MORE WOOD OF BETTER QUALITY: INTENSIVE SILVICULTURE WITH RAPID-GROWTH IMPROVED *Eucalyptus* spp. FOR PULPWOOD

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ABSTRACT

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

INTRODUCTION

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 help from the Forest Incentives Law (September 1966), it was possible not only to establish forest activities in other Brazilian regions but also to increase forest research and development.

Forestry activities of Aracruz began in 1967. Land and climate in Northern Espirito Santo were suitable for eucalypts growth and enabled the establishment of a forest which could be used for pulpwood.

At that time there were very few experiments in eucalypts plantation in the region and the techniques and species used in São Paulo were adopted. At the same time studies and research to identify species and provenances better adapted to the local soil and climatic conditions were started. Along with these studies new techniques were developed and old ones improved, all related to seedling production, site preparation, forest protection and, more recently, harvesting.

In addition to adaptation to the soil and climate, the improvement of the 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.

The eucalypts forests planted between 1967 and 1975 have on the average an annual mean increment of solid wood in the seventh year ranging between 22 and 42 m^3/ha/yr, including bark. Wood density ranges between 0.40 and 0.75 g/cm^3 and the bleached paper yields range between 45.6 and 54.3%.

After the logging started last year, part of the land was replanted with rooted cuttings obtained from natural hybrids selected in the original plantations. The selected trees had good characteristics, specially for volume (1 m^3 per tree, 7 year aged) and wood density (over 0.55 g/cm^3). If such trees are used in a normal plantation one can expect an annual increment ranging from 45 to 65 m^3/ha/yr, in the seventh year; this has been verified in experimental plantations.

The tree improvement program has now developed into a second phase with the objective of obtaining even better genetic gains. New pure species and hybrids are being tested aiming at producing more cellulose per ha per unit time.

THE PROJECT - BRIEF DESCRIPTIONS

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. The first region or block of forest is in Aracruz county with an area of 43,784 ha and the second is in São Mateus and Conceição da Barra counties with an area of 30,633 ha. The total gross area contains 74,417 ha. From this total, 59,100 ha are planted with *Eucalyptus* spp.. The rest of the area is covered by native forests, rivers, lakes, beaches, forest research, roads, industries, and residential areas for the company workers.

The pulp mill is located 35 km from BR - 101, a Federal Road, which goes all the way from South Brazil to the North along the coast. It is completely paved. The city of Vitória, the State Capital, is 60 km south and the city of Rio de Janeiro is 600 km south.

Some ecological characteristics:

	ARACRUZ	S.MATEUS/C.BARRA
Latitude	19°48'S	18°40'S
Longitude	40°17'W	39°45'W
Altitude	5 to 59 m	5 to 60 m
Annual Rainfall	1,364 mm	1,285 mm
Annual Average Temperature	23.6°C	24.4°C
-Max. Average Temperature	29.2°C	29.5°C
-Min. Average Temperature	19.1°C	19.5°C
Annual Relative Humidity	80%	95%
Topography	Flat Land	Flat Land
Soil	Oxisol-Red-Yellow-Clayey	Oxisol-Red-Yellow-Clayey

The areas where the forest is being planted were originally covered by a tropical rain forest which was exploited in a predatory way until its disapearance. First the valuable wood was exploited for sawmills (wood for furniture and civil construction) being the rest of the forest transformed in charcoal for siderurgy.

In the beginning of the project the whole area was covered by grass and scrub with no agriculture or cattle raising activity economically significant.

The soils are sediments from the Barreiras formation (Barreira Genesis) yellow colored, clayish with a total predominance of kaolinite.

The regions are flat, with many small rivers in deep valleys (from 10 to 20 m).

FORESTS

The net area of 59,100 ha of forest was planted in 10 years with yearly planting programs starting with 1,300 ha/yr building up to 15,300 ha/yr as a consequence of experience and correct techniques applied. The flat topography allows a major use of mechanization.

