DEVELOPMENT OF THE EUCALYPTUS TREE OF THE FUTURE

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SUMMARY

This paper gives emphasis to the role of applied research as one of the most important means of increasing the yield of forests and improving the quality of the product, while increasing industrial production without additional investment.

Both genetic and tree improvement research are priorities which form the basis for the development of future forestry research programs. Both approaches are used to evaluate the overall effects of the different variables under study.

This paper also demonstrates the yields which can be obtained in terms of volume, pulp manufacture productivity and wood quality of **Eucalyptus** spp. when producing high quality bleached market pulp. The possibilities of combining new biotechnological techniques and standard breeding programs to obtain highly productive hybrid trees are described.

FORESTRY RESEARCH

In 1967 in the State of Espirito Santo and more recently in the south of the State of Bahia, Aracruz started a program of **Eucalyptus** spp. planting.

A variety of problems were encountered in the forestry performance due to the lack of experience with **Eucalyptus** in that area and the precarious availability of improved seeds.

This resulted in the susceptibility of the species to canker disease (**Cryphonectria cubensis**) which attacked up to 60% of trees planted, especially the **Eucalyptus saligna.** The slower growth rate and high heterogeneity of **Eucalyptus urophylla** also caused major concern despite showing high resistance to the disease.

The **E. grandis**, however, performed better in terms of volume production showing a medium resistance to canker disease. The decision, based on the results of preliminary tests in 1974, was taken to plant **E. grandis** from South Africa and Zimbabwe which resulted in forests with better

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productivity and homogeneity (of the wood) despite a lower basic density (490 kg/m ^{3}) and pulp yield (47.4%).

This, along with the difficulty in obtaining improved seeds, provoked a change in strategy. The challenge to Aracruz was to obtain better plants for a second rotation of planting.

There were risks involved due to the use of unimproved seeds in the region. As speed was essential to the success of the forestry project, Aracruz began plantation in anticipation of the final research results.

Also, at that time, a tree improvement research program was established. The aim of the program was to produce genetic material suited to the local ecological conditions. The research involved the study and eventual introduction of the species, provenances and progenies of **Eucalyptus** to the area. Studies of vegetative propagation by rooted cuttings were also initiated. (Figure 1, appendix).

The results of the rooted cutting trials were better than expected. The company then decided to use the technique of cloning by rooting of cuttings in the operational planting program.

Elite trees adapted to the ecosystem with a high pulp yield in the plantation and progeny tests obtained from controlled pollination were selected.

Aracruz has already planted 110 million trees by rooted cuttings and more recently has started using techniques of "in vitro" propagation (micro propagation) based on research done by AFOCEL - Association Foret Cellulose (France), aiming at:

. The propagation of genotypes considered difficult to root by rooted cuttings.

. The acceleration of the multiplication process of ramets.

. A definition of methods and future needs in the area of cell suspension and protoplast fusion.

CURRENT STATUS OF Eucalyptus TREE IMPROVEMENT

Introduction of Species and Provenances

Since 1973, Aracruz has introduced different species and provenances of **Eucalyptus** to evaluate their genetic potencial in the Aracruz ecological condition. The table below demonstrates the species and provenances that show most potencial in terms of volume, resistance to canker disease, pest as well as their phenotypic characteristics.

TABLE 1 - POTENTIAL SPECIES AND PROVENANCES OF **EUCALYPTUS**

SPECIES	LATITUDE	LONGITUDE	ALTITUDE (m)	PROVENANCES
E. **grandis**	17°15'S	145°42'S	655	Atherton
E. **urophylla**	8°38'S	125°43'S	1,021	S. Dili
E. **pellita**	15°45'S	145°15'S	36	Helenvalle
E. **camaldulensis**	16°10'S	144°50'S	427	Cooktown
E. **tereticornis**	21°30'S	148°20'S	61	Mackay Dist.
E. **torelliana**	-	-	-	Atherton
E. **resinifera**	-	-	-	S8285 *
E. **cloeziana**	18°17'S	145°55'S	1,122	S. W. Kennedy

* CSIRO seed lot number

Emphasis has been given to species for pulp production, but species for other purposes, such as saw mill and energy have also been tested.

Seed Collection

Based on results of progeny tests, Aracruz has made the following seed collection.

TABLE 2 - SEED COLLETION OF **EUCALYPTUS**

YEAR	SPECIES	PROVENANCES	NUMBER OF TREES
1974	E. **urophylla**	Timor (Indonesia)	*
1977	E. **grandis**	Atherton - QLD Australia	160
1981	E. **grandis**	Atherton - QLD Australia	132
1988	E. **grandis**	Atherton - QLD Australia	224

* Basis population (300 kg)

The phenotypical evaluation of each tree (straightness, height, diameter, thickness of branches, spiral grain, etc.) as well as the distance between the selected trees were recorded (a minimum physical distance between selected trees is needed to avoid selection of related trees).

A substantial quantity and variety of seeds for research were also acquired from reliable sources such as CSIRO - Commonwealth Scientific and Industrial Research Organisation, IPEF - Instituto de Pesquisas e

Estudos Florestais and EMBRAPA - Empresa Brasileira de Pesquisa Agropecuária, making up a total of 55 species of **Eucalyptus** from 2,149 provenances and/or families currently being tested at Aracruz, as shown below:

SPECIES	PROVENANCE/FAMILY
E. grandis	1030
E. urophylla	494
E. pellita	111
Other species	514

The company intends to develop its seed collection further in order to meet the strategy demands for the long term breeding program.

Progeny Tests

In accordance with statistical design, progenies of mother trees from Australia were planted in Aracruz. The best trees from the best families were evaluated to establish a breeding group for the long term program and mid term seed orchard.

Improved Seed Production

With the objective of producing improved seeds in a short period, the best individual trees from the best families of the progeny test were selected and propagated by grafting and rooting of cutting from an age of 4 years. As a result, the following seed production areas and seed orchards have been established.

