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pulping and paper-making properties of fast-growing plantation wood species

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F O R E W O R D

This manual is mainly intended to provide information to tree plantation planners who are interested in the pulping and paper-making characteristics of the species considered for planting. The characteristics vary somewhat with growth conditions and age of the trees and the values given in the data sheets always refer to a specific sample of wood from a specific plantation. The conclusions drawn in the text from the data sheets pertain to these samples. The reader should accordingly bear in mind that samples from plantations with different growth conditions may exhibit differing characteristics, as evidenced repeatedly from the data sheets for some species.

The manual was first published in 1976 and consisted then of only one volume. That edition, which is no longer available, is practically identical to Volume I of the present edition.

A C K N O W L E D G E M E N T

The present volume of "Pulping and Papermaking Characteristics of Fast-Growing Plantation Wood Species" was prepared by Mr. B. Kyrklund in 1974 during a four and a half months' consultancy assignment which, in addition to compilation and evaluation of the data, included design of the format to be used.

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1. INTRODUCTION

1.1 BACKGROUND INFORMATION

The information presented in this volume is based on data published in the period 1950 to 1972, with some data from 1973 included. Subsequent volumes give data published in later periods. The intention is to add new volumes from time to time to up-date the information and to give it a broader base.

A list of references is given in Appendix I.

1.2 GENERAL INFORMATION ON THE DATA SHEETS

The data sheets give information on one or several samples of wood for each species. In the latter case, the data for each sample are presented separately on the same data sheet for comparison. The basic information given in the data sheets is divided into three main parts:

(a) Origin of wood sample including age, when known, and any special conditions;

(b) Wood characteristics of sample. This includes basic density, fibre dimensions and chemical characteristics;

(c) Pulping and papermaking characteristics of the wood sample. This may include a range of conditions applied in the same process as well as the corresponding range of properties of the pulps and/or different types of processes applied.

In addition to these data sheets which relate to one reference each, an evaluation of each species has been included in the form of a summary based on the information given in the data sheets on that species as well as additional information obtained. Some guidelines are also given as regards experience with respect to plantations and acclimatization of the species in different parts of the world.

The summary for each species shows the references from which the information has been obtained under 'Plantation experience' and, in a few cases, under 'Pulping characteristics.' The references for 'Wood characteristics' and the main references for 'Pulping characteristics' are given on the relevant data sheets.

The definitions of the terms used are given in Appendix II and a list of the species included is given in Appendix III.

2. INTERPRETATION OF THE DATA SHEETS

2.1 COMPARISON OF PULPING AND PAPERMAKING DATA

Although the determinations of basic density, fibre dimensions and chemical characteristics of wood are fairly straightforward and reasonably well standardized so that values obtained in different laboratories are comparable, this is not so when it comes to determination of the papermaking characteristics of pulps. In spite of the standardization work which has been carried out in this field, there still remains considerable discrepancy in strength property values. The reason for this is basically that the strength properties of a test sheet of pulp depend, to a great extent, on the treatments given to the pulp before the actual determination of a certain strength value is carried out, as well as on the atmospheric conditions in the room where the determination is made. As regards the latter, three atmospheric conditions are used in the pulp and paper industry; the two most common are 23°C and 50% RH (relative humidity) in Canada and the USA and 20°C and 65% RH in Australia, Europe and New Zealand. In countries like India the conditions are 27°C and 65% RH. In other countries the standards vary with one of the three sets of conditions being used.

As regards the pretreatment of the pulp prior to testing, the factors which affect the results are as follows:

(a) The equipment used for refining and/or beating of the pulp;

(b) The freeness of the pulp after refining and/or beating, expressed either in Canadian Standard Freeness (CSF) or Schopper Riegler (SR) units;

(c) The equipment used for making the sheet of paper for testing;

(d) The extent of pressing of the wet sheet prior to drying and also against what surface the sheet has been pressed;

(e) The way of drying of the sheets and also to what extent shrinkage of the sheet has been allowed or prevented during drying;

(f) The grammage (basis weight) of the sheets used for testing;

(g) The grammage used in the calculation of strength properties (oven-dry or as conditioned);

(h) The type of equipment used for the determination.

Several sets of combinations of these critical factors are in use in different countries and laboratories and this is the main reason for the discrepancy of the results of strength testing.

As regards the actual strength testing, once the conditions for beating and sheet making have been set as well as the atmospheric conditions, there still remains the variation due to different items of equipment for testing, but this is of minor importance in this context.

It is evident from the above that as regards the strength properties given in the data sheets, no direct comparison can be made of the values reported by different sources and consideration has to be given to the influence on the results by the factors mentioned above.

2.3 EVALUATION OF THE PULPING AND PAPERMAKING PROPERTIES

In order to facilitate understanding of the results given in the data sheets, an evaluation has been made of each species in the form of a summary where a general rating is used, with wordings like 'under average', 'good' and 'excellent'. These ratings refer only to hardwoods and softwoods separately. The basis for the comparison is an 'average' pulp of a commercial grade, from either hardwood or softwood, of whichever type the species may be. Unfortunately inclusion of reference data for this comparison cannot be given, as they would inevitably lead to misunderstanding due to the reasons given in Section 2.1.

The conslusions arrived at in the evaluation of the results apply only to the samples for which data have been given. It is possible that other wood samples of the same species would lead to other conclusions, due to difference in seed origin, as well as soil and climatic conditions. The age of the tree also exerts an influence on the results.

3. SUMMARIES AND DATA SHEETS FOR INDIVIDUAL SPECIES

Acacia albida

Plantation experience

This species is native to tropical and subtropical Africa on flood plains and riverine alluvials. It is one of the largest trees of the Acacias and relatively uncommon in the natural forests but prominent on cultivated areas. It is found in localities with only 250-400 mm annual rainfall. It does not grow on lateritic soils or soils with impeded drainage. While it withstands short periods of flooding, it does not do well under irrigation, especially on heavy soils. It is fairly frost resistant.

The tree is particularly valuable in agricultural areas on account of its unusual habit of retaining its leaves during the hot weather and dropping them during the rains. The pods and leaves are very good fodder, and the pods - prolific crops of which are produced annually - can be stored. The pod and leaf fall, together with the dung and urine of cattle that seek the shade of the trees in hot weather, improve the nutrient status and physical condition of the soil so that yields of agricultural crops cultivated during the rains are considerably increased. It is an important tree in the village economy and is declared a protected tree in some areas.

It is grown as a scattered tree and never in close plantations. The bark yields tannins.

References: 41, 111

Wood characteristics

The wood is fairly soft and of intermediate density. It is used for rough carpentry and joinery work. It is liable to stain and to attack by borers. The extractives content seems somewhat high and also the lignin content which is apt to affect the quality of pulp produced therefrom, firstly due to fairly severe chemical treatments being required and secondly because precautions have to be taken to lower the content of extractives in the pulp.

The fibres are of average length for hardwood, but with a somewhat high wall thickness which tends to make the fibres stiff and prevent proper bonding in paper.

Pulping characteristics

In spite of the fairly high alkali charge used for sulphate and chemical soda pulping - 17% and 20% Na_2O as active alkali respectively - the Kappa number has remained far above the acceptable range for hadwood pulp. In addition to this, the yield of unbleached pulp is very low. The brightness of the NSSC pulp is also low. None of the processes tried, sulphate, chemical soda and NSSC, seem to give pulps of acceptable quality, either as unbleached or bleached pulp. This species is not recommended for plantations for pulping.

Scientific name: Acacia albida	Common name: Country: Senegal	Reference: 108

Wood sample characteristics

Wood sample origin:

Logs of 22-60 cm diameter from the region of Diourbel

Density and fibre characteristics:

Basic density, g/cm^3	0.54
Fibre length, µ*	1 080
Fibre width, µ*	23
Wall thickness, µ*	6
Lumen width, µ*	11
Length/width ratio	47
Runkel ratio	1.09
Flexibility ratio	0.48

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	4.22
Solubility, %	
in water	8.66
in 1% NaOH	14.8
Ash, %	2.92
Lignin, %	33
Holocellulose, %	
Cross-Bevan cellulose, %	
Pentosans, %	15.6

Additional information:

Pulping and papermaking characteristics

Unbleached			
Process	Sulphate	Soda (170°C)	NSSC
Chemical consumption, %	16.6 - 15.1	13.5 Na_2)	4.6 - 4.7 SO_2
Kappa number	44 - 59	74	-
Yield (unscreened), %	43.0 - 47.4	43.8	67.6 - 60.4
Screenings, %	0.4 - 1.1	1.8	0
Brightness (Photovolt	25 - 26.5	28.5	32.5
Beater or refiner	Bauer	Bauer	Bauer
Freeness	40 SR	40 SR	40 SR
Breaking length, m	4 200 - 4 300	4 100	2 400 - 3 300
Burst factor	22 - 23	20	21 - 24
Tear factor	84 - 79	70	39 - 49
Bleached			
Sequence	CEHH	CEHH	
Chemical consumption, %	9.3 Cl	11.8 Cl	
Yield on bleaching, %			
Total yield, %			
Brightness (Photovolt	83	84	
Beater or refiner	Bauer	Bauer	
Freeness	40 SR	40 SR	
Breaking length	4 800	4 500	
Burst factor	23	21	
Tear factor	81	72	

Additional information:

Acacia auriculiformis

Plantation experience

Indigenous to the islands off the north coast of Australia, this species grows fast on poor soils in rainfalls of about 1 500-1 800 mm a year and a dry season of 6 months. It has been introduced successfully as an exotic in India and Malaysia, both on the mainland and Sarawak as well as in Tanzania, on the mainland and on Zanzibar. It adapts itself to a wide range of soils and has been used successfully on steep slopes to check soil erosion.

References: 41, 123

Wood characteristics

The chemical composition of the wood does not imply any difficulties with regard to reactivity in pulping processes. The fibres are fairly short, even for hardwoods. The thinness of the fibres implies a fair amount of stiffness, although this cannot be ascertained due to the lack of data on the wall thickness or lumen width.

Pulping characteristics

The yield of pulp is on the low side in sulphate pulping, although be due to over-cooking (no indication is given of the degree of delignification arrived at). The strength properties of the sulphate pulps, both unbleached and bleached, are not up to normal requirements for hardwood sulphate pulp. The NSSC process on the other hand seems to give a just acceptable pulp with respect to strength properties, with a yield in the normal range. However, judging from the bleach consumption and the brightness arrived at on bleaching, the unbleached pulp has been very dark in colour. For use in cheap writing and printing grade paper an additional bleaching stage would be required, with a consequent increase in the bleach consumption. As unbleached, the NSSC pulp could be used in products where brightness is of no importance.

Scientific name: Acacia auriculiformis	Common name: Country: India	Reference: 67

Wood sample characteristics

Wood sample origin:

Sample from plantation in West Bengal, logs 15 cm in diameter

Density and fibre characteristics:

Basic density, g/cm^3	
Fibre length, µ*	840
Fibre width, µ*	14
Wall thickness, µ*	
Lumen width, µ*	
Length/width ratio	60
Runkel ratio	
Flexibility ratio	

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	1.16
Solubility, %	
in water	3.12 (hot)
in 1% NaOH	16.8
Ash, %	0.41
Lignin, %	23.6
Holocellulose, %	
Cross-Bevan cellulose, %	59.2
Pentosans, %	18.7

Additional information:

Pulping and papermaking characteristics

Unbleached		
Process	NSSC	Sulphate
Chemical consumption, %	5.8 - 9.0 SO_2*	13.9 - 18.6 Na_2O*
Kappa number	73.4 - 75.1	48.1 - 44.4
Yield (unscreened), %		
Screenings, %		
Brightness		
Beater or refiner	Lampén	Lampén
Freeness	300 CSF	300 CSF
Breaking length, m	3 400 - 4 600	4 200 - 4 700
Burst factor	18 - 30	19 - 18
Tear factor	45 - 56	59 - 56
Bleached		
Sequence	CEH	CEH
Chemical consumption, %	20.1 - 16.7 Cl	8.4 - 7.1 Cl
Yield on bleaching, %		
Total yield, %	52.8 - 48.0	41.4 - 40.0
Brightness (Photovolt)	62 - 68	71 - 75
Beater or refiner	Lampén	Lampén
Freeness	300 CSF	300 CSF
Breaking length	4 000 - 5 500	4 600 - 4 900
Burst factor	27 - 43	23 - 29
Tear factor	56- 74	66 - 69

Additional information:

* Charge

Acacia dealbata
(Silver Wattle)

Plantation experience

Indigenous to southern Australia, this species is cultivated for its flowers (Mimosa) in southern Europe. It has been introduced successfully as an exotic in Sri Lanka at an altitude of 1 500-1 800 m, in India in the Nilgiri Hills, Kenya, Cyprus, New Zealand, Southern Rhodesia, Uganda, and the Republic of South Africa. However, in most instances it has been replaced by *Acacia decurrens*, the bark of which yields a tanning agent of better quality. The bark of *A. dealbata* contains about 25% tanning agent of inferior quality.

Reference: 123

Wood characteristics

The density of the wood is within the range average for hardwoods. No data for chemical composition or fibre characteristics are available for the present samples.

Pulping characteristics

The alkali consumption in the chemical soda process is in the normal range for hardwoods. The pulp is obtained with a good yield, and by using a less severe treatment so as to achieve a Kappa number of about 20 instead of the value 15, arrived at for the present samples, a slightly higher yield may be expected. This would probably also enhance the strength properties which already are acceptable, and comparable to an average quality poplar chemical soda pulp. The species seems to be suitable for pulping by the sulphate process in which case a further improvement of the strength properties can be expected.

Scientific name:	Common name: Silver wattle	Reference:
Acacia dealbata (Syn. A. decurrens var. dealbata)	Country: Tasmania, Australia	6

Wood sample characteristics

Wood sample origin:

Samples from natural forest at Wesley Vale

a) Mountain region, 42 years old

b) Foothill region, 33 years old

Density and fibre characteristics:

	a)	b)
Basic density, g/cm^3	0.46	0.53
Fibre length, µ*		
Fibre width, µ*		
Wall thickness, µ*		
Lumen width, µ*		
Length/width ratio		
Runkel ratio		
Flexibility ratio		

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %
- Ether
- Methanol
- Ethanol-benzene

Solubility, %
- in water
- in 1% NaOH

Ash, %
Lignin, %
Holocellulose, %
Cross-Bevan cellulose, %
Pentosans, %

Additional information:

Pulping and papermaking characteristics

	a	b
Unbleached		
Process	Soda (170 $^{\circ}$C)	Soda (170 $^{\circ}$C)
Chemical consumption, %	17.7 Na_2O*	17.5 Na_2O*
Kappa number	15	15
Yield (unscreened), %	51.0	52.2
Screenings, %		
Brightness (Tappi)	37	36
Beater or refiner	PFI	PFI
Freeness	250 CSF	250 CSF
Breaking length, m	7 100	8 200
Burst factor	57	63
Tear factor	81	96
Bleached		
Sequence		
Chemical consumption, %		
Yield on bleaching, %		
Total yield, %		
Brightness		
Beater or refiner		
Freeness		
Breaking length		
Burst factor		
Tear factor		

Additional information:

* Charge to obtain Kappa number 15

Acacia decurrens
(Green Wattle)

Plantation experience

This species is native to south-west Australia, where it grows in valleys ascending to subalpine elevations, along the coast. Commercially it is a very important species because of its bark, which yields a good quality tanning agent.

It prefers moist sites and cool winters with an annual rainfall of 1 000 mm or more. It has been extensively cultivated for its tanbark in Australia; New Zealand; South, Central and East Africa; India and Sri Lanka.

References: 15, 43, 123

Wood characteristics

The fibres of this species are fairly short and also thin, which implies a certain amount of undesirable stiffness, although this cannot be ascertained from the present data due to the lack of information on wall thickness or lumen width. The chemical composition is typical for a hardwood which would offer no difficulties on pulping.

Pulping characteristics

The alkali requirement on sulphate pulping is slightly on the high side but the pulp is obtained with a good yield. The strength properties of the bleached pulp (semi-bleached - no indication is given of the resulting brightness) are similar to those of a poplar sulphate pulp.

The species also adapts itself well to production of crude sulphate or crude chemical soda pulp (yield 60-70%), with good strength characteristics, although the burst factor is somewhat low. This type of pulp from *A. decurrens* has been used successfully in pilot runs for the production of wrapping paper, with an addition of 30% long-fibre pulp (bamboo) to the furnish (12). Although the energy requirement on application of a mechanical stone grinder process is in the range normal for this kind of pulp, the strength properties of the resulting pulp are far too low for newsprint.

Scientific name: Acacia decurrens	Common name: Green wattle Country: India	Reference: 15

Wood sample characteristics

Wood sample origin:

Sample from plantation at Kodaikanal

Density and fibre characteristics:

Basic density, g/cm^3	
Fibre length, μ*	860
Fibre width, μ*	14
Wall thickness, μ*	
Lumen width, μ*	
Length/width ratio	61
Runkel ratio	
Flexibility ratio	

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	0.36
Methanol	
Ethanol-benzene	1.07
Solubility, %	
in water	2.26 (hot
in 1% NaOH	15.6
Ash, %	0.36
Lignin, %	21.2
Holocellulose, %	
Cross-Bevan cellulose, %	63.2
Pentosans, %	19.4

Additional information:

Pulping and papermaking characteristics

Unbleached

Process	Sulphate
Chemical consumption, %	17.8 - 19.0 Na_2O
Kappa number	
Yield (unscreened), %	59.0 - 51.0
Screenings, %	
Brightness	
Beater or refiner	
Freeness	
Breaking length, m	
Burst factor	
Tear factor	

Bleached

Sequence	HEH
Chemical consumption, %	2.1 - 2.3 Cl
Yield on bleaching, %	
Total yield, %	55.0 - 50.0
Brightness	
Beater or refiner	Lampén
Freeness	320 CSF
Breaking length	8 500 - 6 900
Burst factor	51 - 35
Tear factor	91 - 54

Additional information:

Scientific name: Acacia decurrens	Common name: Green wattle Country: India	Reference: 12

Wood sample characteristics

Wood sample origin:	Chemical characteristics:
Sample from Madurai, Madras	Extractives, % Ether Methanol Ethanol-benzene
	Solubility, % in water in 1% NaOH
Density and fibre characteristics: Basic density, g/cm^3 Fibre length, µ* Fibre width, µ* Wall thickness, µ* Lumen width, µ* Length/width ratio Runkel ratio Flexibility ratio	Ash, % Lignin, % Holocellulose, % Cross-Bevan cellulose, % Pentosans, %
Additional information:	Additional information:
* 1000 µ (microns) = 1 mm	

Pulping and papermaking characteristics

Unbleached		
Process	Sulphate	Soda (142-162°C)
Chemical consumption, %	7.8 - 10.8 Na_2O*	7.8 - 10.8 Na_2O*
Kappa number		
Yield (unscreened), %	72.9 - 62.5	76.7 - 62.6
Screenings, %		
Brightness		
Beater or refiner	Lampén	Lampén
Freeness	300 CSF	300 CSF
Breaking length, m	7 300 - 8 900	6 000 - 7 900
Burst factor	34 - 46	26 - 45
Tear factor	63 - 90	55 - 79
Bleached		
Sequence		
Chemical consumption, %		
Yield on bleaching, %		
Total yield, %		
Brightness		
Beater or refiner		
Freeness		
Breaking length		
Burst factor		
Tear factor		

Additional information:

* Charge.

Scientific name:	Common name: Green wattle	Reference:
Acacia decurrens	Country: India	16

Wood sample characteristics

Wood sample origin:

Sample from the Nilgiris Division, 9 years old

Density and fibre characteristics:

Basic density, g/cm^3
Fibre length, μ*
Fibre width, μ*
Wall thickness, μ*
Lumen width, μ*

Length/width ratio
Runkel ratio
Flexibility ratio

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %
  Ether
  Methanol
  Ethanol-benzene

Solubility, %
  in water
  in 1% NaOH

Ash, %
Lignin, %
Holocellulose, %
Cross-Bevan cellulose, %
Pentosans, %

Additional information:

Pulping and papermaking characteristics

Unbleached	
Process	Groundwood
Chemical consumption, %	
Kappa number	
Yield (unscreened), %	
Screenings, %	
Brightness	
Beater or refiner	Voith stone grinder
Freeness	115 CSF
Breaking length, m	1 200
Burst factor	4
Tear factor	16
Bleached	
Sequence	
Chemical consumption, %	
Yield on bleaching, %	
Total yield, %	
Brightness	
Beater or refiner	
Freeness	
Breaking length	
Burst factor	
Tear factor	

Additional information: Peripheral speed of grinder 180 m/s.

Acacia mollissima
(Black Wattle)

Plantation experience

Indigenous to south-west Australia, this species is considered to yield the best tanning agent of all the Acacia spp. It grows well in a climate with cool, moist winters and on moist soils in valleys or on hillsides. A very adaptable species. It has been planted extensively because of its tanbark in Australia; New Zealand; South, Central and East Africa; India and Sri Lanka and is often used as an under-storey in eucalypt plantations.

References: 15, 40, 41, 44, 123

Wood characteristics

The fibres of this species are very short and thin, the latter implying a certain amount of undesirable stiffness although this cannot be ascertained from the present data due to the lack of information on wall thickness or lumen width. The chemical characteristics of the wood exhibit a low content of extractives and lignin which implies ease of chemical pulping and no extractives problems in the pulp.

Pulping characteristics

The chemical consumption in the sulphate process is in the normal range for hardwoods and the pulp is obtained with a good yield. The strength properties of the semi-bleached pulp (no indication is given of the brightness arrived at) are somewhat better than those of a beech sulphate pulp, and thus slightly under average for short-fibre pulps. However, in view of the small fibre size, the pulp may exhibit excellent opacity, although no data have been given for the present sample.

High-alpha cellulose pulp for rayon has been prepared in the laboratory (119 by means of the prehydrolysis sulphate process with a yield normal for dissolving pulp (37% bleached pulp), high-alpha cellulose content (98%) and an acceptable level of pentosans content (2%). However, the processability of the pulp in the rayon process has not been tested.

Scientific name: Acacia mollissima (Syn. A. mearnsin)	Common name: Black wattle Country: India	Reference: 16

Wood sample characteristics

Wood sample origin:

Sample from plantation at Kodaikanal

Density and fibre characteristics:

Basic density, g/cm^3	
Fibre length, μ*	700
Fibre width, μ*	14
Wall thickness, μ*	
Lumen width, μ*	
Length/width ratio	49
Runkel ratio	
Flexibility ratio	

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	0.16
Methanol	
Ethanol-benzene	0.60
Solubility, %	
in water	3.28 (hot)
in 1% NaOH	16.0
Ash, %	0.36
Lignin, %	21.2
Holocellulose, %	
Cross-Bevan cellulose, %	64.0
Pentosans, %	20.3

Additional information:

Pulping and papermaking characteristics

Unbleached	
Process	Sulphate
Chemical consumption, %	15.2 - 16.0 Na_2O
Kappa number	
Yield (unscreened), %	62.5 - 55.0
Screenings, %	
Brightness	
Beater or refiner	
Freeness	
Breaking length, m	
Burst factor	
Tear factor	
Bleached	
Sequence	HEH
Chemical consumption, %	3.3 - 2.5
Yield on bleaching, %	
Total yield, %	60.0 - 53.7
Brightness	
Beater or refiner	Lampén
Freeness	315 CSF
Breaking length	7 700 - 5 800
Burst factor	46 - 35
Tear factor	90 - 57

Additional information:

Acacia nilotica

Plantation experience

Native to India, Arabia and North Africa, the species occurs on soils that are seasonally inundated. In the Sudan it is found chiefly in small basins at the bend of large rivers which are flooded when the rivers are high, and in such situations it is intensively managed and cultivated. It is highly drought resistant provided it gets the equivalent of at least 400 mm rainfall in the form of rain, floodwater or irrigation. It tolerates high temperatures (up to 50°C) but is not frost hardy. It is recommended for plantations in its natural habitat or in similar conditions.

References: 111, 123

Wood characteristics

The basic density of the wood is high and this suggests a hardness which may cause excessive wear on chipper knives in a pulp mill. The fibres are of average length, width and wall thickness for hardwoods used for pulping. Judging from the fibre dimensions, the fibres should be reasonably flexible and capable of forming acceptable inter-fibre bonding in paper.

Pulping characteristics

A fairly high alkali charge, although still in the normal range for hardwoods, is required for pulping to a Kappa number of 20 by means of the sulphate process. At the same time the yield of pulp is low and the resulting pulp is very dark in colour. The strength properties are around average for hardwood, except for the tear factor, which is good. The pulp ranks somewhere between poplar and beech sulphate pulp.

The chemical soda pulping process gives a pulp with strength properties below the average for hardwoods and resembles a beech pulp of the corresponding grade. NSSC pulping gives a good quality pulp, but the yield of pulp is very low.

Scientific name: Acacia nilotica var. pubescens	Common name: Gonakie Country: Senegal	Reference: 111

Wood sample characteristics

Wood sample origin:

Logs 15 - 24 cm in diameter

Density and fibre characteristics:

Basic density, g/cm^3	0.94 (dry volume)
Fibre length, μ*	1 134
Fibre width, μ*	20
Wall thickness, μ*	4.5
Lumen width, μ*	11
Length/width ratio	67
Runkel ratio	0.82
Flexibility ratio	0.55

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %
- Ether
- Methanol
- Ethanol-benzene

Solubility, %
- in water
- in 1% NaOH

Ash, %
Lignin, %
Holocellulose, %
Cross-Bevan cellulose, %
Pentosans, %

Additional information:

Pulping and papermaking characteristics

Unbleached

Process	Sulphate	Soda (179°C)	NSSC
Chemical consumption, %	19.1 - 13.5 Na_2O	16.1 - 14.3 Na_2O	8.5 - 7.8 SO
Kappa number	22 - 44	28 - 44	-
Yield (unscreened), %	45.2 - 50.3	46.1 - 52.9	52.2 - 55.2
Screenings, %	0.9 - 4.4	1.5 - 4.4	0.2 - 0.9
Brightness (Photovolt)	19 - 14	22.5 - 20	26.5
Beater or refiner	Bauer	Bauer	Bauer
Freeness	40 SR	40 SR	40 SR
Breaking length, m	5 000 - 5 200	4 000	5 100 - 5 300
Burst factor	30 - 33	28 - 29	33 - 32
Tear factor	135 - 91	76 - 78	93 - 87

Bleached

Sequence	CEHH	CEHH	
Chemical consumption, %	4.4 - 7.8 Cl	6.9 Cl	
Yield on bleaching, %			
Total yield, %			
Brightness (Photovolt)	71 - 74	78	
Beater or refiner	Bauer	Bauer	
Freeness	40 SR	40 SR	
Breaking length	4 200 - 4 000	4 500	
Burst factor	26	27	
Tear factor	110 - 74	71	

Additional information:

Albizzia falcata

Plantation experience

In its natural range, the Moluccas, and throughout the Far East, this species is planted for shade to coffee and tea plantations. It is a very fast-growing tree and has been introduced successfully in Sri Lanka, where it grows well at altitudes over 1 500 m although bettter at lower elevations, as well as in Kenya and the Philippines. It is grown for pulpwood in Malaysia. Although excellent growth was recorded in Fiji, shallow rooting was considered a disadvantage. It has also been introduced in West, Central and East Africa with varying results.

References: 111, 123, 129, 130

Wood characteristics

The basic density of the wood is low which implies softness of the wood and consequently ease of chipping. At the same time, however, it tends to lower the tonnage capacity of the digester due to a higher liquor to wood ratio than normal being required. The fibre length is about the average for hardwoods. Due to the fibres being fairly thick with thin walls, they tend to be flexible with good fibre-to-fibre bonding in paper. No chemical characteristics are given for the present samples.

Pulping characteristics

The chemicals consumption in the sulphate and chemical soda processes is fairly low and the pulps are obtained with good yields. The strength properties of the pulps, both unbleached and bleached, are excellent and comparable to good quality eucalypt sulphate and chemical soda pulps. However, due to the higher thickness of the fibres in comparison with eucalypt fibres, the opacity of the pulp may be somewhat lower (no data are given for opacity of the present samples).

The NSSC process gives pulps with excellent strength properties and good brightness. However, a light bleaching treatment is still required for grades like cheap printing and writing paper.

Scientific name: Albizzia falcata (Syn. A. molucoana)	Common name: Moluccan sau Country: Philippines	Reference: 32

Wood sample characteristics

Wood sample origin:

Sample from plantation

Density and fibre characteristics:

Basic density, g/cm^3	
Fibre length, μ*	1 110
Fibre width, μ*	24
Wall thickness, μ*	3.5
Lumen width, μ*	17
Length/width ratio	46
Runkel ratio	0.41
Flexibility ratio	0.71

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %
  Ether
  Methanol
  Ethanol-benzene

Solubility, %
  in water
  in 1% NaOH

Ash, %
Lignin, %
Holocellulose, %
Cross-Bevan cellulose, %
Pentosans, %

Additional information:

Pulping and papermaking characteristics

<u>Unbleached</u>	
Process	Sulphate
Chemical consumption, %	15.6 Na_2O (charge)
Kappa number	
Yield (unscreened), %	
Screenings, %	
Brightness	
Beater or refiner	Valley
Freeness	300 CSF
Breaking length, m	12 300
Burst factor	97
Tear factor	74
<u>Bleached</u>	
Sequence	
Chemical consumption, %	
Yield on bleaching, %	
Total yield, %	
Brightness	
Beater or refiner	
Freeness	
Breaking length	
Burst factor	
Tear factor	

Additional information:

Scientific name: Albizzia falcata (Syn. A. moluccana)	Common name: Country: Cameroun	Reference: 111

Wood sample characteristics

Wood sample origin:

Logs 18 – 40 cm in diameter

Density and fibre characteristics:

Basic density, g/cm^3	0.29 (dry volume)
Fibre length, μ*	1 040
Fibre width, μ*	42
Wall thickness, μ*	2.5
Lumen width, μ*	37
Length/width ratio	25
Runkel ratio	0.14
Flexibility ratio	0.88

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %
- Ether
- Methanol
- Ethanol-benzene

Solubility, %
- in water
- in 1% NaOH

Ash, %
Lignin, %
Holocellulose, %
Cross-Bevan cellulose, %
Pentosans, %

Additional information:

Pulping and papermaking characteristics

<u>Unbleached</u>			
Process	Sulphate	Soda (170°C)	NSSC
Chemical consumption, %	13.7 - 12.2 Na_2O	13.7 - 11.8 Na_2O	7.4 - 7.2 SO_2
Kappa number	20 - 43	26 - 65	-
Yield (unscreened), %	53.1 - 56.3	51.3 - 54.6	65.9 - 70.4
Screenings, %	0.2 - 2.6	0.1 - 4.1	
Brightness (Photovolt)	35.5 - 33	38.5 - 34	45.5 - 43.5
Beater or refiner	Lamort	Bauer	Bauer
Freeness	40 SR	40 SR	40 SR
Breaking length, m	10 800 - 10 600	9 600 - 10 000	9 300 - 9 000
Burst factor	68 - 73	58 - 63	66 - 60
Tear factor	79 - 64	86 - 63	58 - 57
<u>Bleached</u>			
Sequence	CEHH	CEHH	
Chemical consumption, %	5.0 Cl	6.2	
Yield on bleaching, %			
Total yield, %			
Brightness (Photovolt)	83.5	82.5	
Beater or refiner	Lamort	Bauer	
Freeness	40 SR	40 SR	
Breaking length	8 800	10 900	
Burst factor	62	69	
Tear factor	85	58	

Additional information:

Albizzia procera
(White Siris)

Plantation experience

This species is indigenous to India and Burma. It grows on alluvium along streams, in swampy places and low-lying savannas. It has been tried experimentally in the coastal zone of Israel and also planted in Fiji, the Solomon Islands, Kenya, Uganda and the Republic of South Africa.

Reference: 123

Wood characteristics

The fibres are normal for hardwoods in length and width and the chemical characteristics do not exhibit anything which would cause difficulties in the pulping processes.

Pulping characteristics

The chemical consumption in the sulphate process is in the range considered normal for hardwoods and the pulp is obtained with a good yield. The ease of bleaching, both as regards chemical consumption and final brightness imply that a slight increase in yield could be achieved by shortening the cooking time. This would probably also enhance the strength properties which, as given in the data sheet, are about average for hardwood pulps, with the exception of the tear factor which is good.

The pulp ranks between beech and poplar sulphate pulp with regard to its strength properties.

Scientific name: Albizzia procera	Common name: White siris Country: India	Reference: 69

Wood sample characteristics

Wood sample origin:

Sample from Barkot, Dehra Dun Forest Division

Density and fibre characteristics:

Basic density, g/cm^3	
Fibre length, µ*	900
Fibre width, µ*	21
Wall thickness, µ*	
Lumen width, µ*	
Length/width ratio	43
Runkel ratio	
Flexibility ratio	

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	1.01
Methanol	
Ethanol-benzene	2.17
Solubility, %	
in water	5.21 (hot)
in 1% NaOH	16.8
Ash, %	1.0
Lignin, %	23.6
Holocellulose, %	
Cross-Bevan cellulose, %	60.6
Pentosans, %	

Additional information:

Pulping and papermaking characteristics

Unbleached	
Process	Sulphate
Chemical consumption, %	17.0 - 20.1 Na_2O (charge)
Kappa number	
Yield (unscreened), %	50.7 - 55.0
Screenings, %	
Brightness	
Beater or refiner	
Freeness	
Breaking length, m	
Burst factor	
Tear factor	
Bleached	
Sequence	HEH
Chemical consumption, %	3.3 - 1.8 Cl
Yield on bleaching, %	
Total yield, %	46.5 - 51.0
Brightness (Photovolt)	70 - 72
Beater or refiner	Lampén
Freeness	300 CSF
Breaking length	6 500 - 7 600
Burst factor	42 - 55
Tear factor	84 - 110
Additional information:	

Albizzia stipulata

Plantation experience

This very fast-growing species is distributed as an indigenous tree through India, Burma, Sri Lanka and Malaysia, mostly on moister sites of tropical evergreen forest, mixed hardwood forests and low-lying savannas. It has been introduced as an exotic in West, Central and East Africa as well as along the coastal zone of Israel. It has failed to acclimatize in the Republic of South Africa.

Reference: 123

Wood characteristics

The fibres are of average length and thickness for hardwoods and the chemical composition of the wood implies that it would be suitable for pulping processes.

Pulping characteristics

The chemical consumption in the sulphate process is in the range considered normal for hardwoods and the pulp is obtained with a good yield. Especially with the lower alkali charge corresponding to the higher yield obtained with the present wood sample, the strength properties of the bleached pulp are excellent and fully comparable to a corresponding grade of good-quality eucalypt or birch sulphate pulp. However, to enhance the brightness, a slightly modified bleaching sequence is recommended.

Scientific name: Albizzia stipulata (Syn. A. Chinensis)	Common name: Boivin Country: India	Reference: 12

Wood sample characteristics

Wood sample origin:

Sample from natural forest at Samta Range, Bihar, about 30 years old

Density and fibre characteristics:

Basic density, g/cm^3	
Fibre length, µ*	1 020
Fibre width, µ*	27
Wall thickness, µ*	
Lumen width, µ*	38
Length/width ratio	
Runkel ratio	
Flexibility ratio	

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	0.89
Methanol	
Ethanol-benzene	1.51
Solubility, %	
in water	8.12
in 1% NaOH	17.7
Ash, %	0.6
Lignin, %	23.7
Holocellulose, %	
Cross-Bevan cellulose, %	60.2
Pentosans, %	18.3

Additional information:

Pulping and papermaking characteristics

Unbleached	
Process	Sulphate
Chemical consumption, %	16.5 - 17.1 Na_2O
Kappa number	
Yield (unscreened), %	57.0 - 49.0
Screenings, %	
Brightness	
Beater or refiner	
Freeness	
Breaking length, m	
Burst factor	
Tear factor	
Bleached	
Sequence	HEH
Chemical consumption, %	3.9 - 2.5 Cl
Yield on bleaching, %	
Total yield, %	52.9 - 45.5
Brightness	62 - 61 (Tappi)
Beater or refiner	Lampén
Freeness	300 CSF
Breaking length	10 100 - 8 900
Burst factor	65 - 54
Tear factor	97 - 74

Additional information:

Aleurites moluccana
(Indian Walnut, Candle-Nut Tree)

Plantation experience

A native species of the Malaysian archipelago and the Pacific Islands, but it has been naturalized in India, Sri Lanka, Madagascar, the West Indies and Hawaii. It grows at altitudes up to about 1 000 m in tropical regions. The nuts are rich in oil. It has been introduced also in South, West, Central and East Africa.

Reference: 123

Wood characteristics

The basic density is slightly lower than average for hardwoods used for pulping, but still not low enough to cause any disadvantage with respect to digester capacity. The fibres are slightly longer than the average for hardwoods and the width dimensions imply a fair amount of flexibility with good bonding in paper as a result.

As regards the chemical composition of the wood, the lignin content is higher than average for hardwoods used for pulping, which may affect the ease of delignification in chemical pulping processes. Combined with a fairly high pentosans content, it is apt to affect the yield of alkaline pulping.

Pulping characteristics

In spite of the alkali charge in the sulphate process being on the high side, the Kappa number of the resulting pulp has still remained higher than normal for hardwood sulphate pulps, especially in view of the yield being on the low side. The strength properties are slightly below average and the pulp bears in this respect a certain resemblance to beech sulphate pulps. Further cooking of the pulp to the normal Kappa number level would probably also decrease the strength. However, it is possible that cooking conditions better adapted to this species could improve the strength characteristics of the sulphate pulp.

The cold soda process gives a pulp with very good strength characteristics, a good yield and with a chemical consumption which can be considered normal.

Scientific name: Aleurites moluccana	Common name: Indian walnut, candle-nut tree, lumbang Country: Philippines	Reference: 94, 95

Wood sample characteristics

Wood sample origin:

Sample from plantation in the Philippines

Density and fibre characteristics:

Basic density, g/cm^3	0.34
Fibre length, µ*	1 350
Fibre width, µ*	36
Wall thickness, µ*	5
Lumen width, µ*	26
Length/width ratio	37
Runkel ratio	0.39
Flexibility ratio	0.72

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	1.8
Solubility, %	
in water	10.7
in 1% NaOH	23.6
Ash, %	2.2
Lignin, %	27.1
Holocellulose, %	
Cross-Bevan cellulose, %	
Pentosans, %	20.5

Additional information:

Pulping and papermaking characteristics

Unbleached

Process	Sulphate	Cold Soda		
Chemical consumption, %	20 Na_2O*	14.8 Na_2O		
Kappa number	39			
Yield (unscreened), %	49.2	76.3		
Screenings, %	0.3	3.3		
Brightness		45 (Tappi)		
Beater or refiner	Valley	Bauer 8"	-	Valley
Freeness	350 DSF	783 CSF		300 CSF
Breaking length, m	7 800	1 900		6 000
Burst factor	57	7		31
Tear factor	67	43		54

Bleached

Sequence
Chemical consumption, %
Yield on bleaching, %
Total yield, %

Brightness

Beater or refiner
Freeness
Breaking length
Burst factor
Tear factor

Additional information:

* Charge

Anthocephalus cadamba

(Syn. Anthocephalus chinensis)

Plantation experience

Indigenous to India, Burma and Sri Lanka, this fast-growing species grows on alluvium along rivers. It is very tender to frost. It is planted in its natural habitat and has also been introduced as an exotic in the Republic of South Africa.

References: 123, 129

Wood characteristics

The basic density of the wood is on the low side for hardwoods used for pulping, but should not affect the digester capacity. The fibres have a length above the average for hardwoods and, judging from the width dimensions, they should be fairly flexible with good bonding in paper as a result. The fairly high extractives content of the wood may require special precautions on pulping to lower the extractives content in the pulp. As regards the other chemical characteristics of the wood, none of them imply any difficulty in connection with pulping.

Pulping characteristics

This species seems to pulp fairly easily in the sulphate process already with a low alkali charge (about 15% active alkali as Na_2O). A higher charge lowers the yield and impairs the strength properties. With a proper alkali charge the yield may be about 50% instead of the 46.9% given in one of the data sheets at a Kappa number of 13. A Kappa number of 20 would be more suitable. However, even at the lower Kappa number, the pulp exhibits excellent strength properties. A sulphate pulp comparable to good-quality eucalypt pulp can be produced from this species, perhaps with a slightly lower opacity, judging from the fibre dimensions.

Dissolving pulp of acceptable quality has also been prepared in the laboratory (24, 35) by means of the prehydrolysis sulphate process. However, no tests for processability in the viscose process were carried out. A fairly bright pulp with good strength properties can be produced by means of the cold soda process. With a peroxide bleaching treatment an excellent pulp for cheap writing and printing paper is obtained.

Trials to produce mechanical pulp either by stone grinding or laboratory scale (12 in single-disc) refining, have not been successful, as the pulps exhibit very low strength properties.