The native vegetation was preserved, specially along the rivers; when suitable, native species with commercial value were planted. Fruit trees were also planted to supply the wild animals with food so they would grow in number and settle in the regions. The areas of plantings other than the eucalypts cover about 11,000 ha in both regions.

HARVESTING

The cutting is made by powersaws, being the logs hauled to the road side by medium size forwarders, there are piled. From there are hauled to the mill by 40 ton trucks.

The log length varies from 3.5 to 6.0 m but most logs are 6.0 m long. The minimum diameter used for pulp production is 5 cm outside bark.

In 1980 the mill will reach its total capacity of production (400,000 t/yr) and the consumption of wood is estimated to be 1,680,000 m^3 with bark. As the forest is replaced by improved species this ratio should decrease significantly.

In the Aracruz region the average distance for the wood transport is 17 km. Considering the areas of Aracruz and São Mateus/Conceição da Barra together, the average distance for wood transportation is 80 km, on paved roads.

WOOD WASTE FOR ENERGY

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. Over than 70% of the fuel for this boiler is wood waste. Its production is 170 t/ha of high-pressure steam.

32 MW out of 42 MW of energy consumption is self-generated. 7% of those 32 MW is generated by fuel oil and 93% via wood, being 68% via lignin and 25% via wood waste.

THE INDUSTRY AND THE HARBOUR

The pulp mill, inaugurated in October 1978, has a rated capacity of 400,000 t/yr of bleached eucalypts (with bark) pulp.

The mill site is inside the Aracruz forest and 1.5 km from Barra do Riacho Harbour, which was constructed specially for cellulose pulp exportation.

At 18 km from the mill a residential town for 4,000 people was built.

SILVICULTURAL TECHNIQUES

SITE PREPARATION

The area is divided in compartments with no more than 50 ha which are separated by roads. These areas are plowed and graded. Then the holes for seedling are made, and NPK (5-37-5) fertilizer is applied in each hole (100 g/hole).

The spacing used is 3 x 2 m.

NURSERY

It was necessary to develop a special technique for seedling production according to the climatic conditions in the region. Eucalypts seedlings are easily affect by fungi

which cause damping-off which develop easily in the organic matter of the container.

The containers used are plastic bags, 12 cm high and with a 6 cm diameter. Other kinds of containers are being tested so as improve planting and seedling production.

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 about 1 cm which eliminates twisted roots. When planting in soil the rest of the plastic bag is removed.

PLANTING

Traditionally, eucalypt planting was done on rainy or cloudy days. However, the huge planting programs could not be fully accomplished using this method since the number of days with ideal climatic conditions were not enough.

Thus an irrigated planting technique was developed which consists of adding water to the seedling right after it is planted. The quantity of water varies according to the moisture content of the soil. This techniques has been applied since 1969 with great success. There are several advantages:

(a) young seedlings are planted;

(b) the nursery works all year around;

(c) the number of workers required is fixed;

(d) the nursery and planting operations are more organized and procedure higher quality seedlings.

This technique combined with rainy days, enabled the planting of 15,300 ha in just one year, with an average of 100,000 seedlings per day up to the total of 25 million seedlings results were excellent.

The seedlings are distributed on the planting site by a semi-mechanical system. The planting is done by hand. The water is transported in 4,000 liter tanks and is distributed by means of 5 one inch hoses. Each hose is controlled by one man which directs the water to the seedlings.

FOREST PROTECTION

WEEDING. The forest grows year around since there are no serious dry or cold periods. The air relative humidity is usually high. Such good conditions are also favorable for the 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 eucalyptus is 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. Ants live in colonies below the soil surface down to 2.5 m. There they grow fungi for food using the leaves cut from the trees. Several species of ants have a great preference for eucalypts leaves.

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 baits, which are carried to the colonies by the ants.

SPECIES PLANTED

The first species planted were *E. grandis*, *E. saligna* and *E. "alba"* from Brazil. All the 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 a great variety of plants, some with high levels of quality other which low levels considering vigor, form and wood.

The *E. "alba"* from Brazil is the *E. urophylla* which came from Indonesia with the name of *E. alba*.