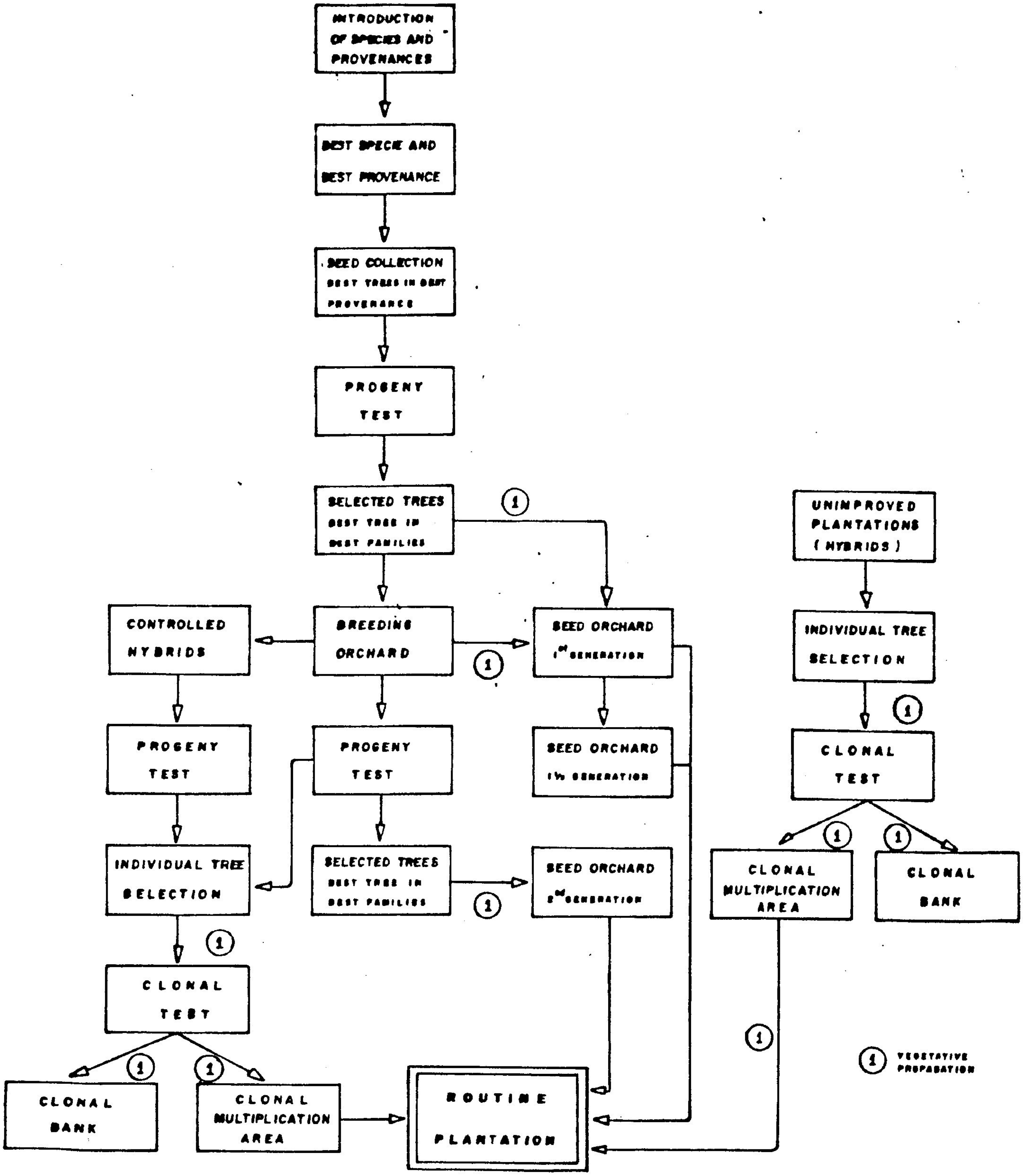
TABLE 4 - IMPROVED SEED PRODUCTION OF **EUCALYPTUS**

SEED PRODUCTION AREAS (SPA)	AREA (ha)	ESTIMATED (kg/year)
E. grandis	126.0	3,000
E. urophylla	9.3	250

SEED ORCHARD (SO)	AREA (ha)	ESTIMATED (kg/year)
E. grandis	11.0	180
E. grandis	6.4	170
E. grandis	3.8	90
E. grandis	11,8	490
E. urophylla	7.4	250
E. grandis x E. urophylla	7.7	150
E. grandis x E. urophylla	7.4	130

FIGURE 1

ARACRUZ TREE IMPROVEMENT BREEDING SCHEDULE
(Eucalyptus Spp)



MAY - 1984

An extensive program of hybrid production by controlled pollination involving **E. grandis**, **E. pellita**, **E. tereticornis**, **E. camaldulensis** and **E. urophylla** was started.

The aim of the program is to produce inter and intra-specific hybrids to increase the genetic basis for vegetative propagation as well as progeny tests of the long term breeding program.

Clonal Banks

Selected trees of different species and provenances, both pure and hybrid are preserved at the breeding orchard by grafting, rooting of cutting and more recently by the use of plantlets cultivated "in vitro".

One of the most important studies developed for the controlled pollination in the clonal bank is the handling and maintenance of pollen. This permits crossing throughout the year due to the varied flowering time of the different species. The technique which involves storing the pollen at $-18^{0}C$, extends the active life of the pollen to more than 8 months.

The company is also involved in a national cooperation program of germoplasm for plant material exchange.

Vegetative Propagation by Rooting of Cuttings

The propagation of selected trees to establish new forests permits rapid development in volume as well as gains in desirable wood characteristics, for pulp production. The mean annual increment of the project is approximately 35 m^3 per year, compared with that of 45 m3 per year in 1985, this lapse being due to an extended period of draught in several regions of Brazil (Table 5, appendix).

In 1989, 21,5 million rooted cuttings were planted, and the projected planting for 1990 is 22,5 million trees. The sum of trees planted throughout the program is expected to reach 126 million by the end of 1990.

The key to the tree improvement program is a perfect interaction between forestry and industrial research.

The quality of trees must meet the requirements of both areas, specifically in volume, resistance to disease, adaptation to the environment quality and volume of bleached pulp production.

THE BREEDING PROGRAM FOR THE FUTURE

The elite trees from **E. grandis** and **E. urophylla** will be crossed in order to obtain super hybrids for future vegetative program by rooting of cuttings. These trees are expected to gather excellent phenotypic and genotypic qualities, showing plasticity for different sites, and a high quality and yield of pulp.

Simultaneously to obtain hybrids from open pollination, seed orchards will be established using one clone of E. **grandis** with several clones of E. **urophylla** and vice-versa.

The aim is to produce a large amount of hybrid seeds which show better results for plantation by comparing them with recently obtained seeds that have shown satisfactory growth abroad and in various regions of Brazil.

The duration of the program is expected to be approximately 15 years with highly compensatory results.

Other species will be included in this program of super hybrids, such as E. **pellita**, E. **saligna**, E. **tereticornis** and E. **camaldulensis**. The program also aims at backcrosses and successive crosses comprising more than two species.

The climate conditions and the species involved stimulate the development of the program because of short rotation and the premature flowering time. The preliminary results are stimulant and can be quickly evaluated, thus making successive step by step improvements possible.