Scientific name: Anthocephalus cadamba (Syn. A. indicus, A. chinensis)	Common name: Kadam Country: India	Reference: 64, 65

Wood sample characteristics

Wood sample origin:

Sample from freshly felled trees from the Forest Research Institute, Dehra Dun. Logs 15 cm in diameter

Density and fibre characteristics:

Basic density, g/cm^3
Fibre length, µ*
Fibre width, µ*
Wall thickness, µ*
Lumen width, µ*

Length/width ratio
Runkel ratio
Flexibility ratio

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %
- Ether
- Methanol
- Ethanol-benzene

Solubility, %
- in water
- in 1% NaOH

Ash, %
Lignin, %
Holocellulose, %
Cross-Bevan cellulose, %
Pentosans, %

Additional information:

Pulping and papermaking characteristics

Unbleached			
Process	Groundwood	Chip Groundwood	Cold Soda
Chemical consumption, %			4.5 - 17.7 Na_2O
Kappa number			
Yield (unscreened), %			88.7 - 69.4
Screenings, %			
Brightness (Photovolt)	69 - 68	68	68
Beater or refiner	Stone grinder	Sprout-Waldron 12"*	Lampén**
Freeness	70 - 100	130 CSF	300 CSF
Breaking length, m	500	580	1 300 - 2 900
Burst factor	1 - 2	3	5 - 16
Tear factor	6	16	18 - 40
	1 200 - 900		
Bleached			
Sequence			H
Chemical consumption, %			5.0 Cl (charge)
Yield on bleaching, %			
Total yield, %			83.7 - 65.0
Brightness (Photovolt)			74 - 76.5
Beater or refiner			Lampén
Freeness			300 CSF
Breaking length			1 500 - 3 900
Burst factor			9 - 17
Tear factor			20 - 46

Additional information:

* 6 passes
** After 5 passes in Sprout-Waldron 12" disc refiner

Scientific name: Anthocephalus cadamba (Syn. A. indicus, A. chinensis)	Common name: Country: O Philippines	Reference: 96

Wood sample characteristics

Wood sample origin	Chemical characteristics

Wood sample origin:

Sample from plantations in the Philippines

Density and fibre characteristics:

Basic density, g/cm^3
Fibre length, µ*
Fibre width, µ*
Wall thickness, µ*
Lumen width, µ*

Length/width ratio
Runkel ratio
Flexibility ratio

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %
  Ether
  Methanol
  Ethanol-benzene

Solubility, %
  in water
  in 1% NaOH

Ash, %
Lignin, %
Holocellulose, %
Cross-Bevan cellulose, %
Pentosans, %

Additional information:

Pulping and papermaking characteristics

Unbleached

Process	Cold Soda	
Chemical consumption, %	Steeping liquor 30 g NaOH/litre	
Kappa number		
Yield (unscreened), %	90.2 (2 passes in Bauer 8" disc refiner)	
Screenings, %		
Brightness (Photovolt)	57.0	
Beater or refiner	Valley	
Freeness	500 CSF	200 CSF
Breaking length, m	2 700	4 300
Burst factor	10	17
Tear factor	34	33

Bleached

Sequence	H	P	HP
Chemical consumption, %	15.0 Cl*	1.0 H_2O_2*	15.0 Cl, 1.0 H_2O_2
Yield on bleaching, %			
Total yield, %	74.6	77.3	71.9
Brightness (Photovolt)	67	65	67
Beater or refiner	Valley	Valley	Valley
Freeness	200 CSF	200 CSF	200 CSF
Breaking length	5 500	6 700	6 500
Burst factor	17	23	19
Tear factor	40	36	49
Brightness/Opacity (CR)	67/94	65/98	66/94

Additional information:

Scientific name: Anthocephalus cadamba (Syn. A. indicus, A. chinensis)	Common name: Kaatoan bankal Country: Philippines	Reference: 94, 95

Wood sample characteristics

Wood sample origin:

Sample from plantation in the Philippines

Density and fibre characteristics:

Basic density, g/cm^3	0.35
Fibre length, µ*	1 430
Fibre width, µ*	35
Wall thickness, µ*	4.5
Lumen width, µ*	26
Length/width ratio	41
Runkel ratio	0.35
Flexibility ratio	0.74

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	4.4
Solubility, %	
in water	6.2
in 1% NaOH	23.9
Ash, %	0.7
Lignin, %	24.0
Holocellulose, %	
Cross-Bevan cellulose, %	
Pentosans, %	17.9

Additional information:

Pulping and papermaking characteristics

Unbleached			
Process	Sulphate	Cold Soda	
Chemical consumption, %	17.1 Na_2O	6.7 Na_2O	
Kappa number	13		
Yield (unscreened), %	46.9	69.1	
Screenings, %	0.5	1.1	
Brightness		54 (Tappi)	
Beater or refiner	Valley	Bauer 8"	– Valley
Freeness	350 CSF	605 CSF	300 CSF
Breaking length, m	10 500	1 800	4 400
Burst factor	52	2	14
Tear factor	88	35	38
Bleached			
Sequence			
Chemical consumption, %			
Yield on bleaching, %			
Total yield, %			
Brightness			
Beater or refiner			
Freeness			
Breaking length			
Burst factor			
Tear factor			

Additional information:

Scientific name:	Common name: Kaatoan bankal	Reference:
Anthocephalus cadamba (Syn. A. indicus, A. chinensis)	Country: Philippines	32

Wood sample characteristics

Wood sample origin:

Sample from plantation

Density and fibre characteristics:

Basic density, g/cm^3	
Fibre length, μ*	1 430
Fibre width, μ*	34
Wall thickness, μ*	5
Lumen width, μ*	24
Length/width ratio	42
Runkel ratio	0.42
Flexibility ratio	0.71

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %
- Ether
- Methanol
- Ethanol-benzene

Solubility, %
- in water
- in 1% NaOH

Ash, %
Lignin, %
Holocellulose, %
Cross-Bevan cellulose, %
Pentosans, %

Additional information:

Pulping and papermaking characteristics	
Unbleached	
Process	Sulphate
Chemical consumption, %	15.6 Na_2O (charge)
Kappa number	
Yield (unscreened), %	
Screenings, %	
Brightness	
Beater or refiner	Valley
Freeness	300 CSF
Breaking length, m	11 900
Burst factor	86
Tear factor	75
Bleached	
Sequence	
Chemical consumption, %	
Yield on bleaching, %	
Total yield, %	
Brightness	
Beater or refiner	
Freeness	
Breaking length	
Burst factor	
Tear factor	
Additional information:	

Araucaria angustifolia
(Paraná Pine, Brazilian Pine)

Plantation experience

The natural habitat of this species is Brazil, where it has also been successfully planted. In Brazilian pulpwood plantations the annual increment has been 6-20 m^3/ha with a rotation of 17 years. It has also been planted in the north-east of Argentina where it seems to be replaced to some extent by Pinus elliottii, in the north-east of Australia as well as in East and South Africa.

References: 18, 31, 44, 53, 97

Wood characteristics

In old trees there is a marked difference in basic density and moisture content between heartwood and sapwood, which has caused some difficulties in pulping. The fibres exhibit great length - up to 7 mm - and also great thickness which has been noticed to decrease the capacity of pulp screens to about 50% compared with other softwood pulps.

Pulping characteristics

The species has been used to quite an extent in the past in Brazil for pulping. Among the strength characteristics the breaking length and burst factor are very low especially for a softwood pulp. On the other hand the pulp exhibits an outstanding resistance to tear, which makes it suitable for use in combination with hardwood pulps of good breaking length and burst factor.

Scientific name: Araucaria angustifolia (Syn. A. brasiliensis)	Common name: Paraná pine, Brazilian pine and Pinho Paraná; Country: Brazil	Reference: 116

Wood sample characteristics

Wood sample origin:

Sample from natural forest in Brazil, over 50 years old

Density and fibre characteristics:

Basic density, g/cm^3
Fibre length, μ*
Fibre width, μ*
Wall thickness, μ*
Lumen width, μ*

Length/width ratio
Runkel ratio
Flexibility ratio

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %
Ether
Methanol
Ethanol-benzene

Solubility, %
in water
in 1% NaOH

Ash, %
Lignin, %
Holocellulose, %
Cross-Bevan cellulose, %
Pentosans, %

Additional information:

Pulping and papermaking characteristics	
Unbleached	
Process	Sulphate
Chemical consumption, %	
Kappa number	32
Yield (unscreened), %	
Screenings, %	
Brightness	
Beater or refiner	Jokro
Freeness	43 SR
Breaking length, m	6 800
Burst factor	50
Tear factor	225
Bleached	
Sequence	
Chemical consumption, %	
Yield on bleaching, %	
Total yield, %	
Brightness	
Beater or refiner	
Freeness	
Breaking length	
Burst factor	
Tear factor	
Additional information:	

Araucaria cunninghamii
(Hoop Pine)

Plantation experience

Outside its natural habitat, Australia and New Guinea, this species has been planted with good results in East, Central and West Africa. Sufficient nitrogen in the soil is usually required for satisfactory growth.

References: 22, 31, 41, 97, 123

Wood characteristics

The basic density is in the normal range for softwoods used for pulping, as are the fibre dimensions, both as regards width and length. The lignin content of the wood is on the high side, which is apt to affect the chemical consumption and the yield of pulp.

Pulping characteristics

The species requires a fairly high charge of active alkali in the sulphate process, especially for a softwood, but the yield of pulp is about average. The pulp exhibits excellent strength properties, comparable to those of North American 'Southern Pine' sulphate pulp.

Scientific name: Araucaria cunninghamii	Common name: Hoop pine Country: Queensland, Australia	Reference: 131

Wood sample characteristics

Wood sample origin:

Sample from plantations at Yarraman and Imbil, butt sections from 14 and 26 year-old trees. Composite sample.

Density and fibre characteristics:

Basic density, g/cm^3	0.457
Fibre length, μ*	3 620
Fibre width, μ*	
Wall thickness, μ*	
Lumen width, μ*	
Length/width ratio	
Runkel ratio	
Flexibility ratio	

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %
- Ether
- Methanol
- Ethanol-benzene

Solubility, %
- in water
- in 1% NaOH

Ash, %
Lignin, %
Holocellulose, %
Cross-Bevan cellulose, %
Pentosans, %

Additional information:

Pulping and papermaking characteristics

Unbleached

Process	Sulphate
Chemical consumption, %	
Kappa number	70.1 - 29.0
Yield (unscreened), %	51.7 - 43.7
Screenings, %	
Brightness	
Beater or refiner	PFI
Freeness	300 CSF
Breaking length, m	10 000 - 9 200
Burst factor	88 - 80
Tear factor	130 - 125

Bleached

Sequence	
Chemical consumption, %	
Yield on bleaching, %	
Total yield, %	
Brightness	
Beater or refiner	
Freeness	
Breaking length	
Burst factor	
Tear factor	

Additional information:

Scientific name:	Common name: Hoop pine	Reference:
Araucaria cunninghamii	Country: New Guinea	79

Wood sample characteristics

Wood sample origin:

Sample from plantation in the Buolo district, 11 years old

Density and fibre characteristics:

Basic density, g/cm^3	0.40
Fibre length, μ*	
Fibre width, μ*	
Wall thickness, μ*	
Lumen width, μ*	
Length/width ratio	
Runkel ratio	0.25
Flexibility ratio	0.80

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	0.9
Solubility, %	
in water	
in 1% NaOH	
Ash, %	0.5
Lignin, %	32.4
Holocellulose, %	73.2
Cross-Bevan cellulose, %	
Pentosans, %	

Additional information:

Pulping and papermaking characteristics	
Unbleached	
Process	Sulphate
Chemical consumption, %	22.0 Na_2O (Charge)
Kappa number	40
Yield (unscreened), %	45.4
Screenings, %	
Brightness	
Beater or refiner	Lampén
Freeness	500
Breaking length, m	10 500
Burst factor	87
Tear factor	110
Bleached	
Sequence	
Chemical consumption, %	
Yield on bleaching, %	
Total yield, %	
Brightness	
Beater or refiner	
Freeness	
Breaking length	
Burst factor	
Tear factor	
Additional information:	

Araucaria klinkii
(Klinki Pine)

Plantation experience

The species has been successfully planted in New Guinea and Malaysia.

Reference: 97

Wood characteristics

The basic density of the wood is in the normal range for softwoods used for pulping, although slighly on the low side. The flexibility ratio and/or the Runkel ratio indicate that good bonding can be expected in paper. The lignin content of the wood is on the high side for softwoods and indicates a high chemical requirement and a fairly low yield on pulping.

Pulping characteristics

The species requires a fairly high charge of active alkali for a softwood in sulphate pulping and the yield is on the low side. However, the strength properties of the pulp are excellent and fully comparable to a Scandinavian pine sulphate pulp.

Scientific name: Araucaria klinkii (Syn. A. hunsteinii)	Common name: Klinki pine Country: New Guinea	Reference: 79

Wood sample characteristics

Wood sample origin:

Sample from plantation in Buolo district, 11 years old

Density and fibre characteristics:

Basic density, g/cm^3	0.37
Fibre length, µ*	
Fibre width, µ*	
Wall thickness, µ*	
Lumen width, µ*	
Length/width ratio	
Runkel ratio	0.33
Flexibility ratio	0.75

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	0.7
Solubility, %	
in water	
in 1% NaOH	
Ash, %	0.6
Lignin, %	31.2
Holocellulose, %	76.1
Cross-Bevan cellulose, %	
Pentosans, %	

Additional information:

Pulping and papermaking characteristics

Unbleached	
Process	Sulphate
Chemical consumption, %	20 Na_2O (charge)
Kappa number	40
Yield (unscreened), %	46.0
Screenings, %	
Brightness	
Beater or refiner	Lampén
Freeness	375 CSF
Breaking length, m	11 100
Burst factor	95
Tear factor	83
Bleached	
Sequence	
Chemical consumption, %	
Yield on bleaching, %	
Total yield, %	
Brightness	
Beater or refiner	
Freeness	
Breaking length	
Burst factor	
Tear factor	

Additional information:

Aucoumea klaineana
(Okoumé)

Plantation experience

This species is indigenous to West Africa and is especially widespread in Gabon, where it is also planted on a large scale for its timber. It is suitable only for lowland tropical rain forest areas of high rainfall.

References: 41, 111

Wood characteristics

The basic density of the wood is in the low range for hardwoods used for pulping. However, it should not affect the digester capacity to a mentionable degree. The fibre length is about the average for hardwoods and, judging from the fibre width dimensions, the fibres should be flexible and capable of good bonding in paper. No chemical composition data are available for the samples at hand.

Pulping characteristics

The consumption of active alkali in the sulphate process and the chemical soda process is in the normal range for hardwoods. The yield of pulp is good, although on the low side at Kappa number 20. The strength properties of the sulphate and chemical soda pulps are good and comparable to those of good-quality poplar pulps. For semi-bleached or fully bleached grades it seems advisable to interrupt the cook at a Kappa number above the normal level, perhaps 25-30 in the sulphate process in order to enhance the strength properties of the bleached pulp. Crude chemical soda pulp with good strength properties and with a good yield can be obtained with a normal alkali consumption. The same probably holds for the adaptability of the species to production of crude sulphate pulp.

The cold soda process gives a good quality pulp, comparable to corresponding types of pulp from eucalypts. However, the brightness of the pulp is too low, even after bleaching with hypochlorite and/or peroxide, for newsprint or cheap writing and printing paper. However, it may be that a bleaching combination with dithionite and peroxide could improve the brightness to the desired level (above 65).

The NSSC process is suitable for manufacture of high-quality pulp from this species.

Scientific name: Aucoumea klaineana	Common name: Okoumé Country: Congo	Reference: 33

Wood sample characteristics

<u>Wood sample origin:</u>

Logs of diameter 25-110 cm for pilot plant trial

<u>Density and fibre characteristics:</u>

Basic density, g/cm^3
Fibre length, μ*
Fibre width, μ*
Wall thickness, μ*
Lumen width, μ*

Length/width ratio
Runkel ratio
Flexibility ratio

Additional information:

* 1000 μ (microns) = 1 mm

<u>Chemical characteristics:</u>

Extractives, %
  Ether
  Methanol
  Ethanol-benzene

Solubility, %
  in water
  in 1% NaOH

Ash, %
Lignin, %
Holocellulose, %
Cross-Bevan cellulose, %
Pentosans, %

Additional information:

Pulping and papermaking characteristics

Unbleached	
Process	Sulphate
Chemical consumption, %	15.5 Na_2O (charge)
Kappa number	19
Yield (unscreened), %	49.0
Screenings, %	3.6
Brightness (Photovolt)	33.5
Beater or refiner	?
Freeness	40 SF
Breaking length, m	9 500
Burst factor	70
Tear factor	95
Bleached	
Sequence	CEHHP
Chemical consumption, %	3.7 Cl and 0.1 peroxide
Yield on bleaching, %	
Total yield, %	
Brightness	78.5 (Photovolt - 77.5 after CEHH)
Beater or refiner	?
Freeness	40 SR
Breaking length	9 000
Burst factor	70
Tear factor	85

Additional information: Trials on pilot PM at 10 m/min for wrapping paper exhibited minor difficulties with respect to runability with a furnish of 100 unbleached okoumé pulp. This difficulty was more pronounced with bleached pulp. The quality of wrapping, off-set and writing papers run on this machine was fully acceptable. In all instances, a minimum addition of 15 percent of long-fibre pulp was required to ensure good runability already at this speed.

Scientific name:	Common name:	Okoumé	Reference:
Aucoumea klaineana	Country:	Congo	33

Wood sample characteristics

Wood sample origin:

Density and fibre characteristics:

Basic density, g/cm^3	0.40 (dry volume)
Fibre length, µ*	
Fibre width, µ*	
Wall thickness, µ*	
Lumen width, µ*	
Length/width ratio	
Runkel ratio	
Flexibility ratio	

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %
- Ether
- Methanol
- Ethanol-benzene

Solubility, %
- in water
- in 1% NaOH

Ash, %
Lignin, %
Holocellulose, %
Cross-Bevan cellulose, %
Pentosans, %

Additional information:

Pulping and papermaking characteristics

Unbleached

Process	Cold Soda	Soda (80–165°C)
Chemical consumption, %	3.2 – 9.0 Na_2O	5.7 – 9.3 Na_2O
Kappa number		
Yield (unscreened), %	93.5 – 86.1	85.7 – 66.5
Screenings, %		
Brightness (Photovolt)	36.5 – 33.5	45 – 22.5
Energy requirement, kWh/kg	2.5 – 3.4	2.0 – 0.6
Beater or refiner	S-W 12"	S-W 12"
Freeness	60 SR	60 SR
Breaking length, m	2 100 – 4 300	5 600 – 10 300
Burst factor	8 – 22	25 – 54
Tear factor	21 – 42	49 – 66

Bleached

Sequence		
Chemical consumption, %	2 – 10 Cl	2 – 24 Cl or 0.7 – 10 percent
Yield on bleaching, %		
Total yield, %		
Brightness (Photovolt)	50	50
Beater or refiner		
Freeness		
Breaking length		
Burst factor		
Tear factor		

Additional information: A semi-industrial trial for soda pulping (impregnation with 10% NaOH) based on wood at 55–60°C followed by refining in a Bauer refiner (double-disc) gave a pulp at about 80% yield, breaking length 3 700, tear factor 52 and brightness 43 (Photovolt), after bleaching with peroxide (1.3%) a brightness of 49 was achieved and a breaking length of 2 900 and tear factor 47.

Scientific name: Aucoumea klaineana	Common name: Okoumé Country: Gabon	Reference: 111

Wood sample characteristics

Wood sample origin:

Composite sample of trees from N'Koulanga and Mondah, age 5-20 years (6 trees 5 years, 4 trees 7 years, 1 tree 14 years and 1 tree 20 years).
Log diameters 9-28 cm.

Density and fibre characteristics:

Basic density, g/cm^3	0.36 (dry volume)
Fibre length, µ*	1 020
Fibre width, µ*	32
Wall thickness, µ*	3
Lumen width, µ*	26
Length/width ratio	32
Runkel ratio	0.23
Flexibility ratio	0.81

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %
- Ether
- Methanol
- Ethanol-benzene

Solubility, %
- in water
- in 1% NaOH

Ash, %
Lignin, %
Holocellulose, %
Cross-Bevan cellulose, %
Pentosans, %

Additional information:

Pulping and papermaking characteristics

Unbleached			
Process	Sulphate	Soda (170°C)	NSSC
Chemical consumption, %	17.3 - 13.5 Na_2O	15.8 - 17.5 Na_2O	11.4 - 10.9 SO_2
Kappa number	20 - 42	29 - 47	-
Yield (unscreened), %	49.4 - 58.2	46.9 - 49.7	57.1 - 67.9
Screenings, %	0 - 0.7	0 - 0.3	0.3 - 0.1
Brightness (Photovolt)	28 - 25	30.5 - 26.5	30 - 39
Beater or refiner	Lamort	Bauer	Bauer
Freeness	40 SR	40 SR	40 SR
Breaking length, m	8 900 - 10 100	8 000 - 9 000	8 800 - 8 300
Burst factor	63 - 73	55 - 57	60
Tear factor	82 - 80	74 - 85	66 - 67
Bleached			
Sequence	CEHH	CEHH	
Chemical consumption, %	4.4 Cl	6.1 Cl	
Yield on bleaching, %			
Total yield, %			
Brightness (Photovolt)	80	81	
Beater or refiner	Lamort	Bauer	
Freeness	40 SR	40 SR	
Breaking length	7 900	8 400	
Burst factor	53	53	
Tear factor	83	78	

Additional information:

Broussonetia papyrifera
(Paper Mulberry)

Plantation experience

This fast-growing species has a valuable inner bark from which Tapa is made. It has a very wide distribution in Malaysia and Polynesia and has been extensively cultivated in East Asia for its bark. It is naturalized in India, China, Japan and the southern U.S.A. It is planted as a potential pulpwood in India and trials have also been made in Southern Rhodesia and Uganda.

References: 9, 123

Wood characteristics

The timber from this wood is very soft and brittle and has only found use as raw material for matchsticks. The fibre length is in the range normal for hardwoods for pulping. The width characteristics of the fibres imply that good bonding could be expected between the fibres in paper at least as far as the sample from the Philippines is concerned. With the exception of an extractives content slightly above average for hardwoods for pulping, the chemical characteristics do not indicate anything which would cause difficulties on pulping.

Pulping characteristics

The consumption of alkali in the sulphate process is in the normal range for hardwoods and the pulp is obtained with a good yield. The strength properties of the pulps, both bleached and unbleached, vary somewhat with provenance, but a quality similar to that of poplar sulphate pulp or slightly lower may be expected.

High-alpha pulp has been made in the laboratory (62) by means of the prehydrolysis sulphate process. In spite of quite a low yield of bleached pulp (33%), the alpha cellulose content remained on the low side (93%) for a prehydrolysis sulphate pulp and the pentosans content on the high side (3%). However, it is possible that by adjustment of the prehydrolysis, cooking and bleaching conditions, the characteristics of the pulp could be improved. No tests for processability of the pulp in the viscose process were carried out.

Cold soda pulping of the wood gives a fairly bright pulp of acceptable quality and with a good yield.

Scientific name:	Common name: Paper mulberry	Reference:
Broussonetia papyrifera	Country: Philippines	94, 95

Wood sample characteristics

Wood sample origin:

Sample from plantation in the Philippines

Density and fibre characteristics:

Basic density, g/cm^3	
Fibre length, μ*	950
Fibre width, μ*	22
Wall thickness, μ*	3
Lumen width, μ*	16
Length/width ratio	43
Runkel ratio	0.38
Flexibility ratio	0.73

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	3.5
Solubility, %	
in water	5.2
in 1% NaOH	21.1
Ash, %	1.5
Lignin, %	22.7
Holocellulose, %	
Cross-Bevan cellulose, %	
Pentosans, %	20.0

Additional information:

Pulping and papermaking characteristics

Unbleached			
Process	Sulphate	Cold Soda	
Chemical consumption, %	16.7 Na_2O	6.0 Na_2O	
Kappa number	19		
Yield (unscreened), %	53.7	82.3	
Screenings, %	0.3	0.5	
Brightness		54 (Tappi)	
Beater or refiner	Valley	Bauer 8"	– Valley
Freeness	350 CSF	464 CSF	300 CSF
Breaking length, m	8 200	2 500	4 400
Burst factor	73	19	30
Tear factor	97	62	68
Bleached			
Sequence			
Chemical consumption, %			
Yield on bleaching, %			
Total yield, %			
Brightness			
Beater or refiner			
Freeness			
Breaking length			
Burst factor			
Tear factor			

Additional information:

Scientific name: Broussonetia papyrifera	Common name: Paper mulberry Country: India	Reference: 9

Wood sample characteristics

Wood sample origin:

Sample from demonstration plantation at Dehra Dun, 8–12 years old

Density and fibre characteristics:

Basic density, g/cm^3	
Fibre length, µ*	820
Fibre width, µ*	30
Wall thickness, µ*	
Lumen width, µ*	
Length/width ratio	27
Runkel ratio	
Flexibility ratio	

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	0.99
Methanol	
Ethanol-benzene	1.92
Solubility, %	
in water	7.93 (hot)
in 1% NaOH	17.96
Ash, %	1.08
Lignin, %	23.4
Holocellulose, %	
Cross-Bevan cellulose, %	59.2
Pentosans, %	16.4

Additional information:

Pulping and papermaking characteristics

Unbleached	
Process	Sulphate
Chemical consumption, %	15.1 - 17.0 Na_2O
Kappa number	
Yield (unscreened), %	52.8 - 52.0
Screenings, %	
Brightness	
Beater or refiner	
Freeness	
Breaking length, m	
Burst factor	
Tear factor	
Bleached	
Sequence	HEH
Chemical consumption, %	3.2 - 3.0 Cl
Yield on bleaching, %	
Total yield, %	48.3 - 48.1
Brightness	
Beater or refiner	Lampén
Freeness	320 CSF
Breaking length	7 400 - 9 000
Burst factor	35 - 48
Tear factor	62 - 82

Additional information:

Casuarina equisetifolia

Plantation experience

Indigenous to north-east and north Australia, the Pacific Islands and Malaysia this species grows also along the coast to Pakistan on sand-dunes close to the sea, as well as on the coast of tropical East Africa. It is usually planted for sand fixation but also on open dunes. As an exotic it may require inoculation of the soil with a specific nitrogen-fixing bacterium of its root-nodules. It has been successfully planted on dry inland sites in the Caribbean; Sri Lanka; Cyprus; and in East, Central and West Africa with varying results.

References: 39, 40, 41, 44, 45, 123, 129

Wood characteristics

The timber is hard and tough, which implies a high basic density. The fibre length is in the range normal for hardwoods. The fibres are very thin which may mean that they are also quite stiff, although no data are available to confirm this for the samples at hand. The extractives content of the wood is on the high side and may require special precautions to avoid a high extractives content in the pulp. Judging from the thinness of the fibres, the opacity of the bleached pulp should be good.

Pulping characteristics

The consumption of active alkali in the sulphate process is quite low and a suitable range of degree of delignification is easily achieved. At the same time the yield of pulp is good. The strength properties of the pulps obtained vary, depending on provenance and the conditions of pulping, between those of good quality beech and poplar sulphate pulps.

The NSSC process gives a pulp of acceptable, although not excellent quality.

The species is not suitable for the stone grinding process for production of mechanical pulp.

Scientific name: Casuarina equisetifolia	Common name: Country: India	Reference: 61

Wood sample characteristics

Wood sample origin:

Sample from Tindivanam, Madras, 50 cm in diameter

Density and fibre characteristics:

Basic density, g/cm^3	
Fibre length, µ*	1 080
Fibre width, µ*	11
Wall thickness, µ*	
Lumen width, µ*	
Length/width ratio	98
Runkel ratio	
Flexibility ratio	

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	2.3
Methanol	
Ethanol-benzene	3.4
Solubility, %	
in water	6.5 (hot)
in 1% NaOH	21.7
Ash, %	0.9
Lignin, %	23.2
Holocellulose, %	
Cross-Bevan cellulose, %	56.7
Pentosans, %	

Additional information:

Pulping and papermaking characteristics

Unbleached	
Process	Sulphate
Chemical consumption, %	12.4 - 15.5 Na_2O (charge)
Kappa number	
Yield (unscreened), %	54.3 - 51.1
Screenings, %	
Brightness	
Beater or refiner	
Freeness	
Breaking length, m	
Burst factor	
Tear factor	
Bleached	
Sequence	HEH
Chemical consumption, %	2.9 - 2.7 Cl
Yield on bleaching, %	
Total yield, %	50.3 - 46.2
Brightness (Photovolt)	78 - 79
Beater or refiner	Lampén
Freeness	300 CSF
Breaking length	5 800 - 6 200
Burst factor	40 - 47
Tear factor	105 - 85

Additional information:

Scientific name: Casuarina equisetifolia	Common name: Country: India	Reference: 70

Wood sample characteristics

Wood sample origin:

Sample from Hyderabad

Density and fibre characteristics:

Basic density, g/cm^3	
Fibre length, µ*	1 080
Fibre width, µ*	11
Wall thickness, µ*	
Lumen width, µ*	
Length/width ratio	98
Runkel ratio	
Flexibility ratio	

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	2.3
Methanol	
Ethanol-benzene	3.4
Solubility, %	
in water	6.5 (hot)
in 1% NaOH	
Ash, %	
Lignin, %	23.2
Holocellulose, %	
Cross-Bevan cellulose, %	56.7
Pentosans, %	19.2

Additional information:

Pulping and papermaking characteristics		
Unbleached		
Process	Sulphate	NSSC
Chemical consumption, %	12.4 - 13.9 Na_2O*	5.2 - 9.3 SO_2*
Kappa number	24 - 19	
Yield (unscreened), %	54.4 - 52.9	71.7 - 60.0
Screenings, %		
Brightness		
Beater or refiner	Lampén	Lampén**
Freeness	250 CSF	250 CSF
Breaking length, m	8 600 - 6 100	4 500 - 3 900
Burst factor	55 - 35	32 - 20
Tear factor	105 - 99	52 - 99
Bleached		
Sequence		
Chemical consumption, %		
Yield on bleaching, %		
Total yield, %		
Brightness		
Beater or refiner		
Freeness		
Breaking length		
Burst factor		
Tear factor		

Additional information: Mechanical pulping (grinding) gave pulps from which no sheets could be made for testing.

* Charge
** After refining in Bauer

Ceiba pentandra
(Kapok Tree)

Plantation experience

The species is indigenous in all tropical countries and widely cultivated in the eastern tropics and in West, Central and East Africa for the seed-poss floss, known as kapok.

References: 44, 111, 123

Wood characteristics

The wood is soft and with a very low basic density which will affect the capacity of the digesters for chemical pulping, expressed as tonnage of pulp. The fibre length is considerably above the average for hardwoods and the wood exhibits fibre width characteristics which imply that the fibres would be flexible and capable of good interfibre bonding in paper. No chemical characteristics are given for the sample at hand.

Pulping characteristics

The chemical consumption in sulphate pulping is on the high side but still within the range normal for hardwoods for pulping. However, the Kappa numbers of the pulps have remained high which implies that an even higher charge of active alkali would be required to arrive at the usual Kappa number for hardwood pulps - around 20. In spite of the high Kappa number, the yield of pulp is extremely low - only 37-40%. The strength properties of the pulps, both unbleached and bleached, are fairly low. The quality of the pulp is comparable to that of beech pulps with a somewhat improved tear factor.

As regards chemical soda pulping, the above comments apply for yield and rate of delignification. The strength properties of the pulps are similar to those of a corresponding beech pulp although the tear factor is somewhat better.

NSSC pulping gives a pulp of good strength properties. However, the yield is quite low.

Scientific name: Ceiba pentandra	Common name: Kapok tree Country: Ivory Coast	Reference: 111

Wood sample characteristics

Wood sample origin:

Logs of 25 - 35 cm diameter

Density and fibre characteristics:

Basic density, g/cm^3	0.25 (dry volume)
Fibre length, µ*	1 720
Fibre width, µ*	36
Wall thickness, µ*	4
Lumen width, µ*	28
Length/width ratio	48
Runkel ratio	0.29
Flexibility ratio	0.78

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %
- Ether
- Methanol
- Ethanol-benzene

Solubility, %
- in water
- in 1% NaOH

Ash, %
Lignin, %
Holocellulose, %
Cross-Bevan cellulose, %
Pentosans, %

Additional information:

Pulping and papermaking characteristics

Unbleached			
Process	Sulphate	Soda (170°C)	NSSC
Chemical consumption, %	18.7 - 18.0 Na_2O	17.3 - 16.2 Na_2O	8.4 - 7.3 SO_2
Kappa number	30 - 45	55 - 85	-
Yield (unscreened), %	37.2 - 40.7	36 - 39	59.7 - 60.7
Screenings, %	0.8 - 0.5	0.5 - 10.9	0
Brightness (Photovolt)	27 - 24.5	25.5 - 22.5	43.5 - 40.5
Beater or refiner	Lamort	Bauer	Bauer
Freeness	40 SR	40 SR	40 SR
Breaking length, m	6 300 - 6 700	6 100 - 6 400	6 400 - 5 800
Burst factor	35 - 38	34 - 37	36 - 32
Tear factor	99 - 90	82 - 85	77 - 75
Bleached			
Sequence	CEHH	CEHH	
Chemical consumption, %	7.0 Cl	8.2 Cl	
Yield on bleaching, %			
Total yield, %			
Brightness (Photovolt)	82.5	82	
Beater or refiner	Lamort	Bauer	
Freeness	40 SR	40 SR	
Breaking length	5 400	4 900	
Burst factor	34	33	
Tear factor	75	64	

Additional information:

Cupressus lusitanica (Mexican Cypress)

Plantation experience

The species is indigenous to Central America where it grows at altitudes of 1 200-3 000 m, usually on moist slopes or near streams. It has long been cultivated in Portugal and other parts of Europe. It seems to require fairly deep, rich soils with good drainage. It has been successfully introduced in Australia and East Africa. Less promising results have been reported from Cyprus, India, Mauritius and Southern Rhodesia.

References: 31, 41, 44, 49, 107, 123

Wood characteristics

No data are available for the sample at hand.

Pulping characteristics

In spite of the extremely low yield (39%) in the sulphate process, the content of screenings has remained unusually high. As regards the strength properties, the breaking length and burst factor are similar to those of North American pine sulphate pulps, whereas the tear factor is lower, although still higher than that of Scandinavian pine sulphate pulps. The present, very incomplete data imply that the species would not be suitable for full chemical market pulp, but may be used in an integrated paper mill in combination with short-fibre pulps. In view of the apparent difficulty of delignification of this species in full chemical pulping, its best use in pulping could be for production of crude sulphate pulp (Kappa number around 60) for linerboard or wrapping paper.

Scientific name: Cupressus lusitanica	Common name: Mexican cypress Country: Kenya	Reference: 107

Wood sample characteristics

Wood sample origin / Density and fibre characteristics	Chemical characteristics
Wood sample origin: Thinnings from plantation	**Chemical characteristics:** Extractives, % Ether Methanol Ethanol-benzene Solubility, % in water in 1% NaOH
Density and fibre characteristics: Basic density, g/cm^3 Fibre length, μ* Fibre width, μ* Wall thickness, μ* Lumen width, μ* Length/width ratio Runkel ratio Flexibility ratio	Ash, % Lignin, % Holocellulose, % Cross-Bevan cellulose, % Pentosans, %
Additional information:	Additional information:

* 1000 μ (microns) = 1 mm

Pulping and papermaking characteristics

Unbleached

Process	Sulphate
Chemical consumption, %	
Kappa number	
Yield (unscreened), %	38.9
Screenings, %	1.5
Brightness	
Beater or refiner	Valley
Freeness	300 CSF
Breaking length, m	9 900
Burst factor	78
Tear factor	100

Bleached

Sequence	
Chemical consumption, %	
Yield on bleaching, %	
Total yield, %	
Brightness	
Beater or refiner	
Freeness	
Breaking length	
Burst factor	
Tear factor	

Additional information:

Eucalyptus 12 ABL

Plantation experience

Probably a hybrid and related to *E. camaldulensis* this species originates in Madagascar. It adapts itself well to tropical conditions and has been successfully introduced in Congo, where it has proved to be more suitable than *E. saligna*. It has also been planted in tropical Asia.

References: 40, 56, 57, 109

Wood characteristics

The basic density of the wood is fairly high but still within the normal range for hardwoods used for pulping. The fibres are of average length for hardwoods, of average width and fairly thin-walled. This suggests a certain amount of flexibility and consequently a potential for forming good inter-fibre bonds in paper. The lignin content is very high for hardwoods and suggests difficulties or a low yield on chemical pulping.

Pulping characteristics

The alkali consumption in the sulphate process varies between average to high for hardwoods and in some instances, in spite of a high alkali charge, the Kappa number arrived at has remained high. The yield in all instances is very low, between 40% and 45%. The strength characteristics of the pulps vary from below average to good, usually in such a way that an easily pulped sample gives better strength properties. The same conclusions apply to chemical soda pulping. In overall strength on the average, the pulps fall between the limits given by the corresponding grades of beech and average quality poplar pulps.

NSSC pulping gives a pulp with good strength properties, but in some instances extremely dark in colour. The yield is fairly low.

Scientific name:	Common name:	Reference:
Eucalyptus 12 ABL	Country: Congo	111

Wood sample characteristics

Wood sample origin:

Sample from plantation at Pointe-Noire, 5 years old.
Seeds from Madagascar.

Density and fibre characteristics:

Basic density, g/cm^3 0.60 (dry volume)
Fibre length, µ*
Fibre width, µ*
Wall thickness, µ*
Lumen width, µ*

Length/width ratio
Runkel ratio
Flexibility ratio

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %
- Ether
- Methanol
- Ethanol-benzene

Solubility, %
- in water
- in 1% NaOH

Ash, %
Lignin, %
Holocellulose, %
Cross-Bevan cellulose, %
Pentosans, %

Additional information:

Pulping and papermaking characteristics

Unbleached

Process	Sulphate
Chemical consumption, %	13.7 Na_2O
Kappa number	34
Yield (unscreened), %	45.7
Screenings, %	0.9
Brightness (Photovolt)	22.5
Beater or refiner	Bauer
Freeness	40 SR
Breaking length, m	8 500
Burst factor	54
Tear factor	120

Bleached

Sequence	CEHH
Chemical consumption, %	7.4 Cl
Yield on bleaching, %	
Total yield, %	
Brightness (Photovolt)	79.5
Beater or refiner	Bauer
Freeness	40 SR
Breaking length	7 900
Burst factor	49
Tear factor	110

Additional information:

Scientific name: Eucalyptus 12 ABL	Common name: Country: Congo	Reference: 111

Wood sample characteristics

<u>Wood sample origin:</u>

Sample from plantation at Pointe-Noire, 5 years old

Seeds from Madagascar.

<u>Density and fibre characteristics:</u>

Basic density, g/cm^3	0.52 (dry volume)
Fibre length, µ*	862
Fibre width, µ*	19
Wall thickness, µ*	4
Lumen width, µ*	11
Length/width ratio	46
Runkel ratio	0.73
Flexibility ratio	0.58

Additional information:

* 1000 µ (microns) = 1 mm

<u>Chemical characteristics:</u>

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	1.21
Solubility, %	
in water	1.42
in 1% NaOH	13.65
Ash, %	0.5
Lignin, %	33.0
Holocellulose, %	
Cross-Bevan cellulose, %	44.5
Pentosans, %	15.6

Additional information:

Pulping and papermaking characteristics

Unbleached		
Process	Sulphate	NSSC
Chemical consumption, %	16.1 - 11.9 Na_2O	8.8 SO_2
Kappa number	20 - 28	-
Yield (unscreened), %	42.5 - 48.0	63.1
Screenings, %	0 - 1.0	0
Brightness (Photovolt)	26 - 23.5	31.5
Beater or refiner	Bauer	Bauer
Freeness	40 SR	40 SR
Breaking length, m	7 000 - 8 300	6 700
Burst factor	40 - 47	40
Tear factor	65 - 95	110
Bleached		
Sequence	CEHH	
Chemical consumption, %	4.8 - 6.1 Cl	
Yield on bleaching, %		
Total yield, %		
Brightness (Photovolt)	76 - 79	
Beater or refiner	Bauer	
Freeness	40 SR	
Breaking length	6 100 - 8 000	
Burst factor	37 - 49	
Tear factor	99 - 115	

Additional information:

Scientific name: Eucalyptus 12 ABL	Common name: Kininy, Kininina Country: Madagascar	Reference: 111

Wood sample characteristics

Wood sample origin:

Logs 16-37 cm in diameter from plantations at Antanimiheva and Menagisy

Density and fibre characteristics:

Basic density, g/cm^3	0.73 (dry volume)
Fibre length, µ*	894
Fibre width, µ*	17
Wall thickness, µ*	4.5
Lumen width, µ*	6
Length/width ratio	53
Runkel ratio	1.50
Flexibility ratio	0.35

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %
- Ether
- Methanol
- Ethanol-benzene

Solubility, %
- in water
- in 1% NaOH

Ash, %
Lignin, %
Holocellulose, %
Cross-Bevan cellulose, %
Pentosans, %

Additional information:

Pulping and papermaking characteristics

Unbleached			
Process	Sulphate	Soda (170°C)	NSSC
Chemical consumption, %	19.0 - 16.7 Na_2O	17.4 - 15.9 Na_2O	7.6 - 7.2 SO_2
Kappa number	31 - 41	37 - 56	-
Yield (unscreened), %	42.3 - 45.1	41.7 - 43.8	58.8 - 62.9
Screenings, %	1.4 - 2.0	1.3 - 2.7	0
Brightness (Photovolt)	23.5	22 - 19.5	15 - 17.5
Beater or refiner	Bauer	Bauer	Bauer
Freeness	40 SR	40 SR	40 SR
Breaking length, m	5 500 - 6 400	5 400 - 5 500	5 400 - 4 500
Burst factor	30 - 38	30 - 31	31 - 27
Tear factor	80 - 91	77 - 76	70 - 62
Bleached			
Sequence	CEHH	CEHH	
Chemical consumption, %	7.3 Cl	8.2 Cl	
Yield on bleaching, %			
Total yield, %			
Brightness (Photovolt)	74	75	
Beater or refiner	Bauer	Bauer	
Freeness	40 SR	40 SR	
Breaking length	5 000	5 700	
Burst factor	31	34	
Tear factor	89	79	

Additional information:

Scientific name: Eucalyptus 12 ABL	Common name: Country: Congo	Reference: 110

Wood sample characteristics

Wood sample origin:

Sample from plantation at Loudima, 5 years old

Density and fibre characteristics:

Basic density, g/cm^3	0.67 (dry volume)
Fibre length, μ*	850
Fibre width, μ*	14
Wall thickness, μ*	4.5
Lumen width, μ*	5
Length/width ratio	61
Runkel ratio	1.80
Flexibility ratio	0.36

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	2.35
Solubility, %	
in water	4.74
in 1% NaOH	15.6
Ash, %	0.33
Lignin, %	34.9
Holocellulose, %	
Cross-Bevan cellulose, %	42.6
Pentosans, %	15.6

Additional information:

Pulping and papermaking characteristics

Unbleached

Process	Sulphate
Chemical consumption, %	19.2 - 13.6 Na_2O*
Kappa number	30 - 52
Yield (unscreened), %	40.8 - 41.8 (screened)
Screenings, %	
Brightness (Photovolt)	18
Beater or refiner	?
Freeness	40 SR
Breaking length, m	7 500 - 8 900
Burst factor	41 - 55
Tear factor	115 - 120

Bleached

Sequence	CEHH
Chemical consumption, %	
Yield on bleaching, %	
Total yield, %	
Brightness (Photovolt)	75 - 78
Beater or refiner	?
Freeness	40 SR
Breaking length	5 500 - 6 700
Burst factor	33 - 42
Tear factor	92 - 120

Additional information:

* Assuming a liquor to wood ratio of 3.3

Eucalyptus albens
(White Box)

Plantation experience

The species is indigenous to eastern Australia where it grows on soils derived from basalt and limestone. It is closely allied to *E. hemiphloia*, although smaller in size. It has been subjected to acclimatization trials in Italy, Cyprus and in West, East and South Africa.

References: 123

Wood characteristics

The timber from natural stands is reportedly very hard which may cause heavy wear of the chipper knives in a pulp mill. The fibres are short, even for a hardwood, thin, but thick-walled, which implies a lack of flexibility and consequently a low potential for forming good inter-fibre bonding in paper. The lignin content is low.