The three species mentioned presented different performances in the region. The *E. saligna* was susceptible to canker disease caused by the fungus *Diaporthe cubensis* and it had a yield of 24 to 28 m^3/ha/yr. The *E. "alba"* had a great variability in the size of the plants, it was resistant to fungi and had a yield of 22 to 24 m^3/ha/yr. The *E. grandis*, which plantings cover more than 70% of the forested area, did not suffer very much with the fungus disease and had a yield of 30 to 42 m^3/ha/yr. All these data were obtained at the age of 7 years.

Based on the above, research was done on *E. grandis* and *E. urophylla* aiming at forest improvement.

The plantings made after 1974 were made with seeds of *E. grandis* from South Africa and Zimbabwe-Rhodesia, which appeared to be the best available seeds for the Aracruz region.

RESEARCH AND FOREST IMPROVEMENT

Based on the results of the first eucalyptus plantigs it was assumed that there was a great need for research on several aspects to improve forest productivity in terms of wood volume and quality, and to assure a continuous supply of wood for the pulp mill. Different research programs were established involving tree improvement, soil, plant nutrition, and entomology with other species besides eucalypts such as tropical *Pinus* spp. and local native trees.

After 1973 several trips were made to Australia and Indonesia to establish contact with the people involved in research and to obtain genetic material from the species and

provenances desired.

TREE IMPROVEMENT

For forest improvement research, two paths were followed to obtain superior plants:

(a) the sexual path using seed production;

(b) the asexual path or vegetative propagation using rooted cuttings from vigorous natural or controlled hybrids and from pure plants.

This method gives greater gains in a shorter time when it works.

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

The two species with the best potential were represented by the majority of the provenances:

E. grandis - 138 provenances
E. urophylla - 237 provenances
other 47 species - 283 provenances.

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

The *E. urophylla*, native in several Indonesian islands (Timor, Flores, Wetar, Alor 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. By means of vegetative propagation (rooted cuttings) identical plants can be obtained not only in the general aspects of the plant but also in genetic constitution. It is an efficient technique in the preparation of natural and artificially produced hybrids.

Hybrid plants resulting from natural crossing, selected at the age of 6 to 10 years in the forests planted in the Aracruz region, are being reproduced by means of rooted cuttings on large scale.

Presently, 3,500 hybrid trees are being strictly 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 as much as possible.

Another important point on the selection of the mother trees is their capacity to adapt to the physical and chemical conditions of the soil, not demanding additional fertilization for the next generation from the same stump.

Based on the results already attained additional research is already under way. The most important deals with the optimum number of trees per hectare in terms of pulp production based on maximum productivity, best quality and the most economic rotation. Harvesting is also under observation in this research.

VEGETATIVE PROPAGATION OF HYBRIDS BY ROOTED CUTTINGS

The techniques was intensively studied and adapted to our climate environmental conditions. It consists of using rooting cuttings from stump sprouts.

The best phenotypes are felled and the following characteristics are analysed: coppicing capacity and intensity, wood basic density, and cellulose content.

If the above three characteristics are satisfactory the next step is the production of rooted cuttings which is done as follow:

(a) the sprouts with 60 to 80 cm (approx. 60 days) are selected and cut near the stump and then transported to the nursery in containers with water;

(b) the sprouts is then divided in cuttings with two pairs of leaves which are treated with a systemic fungicide;

(c) the cuttings are dipped ($\pm$ 2 cm) in hormone to stimulate root growth (Indoleacetic acid, Indolebutyric acid, Naphthaleneacetic acid);

(d) the cuttings are put in the rooting medium of the containers to a depth of 4 cm. The medium used is sub-soil clay with fertilizer;

(e) the cuttings are placed under controlled conditions:

- sunlight control at 50%, obtained by a nylon net;
- natural ventilation controlled by a net;
- intermitent mist to keep the leaves humid.