TABLE 5 - EVOLUTION OF WOOD QUALITY OF EUCALYPTUS FROM DIFFERENT SOURCES, PLANTED AT ARACRUZ

	Brazil Commercial	Zimbabwe and South Africa Commercial	Rooted Cuttings	
			1st Step	2nd Step
Basic Density (kg/m^3)	480	490	490	520
Pulp Yield (%)	47	47.4	49	51.8
Bark Content (%)	18	15	12	10
Specific Wood Consumption (m^3/t90 pulp)	4.87	4.56	4.26	3.71

Biotechnology

The combination of new biotechnology and conventional breeding techniques may produce relatively greater payoffs in forestry than in any other area of agriculture due to the time saving potential of biotechnology.

The procedures concerning direct application of biotechnology to tree improvement include mass propagation "in vitro" (micro propagation) which utilizes both natural variation and variation induced in culture, somatic hybridization, somaclonal and gametoclonal variation and genetic transformation using suitable vectors.

Improved and elite genotypes resulting from conventional breeding program provide the most desirable material for future specific improvement specially for monogenic, oligogenic or single gene traits for which the necessary gene is seldom absent in a population. Examples are resistance to a specific disease, herbicide resistance, stress hydric tolerance etc. which cannot physically or economically be introduced by conventional breeding.

INDUSTRIAL RESEARCH

As earlier described, a perfect interaction between forestry criteria and pulp and paper manufacturing aspects is critical to the overall success of a tree improvement program.

This "team effort" has been characteristic of the Aracruz operation for many years. Selected trees from the Forestry R&D Center are also analysed with regard to their pulp production potential, chemical and morphological characteristics, and paper quality, using the basic density of wood as a reference property, due to its key importance in forest products manufacture (8,9).

PRODUCTIVITY IN KRAFT PULP MANUFACTURE

The tree selection performed at forestry level provides a substantial improvement in terms of wood variability and pulping yield. However, further gains may be obtained through additional screening of the selected trees.

In this process it has been found to be of utmost importance to account for the most critical factors in production. Accordingly, special consideration has been given to: 1) the use of whole tree chips for pulp evaluations; 2) adequate impregnation and the use of laboratory forced circulation digesters, pulping to constant Kappa; 3) constant operating conditions during lab brownstock washing and screening; 4) evaluation of recovery load from each tree as the limiting production factor.

The combination of optimized operation conditions and development of a computer program to calculate both organic and inorganic solid loads to the recovery system have enabled the selection of elite trees, with regard to maximum productivity at constant fixed cost.

This program compares the maximum theoretical production from a tree under analysis with the average maximum production obtained from lab cooks of industrial chips used in the three previous years, which are used as reference. Such procedure also enables the application of laboratory results to mill scale practice.

Typical results obtained in the analysis are illustrated in Table 5. The production gain indicates whether a tree (clones of it), if used alone in the process, would provide a positive or negative deviation relatively to the production from average industrial chips pulped in the three previous years. The selected trees for propagation are only those which allow a positive gain in production.

TABLE 6 - PRODUCTION GAIN CRITERION

TREE	BASIC DENSITY kg/m2	SCREENED PULPING YIELD	PRODUCTION GAIN ADMT/day
10,789	572	51.2	- 2.9
10,838	564	53.7	127.3
10,840	603	56.1	239.8
20,008	460	52.4	27.9
20,034	446	53.4	94.5
20,071	484	50.2	- 77.5
20,078	449	51.4	- 25.8
20,087	532	52.8	53.1

Industrial trials performed at Aracruz mill have confirmed the applicability of such a technique. During selected production periods it has been possible to use 100% wood from elite trees in the process. The results in Table 6 indicate that the wood from the improved forest allows significant gains, through higher pulping yield, lower alkali charge and consequently much lower solids load to the recovery boiler.

TABLE 7 - INDUSTRIAL TRIALS - STANDARD vs. SELECTED TREES

PRODUCTION PARAMETER	STANDARD TREES	SELECTED TREES
Wood Basic Density, kg/m^3	504	500
Effective Alkali Charge, % NaOH	16.2	15.8
Digester Yield, %	54.0	56.7
Digester Production, ADMT/d	1460	1624
Dry Solids to Recovery, kg ds/ADMT	1419	1276

Based on these results, the focus with regard to forest yield has switched from the analysis of wood chemical characteristics (e. g. lignin, extractives and cellulose contents) alone to the estimated effect of pulping characteristics on the chemical recovery system, which is usually the production bottleneck.

Therefore, earlier discussions about eventual correlations of pulping yield with wood basic density (10-13) have lost practical interest to us, and wood chemical characteristics of greater importance to the breeding program are those closely related to paper quality, such as hemicellulose and extractive contents.

The benefits of using standardized procedures and representative sampling of the trees have also become evident, and are in strong contrast with programs on "micropulping" of limited amounts of wood (14).

One important side information, already well documented from the data obtained in this program, is the apparently large proportion of trees with high lignin and (polar) extractives contents among those which produce a high solids load in the black liquor, mostly due to low yield and high effective alkali consumption.

THE PULP QUALITY DILEMMA

Any tree improvement program aimed at the market pulp production must dedicate special attention to product properties. Whether softwoods or hardwoods are the case, the breeder is usually concerned with the effects of fiber morphology and chemistry upon the various combinations of paper properties, as demanded by the end user.

Fiber chemistry

The experience of Aracruz in tree improvement has indicated that, in the production of bleached eucalypt market pulp, the most important chemical properties to account for are the contents of non-polar extractives and hemicelluloses.

This conclusion is based on the production selection criterion, as described in the earlier section, whereby wood with lignin and polar extractives contents higher than average tend to limit pulp production, and are therefore not used for propagation.

With regard to non-polar extractives, which are not as efficiently removed from the pulp during the kraft as the polar entities, attention has been directed at detailed identification of the main components of DCM extracts, and the eventual correlation of those with pitch problems in pulp and paper mills, as well as potential effects on paper liquid absorbancy. Preliminary results have indicated that the presence of the various extraneous components is a complex function of the genetic source plus a number of environmental factors, such as site adaptability, photosynthetic characteristics, average rainfall, etc. Furthermore, no relationship whatsoever has been found between contents of extractives and the basic density of wood. (Figure 2).

The research program in this area is still in its initial stages, and the results have not yet been applied as screening factors.