Pulping characteristics

Cold soda pulping gives a fairly dark pulp. Although the strength properties are acceptable for printing grade paper, the brightness is not, even with application of P/HS bleaching.

Application of the NSSC process gives a pulp with strength properties just acceptable for corrugated medium board. However, since the pulp is fairly bright, it may be preferable to use the pulp for production of printing grade papers after P/HS bleaching.

The sodium bisulphite process gives a dark pulp of unacceptable strength properties and the application of this process is not recommended.

Scientific name: Eucalyptus albens	Common name: Country: Italy	Reference: 19

Wood sample characteristics

Wood sample origin:

Sample from plantation at Terra Apuliae, 10 years old.

Density and fibre characteristics:

Basic density, g/cm^3	
Fibre length, µ*	582
Fibre width, µ*	14
Wall thickness, µ*	5.5
Lumen width, µ*	3
Length/width ratio	42
Runkel ratio	3.67
Flexibility ratio	0.21

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	
Solubility, %	
in water	
in 1% NaOH	
Ash, %	0.4
Lignin, %	17.7
Holocellulose, %	
Cross-Bevan cellulose, %	45.6
Pentosans, %	

Additional information:

Pulping and papermaking characteristics

Unbleached						
Process	NSSC		Cold Soda		Na-bisulphite (p H5)	
Chemical consumption, %	8.5 SO_2*		18.6 Na_2O*		8.5 SO_2*	
Kappa number						
Yield (unscreened), %	71.5		76.5		50.0	
Screenings, %						
Brightness	53		48		44	
Beater or refiner						
Freeness	25 SR	40 SR	25 SR	40 SR	25 SR	40 SR
Breaking length, m	3 200	4 400	2 900	3 400	3 300	3 800
Burst factor	12	18	11	12	13	16
Tear factor	42	58	29	36	36	57
Bleached						
Sequence	HS**		P/HS		HS	
Chemical consumption, %	1 MS*		2 Na_2O_2, 0.5 HS*		73.5	
Yield on bleaching, %						
Total yield, %						
Brightness						
Beater or refiner						
Freeness						
Breaking length						
Burst factor						
Tear factor						

Additional information:

* Charge
** Sodium hydrosulphite

Eucalyptus amygdalina

Plantation experience

The tree has a fine appearance, but its limited growth renders it unattractive for reforestation outside Australia. It has in general given dubious results in the Mediterranean area and in most of the tropical or intertropical countries into which it has been introduced as an exotic. However, at least one trial in Italy has shown some promise.

References: 38, 44, 52, 123

Wood characteristics

The basic density of the samples from the natural forests in Australia is still within the range considered normal for hardwoods for pulping. The fibres are fairly short, even for a hardwood, and thin. Judging from the width characteristics, the fibres are also quite stiff, which is apt to prevent proper bonding in the paper. The chemical characteristics do not reveal anything which would cause difficulties in chemical pulping.

Pulping characteristics

The chemical consumption in the chemical soda process is on the high side for hardwoods, even in view of the Kappa number being lower than usually aimed at. The yield of pulp is low. The strength properties are acceptable, although low for an eucalypt pulp. However, sulphate or chemical soda pulping to a Kappa number of about 20 would most probably increase the strength, although the pulps would probably resemble poplar pulps of corresponding grades, rather than eucalypt pulps.

Cold soda pulping gives a pulp of inferior strength properties and the alkali consumption is high.

The strength properties of the NSSC pulp are below the normal requirements. Bisulphite pulping gives a pulp in the normal yield range with strength properties similar to those of a beech sulphite pulp.

Scientific name:	Common name:	Reference:
Eucalyptus amygdalina (Syn. E. salicifolia)	Country: Tasmania, Australia	6

Wood sample characteristics

Wood sample origin:

Samples from natural forest at Wesley Vale

(a) Mountain region, 117 years old
(b) Foothill region, 83 years old
(c) Coastal region, 61 years old

Density and fibre characteristics:

Basic density, g/cm^3 (a) 0.55; (b) 0.57; (c) 0.55
Fibre length, µ*
Fibre width, µ*
Wall thickness, µ*
Lumen width, µ*

Length/width ratio
Runkel ratio
Flexibility ratio

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %
  Ether
  Methanol
  Ethanol-benzene

Solubility, %
  in water
  in 1% NaOH

Ash, %
Lignin, %
Holocellulose, %
Cross-Bevan cellulose, %
Pentosans, %

Additional information:

Pulping and papermaking characteristics

	a	b	c
Unbleached			
Process	Soda (170°C)	Soda (170°C)	Soda (170°C)
Chemical consumption, %	21.9 Na_2O*	21.0 Na_2O*	21.8 Na_2O*
Kappa number	15	15	15
Yield (unscreened), %	42.9	45.1	43.1
Screenings, %			
Brightness (Tappi)	31	32.5	32
Beater or refiner	PFI	PFI	PFI
Freeness	250 CSF	250 CSF	250 CSF
Breaking length, m	7 000	7 100	6 900
Burst factor	51	50	51
Tear factor	90	90	91
Bleached			
Sequence			
Chemical consumption, %			
Yield on bleaching, %			
Total yield, %			
Brightness			
Beater or refiner			
Freeness			
Breaking length			
Burst factor			
Tear factor			

Additional information:

* Charge to obtain Kappa number 15.

Scientific name: Eucalyptus amygdalina (Syn. E. salicifolia)	Common name: Country: Italy	Reference: 19

Wood sample characteristics

Wood sample origin:

Sample from plantation at Terra Apuliae, 10 years old.

Density and fibre characteristics:

Basic density, g/cm^3	
Fibre length, µ*	631
Fibre width, µ*	14
Wall thickness, µ*	4.5
Lumen width, µ*	5
Length/width ratio	45
Runkel ratio	1.80
Flexibility ratio	0.36

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	
Solubility, %	
in water	
in 1% NaOH	
Ash, %	0.2
Lignin, %	21.1
Holocellulose, %	
Cross-Bevan cellulose, %	45.0
Pentosans, %	

Additional information:

Pulping and papermaking characteristics

<u>Unbleached</u>						
Process	NSSC		Cold Soda		Na-bisulphite (pH5)	
Chemical consumption, %	8.5 SO_2*		18.6 Na_2O*		8.5 SO_2*	
Kappa number						
Yield (unscreened), %	74.0		79.0		51.0	
Screenings, %						
Brightness	54.5		53		48.5	
Beater or refiner						
Freeness	25 SR	40 SR	25 SR	40 SR	25 SR	40 SR
Breaking length, m	3 300	3 900	2 300	2 800	5 900	6 500
Burst factor	11	16	8	11	23	29
Tear factor	34	43	25	30	58	49
<u>Bleached</u>						
Sequence	HS**		P/HS		HS	
Chemical consumption, %	1 HS*		2 Na_2O_2, 0.5 HS*		1 HS	
Yield on bleaching, %						
Total yield, %						
Brightness	65.5		62		75	
Beater or refiner						
Freeness						
Breaking length						
Burst factor						
Tear factor						

Additional information:

* Charge
** Sodium hydrosulphite

Eucalyptus botryoides

Plantation experience

This species has been successfully introduced in the Mediterranean area, where vigorous growth has been recorded. Introduction in Sri Lanka has been a failure whereas the results were satisfactory on sheltered frost-free sites in New Zealand. Growth has been satisfactory in Southern Rhodesia in the tobacco-growing districts and in Kenya. In the Republic of South Africa, fairly rapid growth has been recorded in the southern and eastern coastal districts. It has also been introduced successfully in the coastal zones of California as windbreaks. In Zaire, it tends to be rejected at Katanga while in Rwanda and in Burundi it is a valuable species for propagation.

It appears that this species can give a considerable volume yield on fairly deep soils in subtropical and Mediterranean countries where there is a moist atmosphere, near the ooast and where the climate has not too marked dry seasons.

Note: The species may take on two different forms and it is advisable on choosing seed to give careful heed to its origin.

References: 38, 52, 83, 114, 123

Wood characteristics

The wood is strong, hard and durable. The basic density is within the range of hardwoods used for pulping. The extractives content is slightly on the high side and may require special precautions on pulping for removal of extractives from the pulp. However, as there is considerable difference in lignin content between the sample from Italy and that from Portugal, it may well be that the extractives content of the Italian sample is low, although no data are given in this respect. The lignin content of the sample from Portugal is exceptionally high for a hardwood. The fibre length is within the normal range for hardwoods for pulping. The other fibre dimensions imply a certain amount of stiffness. Judging from the width of the fibres, pulp made from this species should exhibit good opacity.

Pulping characteristics

The alkali consumption has been about average in the sulphate process, as applied to the Portuguese sample. However, the Kappa number arrived at implies that the charge of active alkali has been slightly insufficient. To arrive at a Kappa number of about 20, a charge of active alkali of about 20% Na_2O seems to be required, that is a charge which is often applied to hardwoods although on the high side. At the same time the yield of unbleached pulp would be slightly reduced. The fairly low yield in view of the Kappa number is probably due to the high ligning content of the present sample. The strength properties of the sulphate pulp are good, especially the tear factor, and the pulp is comparable to an average quality eucalypt pulp or a good quality poplar pulp.

The cold soda pulp is obtained with a good yield. The pulp is bright and easily bleachable to a good brightness for printing papers. The strength properties are acceptable after further refining (to about 60 SR) for use in any kind of wood-containing printing paper.

The NSSC pulps are also fairly bright. It seems preferable for grades which will be given a bleaching treatment to carry out the chemical treatment with a higher charge of carbonate to improve the bleachability. The strength properties of the pulps are good.

The sodium bisulphite process gives a fairly dark pulp with a good yield. The strength properties are good and better than those of a beech sulphite pulp.

The possibility of manufacturing dissolving pulp from this species has been thoroughly investigated in Italy.

Scientific name: Eucalyptus botryoides	Common name: Bangalay, Southern Mahogany Country: Italy	Reference: 20

Wood sample characteristics

Wood sample origin:

Sample from plantation at Grosseto, 8 years old.

Density and fibre characteristics:

Basic density, g/cm^3	0.51
Fibre length, μ*	882
Fibre width, μ*	19
Wall thickness, μ*	4.5
Lumen width, μ*	10
Length/width ratio	47
Runkel ratio	0.90
Flexibility ratio	0.53

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	
Solubility, %	
in water	
in 1% NaOH	
Ash, %	0.3
Lignin, %	23.2
Holocellulose, %	
Cross-Bevan cellulose, %	48.0
Pentosans, %	

Additional information:

Pulping and papermaking characteristics

Unbleached								
Process	NSSC (pH5)		Cold Soda		Na bisulphite		NSSC(pH 8.5)	
Chemical consumption, %	8.5 SO_2*		13.9 Na_2O		8.5 SO_2*		8.5 SO_2*	
Kappa number								
Yield (unscreened), %	77.8		86.0		59.4		81.2	
Screenings, %								
Brightness	45		53.5		51		43.5	
Beater or refiner								
Freeness	25 SR	40 SR	25 SR	40 SR	25 SR	40 SR	25 SR	40 SR
Breaking length, m	4 300	5 100	2 900	3 500	6 100	7 300	4 700	5 500
Burst factor	19	21	13	16	29	37	22	29
Tear factor	50	48	39	43	73	69	63	58
Bleached								
Sequence	HS**		P/HS		HS		HS	
Chemical consumption, %	1 HS*		2 Na_2O, 0.5 HS*		1 HS*		1 HS*	
Yield on bleaching, %								
Total yield, %								
Brightness	55.5		75		59.5		68	
Beater or refiner								
Freeness								
Breaking length								
Burst factor								
Tear factor								

Additional information:

* Charge
** Sodium hydrosulphite

Scientific name: Eucalyptus botryoides	Common name: Country: Portugal	Reference: 114

Wood sample characteristics

Wood sample origin:

Logs of 9-23 cm diameter from Herdade da Comporta

Density and fibre characteristics:

Basic density, g/cm^3	0.60
Fibre length, µ*	
Fibre width, µ*	
Wall thickness, µ*	
Lumen width, µ*	
Length/width ratio	
Runkel ratio	
Flexibility ratio	

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	0.5
Methanol	
Ethanol-benzene	3.3
Solubility, %	
in water	7.8 (hot)
in 1% NaOH	
Ash, %	0.2
Lignin, %	30.4
Holocellulose, %	66.7
Cross-Bevan cellulose, %	40.8
Pentosans, %	15.1

Additional information:

Pulping and papermaking characteristics

Unbleached

Process	Sulphate
Chemical consumption, %	17.2 Na_2O (charge)
Kappa number	about 28
Yield (unscreened), %	51.5
Screenings, %	0.8
Brightness	
Beater or refiner	Lampén
Freeness	45 SR
Breaking length, m	9 100
Burst factor	56
Tear factor	140

Bleached

Sequence	
Chemical consumption, %	
Yield on bleaching, %	
Total yield, %	
Brightness	
Beater or refiner	
Freeness	
Breaking length	
Burst factor	
Tear factor	

Additional information:

Eucalyptus camaldulensis

Plantation experience

Together with *E. globulus*, this is the most widely used eucalypt species in plantations. It was introduced in the beginning of the 19th century in the Mediterranean countries. Due to damage by *Armillaria mellea*, its growth in Italy has been less notable than that of *E. botryoides* or *E. maidenii*. Remarkable success has been achieved with commercial-scale plantations in Spain, in the provinces of Seville, Cádiz, Huelva and Malaga as well as in Portugal and North Africa. Good results have also been reported from Turkey, Sri Lanka, Kenya, Southern Rhodesia, Malawi, the Republic of South Africa, California, Brazil, Argentina and Chile. It has failed to acclimatize in many tropical countries and in Democratic Kampuchea and India. Dubious results have been obtained in Indonesia and Zaire.

The species is very adaptable to climate and soil. It can be planted in deep soils in semi-arid and almost arid Mediterranean conditions. In more humid climates it can be planted on comparatively shallow soils. Its upper limit of growth is roughly 1 300-1 400 m in the Moroccan Central Atlas region.

It is liable to be attacked by *Gonipterus scutellatus*.

References: 38, 39, 40, 41, 44, 45, 52, 83, 85, 112, 123, 128, 147

Wood characteristics

The basic density of the wood is in the normal range for hardwoods used for pulping, as is the fibre length. The fibres are thin and fairly flexible which implies good potential bonding in paper. The lignin content of the sample grown in Portugal is high for a hardwood for pulping, whereas that of the Italian sample is normal. Judging from the thinness of the fibres, pulp made from this species should exhibit good opacity.

Pulping characteristics

The alkali consumption in the sulphate process is within the normal range for hardwoods, but probably varies with the ligning content of the wood. The yield of pulp is around the average for hardwoods used for pulping. As regards the Italian sample, the extremely low yield in the sulphate process implies that the pulp has been over-cooked, which also seems to be confirmed by the low strength properties in comparison with the excellent ones obtained with the Portuguese sample. However, the discrepancy between the two sets of data may also be due to the Italian wood sample being unsuitable (extensive drying of the wood on storage, for instance). This would also explain the impregnation difficulties met with at lower pH and the extremely low strength properties of the cold soda and high-yield NSSC pulps. As regards the Portuguese sample, good opacity was noted for the bleached pulp.

(Eucalyptus camaldulensis)

Laboratory tests for the production of dissolving pulp from this species have shown that the bisulphite process was inapplicable, whereas the pre-hydrolysis sulphate process gave good high-alpha pulps with total yields of 30-35%. (37) Commercial production is reported from Morocco.

Cold soda pulp of good quality has been obtained with a good yield at least with the other sample from Italy. However, its bleachability was slightly inferior to the cold soda pulp made from a sample of E. botryoides.

Good quality NSSC pulps have also been made from this species.

The sodium bisulphite process gives good quality hardwood sulphite pulp with a good yield. The strength properties of the pulp are better than those of beech sulphite pulp. However, the brightness of the pulp is low and probably requires a two-stage bleaching process, for instance P/HS, to obtain a brightness acceptable for printing grade papers.

According to pilot plant trials carried out in Italy (2), the species adapts itself to mechanical pulping and gives a pulp which can be used in newsprint.

Scientific name: Eucalyptus camaldulensis (Syn. E. rostrata)	Common name: Country: Italy	Reference: 20

Wood sample characteristics

Wood sample origin:

Sample from plantation at Grosseto, 8 years old.

Density and fibre characteristics:

Basic density, g/cm^3	0.48
Fibre length, µ*	747
Fibre width, µ*	18
Wall thickness, µ*	3
Lumen width, µ*	12
Length/width ratio	42
Runkel ratio	0.50
Flexibility ratio	0.67

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	
Solubility, %	
in water	
in 1% NaOH	
Ash, %	0.4
Lignin, %	23.9
Holocellulose, %	
Cross-Bevan cellulose, %	43.6
Pentosans, %	

Additional information:

Pulping and papermaking characteristics

Unbleached								
Process	NSSC (pH 5)		Cold Soda		Na bisulphite		NSSC (pH 8.5)	
Chemical consumption, %	8.5 SO_2*		13.9 Na_2O*		8.4 SO_2*		8.5 SO_2*	
Kappa number								
Yield (unscreened), %	74.5		83.5		54.0		78.9	
Screenings, %								
Brightness	46		45.5		45		38	
Beater or refiner								
Freeness	25 SR	40 SR	25 SR	40 SR	25 SR	40 SR	25 SR	40 SR
Breaking length, m	5 200	5 800	2 800	3 400	5 300	6 600	4 400	5 400
Burst factor	24	29	13	16	23	31	20	27
Tear factor	53	49	36	38	58	52	56	53
Bleached								
Sequence	HS**		P/HS		HS		HS	
Chemical consumption, %	1 HS*		2 Na_2O_2, 0.5 HS*		1 HS*		1 HS*	
Yield on bleaching, %								
Total yield, %								
Brightness	52		68.5		55.5		62	
Beater or refiner								
Freeness								
Breaking length								
Burst factor								
Tear factor								

Additional information:

* Charge.
** Sodium hydrosulphite.

Scientific name: Eucalyptus camaldulensis (Syn. E. rostrata)	Common name: Country: Portugal	Reference: 113

Wood sample characteristics

Wood sample origin:

Debarked logs of 11-20 cm in diameter, from plantation in the south of Portugal.

Density and fibre characteristics:

Basic density, g/cm^3	0.54
Fibre length, µ*	931
Fibre width, µ*	18
Wall thickness, µ*	
Lumen width, µ*	
Length/width ratio	52
Runkel ratio	
Flexibility ratio	

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	0.3
Methanol	
Ethanol-benzene	1.4
Solubility, %	
in water	4.3 (hot)
in 1% NaOH	
Ash, %	0.4
Lignin, %	29.1
Holocellulose, %	70.6
Cross-Bevan cellulose, %	43.0
Pentosans, %	17.2

Additional information:

Pulping and papermaking characteristics

<u>Unbleached</u>

Process	Sulphate
Chemical consumption, %	19.0 Na_2O (charge)
Kappa number	about 19
Yield (unscreened), %	50.7
Screenings, %	0.7
Brightness	
Beater or refiner	Lampén
Freeness	45 SR
Breaking length, m	11 100
Burst factor	73
Tear factor	120

<u>Bleached</u>

Sequence	HCED
Chemical consumption, %	4.9 Cl
Yield on bleaching, %	
Total yield, %	
Brightness	86.5 (Tappi)
Beater or refiner	Lampén
Freeness	45 SR
Breaking length	8 900
Burst factor	55
Tear factor	115

Additional information: Printing opacity of bleached pulp at 45 SR 83.

Scientific name: Eucalyptus camaldulensis (Syn. E. Rostrata)	Common name: Country: Italy	Reference: 25

Wood sample characteristics

Wood sample origin:	Chemical characteristics:
	Extractives, % Ether Methanol Ethanol-benzene
	Solubility, % in water in 1% NaOH
Density and fibre characteristics: Basic density, g/cm^3 Fibre length, μ* Fibre width, μ* Wall thickness, μ* Lumen width, μ* Length/width ratio Runkel ratio Flexibility ratio	Ash, % Lignin, % Holocellulose, % Cross-Bevan cellulose, % Pentosans, %
Additional information:	Additional information:
* 1000 μ (microns) = 1 mm	

Pulping and papermaking characteristics

Unbleached								
Process	NSSC		NSSC		Cold Soda		Sulphate	
Chemical consumption, %								
Kappa number								
Yield (unscreened), %	84.0		58.7		88.0		44.8	
Screenings, %								
Brightness	68*				66*			
Beater or refiner								
Freeness	30 SR	50 SR	30 SR	50 SR	30 SR	50 SR	30 SR	50 SR
Breaking length, m	1 300	1 400	6 000	7 200	1 100	1 300	6 500	8 000
Burst factor	6	6	40	55	5	6	55	73
Tear factor	17	17	81	70	18	16	84	74
Bleached								
Sequence								
Chemical consumption, %								
Yield on bleaching, %								
Total yield, %	82.7		45.8		83.0		40.2	
Brightness	68*		83*		63*		85*	
Beater or refiner								
Freeness	30 SR	50 SR	30 SR	50 SR	30 SR	50 SR	30 SR	50 SR
Breaking length	2 400	2 800	6 100	7 500	2 400	3 000	5 100	6 900
Burst factor	11	13	53	67	13	18	48	62
Tear factor	31	30	100	88	35	33	75	63

Additional information: Impregnation and cooking with bisulphite liquor (at lower pH than NSSC) was difficult.

* Brightness determined after beating to 30 SR.

Eucalyptus citriodora

Plantation experience

The tree has a clean straight stem, usually excellent for poles, but has rarely been planted commercially. It has been planted in Portugal and North Africa, mainly as an ornamental tree, and in Sri Lanka at 1 000-2 000 m. Varying results have been obtained in India. Good results have been obtained in South, West, Central and East Africa, as well as in Brazil, whereas it has failed to acclimatize in Democratic Kampuchea, India and at low altitudes in Indonesia.

The species is relatively adaptable, as it does equally well both in warm and humid and the Mediterranean climates. However, in order to give profitable results it requires fairly deep soils and not too prolonged dry periods. It is fairly delicate when raised in nurseries and affected even by light frost.

References: 38, 40, 41, 57, 109, 123

Wood characteristics

The basic density of the wood is somewhat higher than usual for hardwoods used for pulping, even in very young trees. This implies a certain hardness which may cause wear on the chipper knives in a pulp mill. The fibre length is in the normal range for hardwoods used for pulping. The fibres are thin although thick-walled which implies a certain amount of undesirable stiffness which may prevent proper inter-fibre bonding in paper. The chemical characteristics do not, in general, imply difficulty of pulping. However, the Indian sample exhibits a fairly high extractives content which may require special precautions for removal of extractives from the pulp.

Pulping characteristics

Although the alkali consumption and pulping yield in the sulphate process are about average for hardwoods used for pulping, the quality of the pulps obtained are not up to the normal requirements for eucalypt pulps. At their best, the strength properties are comparable to those of beech sulphate pulps.

Scientific name: Eucalyptus citriodora	Common name: Country: Congo	Reference: 120

Wood sample characteristics

Wood sample origin:

Sample from plantation at Pointe-Noire, 10 years old.

Density and fibre characteristics:

Basic density, g/cm^3	0.80 (dry volume)
Fibre length, μ*	973
Fibre width, μ*	15
Wall thickness, μ*	5
Lumen width, μ*	5
Length/width ratio	65
Runkel ratio	2.00
Flexibility ratio	0.33

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	1.07
Solubility, %	
in water	1.32
in 1% NaOH	13.6
Ash, %	0.3
Lignin, %	23.2
Holocellulose, %	
Cross-Bevan cellulose, %	55.6
Pentosans, %	16.2

Additional information:

Pulping and papermaking characteristics

<u>Unbleached</u>

Process	Sulphate
Chemical consumption, %	12.2 - 13.3 Na_2O*
Kappa number	16 - 24
Yield (unscreened), %	49.9 - 50.7 (screened)
Screenings, %	
Brightness	26 - 24 (Photovolt)
Beater or refiner	?
Freeness	40 SR
Breaking length, m	6 100
Burst factor	29 - 32
Tear factor	88 - 87

<u>Bleached</u>

Sequence	CEHH
Chemical consumption, %	
Yield on bleaching, %	
Total yield, %	
Brightness	89 - 87 (Photovolt)
Beater or refiner	?
Freeness	40 SR
Breaking length	5 300 - 6 000
Burst factor	31 - 34
Tear factor	97 - 110

Additional information:

* Assuming a liquor to wood ratio of 3.3

Scientific name: Eucalyptus citriodora	Common name: Country: Congo	Reference: 120

Wood sample characteristics

Wood sample origin:

Sample from plantation at Loudima, 6 years old.

Density and fibre characteristics:

Basic density, g/cm^3	0.78 (dry volume)
Fibre length, µ*	938
Fibre width, µ*	15
Wall thickness, µ*	4.5
Lumen width, µ*	6
Length/width ratio	63
Runkel ratio	1.50
Flexibility ratio	0.40

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	2.06
Solubility, %	
in water	1.53
in 1% NaOH	13.6
Ash, %	0.30
Lignin, %	24.2
Holocellulose, %	
Cross-Bevan cellulose, %	52.9
Pentosans, %	20.3

Additional information:

Pulping and papermaking characteristics

Unbleached	
Process	Sulphate
Chemical consumption, %	17.1 - 13.5*
Kappa number	18 - 25
Yield (unscreened), %	48.5 - 48.2 (screened)
Screenings, %	
Brightness	29 - 26 (Photovolt)
Beater or refiner	?
Freeness	40 SR
Breaking length, m	7 000 - 7 700
Burst factor	36 - 47
Tear factor	105 - 110
Bleached	
Sequence	CEHH
Chemical consumption, %	
Yield on bleaching, %	
Total yield, %	
Brightness	78 - 81 (Photovolt)
Beater or refiner	?
Freeness	40 SR
Breaking length	6 500 - 6 900
Burst factor	40 - 42
Tear factor	110 - 125

Additional information:

* Assuming a liquor to wood ratio of 3.3

Scientific name: Eucalyptus citriodora	Common name: Country: India	Reference: 68

Wood sample characteristics

Wood sample origin:

Sample from Dehra Dun Forest Division.

Density and fibre characteristics:

Basic density, g/cm^3	
Fibre length, μ*	1 030
Fibre width, μ*	14
Wall thickness, μ*	
Lumen width, μ*	
Length/width ratio	74
Runkel ratio	
Flexibility ratio	

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	2.95
Methanol	
Ethanol-benzene	3.76
Solubility, %	
in water	9.5 (hot)
in 1% NaOH	22.0
Ash, %	1.5
Lignin, %	23.0
Holocellulose, %	
Cross-Bevan cellulose, %	57.9
Pentosans, %	

Additional information:

Pulping and papermaking characteristics	
Unbleached	
Process	Sulphate
Chemical consumption, %	13.9 - 20.1 Na_2O (charge)
Kappa number	
Yield (unscreened), %	48.8 - 52.5
Screenings, %	
Brightness	
Beater or refiner	
Freeness	
Breaking length, m	
Burst factor	
Tear factor	
Bleached	
Sequence	HEH
Chemical consumption, %	2.3 - 3.1 Cl
Yield on bleaching, %	
Total yield, %	42.5 - 40.2
Brightness	
Beater or refiner	Lampén
Freeness	300 CSF
Breaking length	5 100 - 5 000
Burst factor	30
Tear factor	53 - 68
Additional information:	

Eucalyptus cloeziana

Plantation experience

Sufficient experience has not yet been gained with this species. It is considered to be capable of profitable use because of its rapid growth in relatively dry tropical climates. Good results have been reported from plantation trials in Congo.

References: 38, 57, 109

Wood characteristics

The basic density of the wood is slightly higher than normal for hardwoods used for pulping. The fibres are of average length for hardwoods, thin, but fairly thick-walled, which implies a certain degree of undesirable stiffness which tends to prevent proper inter-fibre bonding in paper. The lignin content of the present sample is high and may affect the yield and ease of chemical pulping.

Pulping characteristics

In spite of a fairly high consumption of alkali in the sulphate process, the Kappa number of the pulp has remained above the normal value for hardwood sulphate pulp. The yield, even at this Kappa number, is low and the resulting pulp is extremely dark in colour. The strength properties, with the exception of the tear factor, which is good, are fairly low and the pulp resembles, with respect to breaking length and burst factor, a good quality beech sulphate pulp.

Scientific name: Eucalyptus cloeziana	Common name: Country: Congo	Reference: 110

Wood sample characteristics

Wood sample origin:

Sample from plantation at Pointe-Noire, 7 years old.

Density and fibre characteristics:

Basic density, g/cm^3	0.69 (dry volume)
Fibre length, µ*	921
Fibre width, µ*	16
Wall thickness, µ*	5
Lumen width, µ*	6
Length/width ratio	58
Runkel ratio	1.67
Flexibility ratio	0.38

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	1.36
Solubility, %	
in water	5.72
in 1% NaOH	10.9
Ash, %	0.1
Lignin, %	30
Holocellulose, %	
Cross-Bevan cellulose, %	48
Pentosans, %	14.2

Additional information:

Pulping and papermaking characteristics

<u>Unbleached</u>

Process	Sulphate
Chemical consumption, %	19.0 - 13.8 Na_2O*
Kappa number	28 - 55
Yield (unscreened), %	46.9 - 42.6 (screened)
Screenings, %	
Brightness	17 - 14 (Photovolt)
Beater or refiner	?
Freeness	40 SR
Breaking length, m	7 000 - 7 700
Burst factor	40 - 48
Tear factor	110

<u>Bleached</u>

Sequence	CEHH
Chemical consumption, %	
Yield on bleaching, %	
Total yield, %	
Brightness	80 - 83 (Photovolt)
Beater or refiner	?
Freeness	40 SR
Breaking length	5 700 - 6 100
Burst factor	35 - 37
Tear factor	83 - 88

Additional information:

* Assuming a liquor to wood ratio of 3.3

Eucalyptus deglupta
(Mindanao Gum, Kamarere)

Plantation experience

The species is indigenous to the Philippine Islands, the Celebes, New Guinea, New Britain and New Ireland, where it grows in almost pure stands on alluvial flats and terraces. It is fast-growing and has acclimatized well in similar tropical island climates, such as those of Java and Cuba. Good results have also been reported from Brazil, Sri Lanka, India, Malaysia, North Borneo and the Solomon Islands. Less satisfactory results have been obtained in Fiji and the Republic of South Africa. The species seems to have failed, in general, to acclimatize in East Africa, whereas it has shown some promise in Congo. It is considered by some to be one of the few eucalypt species that are successful as exotics in tropical climates.

References: 38, 52, 57, 109, 123

Wood characteristics

The basic density of the wood is in the normal range for hardwoods used for pulping. The fibres are fairly short, of average width and not too thick-walled. This suggests a certain amount of desirable flexibility and thus potentially good inter-fibre bonding in paper. The lignin content tends to be on the high side for a hardwood which may affect the yield and ease of chemical pulping.

Pulping characteristics

The species requires a fairly high alkali charge in the sulphate process and the yield of pulp is lower than average for hardwoods, although not excessively so. The strength properties of the pulp are under average for good quality eucalypt pulp and they are, at their best, comparable to poplar sulphate pulp.

Scientific name: Eucalyptus deglupta (Syn. E. naudiana)	Common name: Mindanao Gum, Kamarere Country: New Guinea	Reference: 78

Wood sample characteristics

Wood sample origin:

Sample from plantation at Rabaul, New Britain, 5 years old.

Density and fibre characteristics:

Basic density, g/cm^3	0.43
Fibre length, µ*	870
Fibre width, µ*	20
Wall thickness, µ*	
Lumen width, µ*	
Length/width ratio	44
Runkel ratio	0.38
Flexibility ratio	0.73

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	1.5
Solubility, %	
in water	
in 1% NaOH	
Ash, %	
Lignin, %	27.3
Holocellulose, %	
Cross-Bevan cellulose, %	
Pentosans, %	14.4

Additional information:

Pulping and papermaking characteristics	
Unbleached	
Process	Sulphate
Chemical consumption, %	23 Na_2O (total alkali charge)
Kappa number	26.9
Yield (unscreened), %	50.1
Screenings, %	
Brightness	
Beater or refiner	Lampén
Freeness	300 CSF
Breaking length, m	9 100
Burst factor	67
Tear factor	94
Bleached	
Sequence	
Chemical consumption, %	
Yield on bleaching, %	
Total yield, %	
Brightness	
Beater or refiner	
Freeness	
Breaking length	
Burst factor	
Tear factor	
Additional information:	

Scientific name:	Common name: Mindanao Gum	Reference:
Eucalyptus deglupta (Syn. E. naudiana)	Country: Congo	110

Wood sample characteristics

Wood sample origin:

Samples from plantation at Loudima, 5 years old.
Seeds from New Guinea.

Density and fibre characteristics:

Basic density, g/cm^3	0.49 (dry volume)
Fibre length, µ*	762
Fibre width, µ*	22
Wall thickness, µ*	4
Lumen width, µ*	14
Length/width ratio	35
Runkel ratio	0.57
Flexibility ratio	0.64

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	2.08
Solubility, %	
in water	3.67
in 1% NaOH	13.6
Ash, %	0.45
Lignin, %	32.9
Holocellulose, %	
Cross-Bevan cellulose, %	44.5
Pentosans, %	16.5

Additional information:

Pulping and papermaking characteristics

Unbleached	
Process	Sulphate
Chemical consumption, %	18.7 - 13.4 Na_2O*
Kappa number	25 - 38
Yield (unscreened), %	44.6 - 44.9 (screened)
Screenings, %	
Brightness	22 - 30 (Photovolt)
Beater or refiner	?
Freeness	40 SR
Breaking length, m	7 100 - 9 000
Burst factor	43 - 54
Tear factor	92 - 96
Bleached	
Sequence	CEHH
Chemical consumption, %	
Yield on bleaching, %	
Total yield, %	
Brightness	76 - 78 (Photovolt)
Beater or refiner	?
Freeness	40 SR
Breaking length	6 900 - 7 600
Burst factor	42 - 50
Tear factor	86 - 94

Additional information:

* Assuming a liquor to wood ratio of 3.3

Eucalyptus delegatensis

Plantation experience

This species has not been used in large-scale reforestation and it is not recommended for commercial plantations without fairly lengthy preliminary trials. It is outstanding for its adaptation to wet sites and deep soils as well as for the quality of its timber.

References: 38, 90, 123

Wood characteristics

The basic density is within the normal range for hardwoods for pulping. No other data on the wood characteristics are available for the sample at hand.

Pulping characteristics

The alkali consumption in the chemical soda process is in the normal range for hardwoods and the pulp is obtained with a normal yield, in spite of the very low Kappa number aimed at. The strength properties are good and application of the sulphate process would probably give a pulp which would correspond to average quality eucalypt pulp.

Scientific name: Eucalyptus delegatensis	Common name: Country: Tasmania, Australia	Reference: 6

Wood sample characteristics

Wood sample origin:

Sample from natural forest at Wesley Vale. Mountain region, 102 years old.

Density and fibre characteristics:

Basic density, g/cm^3	0.48
Fibre length, µ*	
Fibre width, µ*	
Wall thickness, µ*	
Lumen width, µ*	
Length/width ratio	
Runkel ratio	
Flexibility ratio	

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %
- Ether
- Methanol
- Ethanol-benzene

Solubility, %
- in water
- in 1% NaOH

Ash, %
Lignin, %
Holocellulose, %
Cross-Bevan cellulose, %
Pentosans, %

Additional information:

Pulping and papermaking characteristics

Unbleached

Process	Soda (170°C)
Chemical consumption, %	18.1 Na_2O (charge for Kappa 15)
Kappa number	15
Yield (unscreened), %	48.8
Screenings, %	
Brightness	34.5 (Tappi)
Beater or refiner	PFI
Freeness	250 CSF
Breaking length, m	7 800
Burst factor	61
Tear factor	105

Bleached

Sequence	
Chemical consumption, %	
Yield on bleaching, %	
Total yield, %	
Brightness	
Beater or refiner	
Freeness	
Breaking length	
Burst factor	
Tear factor	

Additional information:

Eucalyptus globulus
(Blue Gum)

Plantation experience

This is the most widely planted eucalypt species. The annual yields per ha are excellent, for instance in Spain over 30 m^3/ha, in Portugal 8–12 m^3/ha. The species gives its maximum yields on deep soils free of carbonates, in mild climates with uniform rainfall as well as with winter or summer maximum.

References: 38, 40, 41, 43, 44, 52, 83, 85, 114, 123, 147

Wood characteristics

The basic density of the wood is in the normal range for hardwoods for pulping. The fibres are of normal length for hardwoods, thin, but also fairly thin-walled, which implies sufficient flexibility for proper bonding in paper. Judging from the thinness of the fibres, pulp made from this species should exhibit good opacity. The lignin content is around the average for hardwoods for pulping, even slightly on the low side, which implies ease of chemical pulping.

Pulping characteristics

The alkali consumption in the sulphate process seems to be low, but depends on the lignin content of the wood. The yield of pulp is very high. The strength properties of the sulphate pulps are excellent and meet the highest quality demands on short-fibre sulphate pulps. The opacity is high, even at a freeness of 45 SR. The species also adapts itself well to chemical soda pulping and gives a good quality pulp with a good yield.

Cold soda pulping gives a fairly bright and easily bleachable pulp of excellent strength with a high yield.

NSSC pulping gives pulps of excellent strength. If used in printing papers, a higher charge of carbonate is preferable in order to obtain a more easily bleachable pulp. Sodium bisulphite pulping seems to give a fairly dark pulp of average strength properties. If used in printing papers, bleaching should be carried out in two steps - for instance P/HS in order to arrive at an acceptable brightness. The trials on groundwood pulping carried out on a pilot scale in India imply that the species is not suitable for stone grinder pulping.

Successful laboratory tests, including filterability tests of viscose, have been carried out in India for the manufacture of dissolving pulp by the prehydrolysis sulphate process (14, 72). The total yield of pulp was about 35%. The species is also used in Portugal and Spain for commercial production of prehydrolysis sulphate dissolving pulp.

Scientific name: Eucalyptus globulus	Common name: Blue Gum Country: India	Reference: 11

Wood sample characteristics

Wood sample origin:

Samples from the Nilgiris Division, Madras, 15 years old.

Density and fibre characteristics:

Basic density, g/cm^3	
Fibre length, µ*	1 110
Fibre width, µ*	14
Wall thickness, µ*	
Lumen width, µ*	
Length/width ratio	79
Runkel ratio	
Flexibility ratio	

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	0.68
Methanol	
Ethanol-benzene	2.15
Solubility, %	
in water	3.51 (hot)
in 1% NaOH	15.6
Ash, %	0.25
Lignin, %	20.3
Holocellulose, %	
Cross-Bevan cellulose, %	61.0
Pentosans, %	15.5

Additional information:

Pulping and papermaking characteristics

Unbleached		
Process	Sulphate	Soda (153–162 °C)
Chemical consumption, %	13.0 – 15.6 Na_2O	11.8 – 14.2 Na_2O
Kappa number		
Yield (unscreened), %	61.8 – 58.8	65.1 – 60.0
Screenings, %		
Brightness		
Beater or refiner	Lampén	Lampén
Freeness	300 CSF	300 CSF
Breaking length, m	10 800 – 9 600	8 800 – 8 200
Burst factor	68 – 56	48 – 46
Tear factor	135 – 125	105
Bleached		
Sequence		
Chemical consumption, %		
Yield on bleaching, %		
Total yield, %		
Brightness		
Beater or refiner		
Freeness		
Breaking length		
Burst factor		
Tear factor		

Additional information: A pilot plant trail to produce wrapping paper from 100% Blue Gum sulphate ((Yield 57.9%, Freeness 300 CSF) with the following main characteristics:

	Machine direction	Cross direction
Breaking length, m	6 810	3 710
Stretch, %	1.8	4.7
Burst factor	28.0	
Tear factor	81.8	81.3

Scientific name: Eucalyptus globulus	Common name: Blue Gum Country: Italy	Reference: 20

Wood sample characteristics

Wood sample origin:

Sample from plantation at Grosseto, 8 years old.

Density and fibre characteristics:

Basic density, g/cm^3	0.58
Fibre length, μ*	865
Fibre width, μ*	17
Wall thickness, μ*	3
Lumen width, μ*	11
Length/width ratio	51
Runkel ratio	0.55
Flexibility ratio	0.65

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	
Solubility, %	
in water	
in 1% NaOH	
Ash, %	0.4
Lignin, %	19.3
Holocellulose, %	
Cross-Bevan cellulose, %	48.3
Pentosans, %	

Additional information:

Pulping and papermaking characteristics

Unbleached								
Process	NSSC (pH 5)		Cold Soda		Na bisulphite		NSSC (pH 8.5)	
Chemical consumption, %	8.5 SO_2		13.9 Na_2O*		8.5 SO_2		8.5 SO_2	
Kappa number								
Yield (unscreened), %	74.6		83.7		51.2		74.7	
Screenings, %								
Brightness	49		55.5		50.5		49.5	
Beater or refiner	25 SR	40 SR	25 SR	40 SR	25 SR	40 SR	25 SR	40 SR
Freeness	5 300	7 100	3 400	4 100	6 400	7 300	6 400	7 200
Breaking length, m	31	38	16	28	26	39	34	36
Burst factor	72	68	52	50	83	78	71	62
Tear factor								
Bleached								
Sequence	HS**		P/HS		HS		HS	
Chemical consumption, %	1 HS*		2 Na_2O_2, 0.5 HS*		1 HS*		1 HS*	
Yield on bleaching, %								
Total yield, %								
Brightness	57		74		62		66	
Beater or refiner								
Freeness								
Breaking length								
Burst factor								
Tear factor								

Additional information:

* Charge.

** Sodium hydrosulphite.

Scientific name: Eucalyptus globulus	Common name: Blue Gum Country: India	Reference: 16

Wood sample characteristics

Wood sample origin:	Chemical characteristics:
Sample from the Nilgiris Division, Madras, 15 years old.	Extractives, % Ether Methanol Ethanol-benzene Solubility, % in water in 1% NaOH
Density and fibre characteristics: Basic density, g/cm^3 Fibre length, µ* Fibre width, µ* Wall thickness, µ* Lumen width, µ* Length/width ratio Runkel ratio Flexibility ratio	Ash, % Lignin, % Holocellulose, % Cross-Bevan cellulose, % Pentosans, %
Additional information:	Additional information:

* 1000 µ (microns) = 1 mm

Pulping and papermaking characteristics

Unbleached			
Process		Stone groundwood	
Chemical consumption, %			
Kappa number			
Yield (unscreened), %			
Screenings, %			
Brightness			
Beater or refiner		Voith stone grinder	
Freeness	240 CSF	100 CSF	97 CSF
Breaking length, m	840	1 400	1 010
Burst factor	3	6	6
Tear factor	16	19	22
	1 170	930	1 550
Bleached			
Sequence			
Chemical consumption, %			
Yield on bleaching, %			
Total yield, %			
Brightness			
Beater or refiner			
Freeness			
Breaking length			
Burst factor			
Tear factor			

Additional information:

Scientific name: Eucalyptus globulus	Common name: Country: Portugal	Reference: 113

Wood sample characteristics

Wood sample origin:

The data do not refer to a specific sample but to composite values accumulated from numerous studies in Portugal.