The cuttings stay in these conditions for 30 to 40 days so the root system can be formed and the buds start to grow;

(f) the rooted cuttings are transfered to another area with full sunlight. In this area they receive fertilization with NPK 5-17-3 mixed in water. Each rooted cutting receives approx. 1 g of fertilizer;

(g) around 70 to 80 days of age a second selection is made for the best plantlets; the extra buds are cut so the tree has a single leader and only the best trees are left;

(h) three days before the planting in the field, the bottom of the containers is cut

Selected trees	$\bar{D}$ (cm)	$\bar{H}$ (m)	BA (m^2/ha)	A.M.I. (m^3/ha/yr) f.f.0.42
G 10	18.3	20.2	29.6	83.7
G 36	17.1	20.4	25.8	73.6
G 40	16.8	20.1	24.9	70.1
G 34	16.2	22.6	21.9	69.3
G 04	15.0	21.8	20.0	61.0
G 21	15.1	21.6	19.8	59.6
G 31	14.9	21.6	19.7	59.4
G 29	15.3	20.3	20.7	58.8
U 01	14.7	21.5	19.0	57.2
G 18	14.8	21.0	19.2	56.4
G 20	15.5	19.3	20.8	56.3
G 25	14.3	21.3	18.4	54.8
G 15	14.6	20.5	19.0	54.5
U 04	14.2	21.4	18.1	54.3
G 17	14.7	20.3	18.9	53.9
G 22	15.1	19.9	19.3	53.8
U 06	14.6	21.3	17.8	53.3
U 08	14.1	21.0	17.4	51.1
G 32	13.3	20.5	15.7	45.2

Table 1. Eucalypts Hybrids Growth by Cuttings at 36 Months of Age. Spacing 3 x 3 m. The volume is solid wood. 1 m^3/ha/yr is equivalent to 0.116503 cord/acre/yr.

out and placed in boxes for easy transportation. The planting is done as previously described.

PRELIMINARY RESULTS

Vigorous hybrids, propagated by rooted cuttings have yielded the following growth after 3 years in the field (Table 1).

The advantage of propagating vigorous eucalypt hybrids by rooted cuttings is not only in increasing productivity but also it gives the possibility to improve the quality of wood.

The basic wood density of hybrids shows great variation (Table 2).

When an analysis of the variation in bleached cellulose content was made for 490 samples there was a variation from 43.6% to 54.3%. The variation of both basic density and cellulose content is large which allows an improvement of the material more suitable for processing.

Five million rooted cuttings from selected trees will be planted in the Aracruz region in 1980.

Basic density (g/cm^3)	Number of trees analysed
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	2,532

Table 2. Basic Density Analysis of Hybrids.

SOIL AND PLANT NUTRITION

The soil studies are related specially to soil mobilization and soil behavior related to the high wood production. Several studies have already been developed and several others are under way but only after improved trees are attained will it be possible to obtain really

conclusive results.

The type and size of forestry equipment required special consideration relative to soil compaction which will be increased if the wrong equipment is used. The maximum acceptable pressure on the soil was established to be 1.8 kg/cm^2 and this value was used as a standard specification for equipment required.

For site preparation, some techniques are under study such as the depth of soil working (40 to 50 cm) aiming at improving the conditions for root growth and the inversion of the plowing layer so as to force deeper rooting and the elimination of weed seeds. The results of this techniques will be compared with the method used before (superficial plowing - 20 to 30 cm deep) not only from the technical point of view but also the economic aspect should be studied.

Presently, in the replacement of old forests by more productive one, soil preparation is being done by means of bedding with satisfactory results in the experiments performed. It controls unwanted sprouts and develops a good planting site.

It has not been necessary to fertilize after the logging other than at time of planting. Considering that the forest is of fast growth and short harvesting cycle, the nutritional balance of the soil is being closely investigated. The experience on this matter is small and new studies are under way since it is an important aspect is sustaining high wood production over a number of rotations.

ENTOMOLOGY

The susceptibility of the eucalypt forest to insects is well known and the existence of similar problems in forest of the neighboring states is worrisome.

Aracruz forests are divided by strips of native vegetation which will reduce the risk of insect predation but it is not possible to eliminate the danger. It is necessary to know the insects that live in the forest, especially those which are potential enemies of eucalypts. Methods as how to control them with their natural enemies is a necessary security factor and a guarantee to continued good forest production.