FIGURE 2

WOOD DCM EXTRACTIVES CONT VS WOOD CHIP BASIC DENSITY

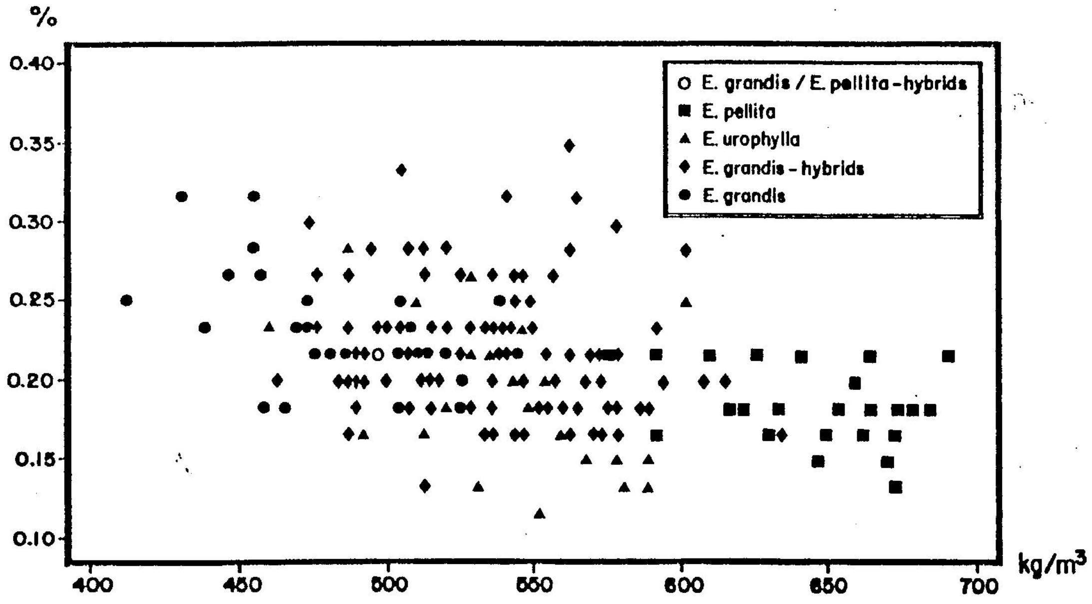
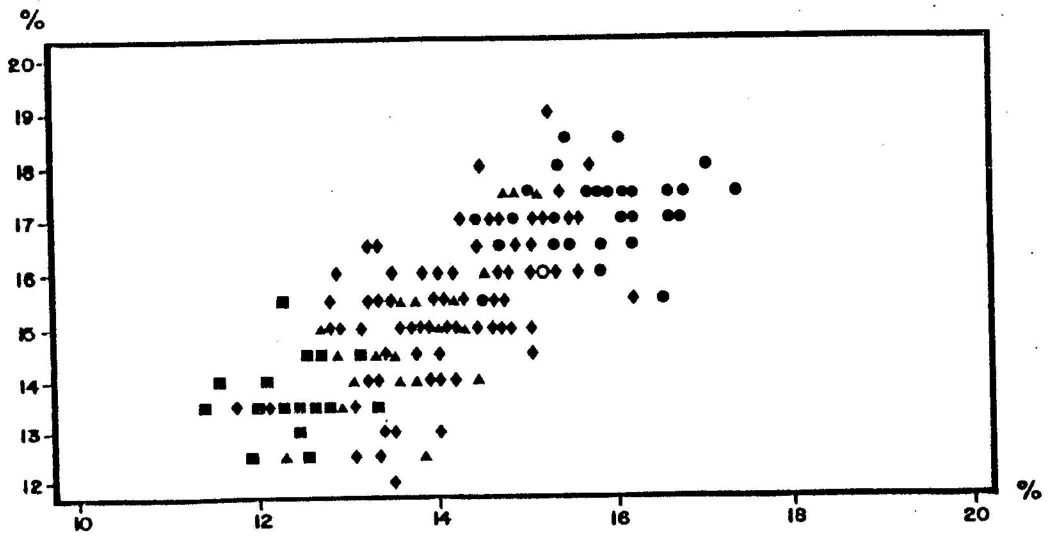


FIGURE 3

PULP PENTOSANS CONTENT VS WOOD PENTOSANS CONTENT



On the other hand the hemicelluloses have deserved a much more simplified approach, since they occur mostly as xylans in eucalypts, and their contents in pulp are strongly correlated with those in wood (Figure 3) as also earlier described (10).

However, the observed decrease in wood pentosans with basic density, as described in the same reference, has not been confirmed for the much larger population of trees analysed to this time. Thus, it has been internally decided to proceed with the monitoring of this chemical characteristic in the selected trees, and hold any decision with regard to selection criteria until the effects of combination of pentosans content and fiber morphology on paper properties have been identified.

Fiber Morphology

Many attempts have been made to describe (or predict) paper structure and properties using basic fiber morphology parameters. The most recent literature, whether dedicated to fundamental modelling (15, 16) or general evaluation of cause and effect (17, 18) has clearly confirmed the great influence of fiber wall thickness, length and strength (to a lower extent) on paper characteristics.

A - Fiber Wall-Thickness

It is also quite well established that fiber flexibility bears a direct relationship with fiber conformability and consolidation of the paper structure (16, 19), and experimental evidence indicates that stiff fibers are usually obtained from wood with high basic density.

Hardwoods in general (18), and particularly eucalypts (10, 20) are no exception to these trends, which characterize wood basic density as the simplest and first indicator of papermaking potential and paper sheet properties.

Accordingly, in Aracruz's tree improvement program, it has been repeatedly evidenced that fibers from high density woods have low flexibility due to the large moments of inertia of the fiber cross-sections (thick-walled fibers) (19), and are thus more resistant to the action of consolidation forces during paper web formation.

The result is a more open structure, with higher bulk, opacity, porosity and surface roughness at any given level of mechanical treatment (refining). These characteristics have important consequences on paper strength properties, which are known to depend mostly on the number and strength of fiber-to-fiber bonds.

Such aspects are illustrated in Figures (4 - 7), for laboratory pulps beaten at 1500 revolutions in the PFI mill (SCAN standards). It can be observed that even for different species and hybrids, which account for most of the scattering of data, the influence of wood basic density (and hence fiber wall thickness) is fundamental with regard to paper quality.

At this point it would appear that the task to draw guidelines and propose limits for desirable paper properties could be limited to finding out special combinations of bulk/porosity/smoothness and strength, as influenced by fiber flexibility (and basic density). In other words, the selection criteria for pulp quality could be defined in terms of minimum and maximum limits of wood basic density to be propagated, and the pentosans contents would be optimized to reach the desired combination of paper properties, as earlier described.

So far this has been the major thrust of this research, in terms of practical results. But it still faces major challenges, such as discovering a right combination of the bulk/porosity/smoothness strength relationship to meet most market needs, and its interaction with actual paper making process variables, such as refining, forming, wet-end chemistry etc.