Density and fibre characteristics:

Basic density, g/cm^3	0.55
Fibre length, µ*	910
Fibre width, µ*	18
Wall thickness, µ*	
Lumen width, µ*	
Length/width ratio	51
Runkel ratio	
Flexibility ratio	

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	0.3
Methanol	
Ethanol-benzene	0.9
Solubility, %	
in water	1.3 (hot)
in 1% NaOH	
Ash, %	0.4
Lignin, %	20.4
Holocellulose, %	73.9
Cross-Bevan cellulose, %	44.8
Pentosans, %	21.6

Additional information:

Pulping and papermaking characteristics

Unbleached

Process	Sulphate
Chemical consumption, %	16.1 Na_2O (charge)
Kappa number	57.4
Yield (unscreened), %	0.1
Screenings, %	
Brightness	
Beater or refiner	Lampén
Freeness	45 SR
Breaking length, m	13 300
Burst factor	91
Tear factor	120

Bleached

Sequence	CEDED
Chemical consumption, %	5.4 Cl
Yield on bleaching, %	
Total yield, %	
Brightness	93 (Tappi)
Beater or refiner	Lampén
Freeness	45 SR
Breaking length	13 300
Burst factor	88
Tear factor	115

Additional information: Printing opacity of bleached pulp at 45 SR 80.

Eucalyptus gomphocephala

Plantation experience

Excellent results have been obtained with this species with plantations in the Mediterranean area, in the Republic of South Africa, California and Chile. Poor results have been reported from most hot and wet tropical countries, such as Brazil, India, Kenya and Zaire. The yield per annum is usually 10 m^3/ha. It adapts itself readily to soils with a high percentage of assimilable carbonates which are harmful to other eucalypt species.

It is resistant to long spells of dry weather and drought, especially in the inter-tropical coastal zones. The tree is wind-firm and thus suitable for planting by the sea as a windbreak.

References: 38, 39, 45, 52, 83

Wood characteristics

The wood is very dense, strong and tough which may cause wear on chipper knives in a pulp mill. The fibres are slightly on the short side, even for a hardwood, thin but fairly thick-walled which implies a certain amount of undesirable stiffness which may prevent proper bonding between the fibres in paper. The lignin content is low, but there is a serious drawback in this species as regards pulping due to the presence of tannin - up to 7% - in the wood.

Pulping characteristics

Pulping by means of the cold soda process gives a fairly bright and easily bleachable pulp with acceptable strength properties for, for instance, printing papers.

The strength properties of the NSSC pulps from this species are also acceptable. If used in printing grade papers a higher charge of carbonate is recommended in order to improve the bleachability of the pulp.

The sodium bisulphite process gives, with an average yield, a fairly dark pulp with acceptable strength properties, similar to those of beech sulphite pulp. Judging from the fibre width, the opacity of the pulp should be good.

Scientific name: Eucalyptus gomphocephala	Common name: Country: Italy	Reference: 20

Wood sample characteristics

Wood sample origin:

Sample from plantation at Grosseto, 8 years old.

Density and fibre characteristics:

Basic density, g/cm^3	0.63
Fibre length, µ*	783
Fibre width, µ*	15
Wall thickness, µ*	4.5
Lumen width, µ*	6
Length/width ratio	52
Runkel ratio	1.50
Flexibility ratio	0.40

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	
Solubility, %	
in water	
in 1% NaOH	
Ash, %	0.4
Lignin, %	18.6
Holocellulose, %	
Cross-Bevan cellulose, %	45.3
Pentosans, %	

Additional information:

Pulping and papermaking characteristics

Unbleached								
Process	NSSC (pH 5)		Cold soda		Na-bisulphite		NSSC (pH 8.5)	
Chemical consumption, %	8.5 SO_2		13.9 Na_2O*		3.5 SO_2*		8.5 SO_2	
Kappa number								
Yield (unscreened), %	69.8		83.8		51.8		73.8	
Screenings, %								
Brightness	46		55		56		44.5	
Beater or refiner	25 SR	40 SR	25 SR	40 SR	25 SR	40 SR	25 SR	40 SR
Freeness	4 800	5 500	3 000	3 500	5 000	6 200	5 200	5 500
Breaking length, m	23	27	13	16	24	34	26	29
Burst factor	52	54	34	38	71	75	62	58
Tear factor								
Bleached								
Sequence	HS**		P/HS		HS		HS	
Chemical consumption, %	1 HS*		2 Na_2O_2, 0.5 HS*		1 HS*		1 HS*	
Yield on bleaching, %								
Total yield, %								
Brightness	56		71		61		65	
Beater or refiner								
Freeness								
Breaking length								
Burst factor								
Tear factor								

Additional information:

* Charge.
** Sodium hydrosulphite.

Eucalyptus grandis
(Rose Gum)

Plantation experience

This species is very often confused with Eucalyptus saligna. Under favourable conditions it grows rapidly - up to 20 mm in diameter and 2 m in height per year. It prefers fresh and friable loams of good fertility and like to be near water although it does not grow in waterlogged areas. It is fairly frost resistant.

References: 38, 52, 83, 85, 125

Wood characteristics

The density of the wood is lower than in most eucalypt species. The fibres have a length in the normal range of hardwoods for pulping. They are also very thin which implies that they may exhibit a certain amount of undesirable stiffness. However, the low density also implies thin walls, which contradicts this conclusion. Unfortunately, no data on wall thickness are available for the samples at hand. The thinness of the fibres indicates that pulps made from this species should exhibit good opacity. As regards the chemical composition, there are no indications of difficulty of pulping.

Pulping characteristics

The best results in sulphate pulping seem to be obtainable with a fairly low charge of active alkali which gives a yield of pulp in the average range. However, the amount of screening seems somewhat high. The strength properties of the pulp are then excellent and comparable to best quality eucalypt sulphate pulps. The strength of the bleached pulp is slightly below normal standard for eucalypt pulp and resembles more that of a poplar pulp.

The cold soda process gives a pulp of low strength, although easily bleachable to good brightness. However, it is possible that application of a P/HS bleaching sequence instead of H in one step may improve the strength properties at least to an acceptable level. Unfortunately no strength properties are given for the unbleached pulp.

The groundwood pulp produced from one of the samples is low in strength but probably not representative for the performance of the species.

Laboratory trials for the manufacture of high-alpha pulp (71) have been successful as regards the chemical composition of the pulp. The total yield was 34%, the alpha-cellulose content 94.5% and the content of pentosans 1.5%. No tests were made as to the processability of the pulp in the viscose process.

Scientific name: Eucalyptus grandis	Common name: Rose gum Country: India	Reference: 60, 122

Wood sample characteristics

Wood sample origin:

Samples from the Pachakkeram Range, Kottayam, Kerala. Logs 15–54 cm in diameter.

Density and fibre characteristics:

Basic density, g/cm^3	
Fibre length, µ*	820
Fibre width, µ*	14
Wall thickness, µ*	
Lumen width, µ*	
Length/width ratio	59
Runkel ratio	
Flexibility ratio	

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	0.80
Methanol	
Ethanol-benzene	1.28
Solubility, %	
in water	1.45 (hot)
in 1% NaOH	10.8
Ash, %	0.39
Lignin, %	21.9
Holocellulose, %	
Cross-Bevan cellulose, %	65.5
Pentosans, %	

Additional information:

Pulping and papermaking characteristics

Unbleached			
Process	Sulphate	Cold Soda	Groundwood
Chemical consumption, %	13.9 Na_2O*	4.3 - 4.7 Na_2O	
Kappa number			
Yield (unscreened), %	53.0	89.7 - 83.5	
Screenings, %	2.5	3.1 - 3.2**	
Brightness			
Beater or refiner	Lampén		Stone grinder
Freeness	250 CSF		
Breaking length, m	13 400		
Burst factor	87		
Tear factor	83		1 190
Bleached			
Sequence		H	H
Chemical consumption, %		7.5 Cl	10.0 Cl*
Yield on bleaching, %			
Total yield, %		65.8 - 67.1	
Brightness (Photovolt)		70 - 72	64
Beater or refiner		Lampén**	
Freeness		250 CSF	125 CSF
Breaking length		2 800 - 2 600	1 100
Burst factor		11	5
Tear factor		29 - 27	14

Additional information:

* Charge
** After 4 passes through Sprout-Waldron 12" disc refiner

Scientific name: Eucalyptus grandis	Common name: Rose gum Country: India	Reference: 122

Wood sample characteristics

Wood sample origin:

Sample from plantation in Kerala.

Density and fibre characteristics:

Basic density, g/cm^3	
Fibre length, μ*	820
Fibre width, μ*	14
Wall thickness, μ*	
Lumen width, μ*	
Length/width ratio	59
Runkel ratio	
Flexibility ratio	

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	0.80
Methanol	
Ethanol-benzene	1.28
Solubility, %	
in water	1.45 (hot)
in 1% NaOH	10.8
Ash, %	0.39
Lignin, %	21.9
Holocellulose, %	
Cross-Bevan cellulose, %	65.5
Pentosans, %	

Additional information:

Pulping and papermaking characteristics	
<u>Unbleached</u>	
Process	Sulphate
Chemical consumption, %	15.0 – 18.0 (charge)
Kappa number	
Yield (unscreened), %	53.3 – 49.7
Screenings, %	
Brightness	
Beater or refiner	
Freeness	
Breaking length, m	
Burst factor	
Tear factor	
<u>Bleached</u>	
Sequence	HEH
Chemical consumption, %	9.2 – 6.9 Cl
Yield on bleaching, %	
Total yield, %	50.0 – 45.8
Brightness (EEL)	76 – 80
Beater or refiner	Lampén
Freeness	300 CSF
Breaking length	8 900 – 5 600
Burst factor	60 – 35
Tear factor	67 – 54
Additional information:	

Eucalyptus hemiphloia

Plantation experience

Planters have usually commented unfavourably on this species with respect to acclimatization outside Australia. However, it has been acclimatized in Portugal, on the French Riviera and North Africa, but its growth has been slow compared with other species introduced there. Dubious results have been obtained in Brazil, Congo, Indonesia, New Zealand, Southern Rhodesia and the Republic of South Africa.

References: 38, 39, 45, 123

Wood characteristics

The wood is very hard and exhibits a very high basic density. It will most probably cause excessive wear of chipper knives in a pulp mill. No data on fibre or chemical characteristics are available for the sample at hand.

Pulping characteristics

The alkali charge used in the sulphate process is in the normal range for hardwoods. However, the yield of pulp is very low. The strength properties of the pulp are not up to the standards of good quality eucalypt sulphate. In this respect it resembles a poplar sulphate pulp.

Scientific name: Eucalyptus hemiphloia	Common name: Country: Australia	Reference: 30

Wood sample characteristics

Wood sample origin:	Chemical characteristics:
	Extractives, % Ether Methanol Ethanol-benzene
	Solubility, % in water in 1% NaOH
Density and fibre characteristics:	
Basic density, g/cm^3 0.93 Fibre length, μ* Fibre width, μ* Wall thickness, μ* Lumen width, μ*	Ash, % Lignin, % Holocellulose, % Cross-Bevan cellulose, % Pentosans, %
Length/width ratio Runkel ratio Flexibility ratio	
Additional information:	Additional information:
* 1000 μ (microns) = 1 mm	

Pulping and papermaking characteristics

Unbleached

Process	Sulphate
Chemical consumption, %	17.5 Na_2O (charge)
Kappa number	24.8
Yield (unscreened), %	43.4
Screenings, %	
Brightness	
Beater or refiner	Lampén
Freeness	300 CSF
Breaking length, m	8 400
Burst factor	54
Tear factor	100

Bleached

Sequence	
Chemical consumption, %	
Yield on bleaching, %	
Total yield, %	
Brightness	
Beater or refiner	
Freeness	
Breaking length	
Burst factor	
Tear factor	

Additional information:

Eucalyptus leucoxylon

Plantation experience

This species has only been tried in small-scale experimental plantations in Italy, North Africa and in the Republic of South Africa. The results in tropical and intertropical countries have been discouraging. The species exhibits somewhat slow growth.

References: 19, 38, 123

Wood characteristics

The wood is fairly hard which may cause some wear on chippers in a pulp mill. The fibres are very short, even for a hardwood, thin and thick-walled. Judging from the width characteristics of the fibres, they exhibit a certain amount of undesirable stiffness which prevents proper inter-fibre bonding in paper. The chemical composition data given do not indicate any difficulty with regard to chemical pulping.

Pulping characteristics

Cold soda pulping gives a fairly dark pulp with low strength characteristics Application of the NSSC process gives a pulp of just acceptable strength for corrugating medium but not for paper. The yield is on the low side. The sodium bisulphite process gives a dark pulp with a low yield and with completely unacceptable strength properties.

The species is not recommended for planting for pulpwood.

Scientific name: Eucalyptus leucoxilon	Common name: Country: Italy	Reference: 19

Wood sample characteristics

Wood sample origin:

Sample from plantation at Terra Apuliae, 10 years old.

Density and fibre characteristics:

Basic density, g/cm^3	
Fibre length, μ*	557
Fibre width, μ*	14
Wall thickness, μ*	4.5
Lumen width, μ*	5
Length/width ratio	40
Runkel ratio	1.80
Flexibility ratio	0.36

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	
Solubility, %	
in water	
in 1% NaOH	
Ash, %	0.4
Lignin, %	21.9
Holocellulose, %	
Cross-Bevan cellulose, %	42.6
Pentosans, %	

Additional information:

Pulping and papermaking characteristics

Unbleached						
Process	NSSC		Cold Soda		Na-bisulphite (pH 5)	
Chemical consumption, %	8.5 SO_2*		18.6 Na_2O		8.5 SO_2*	
Kappa number						
Yield (unscreened), %	69.0		74.0		47.0	
Screenings, %						
Brightness	51		44		45	
Beater or refiner						
Freeness	25 SR	40 SR	25 SR	40 SR	25 SR	40 SR
Breaking length, m	3 200	3 800	2 100	2 500	2 700	3 500
Burst factor	14	17	7	8	12	17
Tear factor						

Bleached			
Sequence	HS**	P/HS	HS
Chemical consumption, %	1 HS*	2 Na_2O_2, 0.5 HS*	1 HS*
Yield on bleaching, %			
Total yield, %			
Brightness	61.5	52	71.5
Beater or refiner			
Freeness			
Breaking length			
Burst factor			
Tear factor			

Additional information:

* Charge
** Sodium hydrosulphite

Eucalyptus maidenii

Plantation experience

Although this species has not been much used in plantations on a commercial scale, it has shown itself to be one of the most adaptable eucalypt species. Excellent results have been obtained in Italy and Portugal with annual yields of about 20 m^3/ha. It is considered one of the best eucalypts for planting in Italy. In Zaire, the species has acclimatized very well in the east with average annual yields of 30 m^3/ha. Satisfactory results have also been obtained in Southern Rhodesia, Malawi, Kenya and in the Republic of South Africa. In the last-mentioned country, damage from *Gonipterus scutellatus* was recorded. In Brazil, Morocco and New Zealand, the results have not been so good.

Excellent results have, in general, been obtained when the species has been planted at appropriate altitudes in countries with a tropical climate.

References: 38, 41, 83, 123

Wood characteristics

The basic density of the wood is in the normal range of hardwoods for pulping. The fibres are of average length for hardwoods used for pulping, although on the low side, thin and thick-walled. This implies a certain amount of undesirable stiffness which is apt to prevent proper inter-fibre bonding in paper. However, it may be that the sample from Portugal differs in this respect, but no data are available for that sample with regard to wall thickness.

As regards the chemical characteristics of the wood, the present data do not exhibit anything which would cause difficulty for chemical pulping.

Pulping characteristics

The species is easily pulped by means of the sulphate process with an average charge of active alkali to the normal range of Kappa number. The yield of pulp is very high. The pulp exhibits excellent strength properties, comparable to best quality eucalypt pulp, both as bleached and as unbleached. The opacity of the bleached pulp is also good.

Cold soda pulping gives a fairly dark pulp with low strength properties. Application of the NSSC process gives a pulp acceptable for corrugating medium but not for paper.

(*Eucalyptus maidenii*)

The sodium bisulphite process gives a dark pulp with an average yield and with strength properties in the normal range for eucalypt sulphite pulp. It seems to be easily bleachable to a brightness acceptable for printing papers.

Research into the possibilities of utilizing this species for manufacture of high-alpha pulp by means of the prehydrolysis sulphate process have been carried out in Italy.

Note: Due to incomplete data on the Portuguese sample it is difficult to assess whether the somewhat contradictory results are due to difference in provenance or a characteristic of the species. However, it seems that the species is more suitable for full chemical pulping than for chemi-mechanical or semi-mechanical processes.

Scientific name: Eucalyptus maidenii	Common name: Country: Portugal	Reference: 113

Wood sample characteristics

Wood sample origin:

Logs of 6–29 cm diameter from Herdade do Rio Frio near Montijo.

Density and fibre characteristics:

Basic density, g/cm^3	0.58
Fibre length, µ*	920
Fibre width, µ*	15
Wall thickness, µ*	
Lumen width, µ*	
Length/width ratio	60
Runkel ratio	
Flexibility ratio	

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	0.5
Methanol	
Ethanol-benzene	1.7
Solubility, %	
in water	
in 1% NaOH	
Ash, %	0.3
Lignin, %	23.8
Holocellulose, %	72.2
Cross-Bevan cellulose, %	46.0
Pentosans, %	17.9

Additional information:

Pulping and papermaking characteristics

Unbleached

Process	Sulphate
Chemical consumption, %	17.0 Na_2C (charge)
Kappa number	about 18
Yield (unscreened), %	59.4
Screenings, %	1.4
Brightness	
Beater or refiner	Lampén
Freeness	45 SR
Breaking length, m	12 000
Burst factor	87
Tear factor	135

Bleached

Sequence	HCED
Chemical consumption, %	5.2 Cl
Yield on bleaching, %	
Total yield, %	
Brightness	90 (Tappi)
Beater or refiner	Lampén
Freeness	45 SR
Breaking length	10 000
Burst factor	67
Tear factor	135

Additional information: Printing opacity of bleached pulp at 45 SR 81.

Scientific name: Eucalyptus maidenii	Common name: Country: Italy	Reference: 19

Wood sample characteristics

Wood sample origin:

Sample from plantation at Terra Apuliae, 10 years old.

Density and fibre characteristics:

Basic density, g/cm^3	
Fibre length, μ*	786
Fibre width, μ*	15
Wall thickness, μ*	4
Lumen width, μ*	7
Length/width ratio	56
Runkel ratio	1.14
Flexibility ratio	0.45

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	
Solubility, %	
in water	
in 1% NaOH	
Ash, %	0.3
Lignin, %	22.3
Holocellulose, %	
Cross-Bevan cellulose, %	40.8
Pentosans, %	

Additional information:

Pulping and papermaking characteristics

Unbleached						
Process	NSSC		Cold Soda		Na-bisulphite (pH 5)	
Chemical consumption, %	8.5 SO_2*		18.6 Na_2O*		8.5 SO_2*	
Kappa number						
Yield (unscreened), %	73		78		52	
Screenings, %						
Brightness	51		47		42	
Beater or refiner	25 SR	40 SR	25 SR	40 SR	25 SR	40 SR
Freeness	3 700	4 600	2 300	2 600	7 000	7 600
Breaking length, m	14	20	7	9	34	36
Burst factor	52	53	31	35	83	75
Tear factor						
Bleached						
Sequence	HS**		P/HS		HS	
Chemical consumption, %	1 HS*		2 Na_2O_2, 0.5 HS*		1 HS*	
Yield on bleaching, %						
Total yield, %						
Brightness	59		56		70	
Beater or refiner						
Freeness						
Breaking length						
Burst factor						
Tear factor						

Additional information:

* Charge
** Sodium hydrosulphite

Eucalyptus obliqua (Messmate)

Plantation experience

This species is not very adaptable. Only a few specimens have been planted in the Mediterranean area, mainly in Spain and North Africa. Satisfactory results, although not strikingly so, have been obtained in Brazil and in the Republic of South Africa, where it has been found to be resistant to mountain frost but not to drought. Yields of 18–30 m^3/ha per year have been reported. Good results have been obtained in New Zealand, whereas numerous failures have been recorded in tropical countries. The results in Zaire have been dubious.

References: 38, 114, 123

Wood characteristics

The basic density of the wood is in the normal range for hardwoods used for pulping. No other wood data are available for the samples at hand.

Pulping characteristics

The species is easily pulped by means of the chemical soda process with a normal charge of alkali. However, the yield is fairly low, even in view of the low Kappa number aimed at in the present case. A higher Kappa number would increase the yield somewhat, although not over a value of 50%. The strength properties of the pulps obtained are good and would probably improve further on cooking to a slightly higher yield and Kappa number (about 20). The results indicate that a good quality eucalypt sulphate pulp could be manufactured from the species, although probably at a yield slightly under average.

The species has been used in Australia since 1957 on a full commercial scale (30 t/day) for production of cold soda pulp for newsprint and similar grades. The addition of this pulp to the newsprint furnish is about 30% (21).

Scientific name: Eucalyptus obliqua	Common name: Messmate Country: Tasmania, Australia	Reference: 6

Wood sample characteristics

Wood sample origin:

Samples from natural forest at Wesley Vale:

(a) Mountain region, 108 years old
(b) Foothill region, 67 years old
(c) Coastal region, 74 years old

Density and fibre characteristics:

Basic density, g/cm^3 (a) 0.54; (b) 0.56; (c) 0.55
Fibre length, µ*
Fibre width, µ*
Wall thickness, µ*
Lumen width, µ*

Length/width ratio
Runkel ratio
Flexibility ratio

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %
Ether
Methanol
Ethanol-benzene

Solubility, %
in water
in 1% NaOH

Ash, %
Lignin, %
Holocellulose, %
Cross-Bevan cellulose, %
Pentosans, %

Additional information:

Pulping and papermaking characteristics

Unbleached	a	b	c
Process	Soda (170°C)	Soda (170°C)	Soda (170°C)
Chemical consumption, %	20.5 Na_2O*	20.7 Na_2O*	22.5 Na_2O*
Kappa number	15	15	15
Yield (unscreened), %	45.6	45.7	43.8
Screenings, %			
Brightness (Tappi)	33	35	32.5
Beater or refiner	PFI	PFI	PFI
Freeness	250 CSF	250 CSF	250 CSF
Breaking length, m	7 800	8 200	8 000
Burst factor	62	66	65
Tear factor	105	110	115

Bleached

Sequence
Chemical consumption, %
Yield on bleaching, %
Total yield, %

Brightness

Beater or refiner
Freeness
Breaking length
Burst factor
Tear factor

Additional information:

* Charge to obtain Kappa number 15.

Eucalyptus occidentalis
(Swamp Yate)

Plantation experience

The species has not been subjected to many acclimatization trials. Good results have been obtained in small-scale plantations in Oran and Morocco, even on soils containing up to 8% chlorides. It does stand up to prolonged drought and does not present any advantages compared with other eucalypts except under very saline soil conditions.

Reference: 38

Wood characteristics

The fibres of this species are fairly short, even for a hardwood, thin, but thick-walled, which implies a certain amount of undesirable stiffness which is apt to prevent proper inter-fibre bonding in paper. The lignin content is low, but the fact that the wood contains 16-25% of tannin, according to the age of the tree, seriously affects its introduction as a pulpwood species.

Pulping characteristics

Cold soda pulping gives a fairly dark pulp which requires more efficient bleaching conditions than those applied in the present example (P/HS) in order to arrive at a brightness sufficient for printing papers. However, the strength properties of the pulp are excellent and the pulp can well be used in papers or boards where brightness is of no importance.

The species adapts itself well to NSSC pulping, giving a fairly bright pulp which can easily be bleached to the required brightness level for printing papers. The strength properties of the pulp are excellent.

The sodium bisulphite process gives a rather dark pulp with an average yield and with strength properties around the average for hardwood sulphite pulp. It is easily bleachable to a brightness of the required level for printing papers. Judging from the fibre dimensions, the opacity of the pulp should be good.

Scientific name: Eucalyptus occidentalis	Common name: Swamp yate Country: Italy	Reference: 19

Wood sample characteristics

Wood sample origin:

Sample from plantation at Terra Apuliae, 10 years old.

Density and fibre characteristics:

Basic density, g/cm^3	
Fibre length, µ*	704
Fibre width, µ*	17
Wall thickness, µ*	5
Lumen width, µ*	7
Length/width ratio	42
Runkel ratio	1.43
Flexibility ratio	0.41

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	
Solubility, %	
in water	
in 1% NaOH	
Ash, %	0.3
Lignin, %	16.7
Holocellulose, %	
Cross-Bevan cellulose, %	46.1
Pentosans, %	

Additional information:

Pulping and papermaking characteristics

	NSSC		Cold Soda		Na-bisulphite (pH 5)	
Unbleached						
Process	NSSC		Cold Soda		Na-bisulphite (pH 5)	
Chemical consumption, %	8.5 SO_2*		18.6 Na_2O*		8.5 SO_2*	
Kappa number						
Yield (unscreened), %	72.5		77.5		50.0	
Screenings, %						
Brightness	53		47		42.5	
Beater or refiner						
Freeness	25 SR	40 SR	25 SR	40 SR	25 SR	40 SR
Breaking length, m	5 700	6 600	4 000	4 700	6 700	7 100
Burst factor	27	34	17	20	30	32
Tear factor	68	68	41	48	70	61
Bleached						
Sequence	HS**		P/HS		HS	
Chemical consumption, %	1 HS*		2 Na_2O_2, 0.5 HS*		1 HS*	
Yield on bleaching, %						
Total yield, %						
Brightness	63		55		70	
Beater or refiner						
Freeness						
Breaking length						
Burst factor						
Tear factor						

Additional information:

* Charge

** Sodium hydrosulphite

Eucalyptus ovata

Plantation experience

Only a few attempts have been made to acclimatize this species. Good results have been reported from the Tell Atlas Mountains in Algeria, where the species proved very resistant to frost and summer drought. Annual yields of 10-15 m^3/ha have been recorded in the Republic of South Africa.

The species has not been of any interest for tropical countries, but it is possibly useful in the wetter Mediterranean climatic zones where the winter is too cold for species such as E. camaldulensis and E. botryoides.

Note: There are numerous allied species. Thus care must be taken in choosing the seeds.

References: 38

Wood characteristics

The basic density of the wood is in the normal range of hardwoods for pulping. No data are available for the fibre or chemical characteristics for the sample at hand.

Pulping characteristics

The species is easily pulped with a fairly low alkali charge by means of the chemical soda process. However, the yield of pulp is somewhat low, even in view of the unusually low Kappa number aimed at. Pulping to a Kappa number of 20 would increase the yield, although probably not over 50%. This would also improve the strength properties to some extent to a good level. The results imply that by sulphate pulping with a fairly low alkali charge to Kappa number 20, a good, although not excellent, quality short-fibre pulp could be produced. The yield of pulp would probably be slightly lower than average.

Scientific name: Eucalyptus ovata	Common name: Country: Tasmania, Australia	Reference: 6

Wood sample characteristics

Wood sample origin:

Sample from natural forest at Wesley Vale:

(a) Foothill region, 48 years old
(b) Coastal region, 61 years old

Density and fibre characteristics:

Basic density, g/cm^3 (a) 0.58; (b) 0.61
Fibre length, μ*
Fibre width, μ*
Wall thickness, μ*
Lumen width, μ*

Length/width ratio
Runkel ratio
Flexibility ratio

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %
Ether
Methanol
Ethanol-benzene

Solubility, %
in water
in 1% NaOH

Ash, %
Lignin, %
Holocellulose, %
Cross-Bevan cellulose, %
Pentosans, %

Additional information:

Pulping and papermaking characteristics

	a	b
Unbleached		
Process	Soda (170°C)	Soda (170°C)
Chemical consumption, %	19.3 Na_2O*	21.1 Na_2O*
Kappa number	15	15
Yield (unscreened), %	48.0	44.9
Screenings, %		
Brightness (Tappi)	34.5	31.5
Beater or refiner	PFI	PFI
Freeness	250 CSF	250 CSF
Breaking length, m	7 000	6 100
Burst factor	49	43
Tear factor	94	85
Bleached		
Sequence		
Chemical consumption, %		
Yield on bleaching, %		
Total yield, %		
Brightness		
Beater or refiner		
Freeness		
Breaking length		
Burst factor		
Tear factor		

Additional information;

* Charge to obtain Kappa number 15.

Eucalyptus regnans

Plantation experience

This species is adaptable to cold sites, but also very fire-sensitive. The growth is very rapid in early life, over 12 mm in diameter per year under good conditions. It is adaptable in various parts of the world, including countries of intertropical zones. Fairly good results have been obtained in New Zealand and in the Republic of South Africa.

References; 38, 90, 132

Wood characteristics

The basic density of the pulp is in the normal range of hardwoods used for pulping. No data on fibre or chemical characteristics are available for the samples at hand.

Pulping characteristics

The species is easily pulped with a fairly low alkali charge by means of the chemical soda process. The yield of pulp is good, in view of the unusually low Kappa number aimed at in the present instance. In spite of slight over-cooking, the strength properties are excellent and would probably be improved further by cooking to Kappa number 20. The results imply that an excellent pulp can be obtained with a good yield by means of the sulphate process with a fairly low charge of active alkali.

Laboratory trials for the production of high-alpha pulp from this species by means of the prehydrolysis sulphate process (89) have been successful as far as the chemical composition of the resulting pulp is concerned. However, the total yield of pulp was somewhat low - 30-32%. No tests for processability in the viscose process were carried out.

The species has been used in Australia since 1957 for commercial-scale production of cold soda pulp for newsprint (21).

Scientific name: Eucalyptus regnans	Common name: Country: Tasmania, Australia	Reference: 6

Wood sample characteristics

Wood sample origin:	Chemical characteristics:
Samples from natural forest at Wesley Vale: (a) Mountain region, 72 years old (b) Foothill region, 57 years old	Extractives, % Ether Methanol Ethanol-benzene Solubility, % in water in 1% NaOH
Density and fibre characteristics: Basic density, g/cm^3 (a) 0.42; (b) 0.45 Fibre length, μ* Fibre width, μ* Wall thickness, μ* Lumen width, μ* Length/width ratio Runkel ratio Flexibility ratio	Ash, % Lignin, % Holocellulose, % Cross-Bevan cellulose, % Pentosans, %
Additional information:	Additional information:
* 1000 μ (microns) = 1 mm	

Pulping and papermaking characteristics

Unbleached	a	b
Process	Soda (170°C)	Soda (170°C)
Chemical consumption, %	18.7 Na_2O*	17.4 Na_2O*
Kappa number	15	15
Yield (unscreened), %	49.9	51.0
Screenings, %		
Brightness (Tappi)	41	40
Beater or refiner	PFI	PFI
Freeness	250 CSF	250 CSF
Breaking length, m	8 800	8 700
Burst factor	68	69
Tear factor	115	115
Bleached		
Sequence		
Chemical consumption, %		
Yield on bleaching, %		
Total yield, %		
Brightness		
Beater or refiner		
Freeness		
Breaking length		
Burst factor		
Tear factor		

Additional information:

* Charge to obtain Kappa number 15.

Eucalyptus robusta
(Swamp Mahogany)

Plantation experience

The species is very widespread throughout the world. It has been planted in Spain, in the south of Portugal, North Africa, Italy and Cyprus, where its rate of growth has proved inferior to species such as E. camaldulensis, E. globulus and E. gomphocephala. In South Africa it grows vigorously but only outside semi-arid zones. In general, satisfactory growth has been recorded on deep, moist soils. Apart from this it shows fairly good adaptability to subtropical land with uniform rainfall or summer maximum as well as to inter-tropical high altitude zones. Good results have been reported from Brazil, Chile, Madagascar, Mauritius (10 m^3/ha), Malawi, India, Malaysia and Zaire (20-30 m^3/ha). It has failed to acclimatize in Katanga and Southern Rhodesia.

The species is more adaptable to acclimatization in wet tropical zones than in arid Mediterranean zones.

References: 38, 39, 40, 42, 45, 57, 109, 111, 123

Wood characteristics

The basic density of the wood is around the upper limit for hardwoods used for pulping. The fibres are of average length for hardwoods, fairly wide in relation to the wall thickness. Judging from these data, the fibres should be fairly flexible and capable of good bonding between the fibres in paper. The lignin content of the wood is very high for a hardwood, at least in the sample from Congo, whereas no data in this respect are available for the other sample. This may have an effect on the yield and ease of pulping.

Pulping characteristics

The species requires a fairly high charge of active alkali in the sulphate process in order to arrive at a Kappa number of 20. The yield of pulp is below the average for hardwoods. The strength properties are below the requirements of a good quality eucalypt sulphate pulp and resemble more those of poplar or beech sulphate pulps, depending on the basic density and/or the provenance.

As regards chemical soda pulping, the rate of delignification is slow and the resulting pulp is obtained in a crude form with a high ligning content and yield. The strength properties are not up to normal requirements for eucalypt chemical soda pulps. Bleaching improves the strength characteristics to an acceptable although still not good level.

The NSSC process gives an extremely dark pulp with a fairly low yield. However, the strength properties of the pulp are quite good.

Scientific name: Eucalyptus robusta	Common name: Swamp mahogany Country: Congo	Reference: 110

Wood sample characteristics

Wood sample origin:

Sample from plantation at Loudima, 5 years old

Density and fibre characteristics:

Basic density, g/cm^3	0.58
Fibre length, μ*	830
Fibre width, μ*	18
Wall thickness, μ*	4
Lumen width, μ*	10
Length/width ratio	46
Runkel ratio	0.80
Flexibility ratio	0.56

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	0.67
Solubility, %	
in water	1.20
in 1% NaOH	15.8
Ash, %	0.42
Lignin, %	33.2
Holocellulose, %	
Cross-Bevan cellulose, %	47.3
Pentosans, %	15.6

Additional information:

Pulping and papermaking characteristics

Unbleached

Process	Sulphate
Chemical consumption, %	18.5 - 13.5 Na_2O*
Kappa number	20 - 45
Yield (unscreened), %	46.2 - 46.7 (screened)
Screenings, %	
Brightness	23 - 20
Beater or refiner	Jokro?
Freeness	40 SR
Breaking length, m	7 900 - 9 000
Burst factor	45 - 54
Tear factor	110 - 115

Bleached

Sequence	CEHH
Chemical consumption, %	
Yield on bleaching, %	
Total yield, %	
Brightness (Photovolt)	78 - 82
Beater or refiner	Jokro?
Freeness	40 SR
Breaking length	6 500 - 7 100
Burst factor	41 - 48
Tear factor	97 - 105

Additional information:

* Assuming a liquor to wood ratio of 3.3

Scientific name: Eucalyptus robusta	Common name: Swamp mahogany Country: Madagascar	Reference: 111

Wood sample characteristics

Wood sample origin:

Composite sample from Ampamaherana, Ambatobe and Anamalazaotra consisting of logs 25-48 cm in diameter.

Density and fibre characteristics:

Basic density, g/cm^3	0.71 (dry volume)
Fibre length, µ*	939
Fibre width, µ*	19
Wall thickness, µ*	4.5
Lumen width, µ*	10
Length/width ratio	49
Runkel ratio	0.90
Flexibility ratio	0.53

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %
- Ether
- Methanol
- Ethanol-benzene

Solubility, %
- in water
- in 1% NaOH

Ash, %
Lignin, %
Holocellulose, %
Cross-Bevan cellulose, %
Pentosans, %

Additional information:

Pulping and papermaking characteristics

Unbleached			
Process	Sulphate	Soda (170°C)	NSSC
Chemical consumption, %	18.2 - 13.5 Na_2O	14.4 - 12.9 Na_2O	7.7 - 7.1 SO_2
Kappa number	24 - 47	54 - 100	-
Yield (unscreened), %	45.6 - 52.9	50.9 - 54.7	66.3 - 68.2
Screenings, %	0 - 0.8	0.3 - 4.4	0.1 - 0.7
Brightness (Photovolt)	23 - 20	23 - 18.5	17.5 - 15
Beater or refiner	Bauer	Bauer	Bauer
Freeness	40 SR	40 SR	40 SR
Breaking length, m	5 500 - 6 800	5 700 - 5 500	5 400 - 4 600
Burst factor	33 - 42	32 - 28	26
Tear factor	95 - 110	95 - 88	74 - 78
Bleached			
Sequence	CEHH	CEHH	
Chemical consumption, %	4.7 - 7.0	8.6 - 14.6	
Yield on bleaching, %			
Total yield, %			
Brightness	75 - 77	76 - 79	
Beater or refiner	Bauer	Bauer	
Freeness	40 SR	40 SR	
Breaking length	6 400 - 7 300	6 300 - 7 200	
Burst factor	38 - 47	37 - 40	
Tear factor	93 - 105	99 - 89	

Additional information:

Eucalyptus saligna

Plantation experience

Several failures have been recorded with trials of this species in low-lying equatorial zones but remarkable results have been achieved in climatic conditions with more or less marked tropical affinities. In Rio Claro in Brazil excellent results have been obtained in rich soil, 625 m^3/ha from 7-year old stands for firewood, pole timber and pulpwood. In the Republic of South Africa it has been planted in large numbers, chiefly on sandy loams over granites, dolorites, quartzites or other parent materials. The average annual yields were 15-35 m^3/ha, the best results being obtained in moist conditions of the foggy zone with comparatively high temperatures and summer rainfall. The species was not very resistant to severe frost or prolonged frost and in some instances damage by Gonipterus scutellatus was reported.

Very encouraging results have been obtained in Chile, Southern Rhodesia, Nigeria, Malawi, Sri Lanka and Kenya, where it is one of the main eucalypt species planted with excellent volumetric yields and a rotation of 8-12 years. It is widespread also in Congo and Zaire with annual increments of 30-40 m^3/ha. Good results have also been obtained in Spain and Italy.

References: 38, 39, 40, 41, 44, 52, 57, 109, 111, 114, 123, 124

Wood characteristics

The basic density of the wood is in the normal range of hardwoods used for pulping. The fibres are of average length for hardwoods, fairly wide and thin-walled which implies good potential bonding between the fibres in paper. However, there seems to be a considerable influence of provenance on the fibre width characteristics. The lignin content in all the present samples is high for a hardwood which implies difficulty of chemical pulping and a low yield of chemical pulp.

Pulping characteristics

The results of the pulping trials summarized in the following pages are quite contradictory and it is evident that heed must be taken to factors such as seed origin and growth conditions.

As expected from the high content of lignin in the wood, the requirement of active alkali in the sulphate process is fairly high. The one exception is the sample from Angola where an exceptionally high yield at Kappa number 20 has been obtained with a relatively low alkali consumption. In all other instances the yield has been low. As expected, a higher alkali charge is required and a lower yield at constant Kappa number is obtained with trees suffering from gummosis although no significant effect can be demonstrated on the strength properties of the sulphate pulps in general, which range from slighly below average for eucalypt pulps (samples from Pointe-Noire, Congo) to excellent (samples from Loudima, Congo, and Angola).

Application of the cold soda process for newsprint-grade pulp has proved feasible in laboratory, pilot plant and mill trials (88). As regards NSSC pulping, the sample from Pointe-Noire exhibits excellent strength properties although low yield and brightness. The strength properties and brightness were impaired considerably when trees from the same plantation suffering from gummosis were used; however, the strength properties were still acceptable. As regards the Italian sample, the NSSC pulp exhibits hardly any bursting strength although the breaking length is in an acceptable range. This peculiarity was still present after bleaching and the sample behaved in the same manner in the sodium bisulphite process which was applied to obtain pulp in the high yield range.

Research into the possibility of manufacturing dissolving pulp from this species has been carried out in Italy.

Scientific name: Eucalyptus saligna	Common name: Country: Congo	Reference: 111

Wood sample characteristics

Wood sample origin:

Sample from plantation at Pointe-Noire, 5 years old.

Density and fibre characteristics:

Basic density, g/cm^3	0.45 (dry volume
Fibre length, µ*	918
Fibre width, µ*	21
Wall thickness, µ*	3.5
Lumen width, µ*	14
Length/width ratio	44
Runkel ratio	0.50
Flexibility ratio	0.67

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	1.80
Solubility, %	
in water	1.67
in 1% NaOH	18.4
Ash, %	0.45
Lignin, %	29.5
Holocellulose, %	
Cross-Bevan cellulose, %	45.0
Pentosans, %	18.5

Additional information:

Pulping and papermaking characteristics

Unbleached

Process	Sulphate	NSSC
Chemical consumption, %	19.0 - 13.6 Na_2O	9.3 SO_2
Kappa number	21 - 28	-
Yield (unscreened), %	44.4 - 51.5	59.5
Screenings, %	0.1 - 2.1	0
Brightness (Photovolt)	25 - 27	26.5
Beater or refiner	Bauer	Bauer
Freeness	40 SR	40 SR
Breaking length, m	6 800 - 9 300	8 600
Burst factor	42 - 58	59
Tear factor	90 - 105	93

Bleached

Sequence	CEHH
Chemical consumption, %	4.8 - 5.5 Cl
Yield on bleaching, %	
Total yield, %	
Brightness (Photovolt)	77 - 79
Beater or refiner	Bauer
Freeness	40 SR
Breaking length	6 300 - 7 600
Burst factor	41 - 49
Tear factor	93 - 115

Additional information:

Scientific name: Eucalyptus saligna	Common name: Country: Congo	Reference: 111

Wood sample characteristics

Wood sample origin:

Sample from plantation at Pointe-Noire, 6 years old. Trees suffering from gummosis.

Density and fibre characteristics:

Basic density, g/cm^3	0.62 (dry volume)
Fibre length, µ*	843
Fibre width, µ*	20
Wall thickness, µ*	4.5
Lumen width, µ*	11
Length/width ratio	42
Runkel ratio	0.82
Flexibility ratio	0.55

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	2.86
Solubility, %	
in water	2.96
in 1% NaOH	16.8
Ash, %	0.39
Lignin, %	33.3
Holocellulose, %	
Cross-Bevan cellulose, %	42.3
Pentosans, %	17.3

Additional information:

Pulping and papermaking characteristics

Unbleached		
Process	Sulphate	NSSC
Chemical consumption, %	19.8 - 16.7 Na_2O	9.5 SO_2
Kappa number	28 - 34	-
Yield (unscreened), %	43.6 - 45.8	57.3
Screenings, %	0.9 - 2.3	0
Brightness (Photovolt)	19.5	17
Beater or refiner	Bauer	Bauer
Freeness	40 SR	40 SR
Breaking length, m	6 500 - 6 800	6 100
Burst factor	40 - 44	37
Tear factor	88 - 92	93
Bleached		
Sequence	CEHH	
Chemical consumption, %	6.2 Cl	
Yield on bleaching, %		
Total yield, %		
Brightness (Photovolt)	74	
Beater or refiner	Bauer	
Freeness	40 SR	
Breaking length	6 700	
Burst factor	40	
Tear factor	105	

Additional information:

Scientific name: Eucalyptus saligna	Common name: Country: Italy	Reference: 108

Wood sample characteristics

Wood sample origin:

Sample from plantation in Italy.

