas are plowed and graded, the holes for the seedlings are made, and NPK (5-37-5) fertilizer is applied in each hole (100 g/hole). The spacing used is 3 × 2 m.

Nursery

It was necessary to develop a special technique for seedling production suited to the climatic conditions in the region. After 75 days, on the average, the seedlings are ready to be field planted. They have by then reached the optimum size (approx. 25 cm) for planting. Before being transported to the planting site, the bottom of the containers are cut 1 cm to eliminate twisted roots. When planting in soil, the rest of the plastic bag is removed.

Planting

To carry out extensive planting programs, it was necessary to develop a method which permitted planting even on sunny days. This was done by adding water to the seedlings immediately after planting. Advantages of this method are: (a) young seedlings are planted; (b) the nursery works all year round; (c) the number of workers required is fixed; and (d) the nursery and planting operations are more organized and produce higher-quality seedlings.

This technique made possible the planting of 15,300 ha (1.5×10^8 m²) in one year, with an average of 100,000 seedlings per day planted to a total of 25 million seedlings. Results were excellent.

Forest protection

Weeding. The forest grows year round since there are no serious dry or cold periods. The air relative humidity is usually high. These conditions are also favorable for weed growth. Thus a great effort is necessary to keep the area clean of weeds until the trees reach the age of 6 months, since eucalypts are highly sensitive to competition. The weeding is done mechanically between the trees and manually around them.

Insect control. There has been no exceptional incidence of insects up to now, except for ants (*Atta* spp. and *Acromyrmex* spp.). They cut the tree leaves at any age and can destroy the forest if they are not controlled. The ants should be eliminated before planting and need to be controlled annually since new colonies are always being established in the forest. The elimination is done by means of poison gas in the colonies or by poison bait, which is carried to the colonies by the ants.

Species planted

The first species planted were *E. grandis*, *E. saligna*, and *E. "alba"* (originally *E. urophylla)* from Brazil. All seeds were produced by commercial plantings obtained from the original eucalypts introduced in Brazil in 1909 in Rio Claro-São Paulo State. There were several uncontrolled crossings of species, which resulted in a great variety of plants, some with high levels of quality, others with inferior vigor, form, and wood.

The three species presented different performance results in the region. *E. saligna* was susceptible to canker disease caused by the fungus *Diaporthe cubensis*, and it gave a yield of 24 to 28 m³/ha/year. *E. "alba"* showed great variability in the size of the plants, was resistant to the fungi, and gave a yield of 22 to 24 m³/ha/yr. *E. grandis*, with plantings covering more than 70% of the forested area, did not suffer very much from the fungus disease and gave a yield of 30 to 42 m³/ha/yr. All data were obtained at the age of 7 years.

Based on this information, research was done on *E. grandis* and *E. urophylla* for the purpose of tree improvement. The plantings made after 1974 were made with seeds of *E. grandis* from South Africa Republic and Zimbabwe-Rhodesia which appeared to be the best available for the Aracruz region.

Tree improvement

Two paths were followed to obtain superior plants: the sexual path using seed production and the asexual path, or vegetative propagation, using rooted cuttings from vigorous natural or controlled hybrids and from pure plants. The asexual method gives greater gains in a shorter time when successful.

Sexual path

Forty-nine species of eucalypts from 658 provenances and/or mother trees were introduced. The seeds were from different regions of natural occurrence and were completely identified. The species were chosen based on theoretical studies and were not limited to species suitable for pulpwood production.

The two species with the best potential were represented by the majority provenances: *E. grandis* (138 provenances); *E. urophylla* (237 provenances); other 47 species (283 provenances).

The *E. grandis* from Atherton, North Queensland, Australia, has performed excellently. In Oct./Nov. 1977, seeds from 170 trees of 21 populations were

II. *Eucalyptus* hybrid growth (cuttings at 36 months); spacing 3 × 3 m; volume expressed as solid wood[a]

Clones	Diameter, cm	Height, m	Basal area, m^2/ha	Mean annual increment, m^3/ha/yr; factor form 0.42	Number of ramets
G 10	18.3	20.2	29.6	83.7	10
G 36	17.1	20.4	25.8	73.6	40
G 40	16.8	20.1	24.9	70.1	110
G 34	16.2	22.6	21.9	69.3	70
G 04	15.0	21.8	20.0	61.0	140
G 21	15.1	21.6	19.8	59.6	120
G 31	14.9	21.6	19.7	59.4	50
U 01	14.7	21.5	19.0	57.2	120
G 18	14.8	21.0	19.2	56.4	100
G 20	15.5	19.3	20.8	56.3	160
G 25	14.3	21.3	18.4	54.8	60
G 15	14.6	20.5	19.0	54.5	60
U 04	14.2	21.4	18.1	54.3	100
G 17	14.7	20.3	18.9	53.9	90
G 22	15.1	19.9	19.3	53.8	70
U 06	14.6	21.3	17.8	53.3	60
U 08	14.1	21.0	17.4	51.1	60
G 32	13.3	20.5	15.7	45.2	30

[a]One m^3/ha/year = 0.117 cords/acre/year.

collected in that region, increasing significantly the genetic base of this species. The best offspring of this genetic material will be used in seed production in orchards using standard techniques.