B - Fiber Length

Another important aspect, not accounted for in the earlier discussion, is the effect of fiber length on paper properties. Since fiber length may be genetically controlled and also changed through silvicultural traits, its importance on a tree breeding program may be higher than earlier anticipated (8), particularly when combined with the selection based on fiber wall thickness (wood basic density).

In this context, a first point to address is the extent of fiber length variability. For the genetic material being studied by Aracruz it can be seen that a large variability is present, and most importantly, it does seem to be quite independent from the basic wood density of trees at same age (Figure 8).

The second aspect to evaluate is the actual effect of fiber length alone on paper properties, and the biggest challenge has been to isolate this effect from that of fiber flexibility, as the latter is strongly correlated with wood density.

A number of model experiments have been specifically designed with this objective, and they have been quite successful. One of them involved pulping and bleaching of wood chips from the heartwood and sapwood separetely, for different trees (21). The fiber cross-sectional dimensions were essentially the same, for the two selected specimens in each tree, but fiber length was considerably different.

The results in Table 8 have indicated that bulkier sheets, with higher porosity, lower opacity, and strength are obtained from longer fibers of virtually the same flexibility (estimated by Luce's factor or moment of inertia) as their shorter counterparts.

In another experiment, the pulps from three different trees were analysed. Again, the main variable was weighted average fiber length, and the conclusions were virtually the same (Table 9).

Such results are in apparent contrast with the more generalized conception that longer fibers produce stronger papers. This somewhat "established" idea is probably based on studies of softwood chemical and mechanical pulps, for which tear strength is a critical property. Furthermore, it has been very difficult to distinguish between the fiber flexibility and fiber length effects, with the types of raw materials utilized in most published results.

The use of automatic fiber length (and coarseness) analysers, coupled with the wide variation in a tree breeding program, such as ours, have enabled the identification of the fundamental effect of fiber length, and most importantly, the number of fibers per gram of pulp on paper