A great number of insects have already been identified and some predators are already being developed in the laboratories for field testing. This method will reduce the need for chemical control of insects.

Ants are particularly difficult since they have no known natural enemies.

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. Some preliminary data are available already due to the short rotation.

The forest 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 t/yr pulp mill, even considering that the original species and provenances yielded much less than the improved trees now used.

The results of studies in tree improvement, started in 1973, are already being applied in extensive planting, starting in 1979. This will mean that seven year old forest which had a yield of 22 to 42 m^3/ha/yr will be replaced by another with much higher production. Initial tests indicate a yield of 45.2 to 83.7 m^3/ha/yr in their third year; in addition, they have increased wood density and cellulose content.

The significant gains in productivity and wood quality in a short time as mentioned above are obtained by vegetative propagation. As the hybrids and pure species have being selected for a high coppicing ability, its possible to foresee many (at least tree) 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 results and conclusions reached so far, which is that a dramatic improvement in yield and quality has been obtained in a very short time.

REFERENCES

1. Anonymous, Circ.Téc.IPEF, 21, 1976.

2. Anonymous, "Estudos de Densidade Básica, Teor de Holocelulose e Rendimento em Celulose de Madeiras de *Eucalyptus grandis*", Piracicaba, Escola Superior de Agricultura Luiz de Queiroz, 1979.

3. Bertolotti, G., Moura, A.L., Gonçalves, A.N., and Ferreira, M., Circ.Téc.IPEF, 54, 1979.

4. Campinhos Jr., E., "O Programa de Melhoramento Florestal de *Eucalyptus* spp., em Desenvolvimento pela Aracruz Florestal S.A." 1º Seminário de Fertilização e Melhoramento Florestal, Belo Horizonte, 19-20 de abril de 1979.

5. Campinhos Jr., E., and Ikemori, Y.K., " Tree Improvement Program of *Eucalyptus* spp. Preliminary Results", Third World Consultation on Forest Tree Breeding, Canberra, Australia, 21-26 March 1977.

6. Chaperon, H., "Amelioration Genetique des Eucalyptus Hybrides au Congo Brazzaville" Third World Consultation on Forest Tree Breeding, Canberra, Australia, 21-26 March 1977.

7. FAO, "Pulping and Papermaking Properties of Fast-Growing Plantation Wood Species", Rome, 1975.

8. Hillis,W.E.,and Brown,A.G.,"Eucalypts for Wood Production";Australia,CSIRO,1978.

9. Hodgson,L.M.,S.A.For.J.,97:18-28,98:32 - 43,1976.

10. Hodgson,L.M.,S.A.For.J.,102:38-42,58-60, 1970.

11. Ikemori,Y.K.,Inf.Têc.Centro de Pesquisas Florestais da Aracruz,1,1975.

12. Ikemori,Y.K.,Inf.Têc.Centro de Pesquisas Florestais da Aracruz,2,1976.

13. Kalish,J.,Reprinted from PPI,Mar.,1979.

14. Martin,B.,and Quillet,G.,Bois For.Trop., 154:41-57,155:15-33,156:39-61,157:21-40, 1974.

15. Petroff,G.,Bois For.Trop.,150:63-67,1973.

16. Poggiani,F.,and Suiter Filho,W.,IPEF,9 : 119-129,1974.

17. Schönau,A.P.G.,S.A.For.J.,100:72-80,1977.

18. Valle,C.F.do,Ferreira,M.,and Caldeira,C. J.,Circ.Têc.IPEF,31,1977.

19. Van Wyk,G.,S.A.For.J.,101:47-53,1977.

20. The Wattle Research Institute,Pieterma - ritzburg,"Handbook on Eucalypt Growing", Pietermaritzburg,1972.

21. Zobel,B.J.,"Principles and Variation to Tree Improvement",Tree Improvement Short Course,June 4-6,1974,Raleigh,N.C. State University,1974.