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PULPING CHARACTERISTICS OF *PINUS PATULA* GROWN IN ZIMBABWE

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Summaries

SUMMARY

Twenty trees of *Pinus patula*, growing on five sites in Zimbabwe as part of a progeny test, were examined and their pulping characteristics determined. The trees were from the same full-sib family and were 12 years old.

No relationship between site, and wood density and fibre dimensions could be inferred because the differences between trees within a site were found to be greater than the differences between sites.

All of the trees were pulped by the sulphate process: when constant digestion conditions with 18% active alkali were used, the yield of pulp from individual trees was from 41.3 to 44.9%. All of the pulps had a good tensile strength, but few had tearing strength sufficient for wrapping paper. Trees suitable for the production of pulps with high tearing strength were most likely to grow on the Grasslands site. For the twenty trees, there was a poor correlation between the rate of growth of a tree and the tearing strength of pulp produced from it; but within any one site the slowest growing tree was most likely to yield the pulp with the highest tearing strength.

RÉSUMÉ

Vingt arbres, appartenant à l'espèce *Pinus patula* et cultivés sur cinq sites au Zimbaboué dans le cadre d'une épreuve de la descendance, ont été examinés afin de définir leurs caractéristiques pour la réduction en pâte. Tous les arbres, âgés de 12 ans, appartenaient à la même famille de plein frère.

Aucune conclusion n'a été tirée à l'égard des sites entre eux, de la densité du bois et des dimensions de la fibre car les différences constatées entre les arbres d'un même site étaient plus grandes que celles constatées entre les sites.

Tous les arbres ont été réduits en pâte par le procédé au sulphate; lorsqu'on a procédé à une cuisson constante avec 18% d'alcali actif, le rendement de pâte pour chacun des arbres allait de 41,3 à 44,9%. Toutes les pâtes avait une bonne résistance à la traction, mais peu d'entre elles offraient une résistance au déchirement suffisante pour les destiner à la fabrication de papier d'emballage. Les arbres convenant à la production de pâtes offrant une résistance élevée au déchirement pourraient probablement être cultivés dans les prairies. Pour les vingt arbres examinés, l'on a constaté une faible corrélation entre le taux de croissance d'un arbre et la résistance au déchirement qu'offre la pâte produite par ce dernier; mais à l'intérieur d'un même site, l'arbre ayant le taux de croissance le plus lent donnerait probablement une pâte offrant la résistance au déchirement la plus élevée.

RESUMEN

Como parte de una prueba de progenie, se llevó a cabo el examen de 20 árboles de *Pinus patula*, cultivados en cinco emplazamientos de Zimbabwe, para determinar sus características de reducción a pasta. Todos los árboles procedían de la misma familia, con 'plena consanguinidad', y tenían 12 años.

No resulta posible deducir relación alguna entre emplazamiento, densidad de la madera y dimensiones de las fibras, debido a que las diferencias observadas entre los árboles del mismo emplazamiento resultaron ser superiores a las diferencias entre emplazamientos.

Todos los árboles fueron reducidos a pulpa siguiendo el método de reducción al bisulfito. Cuando se utilizaron condiciones constantes de digestión con álcali activo al 18%, el rendimiento de pasta de árboles individuales varió entre 41,3 y 44,9%. Si bien todas las pastas mostraron buena resistencia a la tracción, un número reducido poseía suficiente resistencia al desgarro para su utilización como papel de envolver. Los árboles apropiados para la producción de pastas con elevada resistencia al desgarro se encontraban con mayor probabilidad en el emplazamiento de pastizales. Se obtuvo una pobre correlación entre el índice de crecimiento y la resistencia de la pasta al desgarro para los veinte árboles examinados. Valga apuntar, sin embargo, que, dentro de un mismo emplazamiento, existía mayor probabilidad de que el árbol con crecimiento más lento produjera la pasta con la más alta resistencia al desgarro.

Pulping Characteristics of *Pinus patula* Grown in Zimbabwe

INTRODUCTION

In a series of progeny tests in Zimbabwe, described by Barnes and Schweppenhauser (1979), a single full-sib family of 12-year old *Pinus patula* was planted at five sites over an altitudinal range of 700 m to 2,135 m.

Determinations of wood density, using cores taken from trees growing on different sites, had shown considerable difference in the mean density between sites and the edaphic conditions were a contributory factor in causing the variation. The Overseas Development Natural Resources Institute (ODNRI) was asked to examine selected trees from each site to determine the effect of growing conditions on the production and quality of papermaking pulps.

GROWING CONDITIONS

The climatic conditions and soil characteristics at each of the five sites are summarised in Table 1.

SAMPLING

Four trees were sampled from each site. The trees were selected so that two trees were near the average diameter for the trees on the site, one near the minimum and one near the maximum diameter. The length of the bole of each tree from the butt to a diameter of 8 cm over bark was determined and sampling points marked at 10, 30, 50 and 70% of this length. Discs, each approximately 20 mm thick, were cut from each sampling point; for each individual tree the number of discs from each sampling point was the same. However, the numbers taken from different trees varied; more discs were taken from small trees than from large.