FIGURE 4

1,500 PFI REVOLUTIONS

BULK VS WOOD CHIP BASIC DENSITY

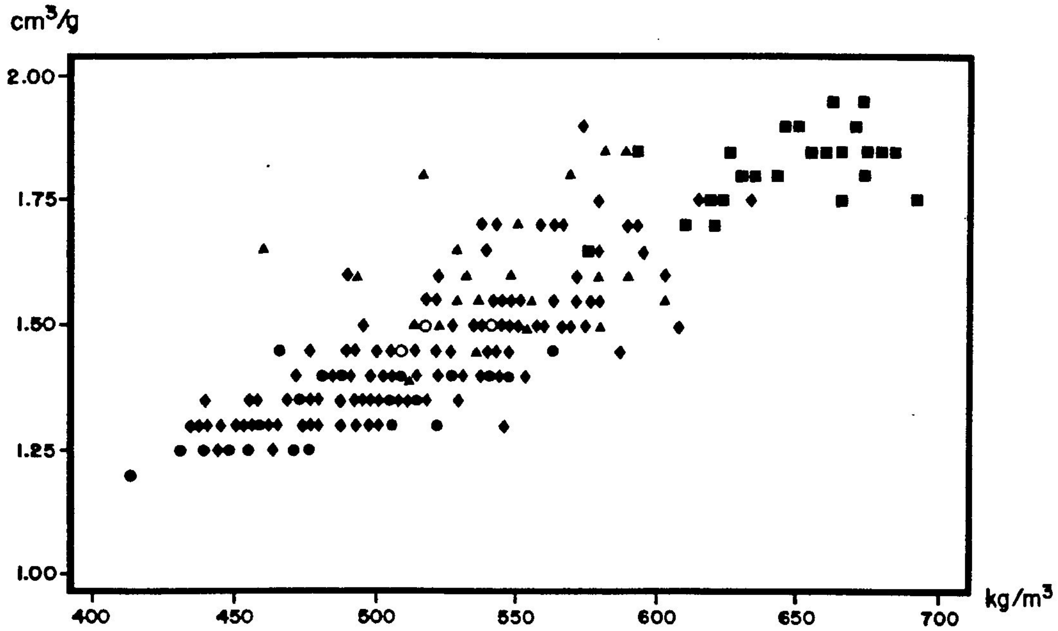


FIGURE 5

1,500 PFI REVOLUTIONS

GURLEY AIR RESIST VS WOOD CHIP DENSITY

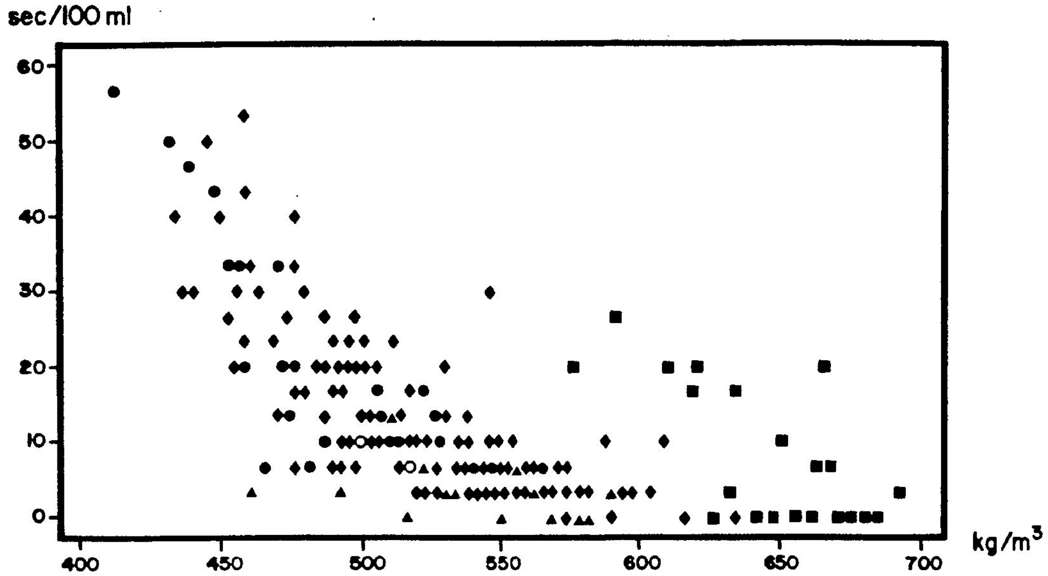


FIGURE 6

1,500 PFI REVOLUTIONS

BENDTSEN ROUGHNESS VS WOOD CHIP BASIC DENSITY

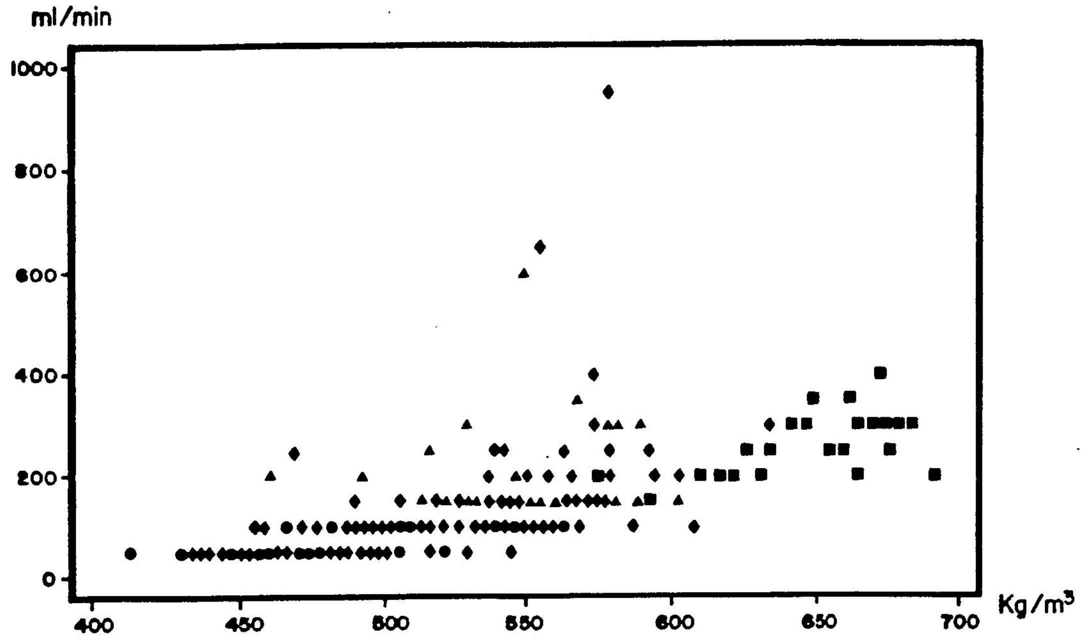


FIGURE 7

1.500 PFI REVOLUTIONS

TENSILE INDEX VS WOOD CHIP BASIC DENSITY

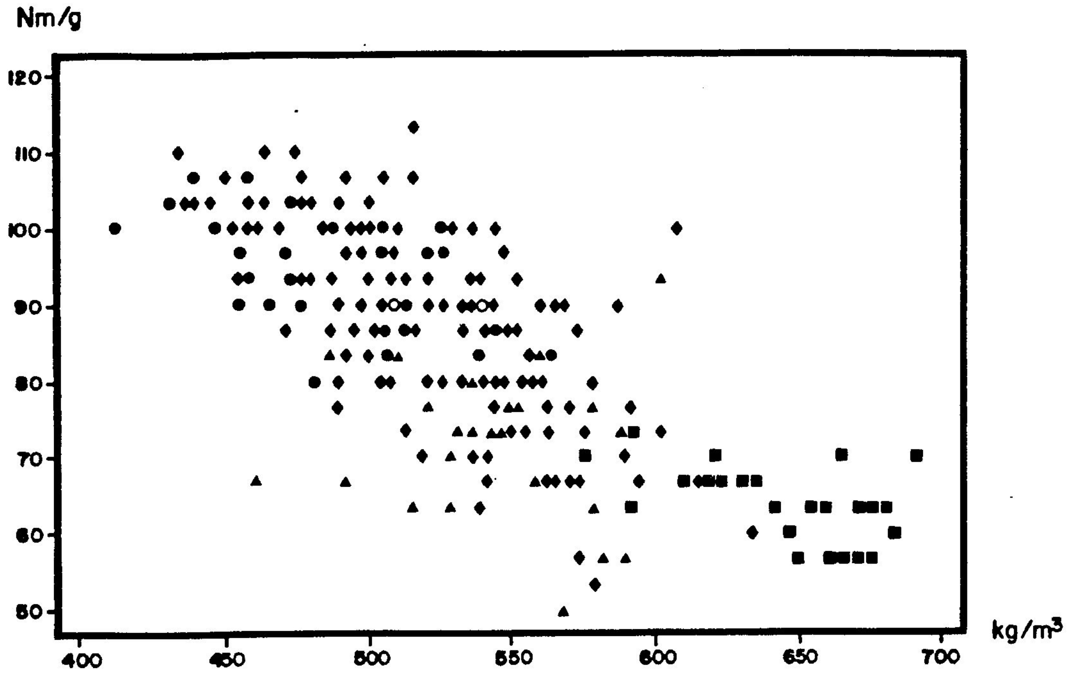


FIGURE 8

KAJAANI FIBER LENGHT VS WOOD CHIP BASIC DENSITY

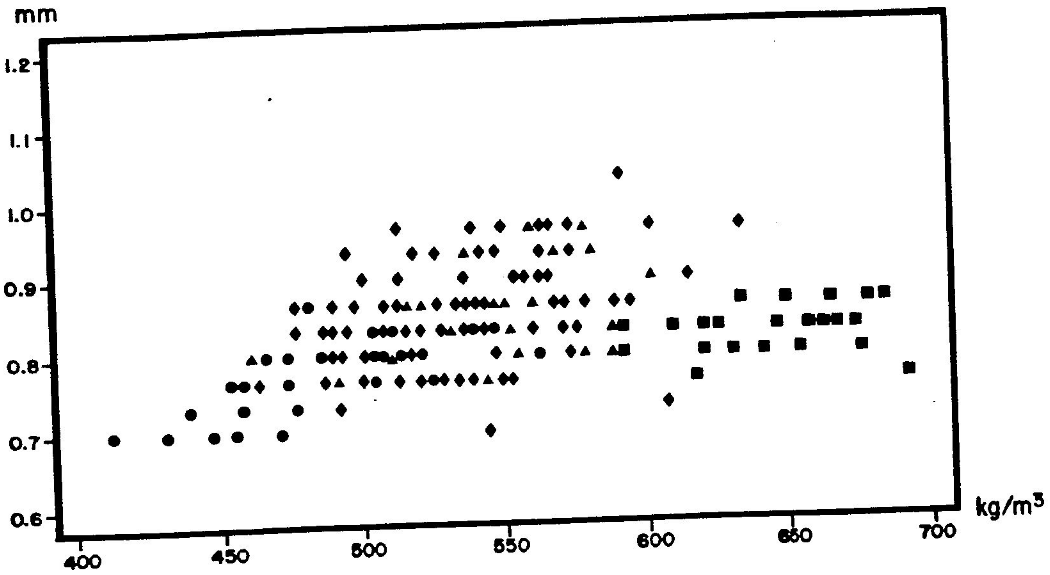


TABLE 8 - LABORATORY PULPS FROM SAME TREE - THE INFLUENCE OF FIBER LENGTH ON PAPER PROPERTIES OF UNBEATEN HANDSHEETS (21)