Density and fibre characteristics:

Basic density, g/cm^3	
Fibre length, µ*	
Fibre width, µ*	
Wall thickness, µ*	
Lumen width, µ*	
Length/width ratio	
Runkel ratio	
Flexibility ratio	

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	2.15
Solubility, %	
in water	3.7 (hot)
in 1% NaOH	
Ash, %	0.3
Lignin, %	24.2
Holocellulose, %	
Cross-Bevan cellulose, %	56.0
Pentosans, %	20.9

Additional information:

Pulping and papermaking characteristics

<u>Unbleached</u>		
Process	NSSC	Na-bisulphite
Chemical consumption, %	8.0 SO_2*	2.4 - 2.8 SO_2*
Kappa number		
Yield (unscreened), %	70.5 - 75	79 - 64
Screenings, %		
Brightness	28 - 25	43
Beater or refiner	Jokro	Jokro
Freeness	25 SR	50 SR**
Breaking length, m	4 600 - 3 900	5 500
Burst factor	3 - 2	3
Tear factor		
<u>Bleached</u>		
Sequence	CEH	CEH
Chemical consumption, %	22 - 25 Cl*	26 - 16 Cl*
Yield on bleaching, %		
Total yield, %	56 - 54.4	55 - 48
Brightness	70 - 72	70 - 80
Beater or refiner	Jokro	Jokro
Freeness	50 SR	50 SR
Breaking length	10 100 - 7 100	6 700 - 6 400
Burst factor	7 - 4	4
Tear factor		

Additional information:

* Charge
** Pulp with 2.8 % SO_2 charge only.

Scientific name: Eucalyptus saligna	Common name: Country: Congo	Reference: 110

Wood sample characteristics

Wood sample origin:

Samples from plantation at Loudima, 4 years old.
Seeds from South Africa.

Density and fibre characteristics:

Basic density, g/cm^3	0.55 (dry volume)
Fibre length, µ*	804
Fibre width, µ*	19
Wall thickness, µ*	3.5
Lumen width, µ*	12
Length/width ratio	42
Runkel ratio	0.58
Flexibility ratio	0.63

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	1.78
Solubility, %	
in water	3.42
in 1% NaOH	18.8
Ash, %	0.32
Lignin, %	30.4
Holocellulose, %	
Cross-Bevan cellulose, % b	46.4
Pentosans, %	18.4

Additional information:

Pulping and papermaking characteristics

Unbleached

Process	Sulphate
Chemical consumption, %	19.3 - 13.5 Na_2O*
Kappa number	20 - 28
Yield (unscreened), %	45.5 - 48.3 (screened)
Screenings, %	
Brightness (Photovolt)	26 - 22
Beater or refiner	Jokro
Freeness	40 SR
Breaking length, m	9 000 - 10 500
Burst factor	53 - 69
Tear factor	88 - 100

Bleached

Sequence	CEHH
Chemical consumption, %	
Yield on bleaching, %	
Total yield, %	
Brightness (Photovolt)	88 - 87
Beater or refiner	Jokro
Freeness	40 SR
Breaking length	6 700 - 8 900
Burst factor	40 - 59
Tear factor	87 - 95

Additional information:

* Assuming a liquor to wood ratio of 3.3

Scientific name: Eucalyptus saligna	Common name: Country: Angola	Reference: 113

Wood sample characteristics

Wood sample origin:

Logs of 7-22 cm diameter from forest areas PRM 1 and PRM 2 and Perimeter of Sanguengue of the Companhia de Celulose do Ultramar Portuguĕs, Angola.

Density and fibre characteristics:

Basic density, g/cm^3	0.48
Fibre length, µ*	942
Fibre width, µ*	16
Wall thickness, µ*	
Lumen width, µ*	
Length/width ratio	59
Runkel ratio	
Flexibility ratio	

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	0.6
Methanol	
Ethanol-benzene	1.2
Solubility, %	
in water	6.2
in 1% NaOH	
Ash, %	0.2
Lignin, %	30.1
Holocellulose, %	70.4
Cross-Bevan cellulose, %	40.8
Pentosans, %	18.4

Additional information:

Pulping and papermaking characteristics	
Unbleached	
Process	Sulphate
Chemical consumption, %	15.0 Na_2O (charge)
Kappa number	about 20
Yield (unscreened), %	59.1
Screenings, %	0.1
Brightness	
Beater or refiner	Lampén
Freeness	45 SR
Breaking length, m	13 500
Burst factor	92
Tear factor	125
Bleached	
Sequence	HCED
Chemical consumption, %	5.7
Yield on bleaching, %	
Total yield, %	
Brightness	89 (Tappi)
Beater or refiner	Lampén
Freeness	45 SR
Breaking length	11 500
Burst factor	78
Tear factor	125
Additional information:	Printing opacity of bleached pulp at 45 SR 77.

Eucalyptus tereticornis

Plantation experience

This species has been introduced as an exotic in Italy, Spain, Portugal, Cyprus and North Africa. It has exhibited inferior growth in semi-arid zones and low resistance to drought. As regards the subtropical and intertropical areas, it has shown good results on a small scale in Indonesia and Zaire, whereas the results have been less satisfactory in Brazil. It cannot be acclimatized at low altitudes.

References: 38, 39, 45, 52, 123

Wood characteristics

The wood of this species is hard and heavy, exhibiting a density of 0.85-1.05 in natural stands in Australia. This may cause serious wear on chipper knives in pulp mills. The fibres are fairly short, even for a hardwood but wide and thin-walled which implies a certain amount of flexibility and consequently a potential for good inter-fibre bonding in paper. Among the chemical characteristics given for the present sample, none imply any difficulty for chemical pulping.

Pulping characteristics

Cold soda pulping gives a somewhat dark and not easily bleachable pulp of just acceptable strength for a grade to be used in newsprint. However, further refining is required.

The NSSC process gives a fairly bright pulp, but the strength properties are lower than usually required for qualities like, for instance, corrugating medium. Application of the sodium bisulphite process results in an easily bleachable pulp of fairly low yield. The pulp develops rapidly an acceptable breaking length on beating although the burst factor remains low. On further beating there is insufficient development of the strength properties. It is mainly comparable to unbleached beech sulphite pulp at low degrees of beating. Judging from the fibre characteristics of the wood, the opacity of the pulp does not seem to be very good.

Scientific name: Eucalyptus tereticornis	Common name: Forest red gum Country: Italy	Reference: 19

Wood sample characteristics

Wood sample origin:

Sample from plantation at Terra Apuliae, 10 years old.

Density and fibre characteristics:

Basic density, g/cm^3	
Fibre length, μ*	621
Fibre width, μ*	26
Wall thickness, μ*	4
Lumen width, μ*	18
Length/width ratio	41
Runkel ratio	0.44
Flexibility ratio	0.69

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	
Solubility, %	
in water	
in 1% NaOH	
Ash, %	0.2
Lignin, %	24.7
Holocellulose, %	
Cross-Bevan cellulose, %	40.8
Pentosans, %	

Additional information:

Pulping and papermaking characteristics

Unbleached

	NSSC		Cold Soda		Na-bisulphite (pH5)	
Process	NSSC		Cold Soda		Na-bisulphite (pH5)	
Chemical consumption, %	8.5 SO_2*		18.6 Na_2O*		8.5 SO_2*	
Kappa number						
Yield (unscreened), %	70		77		47	
Screenings, %						
Brightness	50		46		44	
Beater or refiner						
Freeness	25 SR	40 SR	25 SR	40 SR	25 SR	40 SR
Breaking length, m	3 100	3 700	2 400	3 000	5 100	5 700
Burst factor	11	14	8	11	21	24
Tear factor	37	41	26	28	43	49

Bleached

	NSSC	Cold Soda	Na-bisulphite (pH5)
Sequence	HS**	P/HS	HS
Chemical consumption, %	1 HS*	2 Na_2O_2, 0.5 HS*	1 HS*
Yield on bleaching, %			
Total yield, %			
Brightness	59	52	68
Beater or refiner			
Freeness			
Breaking length			
Burst factor			
Tear factor			

Additional information:

* Charge.
** Sodium hydrosulphite.

Eucalyptus trabutii

Plantation experience

This is a hybrid of E. botryoides and E. camaldulensis which was originally found in Algeria. It exhibits vigorous growth in cool moist coastal zones and is mainly immune to parasites. It is found in plantations in North Africa and has also shown some promise in trials in Italy.

References: 38, 53

Wood charaoteristics

The basic density of the wood is in the normal range for hardwoods used for pulping. The fibres are of average length for hardwoods, fairly thin and thin-walled which implies a certain amount of flexibility and consequently a potential for good inter-fibre bonding in paper. The lignin content is about the average for softwoods.

Pulping characteristics

The cold soda pulping process gives a fairly bright and easily bleached pulp. However, the strength properties are slightly below the normal requirements. It is possible that they can be enhanced by some modifications of the process variables.

NSSC pulping gives a pulp of good strength. If it is to be used in printing grade papers, a higher charge of carbonate is preferable in order to improve the bleachability.

Sodium bisulphite pulping gives a fairly dark pulp with a good yield. As regards the strength properties, the pulp is very similar to beech sulphite pulp at low degrees of beating but does not develop its strength equally well on further beating. Judging from the fibre dimensions, the opacity of the pulp should be good.

Scientific name: Eucalyptus trabutii	Common name: Country: Italy	Reference: 20

Wood sample characteristics

Wood sample origin:

Sample from plantation at Grosseto, 9 years old.

Density and fibre characteristics:

Basic density, g/cm^3	0.50
Fibre length, µ*	802
Fibre width, µ*	19
Wall thickness, µ*	3.5
Lumen width, µ*	12
Length/width ratio	42
Runkel ratio	0.58
Flexibility ratio	0.63

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	
Solubility, %	
in water	
in 1% NaOH	
Ash, %	0.4
Lignin, %	22.4
Holocellulose, %	
Cross-Bevan cellulose, %	44.8
Pentosans, %	

Additional information:

Pulping and papermaking characteristics

Unbleached								
Process	NSSC (pH 5)		Cold Soda		Na bisulphite		NSSC (pH 8.5)	
Chemical consumption, %	8.5 SO_2*		13.9 Na_2O*		8.5 SO_2*		3.5 SO_2*	
Kappa number								
Yield (unscreened), %	76.2		83.5		55.2		78.4	
Screenings, %								
Brightness	45		51		45		42	
Beater or refiner								
Freeness	25 SR	40 SR	25 SR	40 SR	25 SR	40 SR	25 SR	40 SR
Breaking length, m	4 300	5 000	2 800	3 100	5 100	5 300	4 600	5 300
Burst factor	20	23	12	15	24	29	23	28
Tear factor	54	50	38	39	72	63	71	62
Bleached								
Sequence	HS**		P/HS		HS		HS	
Chemical consumption, %	1 HS*		2 Na_2O_2, 0.5 HS*		1 HS*		1 HS*	
Yield on bleaching, %								
Total yield, %								
Brightness	53.5		72.5		55		69.5	
Beater or refiner								
Freeness								
Breaking length								
Burst factor								
Tear factor								

Additional information:

* Charge.
** Sodium hydrosulphite.

Eucalyptus viminalis

Plantation experience

Vigorous growth has been recorded with this species in the Mediterranean area, especially on the Pliocene sands in the south of Portugal. Very encouraging results have also been obtained in California, Chile and the Republic of South Africa with annual increments of 15-30 m^3/ha and at high altitudes in India, Tanzania and Zaire.

The species is mostly utilized in the cooler temperate sub-humid sector of the summer rainfall zone. It is fairly frost-hardy and requires deep soils if it is not to suffer from drought but is only moderately adaptable to hot humid conditions.

References: 38, 41, 44, 42, 83, 114, 123, 128

Wood characteristics

The basic density of the wood is in the normal range of hardwoods for pulping. The fibres are fairly short, even for a hardwood, thin or of intermediate width but thin-walled. This implies a certain amount of desirable flexibility and consequently potentially good inter-fibre bonding in paper. The chemical characteristics given for the present samples do not imply any difficulty for chemical pulping.

Pulping characteristics

The charge of active alkali in the sulphate process is in the normal range for hardwoods. However, the yield of pulp is lower than average, although not seriously so. The strength properties of the pulp, both unbleached and bleached, are good although not excellent, and the opacity of the bleached pulp is slightly below that of the best eucalypt pulps.

Application of the chemical soda pulping process requires an alkali charge around the average for hardwoods, but the yield of pulp is lower than average, even in view of the lower than usual Kappa number aimed at. Pulping to a Kappa number about 20 would increase the yield somewhat and probably also enhance the strength properties, which already are on an acceptable level. Cold soda pulping gives a fairly bright and easily bleachable pulp with a good yield. The strength properties are good and as bleached it can be used in printing papers. NSSC pulping gives pulp of excellent strength. If used in printing papers, a higher charge of carbonate is preferable in order to obtain a more easily bleachable pulp.

Sodium bisulphite pulping gives a fairly dark pulp with a good yield. The strength properties of the pulp are good. If used in printing papers, the required brightness level can be arrived at by application of two-stage P/HS bleaching.

Scientific name: Eucalyptus viminalis	Common name: Country: Italy	Reference: 20

Wood sample characteristics

Wood sample origin:

Sample from plantation at Grosseto, 8 years old.

Density and fibre characteristics:

Basic density, g/cm^3	0.44
Fibre length, µ*	759
Fibre width, µ*	18
Wall thickness, µ*	2.5
Lumen width, µ*	13
Length/width ratio	42
Runkel ratio	0.38
Flexibility ratio	0.72

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	
Solubility, %	
in water	
in 1% NaOH	
Ash, %	0.5
Lignin, %	21.4
Holocellulose, %	
Cross-Bevan cellulose, %	42.6
Pentosans, %	

Additional information:

Pulping and papermaking characteristics								
Unbleached								
Process	NSSC (pH 5)		Cold Soda		Na-bisulphite		NSSC (pH 8.5)	
Chemical consumption, %	8.5 SO_2*		13.9 Na_2O*		8.5 SO_2*		8.5 SO_2*	
Kappa number								
Yield (unscreened), %	72.5		86.0		52.9		78.5	
Screenings, %								
Brightness	52.5		56		57		53.5	
Beater or refiner								
Freeness	25 SR	40 SR	25 SR	40 SR	25 SR	40 SR	25 SR	40 SR
Breaking length, m	5 700	7 400	3 300	4 100	7 000	8 700	6 300	7 100
Burst factor	32	39	15	26	33	44	33	38
Tear factor	61	53	40	40	65	61	58	51
Bleached								
Sequence	HS**		P/HS		HS		HS	
Chemical consumption, %	1 HS*		2 Na_2O_2, 0.5 HS*		1 HS*		1 HS*	
Yield on bleaching, %								
Total yield, %								
Brightness	61		76		64		70	
Beater or refiner								
Freeness								
Breaking length								
Burst factor								
Tear factor								

Additional information:

* Charge.
** Sodium hydrosulphite.

Scientific name: Eucalyptus viminalis	Common name: Country: Tasmania, Australia	Reference: 6

Wood sample characteristics

Wood sample origin:

Sample from natural forest at Wesley Vale:

(a) Mountain region, 108 years old
(b) Foothill region, 67 years old
(c) Coastal region, 74 years old

Density and fibre characteristics:

Basic density, g/cm^3 (a) 0.53; (b) 0.53; (c) 0.55
Fibre length, μ*
Fibre width, μ*
Wall thickness, μ*
Lumen width, μ*

Length/width ratio
Runkel ratio
Flexibility ratio

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %
Ether
Methanol
Ethanol-benzene

Solubility, %
in water
in 1% NaOH

Ash, %
Lignin, %
Holocellulose, %
Cross-Bevan cellulose, %
Pentosans, %

Additional information:

Pulping and papermaking characteristics			
Unbleached	a	b	c
Process	Soda (170°C)	Soda (170°C)	Soda (170°C)
Chemical consumption, %	21.2 Na_2O*	21.2 Na_2O*	22.2 Na_2O*
Kappa number	15	15	15
Yield (unscreened), %	44.6	44.6	43.5
Screenings, %			
Brightness	34.5	33.5	31.5
Beater or refiner	PFI	PFI	PFI
Freeness	250 CSF	250 CSF	250 CSF
Breaking length, m	7 100	7 200	7 100
Burst factor	55	54	55
Tear factor	98	96	100
Bleached			
Sequence			
Chemical consumption, %			
Yield on bleaching, %			
Total yield, %			
Brightness			
Beater or refiner			
Freeness			
Breaking length			
Burst factor			
Tear factor			

Additional information:

* Charge to obtain Kappa number 15.

Scientific name: Eucalyptus viminalis	Common name: Country: Portugal	Reference: 113

Wood sample characteristics

<u>Wood sample origin:</u>

Logs of 7-15 cm diameter from Salvaterra de Magos.

<u>Density and fibre characteristics:</u>

Basic density, g/cm^3	0.57
Fibre length, μ*	723
Fibre width, μ*	11
Wall thickness, μ*	
Lumen width, μ*	
Length/width ratio	66
Runkel ratio	
Flexibility ratio	

Additional information:

* 1000 μ (microns) = 1 mm

<u>Chemical characteristics:</u>

Extractives, %	
Ether	0.4
Methanol	
Ethanol-benzene	1.7
Solubility, %	
in water	5.0 (hot)
in 1% NaOH	
Ash, %	1.0
Lignin, %	25.1
Holocellulose, %	72.5
Cross-Bevan cellulose, %	
Pentosans, %	18.7

Additional information:

Pulping and papermaking characteristics

Unbleached

Process	Sulphate
Chemical consumption, %	17.0 Na_2O (charge)
Kappa number	18
Yield (unscreened), %	48.4
Screenings, %	0.2
Brightness	
Beater or refiner	Lampén
Freeness	45 SR
Breaking length, m	11 800
Burst factor	78
Tear factor	135

Bleached

Sequence	(C/D)EDAD
Chemical consumption, %	5.4 Cl
Yield on bleaching, %	
Total yield, %	
Brightness	92 (Elrepho)
Beater or refiner	Lampén
Freeness	45 SR
Breaking length	8 000
Burst factor	52
Tear factor	105

Additional information: Printing opacity of bleached pulp at 45 SR 76.

Gmelina arborea

Plantation experience

The species is widely distributed through India, Burma and in the moist regions of Sri Lanka. The tree grows on a wide variety of soils but seems to thrive best in valleys on moist fertile alluvium with good drainage. It is resistant to moderate frost but not to extreme drought. It has been planted as an exotic with very varying results in West, Central and East Africa as well as in the Republic of South Africa, Malaysia, Borneo, Fiji and the Philippines.

References: 27, 40, 41, 81, 123, 129

Wood characteristics

The basic density of the wood is lower than usual in hardwoods used for pulping, although not to such an extent that it would seriously affect the tonnage capacity of the digesters. The fibres are of average length for hardwoods, wide and thin-walled which implies a fair amount of flexibility and consequently potentially good inter-fibre bonding in paper. Chemical characteristics are given only for one of the samples (Nigeria). The lignin content, as judged from the content of holocellulose seems low, although still in the normal range for hardwoods, and indicates good yield and low chemical consumption of chemical pulping. The extractives content is on the high side and may require precautions for removal of extractives during pulping.

Pulping characteristics

The consumption of active alkali in the sulphate process varies from low to intermediate, depending on the provenance of the wood sample. The yield of pulp varies correspondingly from good to fair. The same variation is found in the strength properties and thus it can be said that when easily pulped with a low alkali consumption an excellent pulp is obtained with a good yield. The quality of the pulp with regard to strength is comparable to good quality eucalypt sulphate pulp. However, judging from the fibre characteristics, the opacity will probably be inferior to that of eucalypt pulp.

The same conclusions can be drawn from the results of chemical soda pulping.

As regards NSSC pulping there seems to be a minor influence from the provenance of the wood sample and the pulps obtained are all of good quality, although in this case the wood sample from the Ivory Coast exhibits somewhat better characteristics at the same yield of pulp. The brightness of the unbleached pulp is in the normal range.

Scientific name: Gmelina arborea	Common name: Country: Nigeria	Reference: 27

Wood sample characteristics

Wood sample origin:

Sample from plantation near Ibadan, Western Nigeria, coppice regrowth, cut about 4 years after the previous coppicing mixed with other young trees of the same age.

Density and fibre characteristics:

Basic density, g/cm^3	0.38
Fibre length, μ*	1 010
Fibre width, μ*	28
Wall thickness, μ*	3
Lumen width, μ*	22
Length/width ratio	36
Runkel ratio	0.27
Flexibility ratio	0.79

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	4.9
Solubility, %	
in water	5.1
in 1% NaOH	15.1
Ash, %	1.2
Lignin, %	
Holocellulose, %	81.0
Cross-Bevan cellulose, %	46.4
Pentosans, %	

Additional information:

Pulping and papermaking characteristics			
Unbleached			
Process	Sulphate	NSSC	NSSC
Chemical consumption, %	12.9 Na_2O	9.4 SO_2*	9.4 SO_2*
Kappa number			
Yield (unscreened), %	55.5	66.5	75.7
Screenings, %	0.6	1.2**	2.6**
Brightness			
Beater or refiner	Lampén	Lampén	Lampén
Freeness	500 CSF	500 CSF	500 CSF
Breaking length, m	10 400	5 500	4 500
Burst factor	62	22	16
Tear factor	115	99	67
Bleached			
Sequence	CEH		H
Chemical consumption, %	5.5 Cl*		12.0 Cl*
Yield on bleaching, %			
Total yield, %	44.3		75.1
Brightness (EEL)	80		68
Beater or refiner	Lampén		Lampén
Freeness	500 CSF		500 CSF
Breaking length	10 300		6 600
Burst factor	58		26
Tear factor	125		45

Additional information:

* Charge.

** After three passes through Sprout-Waldron disc refiner.

Scientific name: Gmelina arborea	Common name: Yemane Country: Philippines	Reference: 36

Wood sample characteristics

Wood sample origin:

Sample from plantation at Surigao, Mindanao.

Density and fibre characteristics:

Basic density, g/cm^3	
Fibre length, μ*	980
Fibre width, μ*	30
Wall thickness, μ*	5
Lumen width, μ*	20
Length/width ratio	33
Runkel ratio	0.50
Flexibility ratio	0.67

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %
- Ether
- Methanol
- Ethanol-benzene

Solubility, %
- in water
- in 1% NaOH

Ash, %
Lignin, %
Holocellulose, %
Cross-Bevan cellulose, %
Pentosans, %

Additional information:

Pulping and papermaking characteristics

Unbleached

Process	Sulphate	Soda (170°C)
Chemical consumption, %	14.9 - 13.9 Na_2O	11.8 Na_2O
Kappa number	16	18
Yield (unscreened), %	55.8 - 59.1	53.9
Screenings, %	0.1 - 0.2	0.1
Brightness		
Beater or refiner	Valley	Valley
Freeness	300 CSF	300 CSF
Breaking length, m	12 000 - 9 600	9 500
Burst factor	77 - 72	63
Tear factor	53 - 63	45

Bleached

Sequence		
Chemical consumption, %		
Yield on bleaching, %		
Total yield, %		
Brightness		
Beater or refiner		
Freeness		
Breaking length		
Burst factor		
Tear factor		

Additional information:

Scientific name:	Common name:	Reference:
Gmelina arborea	Country: Ivory Coast	111

Wood sample characteristics

Wood sample origin:

Log of 40 cm diameter from plantation at Banco.

Density and fibre characteristics:

Basic density, g/cm^3	0.40 (dry volume)
Fibre length, μ*	1 043
Fibre width, μ*	38
Wall thickness, μ*	3.5
Lumen width, μ*	31
Length/width ratio	28
Runkel ratio	0.23
Flexibility ratio	0.82

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %
- Ether
- Methanol
- Ethanol-benzene

Solubility, %
- in water
- in 1% NaOH

Ash, %
Lignin, %
Holocellulose, %
Cross-Bevan cellulose, %
Pentosans, %

Additional information:

Pulping and papermaking characteristics

Unbleached

Process	Sulphate	Soda (170°C)	NSSC
Chemical consumption, %	15.0 - 13.3 Na_2O	13.5 - 12.6 Na_2O	5.4 - 5.9 SO_2
Kappa number	22 - 44	38 - 100	-
Yield (unscreened), %	49.0 - 53.3	49.2 - 52.5	72.5 - 72.7
Screenings, %	0	0 - 1.6	0
Brightness (Photovolt)	35 - 33	36 - 28	47.5 - 45.5
Beater or refiner	Bauer	Bauer	Bauer
Freeness	40 SR	40 SR	40 SR
Breaking length, m	7 700 - 7 900	6 300 - 6 800	6 000
Burst factor	53 - 49	45 - 43	32 - 33
Tear factor	94 - 93	78 - 76	92 - 81

Bleached

Sequence	CEHH	CEHH
Chemical consumption, %	5.2 Cl	8.1 Cl
Yield on bleaching, %		
Total yield, %		
Brightness (Photovolt)	78.5	79.5
Beater or refiner	Lamort	Bauer
Freeness	40 SR	40 SR
Breaking length	6 100	7 500
Burst factor	45	47
Tear factor	75	93 (?)

Additional information:

Hevea brasiliensis
(Para Rubber)

Plantation experience

Native of the Amazon basin in Brazil, this species is the most important source of commercial rubber in the world. In its native region it grows in tropical rain forests on the flood plains, associated with various palms. It is cultivated on a large scale in many parts of the tropics, especially in Malaysia, the East and West Indies, southern India, Burma, Sri Lanka and tropical Africa.

References: 1, 44, 123

Wood characteristics

The basic density of the wood is in the normal range for hardwoods used for pulping. The fibres are of average length for hardwoods, thin and thin-walled which implies a certain amount of desirable flexibility and consequently potentially good bonding between the fibres in paper. The extractives content of the wood is fairly high and especially the presence of latex may cause difficulties on pulping and in the pulp unless special precautions are taken. The lignin content is around or below average for hardwoods and the pentosans content seems to vary considerably with provenance.

Pulping characteristics

The alkali consumption in the sulphate process is in the normal range for hardwoods. However, the yield of pulp varies from very low to average. The strength properties of the pulp vary somewhat with provenance, but in general it can be said that they are lower than average for hardwoods and the quality of the pulp is best compared to that of beech sulphate pulp.

Laboratory trials for the manufacture of dissolving pulp by means of the prehydrolysis sulphate process have shown some promise (1). The alpha cellulose and pentosans content of the pulp was satisfactory, but the total yield was low - below 30%. No tests for reactivity in the viscose process were carried out.

Chemical or crude soda pulping gives pulps of satisfactory strength properties. It has been noted that older trees, at constant Kappa number, give lower yields of pulp than younger trees, but with better strength properties.

The cold soda pulping, as applied to the sample from Liberia, has given a pulp for corrugating medium of insufficient strength and stiffness for corrugating medium. The Ring crush and Flat crush values reported are only about 50% of those required for corrugating medium.

NSSC pulping gives a pulp of good strength properties and seems to be the most suitable process for this species.

Scientific name: Hevea brasiliensis	Common name: Rubberwood, Para Rubber Country: Indonesia	Reference: 1

Wood sample characteristics

Wood sample origin:

Sample logs, 30 cm in diameter, from plantation at Tjikumpaj, 38 years old.

Density and fibre characteristics:

Basic density, g/cm^3	
Fibre length, μ*	1 290
Fibre width, μ*	16
Wall thickness, μ*	2.5
Lumen width, μ*	11
Length/width ratio	81
Runkel ratio	0.46
Flexibility ratio	0.69

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	4.01
Solubility, %	
in water	2.72
in 1% NaOH	18.3
Ash, %	0.86
Lignin, %	24.4
Holocellulose, %	
Cross-Bevan cellulose, %	
Pentosans, %	23.5

Additional information:

Pulping and papermaking characteristics		
Unbleached		
Process	Soda (155-165°C)	NSSC
Chemical consumption, %		
Kappa number	18 - 52	
Yield (unscreened), %	46.8 - 68.5	53.6 - 64.6
Screenings, %		
Brightness		
Beater or refiner	Niagara	S-W 12"
Freeness	61 - 55 SR	45 SR
Breaking length, m	6 600 - 6 900	7 300 - 5 900
Burst factor	34 - 37	40 - 35
Tear factor	105 - 115	86 - 84
Bleached		
Sequence		
Chemical consumption, %		
Yield on bleaching, %		
Total yield, %		
Brightness		
Beater or refiner		
Freeness		
Breaking length		
Burst factor		
Tear factor		

Additional information: Soda pulping of trees of different age (25 and 50 years old) revealed that the older tree, at the same permanganate number, gave pulp of lower yield but higher strength. This confirmed previous experience that rubberwood after an age of 30 years exhibits these characteristics.

Scientific name: Hevea brasiliensis	Common name: Rubberwood, Para Rubber Country: Indonesia	Reference: 1

Wood sample characteristics

Wood sample origin:

Sample logs, 65 cm in diameter, from plantation at Radjamandala (W. Java), 45-50 years old.

Density and fibre characteristics:

Basic density, g/cm^3	
Fibre length, μ*	1 330
Fibre width, μ*	17
Wall thickness, μ*	2.5
Lumen width, μ*	12
Length/width ratio	78
Runkel ratio	0.42
Flexibility ratio	0.71

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %
- Ether
- Methanol
- Ethanol-benzene

Solubility, %
- in water
- in 1% NaOH

Ash, %

Lignin, %

Holocellulose, %

Cross-Bevan cellulose, %

Pentosans, %

Additional information:

Pulping and papermaking characteristics	
Unbleached	
Process	Sulphate
Chemical consumption, %	
Kappa number	25 - 30
Yield (unscreened), %	49.3 - 50.1
Screenings, %	
Brightness	
Beater or refiner	?
Freeness	40 SR
Breaking length, m	6 900 - 7 800
Burst factor	43 - 48
Tear factor	130
Bleached	
Sequence	
Chemical consumption, %	
Yield on bleaching, %	
Total yield, %	
Brightness	
Beater or refiner	
Freeness	
Breaking length	
Burst factor	
Tear factor	
Additional information:	

Scientific name: Hevea brasiliensis	Common name: Rubberwood, Para Rubber Country: India	Reference: 65

Wood sample characteristics

Wood sample origin:

Samples obtained from the Rubber Research Institute, Kottayam, Kerala:

(a) Stems, 20 cm in diameter
(b) Branches, 8 cm in diameter

Density and fibre characteristics:

Basic density, g/cm^3	(a)	0.49	(b)	0.48
Fibre length, µ*	(a)	1 120	(b)	1 100
Fibre width, µ*	(a)	21	(b)	20
Wall thickness, µ*				
Lumen width, µ*				
Length/width ratio	(a)	58	(b)	55
Runkel ratio				
Flexibility ratio				

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %				
Ether				
Methanol				
Ethanol-benzene	(a)	4.8	(b)	3.9
Solubility, %				
in water	(a)	6.9	(b)	7.3
in 1% NaOH	(a)	20.5	(b)	19.0
Ash, %	(a)	0.8	(b)	0.9
Lignin, %	(a)	20.5	(b)	20.0
Holocellulose, %				
Cross-Bevan cellulose, %				
Pentosans, %	(a)	14.8	(b)	12.5

Additional information:

Pulping and papermaking characteristics

	a	b
Unbleached		
Process	Sulphate	Sulphate
Chemical consumption, %	13.9 – 18.6 Na_2O*	13.9 – 18.6 Na_2O*
Kappa number	43 – 26	28 – 23
Yield (unscreened), %	43.0 – 40.2	42.7 – 28.0
Screenings, %		
Brightness		
Beater or refiner	Lampén	Lampén
Freeness	250 CSF	250 CSF
Breaking length, m	6 700 – 4 000	7 100 – 4 000
Burst factor	36 – 21	45 – 16
Tear factor		
Bleached		
Sequence	HEHH	HEHH
Chemical consumption, %	12.8 – 8.8 Cl	10.0 – 7.6 Cl
Yield on bleaching, %		
Total yield, %	39.0 – 37.6	39.7 – 25.0
Brightness (Photovolt)	65	65
Beater or refiner	Lampén	Lampén
Freeness	250 CSF	250 CSF
Breaking length	5 600 – 3 100	5 900 – 3 300
Burst factor	27 – 14	30 – 11
Tear factor	64 – 40	72 – 38

Additional information:

* Charge.

Scientific name: Hevea brasiliensis	Common name: Rubberwood, Para rubber Country: Liberia	Reference: 77

Wood sample characteristics

Wood sample origin:

Composite sample from plantation, consisting of logs from 24 and 27 years old trees.

Density and fibre characteristics:

Basic density, g/cm^3	0.57 (dry volume)
Fibre length, µ*	1 300
Fibre width, µ*	27
Wall thickness, µ*	
Lumen width, µ*	
Length/width ratio	48
Runkel ratio	
Flexibility ratio	

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	4.26
Solubility, %	
in water	
in 1% NaOH	
Ash, %	0.72
Lignin, %	19.3
Holocellulose, %	
Cross-Bevan cellulose, %	45.3
Pentosans, %	15.2

Additional information:

Pulping and papermaking characteristics

<u>Unbleached</u>

Process	Sulphate	Cold Soda
Chemical consumption, %	18.6 Na_2O (charge	9.3 Na_2O (charge)
Kappa number	20	
Yield (unscreened), %	51.0	84.5
Screenings, %	1.3	
Brightness		
Beater or refiner	Valley	Bauer
Freeness	50 SR	
Breaking length, m	9 800	11*
Burst factor	55	38*
Tear factor	59	Ring crush, lb 26*
		Flat crush, psi 20*

<u>Bleached</u>

Sequence	CEHEH
Chemical consumption, %	7.0 Cl
Yield on bleaching, %	88.0
Total yield, %	44.0
Brightness (Tappi)	82.5
Beater or refiner	Valley
Freeness	25 SR
Breaking length	7 200
Burst factor	44
Tear factor	55

Additional information: A prehydrolysis kraft cook of high-alpha pulp gave a total yield of 37.0% after bleaching with the sequence CEHEH to brightness 84 (Tappi) and alpha-cellulose content 93.7%.

* Grammage of test sheet 128 g/m^2.

Leucaena glauca (Horse Tamarind)

Plantation experience

This fast-growing, small tree, up to 6 m high, is native to tropical America but naturalized in other parts of the tropics. It is utilized to suppress weed-growth in preparation of afforestation in the Philippines, and to provide a cover crop for soil protection when interplanted with teak in Java and India. In Nigeria it is used to check soil erosion, and to give shade and green manure to coffee and other plantation in Africa and Sri Lanka. Its avidity for water may turn it into a weed and it is consequently, although useful, also a dangerous species.

References: 40, 123

Wood characteristics

The basic density of the wood is on the high side for hardwoods used for pulping. This implies a certain hardness which may cause some wear on chipper knives in pulp mills. The fibres are of average length for hardwoods, fairly wide and thin-walled which implies a reasonable flexibility and thus potentially good inter-fibre bonding in paper. The chemical composition of the wood implies ease of chemical pulping, although the very high extractives content may require special precautions for removal of extractives from the pulp.

Pulping characteristics

The alkali consumption in the sulphate process is in the normal range for hardwoods, but the yield of pulp is fairly low. The strength properties of the pulp are acceptable and resemble those of beech sulphate pulp. However, judging from the fibre dimensions, the opacity of the pulp, as bleached, would probably be inferior to beech sulphate pulp.

Cold soda pulping gives a pulp of entirely unsatisfactory quality.

Scientific name:	Common name: Horse tamarind	Reference:
Leucaena glauca	Country: Philippines	94, 95

Wood sample characteristics

<u>Wood sample origin:</u>

Sample from plantation in the Philippines.

<u>Density and fibre characteristics:</u>

Basic density, g/cm^3	0.73
Fibre length, µ*	1 010
Fibre width, µ*	24
Wall thickness, µ*	4.5
Lumen width, µ*	15
Length/width ratio	42
Runkel ratio	0.60
Flexibility ratio	0.63

Additional information:

* 1000 µ (microns) = 1 mm

<u>Chemical characteristics:</u>

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	7.6
Solubility, %	
in water	5.7
in 1% NaOH	18.6
Ash, %	0.8
Lignin, %	25.6
Holocellulose, %	
Cross-Bevan cellulose, %	
Pentosans, %	17.9

Additional information:

Pulping and papermaking characteristics

Unbleached

Process	Sulphate	Cold Soda	
Chemical consumption, %	15.7 Na_2O	6.2 Na_2O	
Kappa number	24		
Yield (unscreened), %	46.8	68.1	
Screenings, %	0.8	1.5	
Brightness		24 (Tappi)	
Beater or refiner	Valley	Bauer 8" + Valley	
Freeness	350 CSF	555 CSF	300 CSF
Breaking length, m	7 300	360	620
Burst factor	53	4	13
Tear factor	97	29	47

Bleached

Sequence	
Chemical consumption, %	
Yield on bleaching, %	
Total yield, %	
Brightness	
Beater or refiner	
Freeness	
Breaking length	
Burst factor	
Tear factor	

Additional information:

Musanga cecropioides
(Umbrella tree)

Plantation experience

Native to West and Central Africa, where it grows in tropical hardwood forests, the species has been subjected to plantation trials in its natural habitat since 1941. It is now considered a very promising species for plantations. It is extremely fast-growing and reaches a diameter of 25-30 cm in 6-7 years.

References: 32

Wood characteristics

The basic density of the wood is extremely low and corresponds to that of balsa. Accordingly it will restrict the tonnage capacity of the digesters in a pulp mill due to the high liquor to wood ratio required. The fibres are of average length for hardwoods used for pulping, very thick but thin-walled, which suggests a high degree of flexibility and consequently a high potential for forming inter-fibre bonds in paper. No chemical characteristics are given for the present samples.

Pulping characteristics

The consumption of alkali in the sulphate process is fairly low, although still in the normal range for hardwoods. The yield of pulp is good and the strength properties of the pulps are excellent, comparable to those of good-quality eucalypt or birch sulphate pulps. However, judging from the fibre dimensions, the opacity of the pulp will be fairly low compared with eucalypt pulp.

Chemical soda pulping also gives a good-quality pulp with a good yield. In the semi-chemical range of this process, pulps with excellent strength properties are obtained, provided that the basic density of the wood is not too high. This probably applies to the chemical soda and sulphate processes as well. A chemi-groundwood type pulp can be produced from this species by means of a sodium carbonate treatment. The resulting pulp has excellent strength properties. However, the pulp is very difficult to bleach with the processes applied. A P/HS bleaching combination would probably be more successful. Cold soda as well as NSSC pulping gives pulp with a good yield with excellent strength properties.

Mechanical pulping, both by stone grinding and disc refining, gives pulps of good quality suitable for newsprint, although bleaching will be required to bring the brightness to an acceptable level.

In general it can be said that the species gives good quality pulp according to any pulping process provided that wood of comparatively high density is avoided.

Scientific name: Musanga cecropioides	Common name: Parasolier, Umbrella tree Country: Congo	Reference: 32, 111

Wood sample characteristics

Wood sample origin:

Logs 8-20 cm in diameter.

Density and fibre characteristics:

Basic density, g/cm^3	0.20 (dry volume)
Fibre length, µ*	1 264
Fibre width, µ*	56
Wall thickness, µ*	3.5
Lumen width, µ*	49
Length/width ratio	23
Runkel ratio	0.14
Flexibility ratio	0.88

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %
- Ether
- Methanol
- Ethanol-benzene

Solubility, %
- in water
- in 1% NaOH

Ash, %
Lignin, %
Holocellulose, %
Cross-Bevan cellulose, %
Pentosans, %

Additional information:

Pulping and papermaking characteristics			
Unbleached			
Process	Sulphate	Soda (170°C)	NSSC
Chemical consumption, %	14.5 - 13.4 Na_2O	12.3 - 11.9 Na_2O	8.9 - 8.1 SO_2
Kappa number	20 - 32	37 - 54	-
Yield (unscreened), %	55.5 - 56.3	55.7 - 58.7	65.7 - 67.3
Screenings, %	2.3 - 4.6	5.7 - 7.4	0.4 - 0.6
Brightness (Photovolt)	33 - 30.5	33.5 - 31.5	41 - 36.5
Beater or refiner	Bauer	Bauer	Bauer
Freeness	40 SR	40 SR	40 SR
Breaking length, m	10 100 - 10 700	10 200 - 10 700	9 800 - 9 900
Burst factor	59 - 65	57 - 67	60
Tear factor	63 - 67	69 - 65	55 - 56
Bleached			
Sequence	CEHH	CEHH	
Chemical consumption, %	5.1 - 6.5 Cl	7.9 Cl	
Yield on bleaching, %			
Total yield, %			
Brightness (Photovolt)	81.5 - 81	83	
Beater or refiner	Bauer	Bauer	
Freeness	40 SR	40 SR	
Breaking length	8 800 - 8 200	8 200	
Burst factor	57 - 50	51	
Tear factor	57	56	

Additional information: Mechanical and cold soda pulping were also successfully carried out, using a laboratory Sprout-Waldron disc refiner for the mechanical stage. At 60 SR the breaking length, burst factor and tear factor for the mechanical pulp were 2 800, 13 and 42. With an alkali concentration of 50 g/l, the corresponding values for the cold soda pulp, also at 60 SR, were 9 400, 52 and 45. The brightness values of the two pulps were 61.5 and 52.5, respectively (Photovolt).