GROWTH RATE

The height and diameter at breast height of each tree sampled is recorded in Table 2. The shortest trees were found at Nyangui and the tallest at Grasslands; trees with the smallest diameter were found at Stapleford and those with the largest diameter at Chiwengwa.

There appeared to be no correlation between height and diameter of trees. The differences in diameter between sites were small and not significant, because the difference between trees on any one site was greater than the differences of average diameters between sites.

EXPERIMENTAL PROCEDURES, RESULTS AND DISCUSSION

All evaluations were carried out as prescribed in the appropriate International and British Standard Methods or the standards published by the Technical Association of the [USA] Pulp and Paper Industry (TAPPI).

Wood density was determined by a water displacement technique and recorded as oven-dry weight/green volume. Fibre dimensions were determined using a well-cooked sulphate pulp by direct measurement of the magnified image and, for length, by McNett classification. All samples were digested by the sulphate process and the resultant pulps were evaluated by forming sheets on a British Standard sheet machine and testing after conditioning in an atmosphere maintained at $23 \pm 1°C$, $50 \pm 2\%$ relative humidity. Full details of experimental procedures are given in ODNRI Bulletin No. 7 (Palmer *et al.*, 1988).

Apparent Wood Density

The density (oven-dry weight/green volume), determined using one disc from each sampling point, is reported in Table 3.

The least dense tree came from the site at Martin; the most dense from Grasslands. However, no influence of site on wood density could be inferred since the difference between trees on any one site was as great as the difference between the average density for different sites. There was an indication that trees with smaller diameters had wood of higher density, but the evidence was not conclusive and more intense sampling would be required before a definitive conclusion could be drawn.

The wood from upper parts of the tree had a lower density than that from lower parts. This factor might have a significant effect on the quality of wood pulp if, in multiple-use forestry, the lower parts of a tree were used for timber and the upper parts for pulp.

The density of temperate pines commonly used in the pulping industry is between 340 and 560 kg/m^{-3} (Rydholm, 1965); all of these samples of *P. patula* were towards the lower end of this range.

Fibre Dimensions

The length, width and wall thickness of the fibres (tracheids) in a well-cooked sulphate pulp are reported in Table 4.

All of the trees yielded pulps with fibres between 2.4 and 3.0 mm long and 29 and 45 μm wide. These values are in the same range as those reported for *P. patula* grown in Kenya (Palmer *et al.*, 1982) and Tanzania (Palmer *et al.*, 1984). The differences between the dimensions of fibres in pulps from trees on any one site were as great as the differences between sites, and it was not possible to detect the influence of site on fibre dimensions determined by direct measurement. However, use of classification techniques showed that all the trees on the Martin and Grassland sites and two trees on the Chiwengwa site yielded pulps with a large proportion of long, coarse fibres.

Chemical Analysis

Those chemical components which influence pulping by the sulphate process are reported for each tree in Table 5.

All of the trees on the Chiwengwa site and one (tree 2) on the Nyangui site had a higher resin content. The lignin content, between 25 and 28%, is a little lower, and the alpha cellulose, between 39 and 43%, within the range, of values reported for samples from Kenya and Tanzania (Palmer *et al.*, 1982; 1984). Samples with the composition reported were not expected to present any problems when pulped by the sulphate process.

Sulphate Pulping and Pulp Evaluation

Each tree was pulped by the sulphate process, in which the active chemicals are sodium hydroxide and sodium sulphide using three levels of alkali charge. Each digestion was duplicated and the values reported are the average of two determinations.

Details of pulping conditions and a summary of pulp properties are presented in Table 6, for Stapleford site; Table 7, Martin; Table 8; Chiwengwa; Table 9, Nyangui; and Table 10, Grasslands. Detailed pulp evaluation data are given in Table 11, for Stapleford site; Table 12, Martin; Table 13, Chiwengwa; Table 14, Nyangui; and Table 15, Grasslands.

All of the trees were digested without difficulty. There were significant differences in pulp yield and lignin content of pulp between sites. Trees from Chiwengwa yielded from 41.3 to 42.5% of pulp when digested using 18% active alkali; those from Martin between 44.4 and 44.9%. The low yield of pulp from Chiwengwa-grown trees was associated with their high resin content. The kappa number is an indirect measure of the lignin content of pulp: using 18% active alkali, trees from Martin yielded pulps with kappa numbers between 28 and 33; those from Stapleford between 34 and 38. This indicates that trees from Martin require lower concentrations of chemical for digestion.

Pulps from pine species are most frequently used for the production of strong wrapping and sack papers. The strength criteria determining the suitability of a pulp for this purpose are: sack kraft – tensile index over 60 N m g^{-1}, tear index over 14 mN m^2g^{-1}; wrapping paper – tensile index over 45 N m g^{-1}, tear index over 12.5 mN m^2g^{-1}. All of the pulps produced exceeded the tensile strength requirement. Therefore the tearing strength is the most critical factor in determining suitability, and only tree 4 from Martin and trees 1, 2 and 3 from Grasslands yielded pulps likely to be appropriate for wrapping paper.