SAMPLES	MOMENT OF INXERTIA, FIBER CROSS SECTION (μm^4)	LUCE'S SHAPE FACTOR	KAJAANI FIBER LENGHT (mm)	NUMBER OF FIBERS PER GRAM (million)	TENSILE INDEX (Nm/g)	GURLEY-AIR RESISTANCE (SEC/100 ml)	APPARENT DENSITY (kg/m^3)	LIGTH SCATTERING COEFFICIENT (m^2/kg)
Heartwood Fibers	1,851	0.59	0.85	16.7	35.9	1.03	574	38.5
Heartwood + sapwood Fibers (40/60 mixture)	1,613	0.58	0.74	21.6	40.6	2.16	615	41.4
Sapwood Fibers	1,577	0.57	0.64	27.2	43.3	3.84	662	44.0

TABLE 9 - FIBER LENGTH VS PAPERMAKING PROPERTIES OF EUCALYPTS (1500 revs. PFI)

PULP	WEIGHTED AVE. FIBER LENGTH (mm)	FIBER COARSENESS (mg/100m)	FIBERS PER GRAM (million)	BULK (cm^3/g)	AIR RESISTANCE (sec/100 ml)	LIGTHT SCATTERING COEF. (m^2/kg)	TENSILE INDEX (N m/g)
A	0.60	8.2	21.7	1.44	18.6	41.2	62.7
B	0.63	8.2	20.5	1.53	7.5	37.8	58.8
C	0.66	8.5	16.5	1.58	5.2	36.2	52.4