The *E. urophylla*, native in several Indonesian islands (Timor, Flores, Alor, Wetar, etc.), is resistant to *Diaporthe cubensis* and, when crossed with *E. grandis*, generally produces vigorous and resistant hybrids which can be propagated by cuttings.

Asexual path

Hybrid plants resulting from natural crossing, selected at the age of 6 to 10 years in the forest planted in the Aracruz region, are being produced by means of rooted cuttings on large scale. Presently, 3500 hybrid trees are being selected.

Coppicing ability is a great advantage of eucalypts since it allows several crops from the same planting, but this is an advantage only if a majority of stumps sprout after every crop. The mother trees are selected for coppicing ability.

Another important point in the selection of the mother trees is their capacity to adapt to the physical and chemical conditions of the soil, so that they will not require additional fertilization for the next generation from the same stump.

Vegetative propagation

Technique

The technique was intensively studied and adapted to our environmental conditions. It consists of using rooted cuttings from stump sprouts. The best phenotypes are felled and the following characteristics analyzed: coppicing ability and intensity, wood basic density, and cellulose content. If these three characteristics are satisfactory, the next step is the production of rooted cuttings as follows:

1. Sprouts of 60 to 80 cm (approx. 60 days) are selected and cut near the stump and then transported to the nursery, where they are divided into cuttings with two pairs of leaves which are treated with a systemic fungicide.

2. The cuttings are dipped (±2 cm) in hormone to stimulate root growth (indole acetic acid, indole butyric acid, naphthalene acetic acid) and placed in containers filled with rooting medium to a depth of 4 cm. The medium used is subsoil clay with no fertilizer.

3. The cuttings are placed under the following conditions: sunlight at 50%, controlled by a nylon net; natural ventilation, controlled by a net; intermittent mist to keep the leaves humid. The cuttings are left under these conditions for 30 to 40 days so that the root system can be formed and the buds start to grow.

4. The rooted cuttings are moved to another area with full sunlight and fertilized with NPK (5-17-3) mixed in water. Each rooted cutting receives approximately 1 g of fertilizer.

5. At around 70 to 80 days of age, a second selection is made for the best plantlets; the extra buds are cut so that the tree has a single leader and only the best trees are left.

6. Three days before planting in the field, the bottoms of the containers are cut out and the latter placed in boxes for easy transportation. The planting is done as previously described.

III. Basic density analysis of hybrids

Basic density, g/cm^3	Number of trees analyzed
0.40–0.45	100
0.45–0.50	617
0.50–0.55	979
0.55–0.60	616
0.60–0.65	164
0.65–0.70	43
0.70–0.75	13
Total	2532

Preliminary results

Vigorous hybrids, propagated by rooted cuttings, have yielded the growth shown in Table II after 3 years in the field. The basic wood density of hybrids shows great variation (Table III).

An analysis of variation of cellulose content in bleached pulp was made for 490 samples and showed a range from 43.6% to 54.3%.

Five million rooted cuttings from selected trees will be planted during 1980.

Conclusions

The establishment of a eucalypt forest of high yield is feasible. The feasibility of the project is strongly related to the short time in which the tests and research results are obtained.

In addition to adaptation to the soil and climate, the improvement of new pure species and provenances gave special emphasis to volume, wood density, and resistance to disease. In developing hybrids to be used with vegetative propagation, cellulose content was also considered. Some preliminary data are already available and some good trees have been reproduced and planted since last year.

The significant gains in productivity and wood quality in a short time, as previously mentioned, are obtained by vegetative propagation. As the hybrids and pure species have been selected for a high coppicing ability, it is possible to foresee many (at least three) crops from the same stump. It is also possible to foresee that a low percentage of stumps will die after each crop. This way the decline of production from crop to crop will be slow, and the replacement of the stumps for new seedlings will be made after many years (at least 21 years).

There are a number of other aspects to be studied and developed, such as studies about fiber quality, cellulose and hemicellulose content, extractives, etc. These have not been started yet. The results of these new studies can only help the dramatic improvements in yield and quality that we have attained in a very short time.

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