Scientific name: Musanga cecropioides	Common name: Umbrella tree, Parasolier Country: (a) Ivory Coast; (b) Ivory Coast; (c) Cameroun	Reference: 32

Wood sample characteristics

Wood sample origin and density/fibre characteristics	Chemical characteristics
Wood sample origin: Samples of three different origins and densities.	**Chemical characteristics:** Extractives, % Ether Methanol Ethanol-benzene Solubility, % in water in 1% NaOH
Density and fibre characteristics: Basic density, g/cm^3 (a) 0.43; (b) 0.22; (c) 0.14 (dry volume) Fibre length, μ* Fibre width, μ* Wall thickness, μ* Lumen width, μ* Length/width ratio Runkel ratio Flexibility ratio	Ash, % Lignin, % Holocellulose, % Cross-Bevan cellulose, % Pentosans, %
Additional information: * 1000 μ (microns) = 1 mm	Additional information:

Pulping and papermaking characteristics

Unbleached	a	b	c
Process	Chip groundwood	Chip groundwood	Chip groundwood
Chemical consumption, %			
Kappa number			
Yield (unscreened), %			
Screenings, %			
Brightness (Photovolt)	51	52	50
Beater or refiner	S-W 12"	S-W 12"	S-W 12"
Freeness	75 SR*	75 SR	75 SR
Breaking length, m	1 800	2 800	3 100
Burst factor	8	12	14
Tear factor	18	20	41
Bleached			
Sequence			
Chemical consumption, %			
Yield on bleaching, %			
Total yield, %			
Brightness			
Beater or refiner			
Freeness			
Breaking length			
Burst factor			
Tear factor			

Additional information: A pilot plant scale trial with other wood samples (density 0.21-0.29) for stone groundwood gave pulps with breaking length 2 100-2 400, burst factor 7.5-10.5, brightness 45-50 (Photovolt) as long as the power consumption kept below 60 kW. Freeness 69-75 SR (90-75 CSF).

* About 75 CSF.

Scientific name: *Musanga cecropioides*	Common name: Parasolier, Umbrella tree Country: (a) Ivory Coast; (b) Ivory Coast; (c) Cameroun	Reference: 32

Wood sample characteristics

Wood sample origin and density/fibre characteristics	Chemical characteristics
Wood sample origin: Samples of three different origins and densities. **Density and fibre characteristics:** Basic density, g/cm^3 (a) 0.43; (b) 0.22; (c) 0.14 (dry volume) Fibre length, μ* Fibre width, μ* Wall thickness, μ* Lumen width, μ* Length/width ratio Runkel ratio Flexibility ratio Additional information: * 1000 μ (microns) = 1 mm	**Chemical characteristics:** Extractives, % Ether Methanol Ethanol-benzene Solubility, % in water in 1% NaOH Ash, % Lignin, % Holocellulose, % Cross-Bevan cellulose, % Pentosans, % Additional information:

Pulping and papermaking characteristics

Unbleached	a	b	c
Process	Soda (110°C)	Soda (110°C)	Soda (110°C)
Chemical consumption, %	8.3 NaOH	8.4 NaOH	8.7 NaOH
Kappa number			
Yield (unscreened), %	83.6	83.8	32.0
Screenings, %	0.6	0.9	0.9
Brightness (Photovolt)	36	43	36
Beater or refiner	S-W 12"	S-W 12"	S-W 12"
Freeness	60 SR*	60 SR	60 SR
Breaking length, m	5 000	9 200	11 200
Burst factor	29	50	60
Tear factor	59	55	45

Bleached

Sequence
Chemical consumption, %
Yield on bleaching, %
Total yield, %

Brightness

Beater or refiner
Freeness
Breaking length
Burst factor
Tear factor

Additional information:

* 60 SR is equivalent to about 120 CSF.

Scientific name: Musanga cecropioides	Common name: Parasolier, Umbrella tree Country: West Africa	Reference: 32

Wood sample characteristics

<u>Wood sample origin:</u>

<u>Density and fibre characteristics:</u>

Basic density, g/cm^3
Fibre length, μ*
Fibre width, μ*
Wall thickness, μ*
Lumen width, μ*

Length/width ratio
Runkel ratio
Flexibility ratio

Additional information:

* 1000 μ (microns) = 1 mm

<u>Chemical characteristics:</u>

Extractives, %
  Ether
  Methanol
  Ethanol-benzene

Solubility, %
  in water
  in 1% NaOH

Ash, %
Lignin, %
Holocellulose, %
Cross-Bevan cellulose, %
Pentosans, %

Additional information:

Pulping and papermaking characteristics

<u>Unbleached</u>	
Process	Chemigroundwood
Chemical consumption, %	13.3 Na_2CO_3 (at 120°C)
Kappa number	
Yield (unscreened), %	89.1
Screenings, %	
Brightness (Photovolt)	45
Energy consumption	1.4
Beater or refiner	Probably S-W 12"
Freeness	60 SR*
Breaking length, m	8 500
Burst factor	44
Tear factor	34
<u>Bleached</u>	
Sequence	
Chemical consumption, %	8-16 Cl or 1-4 peroxide
Yield on bleaching, %	
Total yield, %	
Brightness (Photovolt)	50 - 60
Beater or refiner	
Freeness	
Breaking length	
Burst factor	
Tear factor	

Additional information:

* About 120 CSF.

Ochroma lagopus
(Balsa)

Plantation experience

The species is indigenous to South and Central America and the Caribbean but is widely cultivated in the tropics. It is fast-growing in its natural habitat, but often grows slowly as an exotic, producing heavier wood which is commercially unacceptable. To obtain the best results, it must be grown on rich well-drained soils at low altitudes.

References: 40, 123

Wood characteristics

The basic density is very low and this will affect the tonnage capacity of the digesters. The fibres are fairly long for a hardwood and fairly thin-walled in relation to their total width. This implies a certain amount of flexibility of the fibres and consequently potentially good inter-fibre bonding in paper. The lignin content is high which may imply a fairly high consumption of chemicals and a low yield on chemical pulping. The content of extractives is above average for hardwoods but not seriously so.

Pulping characteristics

The present example of application of the cold soda process to this species shows that a good-quality cold soda pulp can be obtained. The yield in this exaple is somewhat low, but it could possibly be improved without loss in quality by proper selection of the process variable.

Scientific name:	Common name: Balsa	Reference:
Ochroma lagopus (Syn. O. pyramidale, O. grandiflora)	Country: Philippines	94

Wood sample characteristics

Wood sample origin:

Sample from plantation in the Philippines.

Density and fibre characteristics:

Basic density, g/cm^3	0.23
Fibre length, µ*	1 590
Fibre width, µ*	29
Wall thickness, µ*	5.5
Lumen width, µ*	18
Length/width ratio	55
Runkel ratio	0.61
Flexibility ratio	0.62

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	3.0
Solubility, %	
in water	
in 1% NaOH	17.2
Ash, %	2.7
Lignin, %	29.9
Holocellulose, %	
Cross-Bevan cellulose, %	
Pentosans, %	19.2

Additional information:

Pulping and papermaking characteristics

Unbleached

Process	Cold Soda	
Chemical consumption, %	7.3 Na_2O	
Kappa number		
Yield (unscreened), %	72.3	
Screenings, %	1.6	
Brightness		
Beater or refiner	Bauer 8" +	Valley
Freeness	618 CSF	300 CSF
Breaking length, m	2 900	5 800
Burst factor	13	32
Tear factor	77	79

Bleached

Sequence	
Chemical consumption, %	
Yield on bleaching, %	
Total yield, %	
Brightness	
Beater or refiner	
Freeness	
Breaking length	
Burst factor	
Tear factor	

Additional information:

Pinus brutia
(Cyprus Pine)

Plantation experience

In its natural habitat the species is found mainly in Cyprus from sea level up to 1 500 m and in southern Turkey, northern Syria and Iraq. It is very adaptable to different soils, from highly calcareous types to slightly acid podzols. On ridges and rocky slopes it forms very open forests but well-stocked stands in mountain valleys. The tree has been used extensively for afforestation by direct sowing. Plantations have shown promise in Australia on difficult limestone sites and in south-east Africa.

References: 31, 39, 45, 123

Wood characteristics

The basic density is slightly higher than average for softwoods used for pulping, although not to an extent which would affect its applicability to pulping processes. The fibres are of average length for softwoods, comparatively thin and thick-walled. However, the Runkel ratio and/or the flexibility ratio imply an acceptable degree of flexibility and consequently potentially a good inter-fibre bonding in paper. The lignin content of the wood is fairly low but still in the normal range for softwoods.

Pulping characteristics

The wood is pulped with an active alkali charge within the normal range for softwoods in the sulphate process. The yield of pulp is also in the normal range. The consumption of chemicals on bleaching is somewhat higher than usual in view of the Kappa number. As regards strength properties, both unbleached and bleached, the pulps exhibit a fairly low breaking length but a very good tear factor. They consequently resemble with regard to their strength properties sulphate pulps from North American southern pines, and accordingly the quality of the pulps in this respect can be considered to be very good. A pilot plant sack paper run at 90 m/min gave paper of good strength properties but poor formation due to flocculation of the fibres under the conditions applied.

The trial for crude sulphate pulp given in the data sheet gives a good-quality pulp with normal alkali charge, although with a somewhat low yield.

Scientific name: Pinus brutia (Syn. P. halepensis var. brutia)	Common name: Cyprus pine Country: Turkey	Reference: 3

Wood sample characteristics

Wood sample origin:

Density and fibre characteristics:

Basic density, g/cm^3	0.542
Fibre length, μ*	2 950
Fibre width, μ*	41
Wall thickness, μ*	8
Lumen width, μ*	25
Length/width ratio	72
Runkel ratio	0.64
Flexibility ratio	0.61

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	6.87
Methanol	
Ethanol-benzene	7.59
Solubility, %	
in water	
in 1% NaOH	
Ash, %	0.37
Lignin, %	24.1
Holocellulose, %	
Cross-Bevan cellulose, %	
Pentosans, %	
Cellulose, %	41.0
Xylan, %	6.6
Glucomannan, %	17.0

Additional information:

Pulping and papermaking characteristics

Unbleached		
Process	Sulphate	Sulphate
Chemical consumption, %	17.5 - 18.0 Na_2O (charge)	11.5 Na_2O (charge)
Kappa number	25.5 - 28.4	100
Yield (unscreened), %	43.3 - 45.9	55.9
Screenings, %	0.6 - 2.3	-
Brightness		
Beater or refiner	Valley	Valley
Freeness	40 SR	40 SR
Breaking length, m	7 600 - 8 000	7 600
Burst factor	65 - 70	65
Tear factor	200	170
Bleached		
Sequence	CEDED	
Chemical consumption, %	9.46 Cl	
Yield on bleaching, %	94.6	
Total yield, %	40.7	
Brightness	89.5 (Elrepho)	
Beater or refiner	Valley	
Freeness	25 SR	
Breaking length	6 700	
Burst factor	61	
Tear factor	220	

Additional information: A pilot plant trial for sack paper, run at 90 m/min gave a paper with good strength properties, although the formation was not as good as a run with a corresponding pulp made from Scots pine.

Pinus caribaea
(Caribbean Pine)

Plantation experience

This species consists of three different varieties, P. caribaea var. bahamensis, P. caribaea var. caribaea and P. caribaea var. hondurensis, which are slightly different with respect to soil and climate requirements. Unfortunately, the different sources quoted do not always state which variety their findings refer to. However, as regards growth characteristics, it can in general be said that the best results are obtained in conditions similar to the natural environment of the variety. In order to obtain good form in P. caribaea var. hondurensis it is of importance to plant it on sites where it is subjected to sufficient moisture stress to ensure that a band of thick-walled cells are laid down in each year's growth, especially on windy sites. If too shallow a soil is chosen growth and yield will be less and, later in the life of the tree, a high proportion of latewood in the ring will make the wood strong but heavy and unsuitable for pulpwood. Much selective breeding combined with discrimination in choice of site and manipulation of silvicultural practice will be necessary to ensure both good form and adequate growth rate.

References: 22, 23, 28, 31, 40, 75, 76, 81, 98, 99, 100, 102, 103, 104, 105, 106, 107, 117, 123

Wood characteristics

The basic density of the wood is in the normal range of softwoods used for pulping. The fibre length varies considerably with the provenance wood sample and ranges from far below normal (2.0 mm) to slightly above normal (3.7 mm) for softwoods. The fibre width follows the same pattern and varies between 38 and 63 microns and the cell wall thickness between 4 and 10 microns. The Runkel ratio and/or the flexibility ratio also vary considerably and indicate a potential inter-fibre bonding which ranges from very good to acceptable. The chemical characteristics are, in all instances, in the normal range for softwood.

Pulping characteristics

As in the wood properties, there is considerable variation in the pulping and papermaking properties with the provenance of the wood. The alkali consumption in the sulphate process varies from normal to high for softwoods. As regards the strength properties, the breaking length seems to increase with decreasing basic density of the wood. The general level of breaking length and burst factor is fairly low, at its best comparable to that of North American southern pine sulphate pulps. The tear factor is, in general, on the same level as that of Scandinavian pine sulphate pulps but in some instances very good. In general, pulps made from this species can be said to have the unfavourable characteristics of North American southern pine and Scandinavian pine sulphate pulps, without their compensating advantages. However, there are exceptions. With proper heed being given to seed selection, selection of soil and climate as well as other considerations, a pulp resembling southern pine sulphate pulp can perhaps be obtained from this species. However, the yield tends to be slightly lower than average for pine sulphate pulp.

Scientific name: Pinus caribaea var. hondurensis	Common name: Caribbean pine Country: Belize	Reference: 107

Wood sample characteristics

Wood sample origin:	Chemical characteristics:
Sample from natural forest in the coastal plain of Belize.	Extractives, % Ether Methanol Ethanol-benzene
	Solubility, % in water in 1% NaOH
Density and fibre characteristics: Basic density, g/cm^3 Fibre length, µ* Fibre width, µ* Wall thickness, µ* Lumen width, µ* Length/width ratio Runkel ratio Flexibility ratio	Ash, % Lignin, % Holocellulose, % Cross-Bevan cellulose, % Pentosans, %
Additional information:	Additional information:
* 1000 µ (microns) = 1 mm	

Pulping and papermaking characteristics

<u>Unbleached</u>	
Process	Sulphate
Chemical consumption, %	
Kappa number	40 - 35
Yield (unscreened), %	47.7 - 40.1
Screenings, %	1.5 - 1.2
Brightness	
Beater or refiner	Valley
Freeness	300 CSF
Breaking length, m	6 800 - 7 300
Burst factor	56 - 59
Tear factor	240 - 285
<u>Bleached</u>	
Sequence	
Chemical consumption, %	
Yield on bleaching, %	
Total yield, %	
Brightness	
Beater or refiner	
Freeness	
Breaking length	
Burst factor	
Tear factor	

Additional information:

Scientific name: Pinus caribaea var. hondurensis	Common name: Caribbean pine Country: Queensland, Australia	Reference: 131

Wood sample characteristics

Wood sample origin:

Samples from plantations in Byfield, Rockhampton, $11\frac{1}{2}$ years old.

Density and fibre characteristics:

Basic density, g/cm^3	0.438
Fibre length, μ*	3 660
Fibre width, μ*	
Wall thickness, μ*	
Lumen width, μ*	
Length/width ratio	
Runkel ratio	
Flexibility ratio	

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %
- Ether
- Methanol
- Ethanol-benzene

Solubility, %
- in water
- in 1% NaOH

Ash, %
Lignin, %
Holocellulose, %
Cross-Bevan cellulose, %
Pentosans, %

Additional information:

Pulping and papermaking characteristics

Unbleached	
Process	Sulphate
Chemical consumption, %	
Kappa number	53.4 - 16.9
Yield (unscreened), %	51.5 - 42.6
Screenings, %	
Brightness	
Beater or refiner	PFI
Freeness	300 CSF
Breaking length, m	8 700 - 8 200
Burst factor	72 - 63
Tear factor	180 - 155
Bleached	
Sequence	
Chemical consumption, %	
Yield on bleaching, %	
Total yield, %	
Brightness	
Beater or refiner	
Freeness	
Breaking length	
Burst factor	
Tear factor	

Additional information:

Scientific name: Pinus caribaea var. hondurensis	Common name: Caribbean pine Country: Belize	Reference: 28

Wood sample characteristics

Wood sample origin:

Sample from natural forest at Mountain Pine Ridge. Estimated age of sample tree about 19 years.

Density and fibre characteristics:

Basic density, g/cm^3	
Fibre length, μ*	3 050
Fibre width, μ*	43
Wall thickness, μ*	10
Lumen width, μ*	23
Length/width ratio	71
Runkel ratio	0.87
Flexibility ratio	0.54

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %
- Ether
- Methanol
- Ethanol-benzene

Solubility, %
- in water
- in 1% NaOH

Ash, %
Lignin, %
Holocellulose, %
Cross-Bevan cellulose, %
Pentosans, %

Additional information:

Pulping and papermaking characteristics

Unbleached

Process	Sulphate
Chemical consumption, %	- (charge 22.5 Na_2O)
Kappa number	29
Yield (unscreened), %	47.4
Screenings, %	3.5
Brightness	
Beater or refiner	Valley
Freeness	300 CSF
Breaking length, m	7 300
Burst factor	55
Tear factor	270

Bleached

Sequence	
Chemical consumption, %	
Yield on bleaching, %	
Total yield, %	
Brightness	
Beater or refiner	
Freeness	
Breaking length	
Burst factor	
Tear factor	

Additional information:

Scientific name: Pinus caribaea var. hondurensis	Common name: Caribbean pine Country: Jamaica	Reference: 105

Wood sample characteristics

Wood sample origin:

Samples from plantation trial plot in Jamaica, 10 years old.

Density and fibre characteristics:

Basic density, g/cm^3	0.480
Fibre length, µ*	2 250
Fibre width, µ*	52
Wall thickness, µ*	6
Lumen width, µ*	40
Length/width ratio	45
Runkel ratio	0.30
Flexibility ratio	0.77

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	1.1
Solubility, %	
in water	
in 1% NaOH	9.4
Ash, %	28.2
Lignin, %	64.6
Holocellulose, %	44.8
Cross-Bevan cellulose, %	
Pentosans, %	

Additional information:

Pulping and papermaking characteristics	
Unbleached	
Process	Sulphate
Chemical consumption, %	13.7 - 14.5 Na_2O
Kappa number	31.6 - 21.5
Yield (unscreened), %	47.6 - 45.3
Screenings, %	0.9 - 0.6
Brightness	
Beater or refiner	PFI
Freeness	300 CSF
Breaking length, m	7 500 - 6 800
Burst factor	48 - 41
Tear factor	150 - 135
Bleached	
Sequence	CEHD
Chemical consumption, %	8.4 Cl
Yield on bleaching, %	
Total yield, %	42.6
Brightness	80 (Elrepho)
Beater or refiner	PFI
Freeness	500 CSF
Breaking length	6 200
Burst factor	36
Tear factor	135

Additional information: Printing opacity of bleached pulp at 500 CSF 56, luminance factor 84, scattering coefficient 160.

Scientific name: Pinus caribaea var. hondurensis	Common name: Caribbean pine Country: Jamaica	Reference: 105

Wood sample characteristics

Wood sample origin:

Samples from plantation trial plot in Jamaica, 10 years old.

Density and fibre characteristics:

Basic density, g/cm^3	0.390
Fibre length, μ*	2 330
Fibre width, μ*	53
Wall thickness, μ*	5
Lumen width, μ*	43
Length/width ratio	44
Runkel ratio	0.23
Flexibility ratio	0.81

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	2.5
Solubility, %	
in water	
in 1% NaOH	11.5
Ash, %	
Lignin, %	29.7
Holocellulose, %	59.3
Cross-Bevan cellulose, %	41.1
Pentosans, %	

Additional information:

Pulping and papermaking characteristics

Unbleached	
Process	Sulphate
Chemical consumption, %	13.5 - 15.2 Na_2O
Kappa number	39.0 - 27.3
Yield (unscreened), %	45.8 - 43.7
Screenings, %	2.0 - 0.2
Brightness	
Beater or refiner	PFI
Freeness	300 CSF
Breaking length, m	8 900 - 8 800
Burst factor	61 - 61
Tear factor	165 - 154
Bleached	
Sequence	CEHD
Chemical consumption, %	10.2 Cl
Yield on bleaching, %	
Total yield, %	41.0
Brightness	76 (Elrepho)
Beater or refiner	PFI
Freeness	500 CSF
Breaking length	7 900
Burst factor	48
Tear factor	140

Additional information: Printing opacity of bleached pulp at 500 CSF 58, luminance factor 80, scattering coefficient 150.

Scientific name: Pinus caribaea var. hondurensis	Common name: Caribbean pine Country: Jamaica	Reference: 105

Wood sample characteristics

Wood sample origin:

Samples from plantation trial plot in Jamaica, 10 years old.

Density and fibre characteristics:

Basic density, g/cm^3	0.325
Fibre length, μ*	1 980
Fibre width, μ*	59
Wall thickness, μ*	5
Lumen width, μ*	49
Length/width ratio	34
Runkel ratio	0.20
Flexibility ratio	0.83

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	1.2
Solubility, %	
in water	
in 1% NaOH	10.1
Ash, %	
Lignin, %	31.7
Holocellulose, %	58.3
Cross-Bevan cellulose, %	37.8
Pentosans, %	

Additional information:

Pulping and papermaking characteristics

Unbleached

Process	Sulphate
Chemical consumption, %	14.4 Na_2O
Kappa number	28.9 - 21.3
Yield (unscreened), %	44.0 - 41.9
Screenings, %	0
Brightness	
Beater or refiner	PFI
Freeness	300 CSF
Breaking length, m	9 800 - 9 500
Burst factor	61 - 57
Tear factor	76 - 72

Bleached

Sequence	CEHD
Chemical consumption, %	8.3 Cl
Yield on bleaching, %	
Total yield, %	40.0
Brightness	81 (Elrepho)
Beater or refiner	PFI
Freeness	500 CSF
Breaking length	8 100
Burst factor	51
Tear factor	82

Additional information: Printing opacity of bleached pulp at 500 CSF 56, luminance factor 84, scattering coefficient 150.

Scientific name: Pinus caribaea	Common name: Caribbean pine Country: Malaya (Malaysia)	Reference: 106

Wood sample characteristics

Wood sample origin:

Sample from plantation trial plot in Sungei Bulch Forest Reserve, 10 years old.

Density and fibre characteristics:

Basic density, g/cm^3	0.42
Fibre length, µ*	2 690
Fibre width, µ*	60
Wall thickness, µ*	7
Lumen width, µ*	46
Length/width ratio	43
Runkel ratio	0.30
Flexibility ratio	0.77

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	1.5
Solubility, %	
in water	
in 1% NaOH	10.7
Ash, %	
Lignin, %	
Holocellulose, %	63.7
Cross-Bevan cellulose, %	44.2
Pentosans, %	

Additional information:

Pulping and papermaking characteristics	
Unbleached	
Process	Sulphate
Chemical consumption, %	12.7 - 12.0 Na_2O
Kappa number	18.7 - 32.8
Yield (unscreened), %	42.8 - 45.9
Screenings, %	0.1 - 1.3
Brightness	
Beater or refiner	Lampén
Freeness	300 CSF
Breaking length, m	8 700 - 8 700
Burst factor	61 - 66
Tear factor	98 - 115
Bleached	
Sequence	CEH
Chemical consumption, %	5.0 Cl (charge)
Yield on bleaching, %	
Total yield, %	40.7
Brightness	87 (EEL)
Beater or refiner	Lampén
Freeness	500 CSF
Breaking length	8 400
Burst factor	60
Tear factor	88
Additional information:	

Scientific name: Pinus caribaea	Common name: Caribbean pine Country: Malaya (Malaysia)	Reference: 106

Wood sample characteristics

Wood sample origin:

Sample from plantation trial plot in Sungei Bulch Forest Reserve, 6 years old.

Density and fibre characteristics:

Basic density, g/cm^3	0.31
Fibre length, μ*	2 530
Fibre width, μ*	63
Wall thickness, μ*	7
Lumen width, μ*	49
Length/width ratio	40
Runkel ratio	0.29
Flexibility ratio	0.78

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	1.8
Solubility, %	
in water	
in 1% NaOH	13.4
Ash, %	
Lignin, %	
Holocellulose, %	55.2
Cross-Bevan cellulose, %	37.3
Pentosans, %	

Additional information:

Pulping and papermaking characteristics

Unbleached		
Process	Sulphate	Sulphate
Chemical consumption, %	12.8 - 12.4 Na_2O	11.6 - 11.7 Na_2O
Kappa number	19.9 - 36.7	43.5 - 52.5
Yield (unscreened), %	41.3 - 45.4	43.3 - 45.7
Screenings, %	0.2 - 2.1	0.9 - 3.0
Brightness		
Beater or refiner	Lampén	Lampén
Freeness	500 CSF	300 CSF
Breaking length, m	8 500 - 9 300	9 300 - 9 300
Burst factor	60 - 72	70
Tear factor	80 - 95	100 - 85
Bleached		
Sequence	CEH	
Chemical consumption, %	5.5 - 6.5 Cl (charge)	
Yield on bleaching, %		
Total yield, %	39.4 - 40.5	
Brightness	85 - 76	
Beater or refiner	Lampén	
Freeness	500 CSF	
Breaking length	8 300 - 8 800	
Burst factor	60 - 68	
Tear factor	94 - 80	

Additional information:

Scientific name: Pinus caribaea	Common name: Caribbean pine Country: Malaya (Malaysia)	Reference: 106

Wood sample characteristics

Wood sample origin:

Sample from plantation trial plot in Sungei Bulch Forest Reserve, 8 years old.

Density and fibre characteristics:

Basic density, g/cm^3	0.460
Fibre length, µ*	2 680
Fibre width, µ*	60
Wall thickness, µ*	7
Lumen width, µ*	46
Length/width ratio	45
Runkel ratio	0.30
Flexibility ratio	0.77

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	1.6
Solubility, %	
in water	
in 1% NaOH	11.2
Ash, %	
Lignin, %	
Holocellulose, %	63.8
Cross-Bevan cellulose, %	44.7
Pentosans, %	

Additional information:

Pulping and papermaking characteristics

Unbleached

Process	Sulphate
Chemical consumption, %	13.4 - 12.1 Na_2O
Kappa number	18.8 - 35.6
Yield (unscreened), %	42.2 - 45.2
Screenings, %	0.2 - 1.5
Brightness	
Beater or refiner	Lampén
Freeness	300 CSF
Breaking length, m	6 900 - 7 700
Burst factor	50 - 61
Tear factor	115 - 145

Bleached

Sequence	CEH
Chemical consumption, %	4.5 Cl (charge)
Yield on bleaching, %	
Total yield, %	40.8
Brightness	83 (EEL)
Beater or refiner	Lampén
Freeness	500 CSF
Breaking length	6 800
Burst factor	53
Tear factor	125

Additional information:

Scientific name: Pinus caribaea	Common name: Caribbean pine Country: Malaya (Malaysia)	Reference: 106

Wood sample characteristics

Wood sample origin:

Sample from plantation trial plot in Sungei Burch Forest Reserve, 12 years old.

Density and fibre characteristics:

Basic density, g/cm^3	0.46
Fibre length, μ*	3 650
Fibre width, μ*	62
Wall thickness, μ*	8
Lumen width, μ*	46
Length/width ratio	59
Runkel ratio	0.35
Flexibility ratio	0.74

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	1.3
Solubility, %	
in water	
in 1% NaOH	11.2
Ash, %	
Lignin, %	
Holocellulose, %	66.6
Cross-Bevan cellulose, %	47.8
Pentosans, %	

Additional information:

Pulping and papermaking characteristics	
Unbleached	
Process	Sulphate
Chemical consumption, %	11.6 - 12.2 Na_2O
Kappa number	14.7 - 28.0
Yield (unscreened), %	43.9 - 46.4
Screenings, %	0 - 0.5
Brightness	
Beater or refiner	Lampén
Freeness	300 CSF
Breaking length, m	7 400 - 8 400
Burst factor	54 - 67
Tear factor	125 - 120
Bleached	
Sequence	CEH
Chemical consumption, %	4.0 Cl (charge)
Yield on bleaching, %	
Total yield, %	42.8
Brightness	86 (EEL)
Beater or refiner	Lampén
Freeness	500 CSF
Breaking length	7 400
Burst factor	57
Tear factor	155
Additional information:	

Scientific name: Pinus caribaea	Common name: Caribbean pine Country: Fiji	Reference: 104

Wood sample characteristics

Wood sample origin:

Samples from plantation trial plot at Seaqaqa, 10 years old.

Density and fibre characteristics:

Basic density, g/cm^3	0.480
Fibre length, µ*	2 300
Fibre width, µ*	46
Wall thickness, µ*	5
Lumen width, µ*	36
Length/width ratio	50
Runkel ratio	0.28
Flexibility ratio	0.78

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	1.7
Solubility, %	
in water	
in 1% NaOH	11.5
Ash, %	
Lignin, %	27.7
Holocellulose, %	61.4
Cross-Bevan cellulose, %	40.9
Pentosans, %	

Additional information:

Pulping and papermaking characteristics

<u>Unbleached</u>

Process	Sulphate
Chemical consumption, %	13.4 - 13.7 Na_2O
Kappa number	37.3 - 26.7
Yield (unscreened), %	45.6 - 43.3
Screenings, %	0.5 - 0.2
Brightness	
Beater or refiner	PFI
Freeness	300 CSF
Breaking length, m	8 700 - 7 700
Burst factor	64 - 55
Tear factor	160 - 155

<u>Bleached</u>

Sequence	CEHD
Chemical consumption, %	9.9 Cl
Yield on bleaching, %	
Total yield, %	40.9
Brightness	78.6
Beater or refiner	PFI
Freeness	500 CSF
Breaking length	6 800
Burst factor	49
Tear factor	155

Additional information: Printing opacity of bleached pulp at 500 CSF 59.

Scientific name: Pinus caribaea	Common name: Caribbean pine Country: Fiji	Reference: 104

Wood sample characteristics

Wood sample origin:

Samples from plantation trial plot at Seaqaqa, 5 years old.

Density and fibre characteristics:

Basic density, g/cm^3	0.370
Fibre length, µ*	1 900
Fibre width, µ*	45
Wall thickness, µ*	4
Lumen width, µ*	37
Length/width ratio	42
Runkel ratio	0.22
Flexibility ratio	0.82

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	1.8
Solubility, %	
in water	
in 1% NaOH	12.3
Ash, %	
Lignin, %	29.3
Holocellulose, %	59.2
Cross-Bevan cellulose, %	37.3
Pentosans, %	

Additional information:

Pulping and papermaking characteristics

<u>Unbleached</u>

Process	Sulphate
Chemical consumption, %	13.6 - 14.4 Na_2O
Kappa number	37.0 - 27.0
Yield (unscreened), %	43.0 - 41.1
Screenings, %	0.2 - 0
Brightness	
Beater or refiner	PFI
Freeness	300 CSF
Breaking length, m	9 800 - 8 700
Burst factor	71 - 62
Tear factor	105 - 100

<u>Bleached</u>

Sequence	CEHD
Chemical consumption, %	10.1 Cl
Yield on bleaching, %	
Total yield, %	39.2
Brightness	78.1
Beater or refiner	PFI
Freeness	500 CSF
Breaking length	8 000
Burst factor	56
Tear factor	97

Additional information: Printing opacity of bleached pulp at 500 CSF 61.

Scientific name: Pinus caribaea	Common name: Caribbean pine Country: Fiji	Reference: 104

Wood sample characteristics

Wood sample origin:

Samples from plantation trial plot at Drasa, 15 years old.

Density and fibre characteristics:

Basic density, g/cm^3	0.530
Fibre length, µ*	2 400
Fibre width, µ*	45
Wall thickness, µ*	6
Lumen width, µ*	33
Length/width ratio	53
Runkel ratio	0.36
Flexibility ratio	0.74

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	2.2
Solubility, %	
in water	
in 1% NaOH	12.3
Ash, %	
Lignin, %	26.9
Holocellulose, %	60.8
Cross-Bevan cellulose, %	40.9
Pentosans, %	

Additional information:

Pulping and papermaking characteristics

Unbleached	
Process	Sulphate
Chemical consumption, %	12.9 - 14.3 Na_2O
Kappa number	38.8 - 27.6
Yield (unscreened), %	45.5 - 43.0
Screenings, %	1.0 - 0.2
Brightness	
Beater or refiner	PFI
Freeness	300 CSF
Breaking length, m	7 700 - 7 400
Burst factor	56 - 49
Tear factor	165 - 140
Bleached	
Sequence	CEHD
Chemical consumption, %	10.4 Cl
Yield on bleaching, %	
Total yield, %	40.3
Brightness	75.6
Beater or refiner	PFI
Freeness	500 CSF
Breaking length	6 500
Burst factor	46
Tear factor	140

Additional information: Printing opacity of bleached pulp at 500 CSF 61.

Scientific name: Pinus caribaea	Common name: Caribbean pine Country: Fiji	Reference: 104

Wood sample characteristics

Wood sample origin:

Samples from plantation trial plot at Drasa, 10 years old.

Density and fibre characteristics:

Basic density, g/cm^3	0.470
Fibre length, μ*	2 200
Fibre width, μ*	47
Wall thickness, μ*	5
Lumen width, μ*	37
Length/width ratio	47
Runkel ratio	0.27
Flexibility ratio	0.79

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	1.7
Solubility, %	
in water	
in 1% NaOH	12.3
Ash, %	
Lignin, %	28.2
Holocellulose, %	61.1
Cross-Bevan cellulose, %	40.2
Pentosans, %	

Additional information:

Pulping and papermaking characteristics

Unbleached

Process	Sulphate
Chemical consumption, %	11.9 - 13.6 Na_2O
Kappa number	51.6 - 28.8
Yield (unscreened), %	47.8 - 43.4
Screenings, %	0.7 - 0.1
Brightness	
Beater or refiner	PFI
Freeness	300 CSF
Breaking length, m	8 300 - 8 100
Burst factor	72 - 57
Tear factor	200 - 160

Bleached

Sequence	CEHD	CEHDED
Chemical consumption, %	11.0 - 11.5 Cl	11.2 Cl
Yield on bleaching, %		
Total yield, %	40.9 - 41.1	41.1
Brightness	77 - 75	86
Beater or refiner	PFI	PFI
Freeness	500 CSF	500 CSF
Breaking length	7 200 - 7 800	7 400
Burst factor	51 - 58	53
Tear factor	155	145

Additional information: Printing opacity of CEHD bleached pulp at 500 CSF 59-58.

Scientific name: Pinus caribaea	Common name: Caribbean pine Country: Fiji	Reference: 104

Wood sample characteristics

Wood sample origin:

Samples from plantation trial plot at Drasa, 5 years old

Density and fibre characteristics:

Basic density, g/cm^3	0.400
Fibre length, μ*	2 200
Fibre width, μ*	50
Wall thickness, μ*	4
Lumen width, μ*	42
Length/width ratio	44
Runkel ratio	0.19
Flexibility ratio	0.84

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	2.1
Solubility, %	
in water	
in 1% NaOH	12.1
Ash, %	
Lignin, %	28.0
Holocellulose, %	58.7
Cross-Bevan cellulose, %	36.6
Pentosans, %	

Additional information:

Pulping and papermaking characteristics

Unbleached	
Process	Sulphate
Chemical consumption, %	13.3 Na_2O
Kappa number	36.6 - 27.8
Yield (unscreened), %	44.8 - 42.1
Screenings, %	0.1 - 0
Brightness	
Beater or refiner	PFI
Freeness	300
Breaking length, m	9 000 - 8 700
Burst factor	67 - 66
Tear factor	130 - 120
Bleached	
Sequence	CEHD
Chemical consumption, %	10.3 Cl
Yield on bleaching, %	
Total yield, %	40.1
Brightness	79 (Elrepho)
Beater or refiner	PFI
Freeness	500
Breaking length	7 800
Burst factor	58
Tear factor	120

Additional information: Printing opacity of bleached pulp at 500 CSF 58.

Scientific name: Pinus caribaea	Common name: Caribbean pine Country: Sabah (Malaysia)	Reference: 103

Wood sample characteristics

Wood sample origin:

Samples from plantation trial plot in the Sibuga Forest Reserve, $9\frac{1}{2}$ years old.

Density and fibre characteristics:

Basic density, g/cm^3	0.445
Fibre length, µ*	2 300
Fibre width, µ*	52
Wall thickness, µ*	5
Lumen width, µ*	42
Length/width ratio	44
Runkel ratio	0.24
Flexibility ratio	0.81

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	0.9
Solubility, %	
in water	
in 1% NaOH	12.6
Ash, %	
Lignin, %	28.4
Holocellulose, %	59.8
Cross-Bevan cellulose, %	40.9
Pentosans, %	

Additional information:

Pulping and papermaking characteristics

Unbleached

Process	Sulphate
Chemical consumption, %	12.0 - 14.6 Na_2O
Kappa number	44.2 - 23.9
Yield (unscreened), %	45.9 - 40.7
Screenings, %	1.3 - 0.2
Brightness	
Beater or refiner	PFI
Freeness	300 CSF
Breaking length, m	7 500 - 6 900
Burst factor	51 - 41
Tear factor	125 - 97

Bleached

Sequence	CEHD
Chemical consumption, %	10.0 - 9.1 Cl
Yield on bleaching, %	95.7 - 95.9
Total yield, %	40.3 - 38.8
Brightness	75 - 76 (Elrepho)
Beater or refiner	PFI
Freeness	500 CSF
Breaking length	6 600 - 5 800
Burst factor	43 - 37
Tear factor	110 - 100

Additional information: Printing opacity of bleached pulp at 500 CSF 61-62, luminance factor 78-80, scattering coefficient 160-180.

Scientific name: Pinus caribaea	Common name: Caribbean pine Country: Fiji	Reference: 102

Wood sample characteristics

Wood sample origin:

Samples from plantation trial plot in Seaqaqa, 10 years old.

Density and fibre characteristics:

Basic density, g/cm^3	0.46
Fibre length, µ*	2 200
Fibre width, µ*	54
Wall thickness, µ*	6
Lumen width, µ*	42
Length/width ratio	41
Runkel ratio	0.29
Flexibility ratio	0.78

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	2.4
Solubility, %	
in water	
in 1% NaOH	13.9
Ash, %	
Lignin, %	
Holocellulose, %	59.6
Cross-Bevan cellulose, %	38.0
Pentosans, %	

Additional information:

Pulping and papermaking characteristics

Unbleached	
Process	Sulphate
Chemical consumption, %	12.6 - 13.4 Na_2O
Kappa number	44.5 - 24.5
Yield (unscreened), %	44.4 - 39.2
Screenings, %	0.1 - 0.1
Brightness	
Beater or refiner	Valley
Freeness	300 CSF
Breaking length, m	9 500 - 9 000
Burst factor	68 - 60
Tear factor	190 - 155
Bleached	
Sequence	CEH
Chemical consumption, %	7.0 Cl
Yield on bleaching, %	93
Total yield, %	36.4
Brightness	66 (Elrepho)
Beater or refiner	Valley
Freeness	500 CSF
Breaking length	8 200
Burst factor	55
Tear factor	133

Additional information: Printing opacity of bleached pulp at 500 CSF 62.

Scientific name: Pinus caribaea	Common name: Caribbean pine Country: Sabah (Malaysia)	Reference: 98

Wood sample characteristics

Wood sample origin:

Samples from trial plot in Sandakan, 5 years old.

Density and fibre characteristics:

Basic density, g/cm^3	0.37
Fibre length, µ*	2 570
Fibre width, µ*	47
Wall thickness, µ*	4
Lumen width, µ*	39
Length/width ratio	55
Runkel ratio	0.21
Flexibility ratio	0.83

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	3.47
Solubility, %	
in water	
in 1% NaOH	9.81
Ash, %	
Lignin, %	
Holocellulose, %	69.1
Cross-Bevan cellulose, %	40.3
Pentosans, %	

Additional information:

Pulping and papermaking characteristics

<u>Unbleached</u>

Process	Sulphate
Chemical consumption, %	11.5 – 13.2 Na_2O
Kappa number	58 – 35
Yield (unscreened), %	56.0 – 46.8
Screenings, %	6.2 – 0.2
Brightness	
Beater or refiner	Valley
Freeness	300 CSF
Breaking length, m	9 350 – 9 200 (max 9 600 at Kappa 45)
Burst factor	71 – 63
Tear factor	127 – 130

<u>Bleached</u>

Sequence
Chemical consumption, %
Yield on bleaching, %
Total yield, %

Brightness

Beater or refiner
Freeness
Breaking length
Burst factor
Tear factor

Additional information:

Scientific name: Pinus caribaea var. hondurensis	Common name: Caribbean pine Country: Trinidad	Reference: 100

Wood sample characteristics

<u>Wood sample origin:</u>

Samples from plantation near Piarco Airport, 12 years old.

<u>Density and fibre characteristics:</u>

Basic density, g/cm^3	0.46
Fibre length, µ*	3 250
Fibre width, µ*	53
Wall thickness, µ*	6
Lumen width, µ*	41
Length/width ratio	61
Runkel ratio	0.29
Flexibility ratio	0.77

Additional information:

* 1000 µ (microns) = 1 mm

<u>Chemical characteristics:</u>

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	3.2
Solubility, %	
in water	
in 1% NaOH	12.6
Ash, %	
Lignin, %	
Holocellulose, %	61.1
Cross-Bevan cellulose, %	40.7
Pentosans, %	

Additional information:

Pulping and papermaking characteristics

<u>Unbleached</u>

Process	Sulphate
Chemical consumption, %	12.7 Na_2O
Kappa number	33.6
Yield (unscreened), %	46.0
Screenings, %	0.5
Brightness	
Beater or refiner	Valley
Freeness	300 CSF
Breaking length, m	8 000
Burst factor	66
Tear factor	185

<u>Bleached</u>

Sequence	
Chemical consumption, %	
Yield on bleaching, %	
Total yield, %	
Brightness	
Beater or refiner	
Freeness	
Breaking length	
Burst factor	
Tear factor	

Additional information:

Scientific name: Pinus caribaea var. hondurensis	Common name: Caribbean pine Country: Trinidad	Reference: 100

Wood sample characteristics

Wood sample origin:

Samples from plantation at McNair and Ravine Sable Forest Reserve, 12 years old.

Density and fibre characteristics:

Basic density, g/cm^3	0.37
Fibre length, µ*	3 240
Fibre width, µ*	57
Wall thickness, µ*	5
Lumen width, µ*	47
Length/width ratio	57
Runkel ratio	0.21
Flexibility ratio	0.83

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	1.7
Solubility, %	
in water	
in 1% NaOH	11.6
Ash, %	
Lignin, %	
Holocellulose, %	61.5
Cross-Bevan cellulose, %	40.7
Pentosans, %	

Additional information:

Pulping and papermaking characteristics

<u>Unbleached</u>

Process	Sulphate
Chemical consumption, %	13.2 Na_2O
Kappa number	32.7
Yield (unscreened), %	45.5
Screenings, %	0.1
Brightness	
Beater or refiner	Valley
Freeness	300 CSF
Breaking length, m	9 100
Burst factor	72
Tear factor	140

<u>Bleached</u>

Sequence	
Chemical consumption, %	
Yield on bleaching, %	
Total yield, %	
Brightness	
Beater or refiner	
Freeness	
Breaking length	
Burst factor	
Tear factor	

Additional information:

Scientific name: Pinus caribaea	Common name: Caribbean pine Country: Fiji	Reference: 99

Wood sample characteristics

<u>Wood sample origin:</u>

Samples from plantation at Verata, nearly 9 years old.