FIGURE 9

UNBEATEN PULP

BULK VS NUMBER OF FIBERS PER GRAM

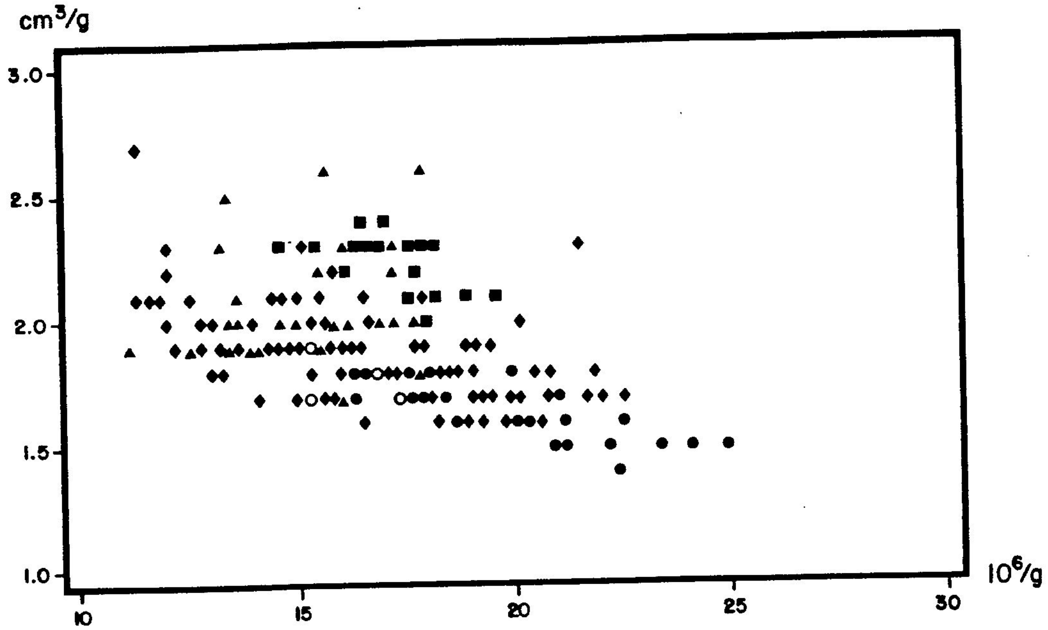


FIGURE 10

UNBEATEN PULP

GURLEY AIR RESIST VS NUMBER OF FIBERS PER GRAM

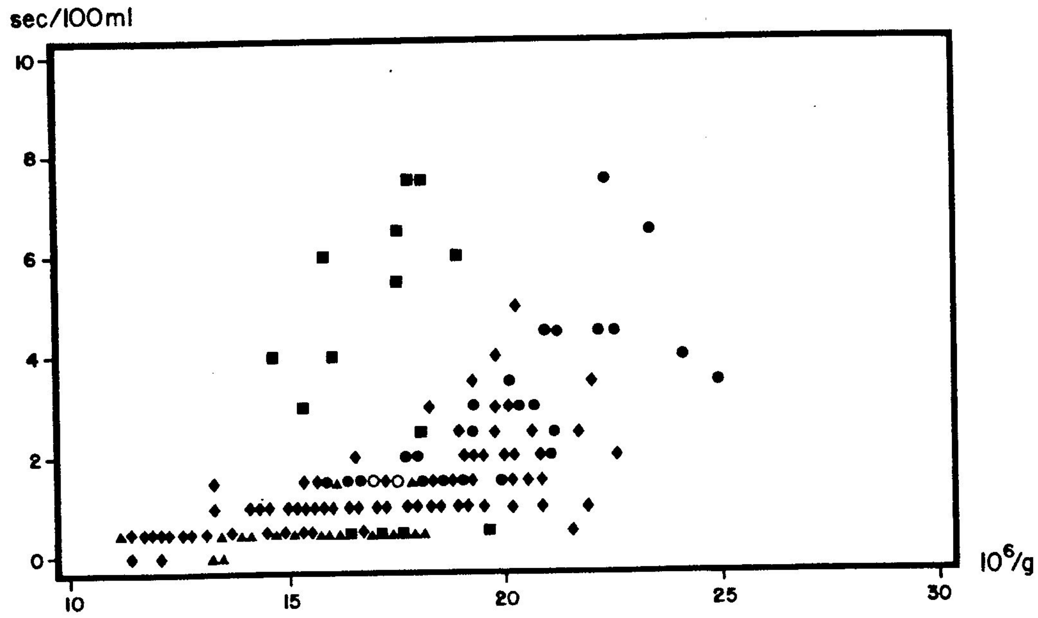


FIGURE 11

UNBEATEN PULP

BENDTSEN ROUGHNESS VS NUMBER OF FIBERS PER GRAM

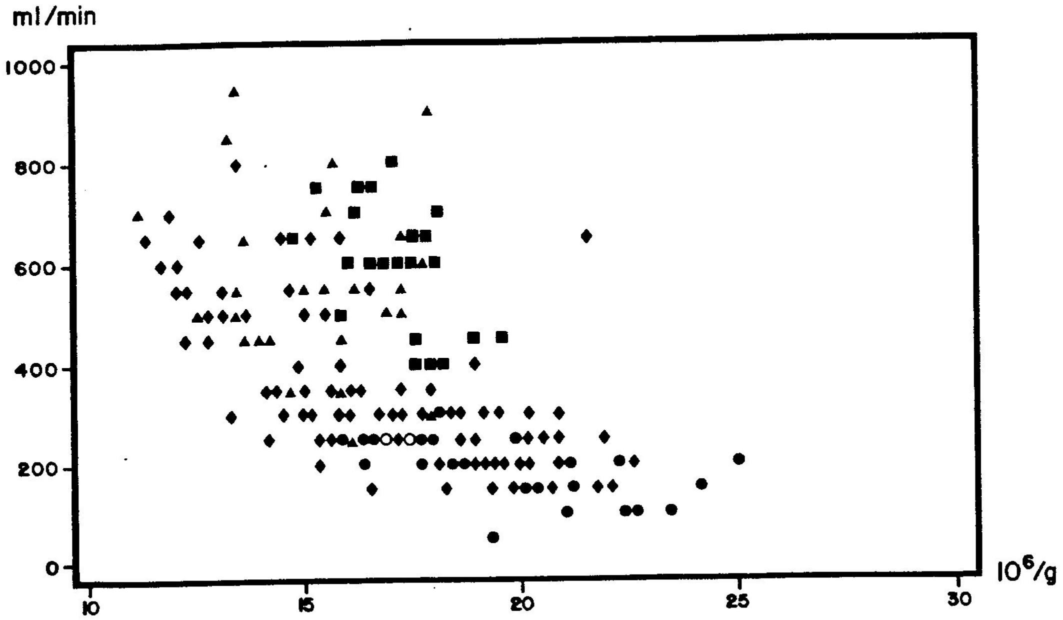
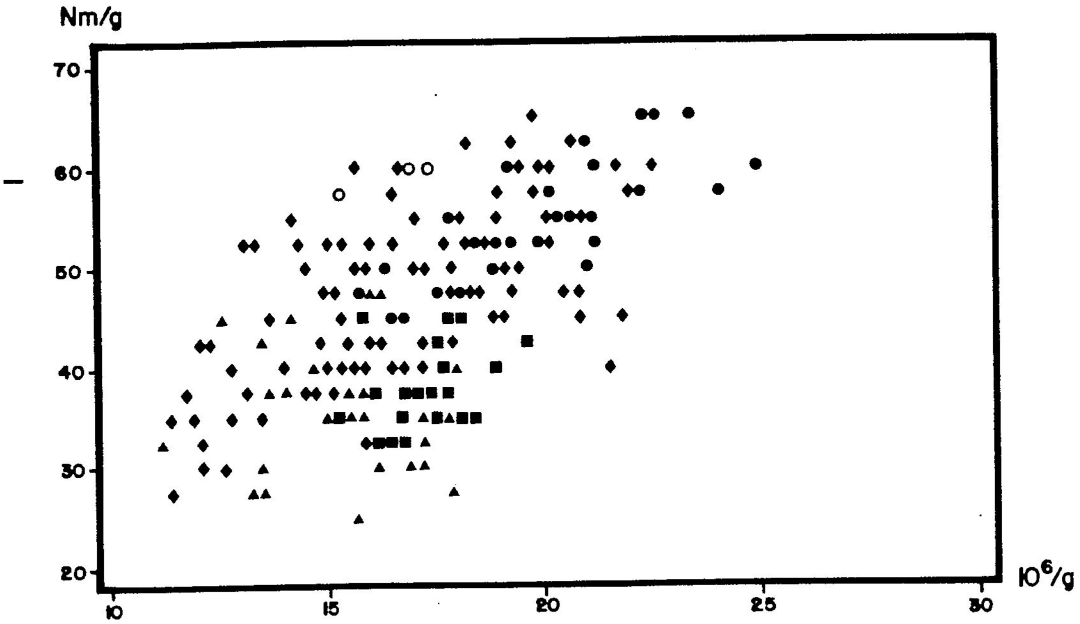


FIGURE 12

UNBEATEN PULP

TENSILE INDEX VS NUMBER OF FIBERS PER GRAM



properties. The results illustrated in Figures 9 to 12 are indicative of this phenomenon.

Certainly those results do not reflect the effect of fiber length alone, since the number of fibers per gram is inversely proportional to fiber coarseness, and the latter is also influenced by fiber wall thickness. The use of the number of fibers per gram of pulp provides a better physical interpretation of its correlation with paper properties than fiber length per se, and it brings other anatomical characteristics into the picture, such as fiber width and cell wall density, which also have impacts on fiber coarseness.

The scientific and technical discussion brought up from these findings is still in its initial stages. There is a somewhat generalized understanding that much has yet to be discovered and analysed about fiber length, fiber coarseness and their influence on paper structure, especially when combined with fiber flexibility.

Anyhow, some preliminary information in this direction may already be obtained from the application of available statistical techniques, such as stepwise multiple regressions. Examples of those are included in Table 10 below.

TABLE 10 - MULTIPLE LINEAR REGRESSIONS - PAPER PROPERTIES vs WOOD CHIP BASIC DENSITY AND NUMBER OF FIBERS PER GRAM OF PULP - RESULTS FOR 156 SELECTED TREES - 1500 REVS PFI MILL.

PAPER PROPERTY	DEPENDENT VARIABLES	r^2	F
Tensile Index	+ NF	0.42	112
	+ NF - BD	0.49	74
Bulk	- BD	0.45	127
	- BD + NF	0.56	98
Porosity	+ BD	0.54	182
	+ BD - NF	0.67	158

BD - Wood Chip Basic Density (range 414 to 634 kg/m^3)
NF - Number of Fibers per gram of pulp (range 11,2 to 19,2 million)
All results significant at 99.99% confidence level.

Undoubtelly this is a very ambitious tree selection program. The results in terms of forest yield and manufacturing productivity are good examples of successful applied research. With regard to pulp quality, the great challenge is to find out the right technical answers, and part of the dilemma is to understand exactly what the papermaker wants.

Aracruz would like to select trees that would give the best possible fibers for different paper grades. The job is gigantic, but is has been performed with enthusiasm, and from quality point-of-view it already provides the great advantage of better fiber uniformity from the cloned trees.

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