<u>Density and fibre characteristics:</u>

Basic density, g/cm^3	0.44
Fibre length, μ*	3 380
Fibre width, μ*	39
Wall thickness, μ*	5
Lumen width, μ*	29
Length/width ratio	87
Runkel ratio	0.34
Flexibility ratio	0.74

Additional information:

* 1000 μ (microns) = 1 mm

<u>Chemical characteristics:</u>

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	2.11
Solubility, %	
in water	
in 1% NaOH	10.8
Ash, %	
Lignin, %	
Holocellulose, %	63.8
Cross-Bevan cellulose, %	42.5
Pentosans, %	

Additional information:

Pulping and papermaking characteristics

Unbleached	
Process	Sulphate
Chemical consumption, %	11.9 - 13.9 Na_2O
Kappa number	32 - 23
Yield (unscreened), %	49.2 - 45.6
Screenings, %	0.1 - 0
Brightness	
Beater or refiner	Valley
Freeness	300 CSF
Breaking length, m	8 600 - 8 300
Burst factor	65 - 64
Tear factor	175 - 185
Bleached	
Sequence	CEH
Chemical consumption, %	6.0 Cl
Yield on bleaching, %	95.3
Total yield, %	43.5
Brightness	72 (EEL)
Beater or refiner	Valley
Freeness	500 CSF
Breaking length	6 800
Burst factor	47
Tear factor	115

Additional information:

Scientific name: Pinus caribaea	Common name: Caribbean pine Country: Fiji	Reference: 99

Wood sample characteristics

Wood sample origin:

Samples from plantation at Madarivatu, 10 years old.

Density and fibre characteristics:

Basic density, g/cm^3	0.31
Fibre length, µ*	2 670
Fibre width, µ*	38
Wall thickness, µ*	4
Lumen width, µ*	30
Length/width ratio	70
Runkel ratio	0.27
Flexibility ratio	0.79

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	2.81
Solubility, %	
in water	
in 1% NaOH	12.7
Ash, %	
Lignin, %	
Holocellulose, %	62.1
Cross-Bevan cellulose, %	39.0
Pentosans, %	

Additional information:

Pulping and papermaking characteristics

Unbleached

Process	Sulphate
Chemical consumption, %	12.6 - 14.9
Kappa number	34 - 24
Yield (unscreened), %	46.8 - 46.9
Screenings, %	0.1 - 0
Brightness	
Beater or refiner	Valley
Freeness	300 CSF
Breaking length, m	9 700 - 9 300
Burst factor	75 - 62
Tear factor	110 - 100

Bleached

Sequence	CEH
Chemical consumption, %	6.5 Cl
Yield on bleaching, %	88.7
Total yield, %	41.6
Brightness	85 (EEL)
Beater or refiner	Valley
Freeness	500 CSF
Breaking length	7 600
Burst factor	51
Tear factor	85

Additional information:

Scientific name: Pinus caribaea	Common name: Caribbean pine Country: Fiji	Reference: 99

Wood sample characteristics

Wood sample origin:

Samples from plantation at Drasa, 10 years old.

Density and fibre characteristics:

Basic density, g/cm^3	0.44
Fibre length, µ*	2 930
Fibre width, µ*	38
Wall thickness, µ*	4
Lumen width, µ*	30
Length/width ratio	77.1
Runkel ratio	0.27
Flexibility ratio	0.79

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	2.71
Solubility, %	
in water	
in 1% NaOH	12.4
Ash, %	
Lignin, %	
Holocellulose, %	59.6
Cross-Bevan cellulose, %	39.7
Pentosans, %	

Additional information:

Pulping and papermaking characteristics

Unbleached

Process	Sulphate
Chemical consumption, %	13.2 - 14.7 Na_2O
Kappa number	43 - 22.5
Yield (unscreened), %	50.9 - 43.9
Screenings, %	0.2 - 0
Brightness	
Beater or refiner	Valley
Freeness	300 CSF
Breaking length, m	10 000 - 6 900
Burst factor	75 - 44
Tear factor	195 - 80

Bleached

Sequence	CEH
Chemical consumption, %	5.5 Cl
Yield on bleaching, %	96.0
Total yield, %	42.2
Brightness	79 (EEL)
Beater or refiner	Valley
Freeness	500 CSF
Breaking length	5 900
Burst factor	38
Tear factor	67

Additional information:

Pinus contorta
(Lodgepole Pine)

Plantation experience

Indigenous to western North America and Mexico, this species is widely distributed in two forms; on coastal sand-dunes it forms trees with crooked boles and twisted branches, whereas in the Rocky Mountains and other mountain areas it forms straight boles and narrow crowns, at altitudes up to 1 800 m in the north and 3 500 m in the south of its range. It grows mostly on poor rocky soils. It has been introduced successfully as a species of major importance in the United Kingdom and promising results have been reported from trials in Sweden. In Australia, excellent results have been obtained in trials in the Capital Territory at an altitude of 700-1 400 m, as well as in Tasmania, whereas it has failed to acclimatize in Victoria. It has also been successful in New Zealand. Trials in South Africa have not been successful.

References: 31, 73, 80, 107, 123

Wood characteristics

No representative results are available for the present samples as regards wood characteristics. The chemical composition does not imply any difficulty in pulping.

Pulping characteristics

The species is easily pulped by means of the sulphate process with a charge of alkali in the normal range for softwoods. The yield of pulp is about the average for softwoods. The strength properties of the pulp are characterized by high breaking length and a fairly low tear factor; it is comparable to Scnadinavia pine sulphate pulp.

Scientific name: Pinus contorta	Common name: Lodgepole pine Country: New Zealand	Reference: 126

Wood sample characteristics

Wood sample origin:

Samples from plantations in Kaingaroa Forest:

(a) 15 years old
(b) 20 years old

Density and fibre characteristics:

Basic density, g/cm^3
Fibre length, µ*
Fibre width, µ*
Wall thickness, µ*
Lumen width, µ*

Length/width ratio
Runkel ratio
Flexibility ratio

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:	(a)	(b)
Extractives, %		
Ether		
Methanol	2.0	2.6
Ethanol-benzene		
Solubility, %		
in water		
in 1% NaOH		
Ash, %		
Lignin, %	27.0	26.8
Holocellulose, %		
Cross-Bevan cellulose, %		
Pentosans, %	8.6	8.3

Additional information:

Pulping and papermaking characteristics

	a	b
Unbleached		
Process	Sulphate	Sulphate
Chemical consumption, %	14 - 18	14 - 18
Kappa number	60 - 52	65 - 50
Yield (unscreened), %	53.1 - 47.2	52.4 - 49.6
Screenings, %	5.8 - 0.8	6.4 - 2.5
Brightness		
Beater or refiner	Lampén	Lampén
Freeness	700 CSF	700 CSF
Breaking length, m	8 900	8 900
Burst factor	59	66
Tear factor	135	145
Bleached		
Sequence		
Chemical consumption, %		
Yield on bleaching, %		
Total yield, %		
Brightness		
Beater or refiner		
Freeness		
Breaking length		
Burst factor		
Tear factor		

Additional information:

Pinus elliottii
(Slash Pine)

Plantation experience

Indigenous to the coastal plains from southern Carolina to central Florida and south-eastern Louisiana at low elevation on both wet and dry sites, this is one of the North American 'southern pines'. It is the only pine species which will grow on the flats close to the sea, and is widely used in its natural habitat for afforestation of denuded land, mainly on shallow soils overlying clay, both for timber and for pulpwood. As a special feature of this species may be mentioned that it yields the highest quality and quantity of commercial turpentine of all the American 'pitch pines' (a turpentine with a comparatively high content of beta pinene which is the most valuable component for further processing in the chemical industry).

It has been successfully introduced in northern Argentina, Brazil, Australia, New Zealand, Fiji, Malawi, Southern Rhodesia and the Republic of South Africa. The results have been less satisfactory in Kenya and Malaysia. A very important pulpwood species.

References: 8, 41, 44, 47, 55, 87, 123, 133

Wood characteristics

The basic density of the wood is in the normal range of softwoods used for pulping. The fibre length varies from about average to slightly above average for softwoods and its chemical composition does not imply any difficulty on pulping.

Pulping characteristics

The species is easily pulped by the sulphate process with a charge of active alkali in the normal range for softwoods and the pulp is obtained with an average yield. Like all sulphate pulps from North American southern pines, the pulp is characterized by a high tear factor and a fairly low breaking length as compared with Scandinavian pine sulphate pulps. However, the overall strength properties are excellent, both as full chemical and crude sulphate pulp. The only exception from this is the results obtained with samples from Mauritius. However, this is probably due to the growth conditions of those trees. High-yield sodium bisulphite pulping gives an excellent quality pulp as does NSSC pulping, especially in the lower yield range (around 65%) for the latter process.

Scientific name: Pinus elliottii	Common name: Slash pine Country: Queensland, Australia	Reference: 133

Wood sample characteristics

Wood sample origin:

Samples from plantations at Brisbane:

(a) 8 years old
(b) 13 years old
(c) 18 years old
(d) 24 years old

Density and fibre characteristics:

Basic density, g/cm^3 (a) 0.39; (b) 0.44; (c) 0.51; (d) 0.63
Fibre length, µ* (a) 2 690; (b) 3 010
Fibre width, µ*
Wall thickness, µ*
Lumen width, µ*

Length/width ratio
Runkel ratio
Flexibility ratio

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %
Ether (a) 3.0; (b) 3.2; (c) 2.5; (d) 2.8
Methanol
Ethanol-benzene (a) 5.6; (b) 5.3; (c) 4.2; (d) 3.9

Solubility, %
in water (a) 3.2; (b) 4.2; (c) 4.0; (d) 5.0
in 1% NaOH

Ash, %
Lignin, %
Holocellulose, %
Cross-Bevan cellulose, %
Pentosans, %

Additional information:

Pulping and papermaking characteristics

Unbleached	a	b	c	d
Process	Sulphate	Sulphate	Sulphate	Sulphate
Chemical consumption, %	16 - 18*	16 - 18*	16 - 18*	16 - 17*
Kappa number	95 - 58	72 - 46	54 - 46	50 - 61
Yield (unscreened), %	52.3 - 47.0	49.9 - 47.4	49.3 - 47.8	48.8 - 49.1
Screenings, %	2.5 - 0.2	1.1 - 0.1	0.2 - 0.1	0.1
Brightness				
Beater or refiner	Valley	Valley	Valley	Valley
Freeness	450 CSF	450 CSF	450 CSF	450 CSF
Breaking length, m	7 800 - 8 900	8 800 - 8 900	8 300 - 8 000	8 600 - 8 200
Burst factor	59 - 70	69 - 68	67 - 66	69 - 67
Tear factor	135 - 155	195 - 205	235 - 220	280 - 250
Bleached				
Sequence				
Chemical consumption, %				
Yield on bleaching, %				
Total yield, %				
Brightness				
Beater or refiner				
Freeness				
Breaking length				
Burst factor				
Tear factor				

Additional information:

* Charge as Na_2O.

Scientific name: Pinus elliottii	Common name: Slash pine Country: Queensland, Australia	Reference: 133

Wood sample characteristics

Wood sample origin:

Samples from plantation at Brisbane:

(a) 8 years old
(b) 13 years old

Density and fibre characteristics:

Basic density, g/cm^3	(a) 0.39; (b) 0.44
Fibre length, μ*	(a) 2 690; (b) 3 010
Fibre width, μ*	
Wall thickness, μ*	
Lumen width, μ*	
Length/width ratio	
Runkel ratio	
Flexibility ratio	

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	(a) 3.0; (b) 3.2
Methanol	
Ethanol-benzene	(a) 5.6; (b) 5.3
Solubility, %	
in water	(a) 3.2; (b) 4.2
in 1% NaOH	
Ash, %	
Lignin, %	
Holocellulose, %	
Cross-Bevan cellulose, %	
Pentosans, %	

Additional information:

Pulping and papermaking characteristics

Unbleached	a		b	
Process	NSSC	Na-bisulphite	NSSC	NSSC
Chemical consumption, %	9.4 SO_2*	11.1 SO_2*	9.4 SO_2*	1.9 SO_2*
Kappa number				
Yield (unscreened), %	72.4 - 77.9	63.7 - 56.9	71.7 - 64.6	87.5
Screenings, %				
Brightness				62 (Tappi)
Beater or refiner	Valley**	Valley**	Valley**	Valley**
Freeness	600 CSF	600 CSF	600 CSF	105 CSF
Breaking length, m	4 500 - 3 800	6 100 - 6 400	4 600 - 6 200	-
Burst factor	26 - 21	38 - 42	25 - 38	10
Tear factor	97 - 83	110 - 120	125 - 115	

Bleached

Sequence
Chemical consumption, %
Yield on bleaching, %
Total yield, %

Brightness

Beater or refiner
Freeness
Breaking length
Burst factor
Tear factor

Additional information:

* Charge
** After three passes in Sprout-Waldron 12" disc refiner.

Scientific name: *Pinus elliottii*	Common name: Slash pine Country: Mauritius	Reference: 29

Wood sample characteristics

Wood sample origin:

Samples from plantations in Mauritius:

(a) 14 years old; and
(b) 22 years old trees

Density and fibre characteristics:

Basic density, g/cm^3	(a) 0.52; (b) 0.58
Fibre length, µ*	
Fibre width, µ*	
Wall thickness, µ*	
Lumen width, µ*	
Length/width ratio	
Runkel ratio	
Flexibility ratio	

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	(a) 1.4; (b) 1.1
Solubility, %	
in water	
in 1% NaOH	
Ash, %	(a) 0.23; (b) 0.23
Lignin, %	
Holocellulose, %	(a) 72.5; (b) 70.3
Cross-Bevan cellulose, %	
Pentosans, %	(a) 11.4; (b) 10.9

Additional information:

Pulping and papermaking characteristics

Unbleached	14 years old	22 years old
Process	Sulphate	Sulphate
Chemical consumption, %	12.7	15.5
Kappa number	46	44
Yield (unscreened), %	41.1	47.0
Screenings, %	1.0	1.0
Brightness		
Beater or refiner	Lampén	Lampén
Freeness	300 CSF	300 CSF
Breaking length, m	6 200	4 800
Burst factor	43	31
Tear factor	150	115

Bleached

Sequence
Chemical consumption, %
Yield on bleaching, %
Total yield, %

Brightness

Beater or refiner
Freeness
Breaking length
Burst factor
Tear factor

Additional information:

Scientific name: Pinus elliottii	Common name: Slash pine Country: Australia	Reference: 87

Wood sample characteristics

Wood sample origin:

Samples from plantations in Australia:

(a) 8 years old
(b) 13 years old
(c) 18 years old
(d) 24 years old

Density and fibre characteristics:

Basic density, g/cm^3 (a) 0.39; (b) 0.44; (c) 0.54; (d) 0.69
Fibre length, µ*
Fibre width, µ*
Wall thickness, µ*
Lumen width, µ*

Length/width ratio
Runkel ratio
Flexibility ratio

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %
Ether
Methanol
Ethanol-benzene

Solubility, %
in water
in 1% NaOH

Ash, %
Lignin, %
Holocellulose, %
Cross-Bevan cellulose, %
Pentosans, %

Additional information:

Pulping and papermaking characteristics

Unbleached	a	b	c	d
Process	Sulphate	Sulphate	Sulphate	Sulphate
Chemical consumption, %	16.0 - 18.0 Na_2O*	17.0 - 18.0 Na_2O	18.0 Na_2O*	16.0 Na_2O*
Kappa number	79 - 58	64 - 46	46	50
Yield (unscreened), %	52.1 - 47.2	50.5 - 47.5	47.8	48.9
Screenings, %				
Brightness				
Beater or refiner	450 CSF	450 CSF	450 CSF	450 CSF
Freeness	8 200 - 8 900	8 800 - 8 900	8 000	8 600
Breaking length, m	66 - 70	69 - 68	66	69
Burst factor	160	205	220	280
Tear factor				

Bleached	a	b	c	d
Sequence				
Chemical consumption, %				
Yield on bleaching, %				
Total yield, %				
Brightness				
Beater or refiner				
Freeness				
Breaking length				
Burst factor				
Tear factor				

Additional information:

* Charge

Scientific name: Pinus elliottii	Common name: Slash pine Country: Queensland, Australia	Reference: 131

Wood sample characteristics

Wood sample origin:

Sample from plantation at Beerburrum, butt sections from 11 and 20 years old trees (composite sample)

Density and fibre characteristics:

Basic density, g/cm^3	0.473
Fibre length, µ*	3 480
Fibre width, µ*	
Wall thickness, µ*	
Lumen width, µ*	
Length/width ratio	
Runkel ratio	
Flexibility ratio	

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %
- Ether
- Methanol
- Ethanol-benzene

Solubility, %
- in water
- in 1% NaOH

Ash, %
Lignin, %
Holocellulose, %
Cross-Bevan cellulose, %
Pentosans, %

Additional information:

Pulping and papermaking characteristics

Unbleached	
Process	Sulphate
Chemical consumption, %	
Kappa number	50.1 - 17.0
Yield (unscreened), %	54.9 - 45.8
Screenings, %	1.0 - 0
Brightness	
Beater or refiner	PFI
Freeness	300 CSF
Breaking length, m	8 900 - 8 200
Burst factor	73 - 62
Tear factor	170 - 160
Bleached	
Sequence	
Chemical consumption, %	
Yield on bleaching, %	
Total yield, %	
Brightness	
Beater or refiner	
Freeness	
Breaking length	
Burst factor	
Tear factor	

Additional information:

Scientific name: Pinus elliottii	Common name: Slash pine Country: Malawi	Reference: 107

Wood sample characteristics

Wood sample origin:

Samples from plantations in Malawi:

(a) 13 years old trees
(b) 16 years old trees

Density and fibre characteristics:

Basic density, g/cm^3
Fibre length, µ*
Fibre width, µ*
Wall thickness, µ*
Lumen width, µ*

Length/width ratio
Runkel ratio
Flexibility ratio

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %
Ether
Methanol
Ethanol-benzene

Solubility, %
in water
in 1% NaOH

Ash, %
Lignin, %
Holocellulose, %
Cross-Bevan cellulose, %
Pentosans, %

Additional information:

Pulping and papermaking characteristics		
Unbleached	13 years old	16 years old
Process	Sulphate	Sulphate
Chemical consumption, %		
Kappa number	37.2 - 25.2	45.2 - 23.8
Yield (unscreened), %	46.3 - 43.2	45.3 - 46.1
Screenings, %	0.2 - 0.1	1.0 - 0
Brightness		
Beater or refiner	PFI	PFI
Freeness	300 CSF	300 CSF
Breaking length, m	9 200 - 8 400	9 400 - 8 700
Burst factor	67 - 62	70 - 58
Tear factor	165 - 120	180 - 135
Bleached		
Sequence		
Chemical consumption, %		
Yield on bleaching, %		
Total yield, %		
Brightness		
Beater or refiner		
Freeness		
Breaking length		
Burst factor		
Tear factor		
Additional information:		

Pinus kesiya

Plantation experience

The species is indigenous to Assam, through Upper Burma and the Shan States to Thailand and Vietnam. It grows at 500-2 500 m in a climate of the sub-temperate type and is adaptable to a wide range of soils which, however, must be well drained. Acclimatization has been promising in the Republic of South Africa and in East Africa. Varying results have been obtained in Australia. It has failed to acclimatize in Fiji, Malaysia, Borneo and Uganda.

References: 22, 31, 40, 41, 59, 101, 123

Wood characteristics

The basic density of the wood is in the normal range for softwoods used for pulping. The fibre length varies with the provenance of the sample from below average to above average for softwoods. The fibres are wide but thin-walled which implies good flexibility and thus also a good potential for inter-fibre bonding in paper. The extractives content is low and none of the chemical characteristics available imply any difficulty on chemical pulping.

Pulping characteristics

The species is easily pulped by means of the sulphate process with an alkali charge in the normal range. The yield of pulp is about average for softwoods. As regards the strength properties, the tear factor is very high whereas the breaking length is on the low side. However, the overall strength is excellent and comparable to North American Douglas Fir sulphate pulp, both as unbleached and bleached.

As regards chemical soda pulping, the same conclusions apply as for the sulphate process.

An excellent quality pulp can be obtained by means of the NSSC process.

Scientific name: Pinus kesiya (Syn. P. insularis)	Common name: Country: Zambia	Reference: 101

Wood sample characteristics

Wood sample origin:

Samples from trial plantation at Dola Hill, 22 years old

Density and fibre characteristics:

Basic density, g/cm^3	0.48
Fibre length, µ*	2 520
Fibre width, µ*	50
Wall thickness, µ*	7
Lumen width, µ*	36
Length/width ratio	51
Runkel ratio	0.39
Flexibility ratio	0.72

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	1.2
Solubility, %	
in water	
in 1% NaOH	12.2
Ash, %	
Lignin, %	
Holocellulose, %	64.2
Cross-Bevan cellulose, %	42.0
Pentosans, %	

Additional information:

Pulping and papermaking characteristics	
Unbleached	
Process	Sulphate
Chemical consumption, %	12.6 – 13.8 Na_2O
Kappa number	41.4 – 24.8
Yield (unscreened), %	50.0 – 46.3
Screenings, %	0.7 – 0.1
Brightness	
Beater or refiner	Valley
Freeness	300 CSF
Breaking length, m	9 300 – 8 400
Burst factor	74 – 67
Tear factor	240 – 190
Bleached	
Sequence	CEH
Chemical consumption, %	7.0 Cl
Yield on bleaching, %	
Total yield, %	46
Brightness	62 (Elrepho)
Beater or refiner	Valley
Freeness	500
Breaking length	8 000
Burst factor	61
Tear factor	205

Additional information: Printing opacity of bleached pulp at 500 CSF 68, luminance factor 70, scattering coefficient 160.

Scientific name: Pinus kesiya	Common name: Kesika Country: Madagascar	Reference: 111

Wood sample characteristics

Wood sample origin:

Composite sample from plantations at Manjakatompo, Ampamaherana and Ambositra, 10–34 years old. Logs 20–35 cm in diameter.

Density and fibre characteristics:

Basic density, g/cm^3	0.40 (dry volume
Fibre length, µ*	3 662
Fibre width, µ*	62
Wall thickness, µ*	5
Lumen width, µ*	52
Length/width ratio	59
Runkel ratio	0.19
Flexibility ratio	0.84

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %
- Ether
- Methanol
- Ethanol-benzene

Solubility, %
- in water
- in 1% NaOH

Ash, %
Lignin, %
Holocellulose, %
Cross-Bevan cellulose, %
Pentosans, %

Additional information:

Pulping and papermaking characteristics

Unbleached			
Process	Sulphate	Soda (170°C)	NSSC
Chemical consumption, %	16.0 – 14.5 Na_2O	13.5 Na_2O	6.8 – 5.5 SO_2
Kappa number	30 – 54	95	–
Yield (unscreened), %	42.8 – 47.1	47.1	65.2 – 69.2
Screenings, %	0.1 – 0.6	0.4	0
Brightness (Photovolt)	27 – 24.5	27	30.5 – 31
Beater or refiner	Bauer	Bauer	Bauer
Freeness	40 SR	40 SR	40 SR
Breaking length, m	6 900 – 7 800	7 200	7 200 – 6 200
Burst factor	50 – 57	54	53 – 42
Tear factor	98 – 110	110	77 – 84

Bleached		
Sequence	CEHH	CEHH
Chemical consumption, %	7.1 Cl	11.3 Cl
Yield on bleaching, %		
Total yield, %		
Brightness (Photovolt)	79	77
Beater or refiner	Bauer	Bauer
Freeness	40 SR	40 SR
Breaking length	6 700	7 200
Burst factor	47	51
Tear factor	90	83

Additional information:

Scientific name: Pinus kesiya (Syn. P. insularis)	Common name: Country: Philippines	Reference: 101

Wood sample characteristics

Wood sample origin:

Samples from natural forest in the Mountain Province near Baquio, 75 to 200 years old.

Density and fibre characteristics:

Basic density, g/cm^3	0.55
Fibre length, µ*	2 900
Fibre width, µ*	52
Wall thickness, µ*	7
Lumen width, µ*	38
Length/width ratio	56
Runkel ratio	0.37
Flexibility ratio	0.73

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	2.4
Solubility, %	
in water	
in 1% NaOH	14.4
Ash, %	
Lignin, %	
Holocellulose, %	61.7
Cross-Bevan cellulose, %	41.6
Pentosans, %	

Additional information:

Pulping and papermaking characteristics

Unbleached

Process	Sulphate
Chemical consumption, %	12.2 - 13.3 Na_2O
Kappa number	44.7 - 26.0
Yield (unscreened), %	47.8 - 43.2
Screenings, %	1.7 - 0.2
Brightness	
Beater or refiner	Valley
Freeness	300 CSF
Breaking length, m	7 800 - 7 900
Burst factor	61 - 62
Tear factor	250 - 240

Bleached

Sequence	CEH
Chemical consumption, %	7.5 Cl
Yield on bleaching, %	
Total yield, %	43
Brightness	65 (Elrepho)
Beater or refiner	Valley
Freeness	500 CSF
Breaking length	7 500
Burst factor	51
Tear factor	285

Additional information: Printing opacity of bleached pulp at 500 CSF 67, luminance factor 72, scattering coefficient 175.

Pinus muricata
(Bishop Pine)

Plantation experience

As an indigenous species, this species is found scattered through the coastal region of California down to the Mexican border. It grows on rocky headlands under conditions of considerable exposure. It has been extensively planted in southern Australia with good results and also widely distributed in New Zealand. Trials in East Africa and in the Republic of South Africa have not been so successful.

References: 31, 123

Wood characteristics

The basic density of the wood is in the normal range for softwoods for pulping. No fibre or chemical characteristics are available for the sample at hand.

Pulping characteristics

The species is easily pulped by means of the sulphate process to produce crude sulphate pulp of top-liner quality with a good yield. The strength properties of the pulp are excellent and comparable to those of Scandinavian pine sulphate pulp. Further cooking with a somewhat higher charge of active alkali to the range of full chemical pulp would probably give a pulp with similar characteristics as those of North American southern pine sulphate pulps. Judging from the very limited data available, the species shows good promise for utilization as pulpwood.

Scientific name: Pinus muricata	Common name: Bishop pine Country: Australia	Reference: 87

Wood sample characteristics

<u>Wood sample origin:</u>

Sample from plantation, 14 years old.

<u>Density and fibre characteristics:</u>

Basic density, g/cm^3	0.48
Fibre length, µ*	
Fibre width, µ*	
Wall thickness, µ*	
Lumen width, µ*	
Length/width ratio	
Runkel ratio	
Flexibility ratio	

Additional information:

* 1000 µ (microns) = 1 mm

<u>Chemical characteristics:</u>

Extractives, %
  Ether
  Methanol
  Ethanol-benzene

Solubility, %
  in water
  in 1% NaOH

Ash, %
Lignin, %
Holocellulose, %
Cross-Bevan cellulose, %
Pentosans, %

Additional information:

Pulping and papermaking characteristics

Unbleached	
Process	Sulphate
Chemical consumption, %	14.0 Na_2O (charge)
Kappa number	61
Yield (unscreened), %	54.4
Screenings, %	
Brightness	
Beater or refiner	
Freeness	400 CSF
Breaking length, m	11 600
Burst factor	95
Tear factor	110
Bleached	
Sequence	
Chemical consumption, %	
Yield on bleaching, %	
Total yield, %	
Brightness	
Beater or refiner	
Freeness	
Breaking length	
Burst factor	
Tear factor	

Additional information:

Pinus nigra var. calabrica (Corsican Pine)

Plantation experience

This fairly fast-growing variety of Pinus nigra is indigenous to Corsica and southern Italy and reaches its finest development in Corsica at 900-1 200 m altitude. It grows on sandy loams derived from granite as well as siliceous loams, derived from volcanic rocks. In Calabria, in southern Italy, intermediates are found between this variety and P. nigra var. austriaca. It has been planted on a large scale in Australia, in Victoria, although in a mixture with the Austrian variety, with good results. It has also proved successful in south-east Australia in general, although only introduced on a smaller scale. It is widely used as an exotic for pulpwood in New Zealand and the United Kingdom. Some small-scale trials have also been carried out in India with good results. It has failed to acclimatize in Fiji and South Africa.

References: 39, 45, 123

Wood characteristics

The basic density of the samples are in the normal range for softwoods used for pulping. The lignin content is around the average for softwoods.

Pulping characteristics

The variety is easily pulped by means of the sulphate process with an alkali charge in the normal range for softwoods. The yield is also around the average for softwood pulps. As regards the strength properties, the breaking length is slightly below that of Scandinavian pine sulphate pulps, whereas the tear factor is about the same. The pulp resembles in quality that of Pinus radiata sulphate pulp.

Scientific name: Pinus nigra var. calabrica	Common name: Corsican pine Country: New Zealand	Reference: 127

Wood sample characteristics

Wood sample origin:

Samples from plantation in Kangaroa Forest:

(a) 15 years old
(b) 25 years old (samples from growth rings)

Age of sample tree: 46 years

Density and fibre characteristics:

Basic density, g/cm^3	(a) 0.40; (b) 0.42
Fibre length, µ*	
Fibre width, µ*	
Wall thickness, µ*	
Lumen width, µ*	
Length/width ratio	
Runkel ratio	
Flexibility ratio	

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	
Solubility, %	
in water	
in 1% NaOH	
Ash, %	
Lignin, %	(a) 27.2; (b) 27.7
Holocellulose, %	
Cross-Bevan cellulose, %	
Pentosans, %	

Additional information:

Pulping and papermaking characteristics

Unbleached	a	b
Process	Sulphate	Sulphate
Chemical consumption, %	18 Na_2O*	18 Na_2O*
Kappa number	36	37
Yield (unscreened), %	47.1	45.5
Screenings, %	0.9	1.1
Brightness		
Beater or refiner	Lampén	Lampén
Freeness	700 CSF	700 CSF
Breaking length, m	5 900	6 000
Burst factor	54	53
Tear factor	165	180
Bleached		
Sequence		
Chemical consumption, %		
Yield on bleaching, %		
Total yield, %		
Brightness		
Beater or refiner		
Freeness		
Breaking length		
Burst factor		
Tear factor		

Additional information:

* Charge

Pinus oocarpa
(Ocote Pine)

Plantation experience

The species is widely distributed as an indigenous tree in Central America at an altitude of 750-2 300 m. It is very common in the sub-tropical southern areas of Mexico at 1 500-2 000 m where it grows in open stands. However, this seems to be a smaller variety of the species which has not been successful as an exotic. The larger tree of better form appears to be confined to the southern part of Honduras and Nicaragua. The resin obtainable from this species is valuable as a naval stores product. Successful acclimatization has been reported from Kenya and varying success from the different parts of the Republic of South Africa.

References: 22, 31, 44, 46, 123

Wood characteristics

The basic density of the wood is in the normal range for softwoods used for pulping and the extractives content around average. No data on fibre characteristics are available for the samples considered.

Pulping characteristics

The species is easily pulped with an average charge of alkali by means of the sulphate process. The yield of pulp is around average. As regards the strength properties, the tear factor is fairly high and the breaking length slightly low, although there seems to be a variation due to difference in provenance. At its best, it seems that the quality of the pulp would be similar to that of North American southern pine sulphate pulp, but probably slightly lower on the average.

Scientific name: Pinus oocarpa	Common name: Ocote pine Country: Mexico	Reference: 87

Wood sample characteristics

Wood sample origin:	Chemical characteristics:

Wood sample origin:

Sample from natural forest.

Density and fibre characteristics:

Basic density, g/cm^3	0.48
Fibre length, μ*	
Fibre width, μ*	
Wall thickness, μ*	
Lumen width, μ*	
Length/width ratio	
Runkel ratio	
Flexibility ratio	

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	3.6
Solubility, %	
in water	
in 1% NaOH	
Ash, %	
Lignin, %	
Holocellulose, %	
Cross-Bevan cellulose, %	
Pentosans, %	

Additional information:

Pulping and papermaking characteristics

<u>Unbleached</u>

Process	Sulphate
Chemical consumption, %	18.8 Na_2O (charge)
Kappa number	57
Yield (unscreened), %	48.8
Screenings, %	
Brightness	
Beater or refiner	
Freeness	450 CSF
Breaking length, m	8 200
Burst factor	59
Tear factor	150

<u>Bleached</u>

Sequence	
Chemical consumption, %	
Yield on bleaching, %	
Total yield, %	
Brightness	
Beater or refiner	
Freeness	
Breaking length	
Burst factor	
Tear factor	

Additional information:

Scientific name:	Common name:	Reference:
Pinus oocarpa	Country: Belize	107

Wood sample characteristics

Wood sample origin:

Sample from natural forest at Mountain Pine Ridge.
Age unknown.

Density and fibre characteristics:

Basic density, g/cm^3
Fibre length, µ*
Fibre width, µ*
Wall thickness, µ*
Lumen width, µ*

Length/width ratio
Runkel ratio
Flexibility ratio

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %
  Ether
  Methanol
  Ethanol-benzene

Solubility, %
  in water
  in 1% NaOH

Ash, %
Lignin, %
Holocellulose, %
Cross-Bevan cellulose, %
Pentosans, %

Additional information:

Pulping and papermaking characteristics

Unbleached	
Process	Sulphate
Chemical consumption, %	
Kappa number	29
Yield (unscreened), %	45.1
Screenings, %	0.1
Brightness	
Beater or refiner	Valley
Freeness	300 CSF
Breaking length, m	8 800
Burst factor	67
Tear factor	195
Bleached	
Sequence	
Chemical consumption, %	
Yield on bleaching, %	
Total yield, %	
Brightness	
Beater or refiner	
Freeness	
Breaking length	
Burst factor	
Tear factor	

Additional information:

Pinus patula
(Patula Pine, Jelicote Pine)

Plantation experience

This species is common in the central eastern states of Mexico, mostly in the warm and temperate zones at 1 800-2 500 m, with rainfall over 1 000 mm/year and frequent mists. It grows abundantly in pure dense stands. It thrives in ravines and on flats with deep, moist, well-drained soils which are often sandy. Early growth is rapid on good sites and free-growing trees often show only two rings per inch of radius up to about 12 years of age. The tree is also found in Guatemala where its altitudinal range is 1 500-3 000m. It is widely used as an exotic, particularly in South, Central and East Africa. It has also been introduced successfully in India on a small scale, in New Zealand and in some parts of Australia. Dubious results have been obtained in Fiji, Jamaica and Kenya.

References: 31, 40, 41, 44, 48, 59, 87, 123

Wood characteristics

The basic density of the species is in the normal range for softwoods used for pulping, although on the low side. Judging from the results given for the sample from Madagascar, the fibre length is above average for softwoods, but this probably varies considerably with provenance of the sample. The Runkel ratio and/or the flexibility ratio imply a good potential for interfibre bonding in paper. No chemical characteristics are given for the present samples.

Pulping characteristics

The species is easily pulped by means of the sulphate process with an alkali charge in the normal range for softwoods. The yield varies somewhat with provenance and age, from average to above average. There is also considerable variation in the strength characteristics of the pulps with provenance. Thus the strength properties of the pulps made from the samples from Kenya exhibit excellent strength and compare well with Scandinavian pine sulphate pulps. The samples from Malawi and Madagascar have given pulps of equally excellent strength, but more of the type of North American southern pine sulphate pulps.

Chemical soda pulping also gives good-quality pulp of that type with a good yield. The pulp obtained by means of the NSSC process is unsatisfactory in strength.

Scientific name: Pinus patula	Common name: Patula pine, Jelicote pine Country: Malawi	Reference: 107

Wood sample characteristics

Wood sample origin:

Samples from plantations in Malawi:

(a) 13 years old trees; and
(b) 16 years old trees.

Density and fibre characteristics:

Basic density, g/cm^3
Fibre length, μ*
Fibre width, μ*
Wall thickness, μ*
Lumen width, μ*

Length/width ratio
Runkel ratio
Flexibility ratio

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %
Ether
Methanol
Ethanol-benzene

Solubility, %
in water
in 1% NaOH

Ash, %
Lignin, %
Holocellulose, %
Cross-Bevan cellulose, %
Pentosans, %

Additional information:

Pulping and papermaking characteristics

Unbleached	13 years old	16 years old
Process	Sulphate	Sulphate
Chemical consumption, %		
Kappa number	43.2 - 26.4	36.7 - 22.4
Yield (unscreened), %	45.4 - 42.0	46.8 - 48.2
Screenings, %	3.1 - 0.1	0.4 - 0
Brightness		
Beater or refiner	PFI	PFI
Freeness	300 CSF	300 CSF
Breaking length, m	8 500	9 200 - 7 700
Burst factor	60	67 - 49
Tear factor	190	165 - 140

Bleached

Sequence
Chemical consumption, %
Yield on bleaching, %
Total yield, %

Brightness

Beater or refiner
Freeness
Breaking length
Burst factor
Tear factor

Additional information:

Scientific name: Pinus patula	Common name: Patula pine, Jelicote pine Country: Kenya	Reference: 87

Wood sample characteristics

<u>Wood sample origin:</u>

Samples from plantations in Kenya:

(a) 7 years old
(b) 12 years old
(c) 15 years old
(d) 22 years old.

<u>Density and fibre characteristics:</u>

Basic density, g/cm^3 (a) 0.28; (b) 0.47; (c) 0.34; (d) 0.38
Fibre length, µ*
Fibre width, µ*
Wall thickness, µ*
Lumen width, µ*

Length/width ratio
Runkel ratio
Flexibility ratio

Additional information:

* 1000 µ (microns) = 1 mm

<u>Chemical characteristics:</u>

Extractives, %
Ether
Methanol
Ethanol-benzene

Solubility, %
in water
in 1% NaOH

Ash, %
Lignin, %
Holocellulose, %
Cross-Bevan cellulose, %
Pentosans, %

Additional information:

Pulping and papermaking characteristics

Unbleached	a	b	c	d
Process	Sulphate	Sulphate	Sulphate	Sulphate
Chemical consumption, %	16.0 Na_2O*	16.0 Na_2O*	16.0 Na_2O*	16.0 Na_2O*
Kappa number	45	64	45	55
Yield (unscreened), %	52.4	51.4	49.6	49.9
Screenings, %				
Brightness				
Beater or refiner				
Freeness	500 CSF	500 CSF	500 CSF	500 CSF
Breaking length, m	12 600	11 900	13 100	12 600
Burst factor	92	96	99	92
Tear factor	98	100	94	110

Bleached

Sequence
Chemical consumption, %
Yield on bleaching, %
Total yield, %

Brightness

Beater or refiner
Freeness
Breaking length
Burst factor
Tear factor

Additional information:

* Charge.

Scientific name: Pinus patula	Common name: Patula pine, Jelicote pine Country: Kenya	Reference: 107

Wood sample characteristics

Wood sample origin and fibre characteristics	Chemical characteristics
Wood sample origin:	**Chemical characteristics:**
Samples from plantations in Kenya:	Extractives, %
(a) Thinnings, less than 7 years old	Ether
(b) Trees, 7-15 years old; and	Methanol
(c) Trees, over 15 years old.	Ethanol-benzene
	Solubility, %
	in water
	in 1% NaOH
Density and fibre characteristics:	Ash, %
Basic density, g/cm^3	Lignin, %
Fibre length, μ*	Holocellulose, %
Fibre width, μ*	Cross-Bevan cellulose, %
Wall thickness, μ*	Pentosans, %
Lumen width, μ*	
Length/width ratio	
Runkel ratio	
Flexibility ratio	
Additional information:	Additional information:

* 1000 μ (microns) = 1 mm

Pulping and papermaking characteristics

Unbleached	Less than 7 years	7-15 years	Over 15 years
Process	Sulphate	Sulphate	Sulphate
Chemical consumption, %			
Kappa number			
Yield (unscreened), %	50.3 - 52.8	59.9	47.4
Screenings, %	3.9 - 1.9	4.3	0.8
Brightness			
Beater or refiner	Valley	Valley	Valley
Freeness	300 CSF	300 CSF	300 CSF
Breaking length, m	9 500 - 10 200	10 000	8 800
Burst factor	69 - 73	69	67
Tear factor	135 - 120	110	190

Bleached			
Sequence			
Chemical consumption, %			
Yield on bleaching, %			
Total yield, %			
Brightness			
Beater or refiner			
Freeness			
Breaking length			
Burst factor			
Tear factor			

Additional information:

Scientific name: Pinus patula	Common name: Patula pine, Jelicote pine Country: Madagascar	Reference: 111

Wood sample characteristics

Wood sample origin:

Composite sample from different sites of plantation at Manjakatompo. Logs 17-27 cm in diameter.

Density and fibre characteristics:

Basic density, g/cm^3	0.46 (dry volume)
Fibre length, μ*	4 006
Fibre width, μ*	54
Wall thickness, μ*	6
Lumen width, μ*	42
Length/width ratio	74
Runkel ratio	0.29
Flexibility ratio	0.78

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %
- Ether
- Methanol
- Ethanol-benzene

Solubility, %
- in water
- in 1% NaOH

Ash, %
Lignin, %
Holocellulose, %
Cross-Bevan cellulose, %
Pentosans, %

Additional information:

Pulping and papermaking characteristics

Unbleached			
Process	Sulphate	Soda (170°C)	NSSC
Chemical consumption, %	15.8 - 14.0 Na_2O	13.5 - 12.4 Na_2O	6.6 SO_2
Kappa number	27 - 52	74 - 120	-
Yield (unscreened), %	45.7 - 50.3	45.7 - 49.3	63.0
Screenings, %	0 - 1.4	0.1 - 1.7	1.7
Brightness (Photovolt)	30 - 24.5	28.5 - 25	31
Beater or refiner	Bauer	Bauer	Bauer
Freeness	40 SR	40 SR	40 SR
Breaking length, m	6 300 - 6 500	5 400 - 5 700	4 400
Burst factor	44 - 46	38 - 39	28
Tear factor	140 - 160	120 - 125	70
Bleached			
Sequence	CEHH	CEHH	
Chemical consumption, %	7.3 - 11.2 Cl	12.5 Cl	
Yield on bleaching, %			
Total yield, %			
Brightness (Photovolt)	79.5 - 79	79	
Beater or refiner	Bauer	Bauer	
Freeness	40 SR	40 SR	
Breaking length	5 800 - 6 400	5 700	
Burst factor	41 - 64	40	
Tear factor	110 - 130	120	

Additional information:

Pinus pinaster
(Maritime Pine)

Plantation experience

The species is one of the main commercial sources for resin for which it is widely tapped. It is native to the Mediterranean region, chiefly at low altitudes near the sea on well-drained sandy soils. It is planted on a wide scale in its natural habitat, partly for sand-fixation on sand-dunes, but also in shelterbelts. It has been successfully introduced as an exotic in West and South Australia, in Southern Rhodesia and in the Republic of South Africa. Less successful results have been reported from the United Kingdom, India (except in Punjab) and Kenya and it has failed to acclimatize in Mauritius.

References: 31, 39, 44, 45, 92, 93, 123

Wood characteristics

The basic density of the wood is in the normal range for softwoods used for pulping. No data on fibre characteristics or chemical composition are available for the present sample.

Pulping characteristics

The species is easily pulped by means of the sulphate process with a normal charge of active alkali and the yield of pulp around average for softwoods. The breaking length and the burst factor of the pulp is good. The tear factor is slightly on the low side, even compared with a Scandinavian pine sulphate pulp; however, in its general features it is very similar to this pulp although of slightly lower general quality. It is best compared to sulphate pulp from *Pinus radiata*.

Scientific name: Pinus pinaster (Syn. P. maritima)	Common name: Maritime pine Country: Australia	Reference: 87

Wood sample characteristics

Wood sample origin:

Sample from plantation in Australia, 15 years old.

Density and fibre characteristics:

Basic density, g/cm^3	0.48
Fibre length, μ*	
Fibre width, μ*	
Wall thickness, μ*	
Lumen width, μ*	
Length/width ratio	
Runkel ratio	
Flexibility ratio	

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %
- Ether
- Methanol
- Ethanol-benzene

Solubility, %
- in water
- in 1% NaOH

Ash, %
Lignin, %
Holocellulose, %
Cross-Bevan cellulose, %
Pentosans, %

Additional information:

Pulping and papermaking characteristics	
Unbleached	
Process	Sulphate
Chemical consumption, %	15.5 Na_2O (charge)
Kappa number	44
Yield (unscreened), %	49.9
Screenings, %	
Brightness	
Beater or refiner	
Freeness	400 CSF
Breaking length, m	11 400
Burst factor	98
Tear factor	115
Bleached	
Sequence	
Chemical consumption, %	
Yield on bleaching, %	
Total yield, %	
Brightness	
Beater or refiner	
Freeness	
Breaking length	
Burst factor	
Tear factor	
Additional information:	

Pinus radiata
(Monterey Pine - Radiata Pine)

Plantation experience

Indigenous to southern California, this species grows exceptionally fast in suitable conditions and gives a correspondingly high yield of cheaply produced wood of wood or adequate quality for lumber or pulp. The mean annual increment is about 25 m^3/ha on a rotation of 25 years. Frost in winter and damp heat or excessive drought in summer rule out this species in many regions where other conifers thrive. A Mediterranean type climate, like in its natural habitat, seems to offer the most favourable conditions.

It has been introduced successfully in Australia, New Zealand, Chile, Spain and in the Republic of South Africa. Good results have been obtained in Kenya and Malawi and at high altitudes (3 500 m) in Ecuador and Bolivia. Certain difficulties, although not of a severe nature, have been reported from Tanzania. Attempts to grow *P. radiata* in Brazil have failed due to an unsuitable climate and attacks of *Diploida* and other pests.

References: 4, 7, 31, 34, 39, 41, 44, 45, 50, 51, 58, 87, 89, 118, 123, 133

Wood characteristics

The basic density of the wood is the normal range for softwoods used for pulping. The fibres of this species are usually about 3.5 mm in length and 40 microns in width, both of which are in the average range for softwoods. No chemical characteristics are given for the present samples.

Pulping characteristics

The species adapts itself well to sulphate pulping with a normal charge of active alkali. The yield of pulp is about the average for softwoods. The strength properties are usually good, although not excellent, with a greaking length and tear factor slightly below those of Scandinavian pine sulphate pulps. It may be mentioned that practically the entire pulp industry in Chile is based on sulphate pulping of this species.

Scientific name: Pinus radiata (Syn. P. insignis)	Common name: Monterey pine (Radiata pine) Country: Kenya	Reference: 87

Wood sample characteristics

Wood sample origin:

Samples from plantations in Kenya:

(a) 7 years old
(b) 12 years old
(c) 17 years old
(d) 22 years old

Density and fibre characteristics:

Basic density, g/cm^3 (a) 0.39; (b) 0.43; (c) 0.39; (d) 0.49
Fibre length, µ*
Fibre width, µ*
Wall thickness, µ*
Lumen width, µ*

Length/width ratio
Runkel ratio
Flexibility ratio

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %
  Ether
  Methanol
  Ethanol-benzene

Solubility, %
  in water
  in 1% NaOH

Ash, %
Lignin, %
Holocellulose, %
Cross-Bevan cellulose, %
Pentosans, %

Additional information:

Pulping and papermaking characteristics

Unbleached	a	b	c	d
Process	Sulphate	Sulphate	Sulphate	Sulphate
Chemical consumption, %	16.0 Na_2O*	16.0 Na_2O*	16.0 Na_2O*	16.5 Na_2O*
Kappa number	43	44	50	45
Yield (unscreened), %	51.4	50.2	49.8	46.9
Screenings, %				
Brightness				
Beater or refiner				
Freeness	500 CSF	500 CSF	500 CSF	500 CSF
Breaking length, m	12 900	13 000	13 500	12 000
Burst factor	96	94	98	86
Tear factor	105	110	100	115

Bleached	
Sequence	
Chemical consumption, %	
Yield on bleaching, %	
Total yield, %	
Brightness	
Beater or refiner	
Freeness	
Breaking length	
Burst factor	
Tear factor	

Additional information:

* Charge.

Scientific name: Pinus radiata (Syn. P. insignis)	Common name: Monterey pine Country: New Zealand	Reference: 87

Wood sample characteristics

Wood sample origin:

Sample from plantation in New Zealand, 23 years old.

Density and fibre characteristics:

Basic density, g/cm^3	0.37
Fibre length, μ*	
Fibre width, μ*	
Wall thickness, μ*	
Lumen width, μ*	
Length/width ratio	
Runkel ratio	
Flexibility ratio	

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %
- Ether
- Methanol
- Ethanol-benzene

Solubility, %
- in water
- in 1% NaOH

Ash, %
Lignin, %
Holocellulose, %
Cross-Bevan cellulose, %
Pentosans, %

Additional information:

Pulping and papermaking characteristics

<u>Unbleached</u>

Process	Sulphate
Chemical consumption, %	20.0 Na_2O (charge)
Kappa number	42
Yield (unscreened), %	44.7
Screenings, %	
Brightness	
Beater or refiner	450 CSF
Freeness	10 900
Breaking length, m	74
Burst factor	120
Tear factor	

<u>Bleached</u>

Sequence	
Chemical consumption, %	
Yield on bleaching, %	
Total yield, %	
Brightness	
Beater or refiner	
Freeness	
Breaking length	
Burst factor	
Tear factor	

Additional information:

Scientific name: Pinus radiata (Syn. P. insignis)	Common name: Monterey pine Country: Kenya	Reference: 107

Wood sample characteristics

Wood sample origin:	Chemical characteristics:
Sample from thinnings from plantation.	Extractives, % Ether Methanol Ethanol-benzene
Density and fibre characteristics:	Solubility, % in water in 1% NaOH
Basic density, g/cm^3 Fibre length, µ* Fibre width, µ* Wall thickness, µ* Lumen width, µ* Length/width ratio Runkel ratio Flexibility ratio	Ash, % Lignin, % Holocellulose, % Cross-Bevan cellulose, % Pentosans, %
Additional information:	Additional information:
* 1000 µ (microns) = 1 mm	

Pulping and papermaking characteristics

Unbleached	
Process	Sulphate
Chemical consumption, %	
Kappa number	48.2
Yield (unscreened), %	2.4
Screenings, %	
Brightness	
Beater or refiner	Valley
Freeness	300 CSF
Breaking length, m	8 700
Burst factor	58
Tear factor	80
Bleached	
Sequence	
Chemical consumption, %	
Yield on bleaching, %	
Total yield, %	
Brightness	
Beater or refiner	
Freeness	
Breaking length	
Burst factor	
Tear factor	

Additional information:

Pinus tabuliformis
(Chinese Pine)

Plantation experience

No information is available on the plantation experience of this species, although it has apparently been tried in Mauritius.

References: 29, 31

Wood characteristics

The basic density of the species is unusually high for a softwood. The data given on chemical composition do not suggest any difficulty on chemical pulping.

Pulping characteristics

The alkali requirement on sulphate pulping is in the normal range for softwoods. However, the yield of pulp is lower than usual. As regards tear factor, the pulp is similar to Scandinavian pine sulphate pulp, but without the compensation of a high breaking length and burst factor. The overall strength characteristics of the pulp is accordingly below the normal requirement for softwood pulps.

Scientific name: Pinus tabuliformis (Syn. P. densata, P. sinensis var. densata)	Common name: Chinese pine Country: Mauritius	Reference: 29

Wood sample characteristics

Wood sample origin:

Sample from Curepipe, Crown Land Montille, Compartment 2, 30 years old.

Density and fibre characteristics:

Basic density, g/cm^3	0.65
Fibre length, µ*	
Fibre width, µ*	
Wall thickness, µ*	
Lumen width, µ*	
Length/width ratio	
Runkel ratio	
Flexibility ratio	

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	1.0
Solubility, %	
in water	
in 1% NaOH	
Ash, %	0.2
Lignin, %	
Holocellulose, %	72.4
Cross-Bevan cellulose, %	
Pentosans, %	8.6

Additional information:

Pulping and papermaking characteristics	
Unbleached	
Process	Sulphate
Chemical consumption, %	13.1 Na_2O
Kappa number	39
Yield (unscreened), %	42.2
Screenings, %	2.0
Brightness	
Beater or refiner	Lampén
Freeness	300 CSF
Breaking length, m	6 400
Burst factor	43
Tear factor	140
Bleached	
Sequence	
Chemical consumption, %	
Yield on bleaching, %	
Total yield, %	
Brightness	
Beater or refiner	
Freeness	
Breaking length	
Burst factor	
Tear factor	
Additional information:	

Pinus taeda
(Loblolly Pine)

Plantation experience

Indigenous to the eastern and southern U.S.A. this species grows on both poorly drained lowland flats and upland soils with abundant moisture and good drainage. It is the fastest growing species of the North American 'southern pines' and regenerates freely. It is tapped for resin, but yields are lower than those obtainable from Pinus palustris. In its natural habitat it is widely planted on the wetter sites of deforested land and used as an exotic up to about 100 miles nort of its natural limit. Successful acclimatization has been reported from eastern Australia, northern New Zealand, India, Mauritius, Malawi, Southern Rhodesia, Uganda, the Republic of South Africa and the coastal regions of Uruguay. Promising results have been obtained in trial plantations in Fiji, but the results have been less good in Kenya.

References: 31, 41, 115, 123

Wood characteristics

The basic density of the wood is in the normal range of softwoods used for pulping. The fibre length is about the average for softwoods. The available data on chemical composition do not indicate any difficulties on chemical pulping.

Pulping characteristics

The species is easily pulped by means of the sulphate process with an alkali charge in the normal range. The yield of pulp seems to be slightly above average for softwoods, but varies with age and provenance. As regards the strength properties of the pulp, the breaking length is fairly low whereas the tear factor is high. On the whole, the pulp is very similar to sulphate pulp from Douglas Fir, although of slightly lower tear strength.

Scientific name: Pinus taeda	Common name: Loblolly pine Country: Mauritius	Reference: 29

Wood sample characteristics

Wood sample origin:

Samples from Curepipe:

(a) Arboretum, 25 years old
(b) Crown Land Beard, Compartment 3, 14 years old.

Density and fibre characteristics:

Basic density, g/cm^3	(a) 0.40; (b) 0.45
Fibre length, µ*	
Fibre width, µ*	
Wall thickness, µ*	
Lumen width, µ*	
Length/width ratio	
Runkel ratio	
Flexibility ratio	

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	(a) 1.0; (b) 1.9
Solubility, %	
in water	
in 1% NaOH	
Ash, %	(a) 0.3; (b) 0.3
Lignin, %	
Holocellulose, %	(a) 68.8; (b) 63.7
Cross-Bevan cellulose, %	
Pentosans, %	(a) 10.7; (b) 12.3

Additional information:

Pulping and papermaking characteristics

Unbleached	25 years old	14 years old
Process	Sulphate	Sulphate
Chemical consumption, %	14.5 Na_2O	12.6 Na_2O
Kappa number	42	52
Yield (unscreened), %	53.6	49.2
Screenings, %	2.5	3.5
Brightness		
Beater or refiner	Lampén	Lampén
Freeness	300 CSF	300 CSF
Breaking length, m	8 200	5 600
Burst factor	55	36
Tear factor	130	120

Bleached	
Sequence	
Chemical consumption, %	
Yield on bleaching, %	
Total yield, %	
Brightness	
Beater or refiner	
Freeness	
Breaking length	
Burst factor	
Tear factor	

Additional information:

Scientific name: Pinus taeda	Common name: Loblolly pine Country: Queensland, Australia	Reference: 131

Wood sample characteristics

Wood sample origin:

Sample from plantation at Beerburrum, butt sections from 27 and 15 years old trees. Composite sample.

Density and fibre characteristics:

Basic density, g/cm^3	0.478
Fibre length, μ*	3 320
Fibre width, μ*	
Wall thickness, μ*	
Lumen width, μ*	
Length/width ratio	
Runkel ratio	
Flexibility ratio	

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %
- Ether
- Methanol
- Ethanol-benzene

Solubility, %
- in water
- in 1% NaOH

Ash, %
Lignin, %
Holocellulose, %
Cross-Bevan cellulose, %
Pentosans, %

Additional information:

Pulping and papermaking characteristics

Unbleached	
Process	Sulphate
Chemical consumption, %	
Kappa number	59.0 - 17.5
Yield (unscreened), %	54.5 - 45.0
Screenings, %	1.0 - 0
Brightness	
Beater or refiner	PFI
Freeness	300 CSF
Breaking length, m	8 900 - 8 200
Burst factor	74 - 62
Tear factor	165 - 165
Bleached	
Sequence	
Chemical consumption, %	
Yield on bleaching, %	
Total yield, %	
Brightness	
Beater or refiner	
Freeness	
Breaking length	
Burst factor	
Tear factor	

Additional information:

Populus betulifolia x P. trichocarpa

Plantation experience

This is an experimental hybrid which has not yet been planted on a wide scale. No information is available specifically on this hybrid.

References: 5, 39, 41, 42, 44, 45, 54, 84, 123

Wood characteristics

The lignin content of the wood is in the normal range for hardwoods used for pulping. No other characteristics are available for the present wood sample.

Pulping characteristics

The wood is easily pulped by means of the sulphate process with an alkali charge in the normal range for hardwoods. In the present case, some overcooking has occurred. In spite of this, the yield of pulp is good and would be slightly increased by pulping to a Kappa number in the region of 20. The strength properties are fairly low and are comparable to those of beech sulphate pulp, but at least a slight improvement in this respect can be expected at a somewhat higher yield.

Scientific name:	Common name:	Reference:
Populus betulifolia x P. trichocarpa	Country: Mass., U.S.A.	86

Wood sample characteristics

Wood sample origin:

Sample from plantation at Lawrence Hopkins Memorial Experimental Forest, Williamstown, Mass., 13-14 years old.

Density and fibre charaoteristics:

Basio density, g/cm^3
Fibre length, µ*
Fibre width, µ*
Wall thickness, µ*
Lumen width, µ*

Length/width ratio
Runkel ratio
Flexibility ratio

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	
Solubility, %	
in water	
in 1% NaCH	
Ash, %	
Lignin, %	24.4
Holocellulose, %	
Cross-Bevan cellulose, %	
Pentosans, %	20.4

Additional information:

Pulping and papermaking characteristics

Unbleached

Process	Sulphate
Chemical consumption, %	18 Na_2O (charge)
Kappa number	14.8
Yield (unscreened), %	52.2
Screenings, %	
Brightness (Elrepho)	28
Beater or refiner	PFI
Freeness	300 CSF
Breaking length, m	8 000
Burst factor	54
Tear factor	62

Bleached

Sequence
Chemical consumption, %
Yield on bleaching, %
Total yield, %

Brightness

Beater or refiner
Freeness
Breaking length
Burst factor
Tear factor

Additional information:

Populus ciliata

Plantation experience

The species is indigenous to the Himalayas where it grows at 1 200-3 000 m altitude. It is planted in Burma, India and Pakistan and has proved to be drought-hardy and fairly frost-resistant.

References: 5, 39, 41, 42, 43, 44, 45, 54, 84, 123

Wood characteristics

The fibres are of average length for hardwoods and fairly wide. The lignin content is around average and none of the chemical characteristics imply any difficulty on pulping.

Pulping characteristics

The wood is easily pulped by means of the sulphate process with an alkali charge in the normal range for hardwoods. The yield of pulp is good. However, the strength properties are lower than average and do not even reach the level of beech sulphate pulp.

Scientific name: Populus ciliata	Common name: Country: India	Reference: 63

Wood sample characteristics

Wood sample origin:

Sample from natural forest in Kulu, 31 years old.

Density and fibre characteristics:

Basic density, g/cm^3	
Fibre length, μ*	1 140
Fibre width, μ*	24
Wall thickness, μ*	
Lumen width, μ*	
Length/width ratio	48
Runkel ratio	
Flexibility ratio	

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	1.12
Methanol	
Ethanol-benzene	2.31
Solubility, %	
in water	3.51
in 1% NaOH	20.1
Ash, %	1.24
Lignin, %	25.3
Holocellulose, %	
Cross-Bevan cellulose, %	62.8
Pentosans, %	17.8

Additional information:

Pulping and papermaking characteristics	
Unbleached	
Process	Sulphate
Chemical consumption, %	15.0 - 18.0 Na_2O (charge)
Kappa number	
Yield (unscreened), %	57.5 - 51.5
Screenings, %	
Brightness	
Beater or refiner	
Freeness	
Breaking length, m	
Burst factor	
Tear factor	
Bleached	
Sequence	HEH
Chemical consumption, %	9.7 - 7.1 Cl
Yield on bleaching, %	
Total yield, %	53.0 - 48.0
Brightness (Photovolt)	72 - 77
Beater or refiner	Lampén
Freeness	300 CSF
Breaking length	7 100 - 4 000
Burst factor	44 - 23
Tear factor	73 - 36
Additional information:	

Populus deltoides x P. caudina

Plantation experience

This is an experimental hybrid which has not as yet been planted on a wide scale. No information is available specifically on this hybrid.

References: 5, 39, 41, 42, 44, 45, 54, 84, 123

Wood characteristics

The lignin content is in the normal range for hardwoods used for pulping. No other characteristics are available for the present wood sample.

Pulping characteristics

In spite of the low Kappa number arrived at the sulphate process has given pulp with a good yield with an alkali charge in the normal range for hardwoods. With a lower alkali charge and cooking to a Kappa number of about 20, the yield would be increased. At the same time there would be an improvement in the strength properties which, as given, are below normal for poplar pulp requirements, with the exception of the burst factor. A pulp, similar to beech sulphate pulp could possibly be obtained from this species if over-cooking were avoided.

Scientific name: Populus deltoides x P. caudina	Common name: Country: Mass., U.S.A.	Reference: 86

Wood sample characteristics

Wood sample origin:

Sample from plantation at Lawrence Hopkins Memorial Experimental Forest, Williamstown, Mass., 13-14 years old.

Density and fibre characteristics:

Basic density, g/cm^3	
Fibre length, μ*	
Fibre width, μ*	
Wall thickness, μ*	
Lumen width, μ*	
Length/width ratio	
Runkel ratio	
Flexibility ratio	

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	2.8
Solubility, %	
in water	
in 1% NaOH	
Ash, %	
Lignin, %	26.8
Holocellulose, %	
Cross-Bevan cellulose, %	
Pentosans, %	21.4

Additional information:

Pulping and papermaking characteristics

Unbleached	
Process	Sulphate
Chemical consumption, %	18 Na_2O (charge)
Kappa number	12.8
Yield (unscreened), %	52.2
Screenings, %	
Brightness (Elrepho)	27
Beater or refiner	PFI
Freeness	300 CSF
Breaking length, m	7 300
Burst factor	55
Tear factor	63
Bleached	
Sequence	
Chemical consumption, %	
Yield on bleaching, %	
Total yield, %	
Brightness	
Beater or refiner	
Freeness	
Breaking length	
Burst factor	
Tear factor	

Additional information:

Populus x euramericana cv. eugenei

Plantation experience

This hybrid is probably a cross of P. x euramericana cv, regenerata x P. nigra italica. It is little known outside the United Kingdom, although it has been introduced elsewhere. It thrives on dryish soils.

References: 5, 39, 41, 42, 43, 44, 45, 54, 84, 123

Wood characteristics

No information as regards basic density or fibre characteristics is available for the present sample. As to the chemical composition, the lignin content is fairly low, although still in the normal range.

Pulping characteristics

The species is easily pulped with a fairly low but still normal charge of alkali in the sulphate process. The yield of pulp is good. The strength properties are a good example of good-quality poplar sulphate pulp.

The sodium sulphite process gives a good poplar sulphite pulp with a good yield.

Scientific name: Populus x euramericana cv. eugenei	Common name: Country: New Zealand	Reference: 125

Wood sample characteristics

Wood sample origin:

Sample from plantation at Rotorua, 28 years old.

Density and fibre characteristics:

Basic density, g/cm^3
Fibre length, µ*
Fibre width, µ*
Wall thickness, µ*
Lumen width, µ*

Length/width ratio
Runkel ratio
Flexibility ratio

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	2.9
Ethanol-benzene	
Solubility, %	
in water	
in 1% NaOH	
Ash, %	
Lignin, %	20.6
Holocellulose, %	
Cross-Bevan cellulose, %	50.6
Pentosans, %	15.4

Additional information:

Pulping and papermaking characteristics

Unbleached		
Process	Sulphate	Na-bisulphite
Chemical consumption, %	14.0 - 16.0 Na_2O*	10.6 SO_2*
Kappa number	17 - 19	28 - 33
Yield (unscreened), %	55.7 - 54.6	57.9 - 57.8
Screenings, %	0.2 - 0.1	0.2 - 0.4
Brightness		
Beater or refiner	PFI	PFI
Freeness	420 CSF	280 CSF
Breaking length, m	11 200 - 10 600	9 100 - 9 300
Burst factor	84 - 77	64 - 67
Tear factor	110	85 - 91
Bleached		
Sequence		
Chemical consumption, %		
Yield on bleaching, %		
Total yield, %		
Brightness		
Beater or refiner		
Freeness		
Breaking length		
Burst factor		
Tear factor		

Additional information:

* Charge.

Populus x euramericana cv. regenerata

Plantation experience

This is a collective name for several female hybrid clones in France, Belgium, the Netherlands, the United Kingdom and Germany. It is probably a result from the cross P. nigra x P. euramericana cv. serotina. Some of the forms are highly susceptible to weeping canker and the clones must be chosen carefully.

The species is well suited to moist, marshy and peaty soils as well as to acid soils. It appears to be inadequately resistant to drought and sea winds.

References: 5, 39, 41, 42, 43, 44, 45, 54, 84, 123

Wood characteristics

No information is available on fibre characteristics or basic density of the present sample. As regards the chemical composition, the lignin content is fairly low, but still in the normal range for hardwoods.

Pulping characteristics

The species is easily pulped by means of the sulphate process with a fairly low alkali charge. In the present sample some over-cooking has occurred, but the pulp is still obtained with a good yield. As regards the strength properties, which are good, the pulp is a typical example of good-quality poplar sulphate pulp.

Good quality hardwood sodium sulphite pulp can also be prepared from this species with a good yield.

Scientific name: Populus x euramericana cv. regenerata	Common name: Country: New Zealand	Reference: 125

Wood sample characteristics

Wood sample origin:

Sample from plantation at Rotorua, 28 years old

Density and fibre characteristics:

Basic density, g/cm^3
Fibre length, µ*
Fibre width, µ*
Wall thickness, µ*
Lumen width, µ*

Length/width ratio
Runkel ratio
Flexibility ratio

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	2.9
Ethanol-benzene	
Solubility, %	
in water	
in 1% NaOH	
Ash, %	
Lignin, %	19.8
Holocellulose, %	
Cross-Bevan cellulose, %	51.4
Pentosans, %	15.8

Additional information:

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Pulping and papermaking characteristics

<u>Unbleached</u>

Process	Sulphate	Na-bisulphite	
Chemical consumption, %	14.0 - 16.0 Na_2O*	10.6 SO_2*	
Kappa number	13 - 12	26 - 88	
Yield (unscreened), %	55.8 - 52.4	55.6 - 67.8	
Screenings, %	0.2 - 0.1	0.2 - 4.8	
Brightness			
Beater or refiner	PFI	PFI	
Freeness	465 CSF	496	650 (Kappa 88)
Breaking length, m	10 400 - 9 700	8 100	7 500
Burst factor	78 - 71	50	48
Tear factor	115	96	93

<u>Bleached</u>

Sequence
Chemical consumption, %
Yield on bleaching, %
Total yield, %

Brightness

Beater or refiner
Freeness
Breaking length
Burst factor
Tear factor

Additional information:

Populus x euramericana cv. robusta

Plantation experience

This is considered to be a hybrid between P. deltoides angulata and P. nigra plantierensis. It grows in fairly light and dry soils as well as in acid soils, but does not adapt well to moist and badly drained sites. It is widely cultivated in France, Belgium, Germany, the United Kingdom and is distributed throughout the world in the 'poplar belt'.

References: 5, 39, 41, 42, 43, 44, 45, 54, 84, 123

Wood characteristics

The basic density of the wood is fairly low although not to an extent to lower the tonnage capacity of digesters. The fibres are of average length for hardwoods, fairly thick and thin-walled, which implies a certain degree of flexibility and thus a potential for good inter-fibre bonding in paper. The lignin content is fairly low, but still in the normal range for hardwoods.

Pulping characteristics

The species is easily pulped by means of the sulphate process with an alkali charge which apparently should be fairly low. In the present case some over-cooking has occurred although the pulp is still obtained with a good yield. The strength properties are around the average for hardwood sulphate pulps, but would probably be slightly improved by less severe pulping conditions.

The overall quality of the pulp would probably correspond to good-quality poplar sulphate pulp.

The sodium sulphite process gives a good hardwood sulphite pulp with a good yield.

Scientific name: Populus x euramericana cv. robusta	Common name: Country: New Zealand	Reference: 125

Wood sample characteristics

Wood sample origin:

Sample from plantation at Rotorua, 28 years old.

Density and fibre characteristics:

Basic density, g/cm^3	0.35
Fibre length, µ*	1 250
Fibre width, µ*	21
Wall thickness, µ*	2.5
Lumen width, µ*	16
Length/width ratio	60
Runkel ratio	0.31
Flexibility ratio	0.76

Additional information:

Tracheids and fibres, %	65
Vessels, %	31

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	2.6
Ethanol-benzene	
Solubility, %	
in water	
in 1% NaOH	
Ash, %	
Lignin, %	20.2
Holocellulose, %	
Cross-Bevan cellulose, %	52.6
Pentosans, %	15.1

Additional information:

Pulping and papermaking characteristics

Unbleached		
Process	Sulphate	Na-bisulphite
Chemical consumption, %	16.0 Na_2O*	10.6 SO_2*
Kappa number	12	39
Yield (unscreened), %	56.7 - 53.1	56.7
Screenings, %	0 - 0.1	0.4
Brightness		
Beater or refiner	PFI	PFI
Freeness	431 - 415 CSF	332 CSF
Breaking length, m	9 100 - 9 300	8 100
Burst factor	60 - 64	51
Tear factor	100	85
Bleached		
Sequence		
Chemical consumption, %		
Yield on bleaching, %		
Total yield, %		
Brightness		
Beater or refiner		
Freeness		
Breaking length		
Burst factor		
Tear factor		

Additional information:

* Charge.

Populus x euramericana cv. serotina

Plantation experience

This species is one of the oldest euramericana poplar hybrids. It grows well in clay and compact soils and is very resistant to sea winds and to canker. During early years it is susceptible to Dothichiza. It is long-lived and cultivated extensively in western Europe.

References: 5, 39, 41, 43, 44, 45, 54, 84, 123

Wood characteristics

The basic density is in the low range for hardwoods used for pulping. The fibres are of average length for hardwoods, fairly thick and thin-walled which implies a certain amount of flexibility and consequently potentially good inter-fibre bonding in paper. The lignin content is fairly low, but still in the normal range for hardwoods.

Pulping characteristics

The species is easily pulped by means of the sulphate process with an alkali charge in the normal range for hardwoods. The yield of pulp is good. The strength properties are excellent and the pulp corresponds in overall quality to Scandinavian birch sulphate pulps.

The sodium bisulphite process gives an excellent quality hardwood sulphite pulp with a good yield.

Scientific name: Populus x euramericana cv. serotina	Common name: Country: New Zealand	Reference: 125

Wood sample characteristics

Wood sample origin:

Sample from plantation at Rotorua, 28 years old.

Density and fibre characteristics:

Basic density, g/cm^3	0.37
Fibre length, µ*	1 240
Fibre width, µ*	21
Wall thickness, µ*	2.5
Lumen width, µ*	16
Length/width ratio	59
Runkel ratio	0.31
Flexibility ratio	0.76

Additional information:

Tracheids and fibres, %	65
Vessels, %	30

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	2.6
Ethanol-benzene	
Solubility, %	
in water	
in 1% NaOH	
Ash, %	
Lignin, %	20.8
Holocellulose, %	
Cross-Bevan cellulose, %	53.9
Pentosans, %	16.2

Additional information:

Pulping and papermaking characteristics

Unbleached		
Process	Sulphate	Na-bisulphite
Chemical consumption, %	16.0 Na_2O*	10.1 - 12.2 SO_2*
Kappa number	16 - 17	35 - 31
Yield (unscreened), %	53.1 - 53.9	53.1 - 55.4
Screenings, %	0.2 - 0.1	0.8 - 0.5
Brightness		
Beater or refiner	Lampén	Lampén
Freeness	520 CSF	370 CSF
Breaking length, m	11 500 - 11 300	10 000 - 9 500
Burst factor	74 - 78	67 - 56
Tear factor	95	67 - 61
Bleached		
Sequence		
Chemical consumption, %		
Yield on bleaching, %		
Total yield, %		
Brightness		
Beater or refiner		
Freeness		
Breaking length		
Burst factor		
Tear factor		

Additional information:

* Charge

Populus maximowiczii x P. trichocarpa

Plantation experience

This is an experimental hybrid which has not as yet been planted on a wide scale. No information is available specifically on this hybrid.

References: 5, 39, 41, 42, 44, 45, 54, 84, 123

Wood characteristics

The lignin and pentosan contents of the wood are in the normal range for hardwoods for pulping. No other characteristics are available for the present sample.

Pulping characteristics

The wood is easily pulped by the sulphate process with an alkali charge in the normal range for hardwoods. Although in this instance some over-cooking has occurred, the yield of pulp is still good. The strength properties are slightly below average for poplar sulphate pulps, but if the wood is cooked to a Kappa number of about 20, there would possibly be an improvement in this respect to the average poplar quality level.

Scientific name: Populus maximowiczii x P. trichocarpa	Common name: Country: Mass., U.S.A.	Reference: 86

Wood sample characteristics

Wood sample origin:

Sample from plantation at Lawrence Hopkins Memorial Experimental Forest, Williamstown, Mass., 13-14 years old.

Density and fibre characteristics:

Basic density, g/cm^3
Fibre length, μ*
Fibre width, μ*
Wall thickness, μ*
Lumen width, μ*

Length/width ratio
Runkel ratio
Flexibility ratio

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	3.4
Solubility, %	
in water	
in 1% NaOH	
Ash, %	
Lignin, %	25.1
Holocellulose, %	
Cross-Bevan cellulose, %	
Pentosans, %	19.3

Additional information:

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Pulping and papermaking characteristics

Unbleached

Process	Sulphate
Chemical consumption, %	18 Na_2O (charge)
Kappa number	13.9
Yield (unscreened), %	52.0
Screenings, %	
Brightness (Elrepho)	29
Beater or refiner	PFI
Freeness	300 CSF
Breaking length, m	8 900
Burst factor	65
Tear factor	72

Bleached

Sequence	
Chemical consumption, %	
Yield on bleaching, %	
Total yield, %	
Brightness	
Beater or refiner	
Freeness	
Breaking length	
Burst factor	
Tear factor	

Additional information:

Samanea saman
(Rain Tree)

Plantation experience

The species is native to Central America and parts of northern South America, where it grows mostly on open country but also on riversides in the forests. It is cultivated throughout the tropics as a shade-tree, particularly on roadsides. It grows fast in heavy rainfall (up to 2 500 mm per year) but tolerates also annual rainfalls as low as 75 mm.

References: 41, 123

Wood characteristics

The wood from this species is usually very hard which may cause considerable wear on chipper knives in a pulp mill. However, the basic density as given for the present sample from the Philippines is in the normal range for hardwoods used for pulping which implies that the hardness may vary with provenance and age. The fibres are fairly short but still in the normal range for hardwoods. The width of the fibres is also around the average, but the cell walls are fairly thick which may cause the fibres to be comparatively stiff and prevent proper inter-fibre bonding in paper. As regards the chemical characteristics, the extractives content is high and may require special precautions for extractives removal from the pulp. The silica content is also high and may affect the alkali recovery in alkaline processes. However, this may also be due to soil conditions on the site from which this sample has been taken.

Pulping characteristics

The wood is easily pulped by means of the sulphate process with alkali charge in the normal range for hardwoods. In view of the very low Kappa number arrived at in the present case, the yield of pulp is good. The strength properties of the pulp are below average for hardwoods and about the same as those of beech sulphate pulps. However, by pulping under less severe conditions to a Kappa number about 20, there would be an increase in yield to about 50% and at the same time there would probably be an improvement in the strength properties, perhaps to the level of average poplar sulphate pulps.

The cold soda process gives a good-quality pulp. If it is to be used in printing type papers, some bleaching treatment will be required.

Scientific name: Samanea saman	Common name: Rain Tree, Acacia Country: Philippines	Reference: 94, 95

Wood sample characteristics

Wood sample origin:

Sample from plantation in the Philippines.

Density and fibre characteristics:

Basic density, g/cm^3	0.51
Fibre length, µ*	870
Fibre width, µ*	23
Wall thickness, µ*	5.5
Lumen width, µ*	12
Length/width ratio	38
Runkel ratio	0.92
Flexibility ratio	0.52

Additional information:

* 1000 µ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	
Methanol	
Ethanol-benzene	8.7
Solubility, %	
in water	10.2
in 1% NaOH	31.9
Ash, %	2.4
Lignin, %	25.3
Holocellulose, %	
Cross-Bevan cellulose, %	
Pentosans, %	18.4
Silica	1.40

Additional information:

Pulping and papermaking characteristics

Unbleached			
Process	Sulphate	Cold Soda	
Chemical consumption, %	16.2 Na_2O	7.5 Na_2O	
Kappa number	12		
Yield (unscreened), %	47.1	82.3	
Screenings, %	0.6	3.7	
Brightness		49.5 (Tappi)	
Beater or refiner	Valley	Bauer 8" + Valley	
Freeness	350 CSF	510 CSF	300 CSF
Breaking length, m	7 600	2 600	4 600
Burst factor	63	14	25
Tear factor	81	48	48
Bleached			
Sequence			
Chemical consumption, %			
Yield on bleaching, %			
Total yield, %			
Brightness			
Beater or refiner			
Freeness			
Breaking length			
Burst factor			
Tear factor			

Additional information:

Sesbania grandiflora

Plantation experience

The species is found in abundance in several countries in south-east Asia, where it is grown traditionally among fruit-trees. Recently, however, there has been an increased interest in this species for pulpwood. It can be easily planted on a large scale and exhibits good growth characteristics.

References: 13

Wood characteristics

The fibre length is about the average for hardwoods used for pulping. The data given on chemical composition of the wood do not imply any difficulty on chemical pulping.

Pulping characteristics

The chemical consumption in the sulphate cook, due to an alkali charge on the low side for hardwoods, has been low, although the high Kappa number arrived at suggests that the charge has been insufficient. However, in spite of the high Kappa number, the yield of pulp has been low. The strength characteristics are below the normal requirements for hardwood sulphate pulps, both as unbleached and bleached.

The species does not seem suitable for the cold soda pulping process, as the resulting strength properties are very low and would probably not reach an acceptable level even with further refining.

The NSSC process gives a pulp with unacceptable strength properties for corrugating medium. However, after bleaching, with a chlorine consumption of 23-27%, a grade suitable for printing papers is obtained.

Scientific name:	Common name:	Reference:
Sesbania grandiflora	Country: India	13

Wood sample characteristics

Wood sample origin:

Samples from plantation, 4½ years old

Density and fibre characteristics:

Basic density, g/cm^3	
Fibre length, μ*	1 070
Fibre width, μ*	
Wall thickness, μ*	
Lumen width, μ*	
Length/width ratio	
Runkel ratio	
Flexibility ratio	

Additional information:

* 1000 μ (microns) = 1 mm

Chemical characteristics:

Extractives, %	
Ether	0.5
Methanol	
Ethanol-benzene	2.7
Solubility, %	
in water	6.3
in 1% NaOH	18.7
Ash, %	1.9
Lignin, %	68.2
Holocellulose, %	
Cross-Bevan cellulose, %	
Pentosans, %	15.8

Additional information:

Pulping and papermaking characteristics

Unbleached

Process	Sulphate	NSSC	Cold Soda
Chemical consumption, %	15.0 Na_2O*	8.5 SO_2*	4.0 - 4.5 Na_2O
Kappa number	43	100 - 135	
Yield (unscreened), %	48.8	70.6 - 65.0	88.6 - 78.8
Screenings, %	2.3		
Brightness (Tappi		33 - 30	36 - 30
Beater or refiner	Valley	Valley	Valley
Freeness	40 SR	40 SR	28 SR
Breaking length, m	5 000	3 500 - 3 800	1 600
Burst factor	37	24	10
Tear factor	70	40	9

Bleached

Sequence	CEHH	CEH
Chemical consumption, %	40.0 Cl	22.8 - 26.7
Yield on bleaching, %	90.7	79.8 - 79.3
Total yield, %	44.2	56.3 - 51.5
Brightness (Tappi)	72	69 - 68
Beater or refiner	Valley	Valley
Freeness	40 SR	40 SR
Breaking length	4 700	4 900 - 6 000
Burst factor	34	35 - 46
Tear factor	67	41 - 67

Additional information:

* Charge.

APPENDIX I

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APPENDIX II

DEFINITION OF TERMS USED IN THE DATA SHEETS

I. Wood sample characteristics

Basic density	The ratio of oven dry weight of the sample to its green (wet) volume
Runkel ratio	2 x fibre wall thickness/lumen width
Flexibility ratio	Lumen width/fibre width
Holocellulose	The residue after extraction and delignification, either with chlorine or chlorite. It is supposed to represent the total content of carbohydrates in the wood - cellulose + hemicellulose (non-cellulosic carbohydrates) - but usually some carbohydrates are lost during the delignification treatment and some lignin is retained.
Cross-Bevan cellulose	The residue in percent of oven dry wood after treatment with a succession of chlorine, sulphur dioxide water, sodium sulphite and a 17.5% solution of sodium hydroxide. It is an approximation of the cellulose content of the wood but can sometimes be seriously in error.

II. Pulping and papermaking characteristics

II.1. Unbleached

Processes:

Sulphate	A process of digestion of the wood with sodium hydroxide and sodium sulphide as chemicals at temperatures between 150°C and 170°C. The pulp obtained with a very low charge of chemicals and at high yield is called crude sulphate pulp.
Chemical soda	A process of digestion of the wood with sodium hydroxide alone as cooking chemical at temperatures between 90°C and 170°C.
Cold soda	A chemi-mechanical or semi-chemical process where the wood is impregnated with sodium hydroxide at ambient temperature and thereafter given a mechanical treatment in order to obtain defibration of the chips.

NSSC	A semi-chemical process, Neutral Sulphite Semi-Chemical, and as the name suggests, it comprises treatment of the wood chips with a sodium sulphite solution with an addition of sodium carbonate in order to arrive at neutral or slightly alkaline conditions. This treatment is carried out at elevated temperatures and followed by mechanical treatment.
Sodium bisulphite	A semi-chemical or chemical process with sodium bisulphite as cooking chemical is carried out at slightly acid conditions. The temperature range is usually 130-160°C. If the yield is left high, a mechanical treatment is given as a second stage (semi-chemical or high-yield bisulphite pulp)
Chip groundwood	A mechanical pulping process where defibration of the chips is obtained by means of refining in disc refiners.
Groundwood	A mechanical pulping process where defibration is achieved by grinding wood billets on a stone grinder.
Chemical consumption	The consumption of chemicals in the process expressed as percent of oven dry wood.
Kappa number	The consumption of a 0.1 N potassium permanganate solution by 1 g of pulp, under specified conditions and expressed as the consumption in ml corresponding to 50% consumption of the volume of solution added. It is a direct measure of the content of residual lignin in the pulp.
Yield (unscreened)	The yield of pulp in the process, expressed in percent of oven-dry wood.
Screenings	The amount of shives and knots in the pulps retained by a screen and expressed in percent of oven-dry wood.
Brightness	The brightness of a sheet of pulp, measured under specified conditions with a blue filter (457 nm) and expressed as reflection factor with smoked magnesium oxide as 100.

Freeness — Also called 'wetness' or 'degree of beating' it expresses how extensive the beating or refining treatment has been. Two scales are applied in this context: a) the Canadian Standard Freeness (CSF) with a graduation from 1000 to 0 and b) the Schopper Riegler (SR) value with a graduation from 1 to 100. They are not linearly related. The following table gives a rough comparison of the two scales:

CSF	SR
700	15
600	20
500	25
400	32
300	40
200	52
100	68

Breaking length — A measure of the tensile strength of the paper under standard conditions

Burst factor — A measure of the pressure at which the paper will burst as determined under standard conditions.

Tear factor — A measure of the tearing resistance of the paper under standard conditions of test.

II.2. Bleached

Sequence — A description of the stages of bleaching applied to the pulp. The following abbreviations are used:

- C Chlorination
- E Extraction with sodium hydroxide
- H Hypochlorite treatment
- D Chlorine dioxide treatment
- P Peroxide treatment
- HS Hydrosulphite (dithionite) treatment

Yield on bleaching — The yield on bleaching expressed in percent of unbleached pulp

Total yield on bleaching — The total yield of pulp after bleaching, expressed in percent of oven-dry wood

Brightness	See 'Unbleached'
Freeness	See 'Unbleached'
Breaking length	See 'Unbleached'
Burst factor	See 'Unbleached'
Tear factor	See 'Unbleached'

APPENDIX III

LIST OF SPECIES EVALUATED FOR PULPING CHARACTERISTICS