The pulp with the highest tearing strength was obtained from most trees when pulped with 18% active alkali. To illustrate the influence of site the average tear index for all the trees on each site was calculated and the results are shown in Figure 1. It was clear that the trees from Grassland yielded pulps with the highest tearing strength. The tearing strength of pulps from individual trees from Grassland are shown in Figure 2 and tree 3 was shown to give the highest values. The only other tree to yield pulps with tearing strength comparable with that of pulps from Grasslands was tree 4 from Martin (see Figure 3).

Tree 3 was the tree on Grasslands with the smallest diameter: tree 4 was the tree on Martin with the smallest diameter. The trees with the smallest diameter from Stapleford and Chiwengwa yielded the pulps with the highest tearing strength for their respective sites. From these observations it would appear that slower growth is associated with high tearing strength, but at the same time there is no evidence that fastest growth is associated with lowest tearing strength.

CONCLUSIONS

1 Although between the trees examined there were differences in growth rate, wood density and fibre dimensions, no relationship with site can be inferred since the difference between trees on any one site was greater than the difference between sites.

2 The chemical composition of the trees showed that all were suitable for pulping by the sulphate process. The only significant difference between the trees was that all from Chiwengwa and one from Nyangui had relatively high resin content, and these five trees were found to give low yields of pulp.

3 There were significant differences in pulp yield between trees and sites.

4 All the trees yielded pulps with tensile strengths high enough to make them suitable for use in wrapping and sack grades of paper; however, few had tearing strengths high enough for this use. The pulps with the highest tearing strength were obtained from trees growing at Grasslands and one tree growing at Martin.

5 On four sites the tree with the smallest diameter yielded pulp with the highest tearing strength for that site; in three cases this was the tree with the highest wood density.

6 The results show that even with fully related trees, site had a major effect on the quality of pulp produced and there was significant variation between trees on one site. Whilst growth rate and wood density would be useful guides in selecting trees within any one site, they would not be helpful in selection from all twenty trees.

7 As a consequence of different sampling techniques, the results reported here are not directly comparable with those reported for *P. caribaea* grown in Zimbabwe (Palmer *et al.*, 1988). However, the tearing strengths of pulps obtained from *P. caribaea* grown at Chiwengwa were so much higher than those of pulps obtained from *P. patula*, it is concluded that *P. patula* should not be grown for pulpwood at low altitudes.

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Table 1

Pinus patula progeny test: site conditions

Site	Location			Mean temperature, °C			Mean annual rainfall, mm	Rain days	Evaporation mm	Soil
	Latitude	Longitude	Altitude, m	Maximum	Minimum	Annual				
Stapleford	18°41′S	32°48′E	1,740	19.2	11.1	15.1	1,820	140	1,100	Doleritic sandy clay loam becoming gravelly below 0.5 m depth; good drainage
Martin	19°45′S	32°57′E	1,250	22.9	12.6	17.7	1,080	125	1,480	Dark red clay loam derived from lower Arigillaceous sillstones and shales
Chiwengwa	18°41′S	32°55′E	700	28.4	13.0	20.7	1,500	110	1,270	Dolerite/granite contact; unobstructed sandy clay loam to depth of 1.0 m; free draining
Nyangui	18°01′S	35°46′E	2,135	18.4	9.0	13.9	1,528	115	1,197	Very shallow sandy loam over multifractured shale at about 0.3 m depth
Grasslands	18°10′S	31°30′E	1,646	23.5	10.7	17.1	885	90	1,733	Granitic sandy loam to good depth; good drainage

Table 2

Pinus patula progeny test: size of trees

Site	Tree identity	Height m	Diameter bhob* cm
Stapleford	1	19.8	21.6
	2	18.3	21.8
	3	20.7	24.1
	4	17.9	19.0
Martin	1	20†	23.0
	2	19†	22.2
	3	22†	28.0
	4	18†	18.0
Chiwengwa	1	17.5	25.7
	2	18.1	25.1
	3	17.1	18.7
	4	16.2	27.2
Nyangui	1	15.7	23.1
	2	17.2	22.3
	3	15.1	23.8
	4	15.0	21.3
Grasslands	1	19.1	21.8
	2	22.9	22.6
	3	19.8	18.9
	4	19.8	24.4

Notes: * bhob = breast height over bark
† Estimates

Table 3

Pinus patula progeny test: density of trees and logs at various heights

Site	Tree identity	Density, kg m^{-3}				
		Height, %				
		10	30	50	70	Tree mean
Stapleford	1	410	367	359	364	383
	2	370	348	339	362	356
	3	347	326	321	326	334
	4	368	342	331	334	349
Martin	1	340	322	294	288	319
	2	335	310	295	296	315
	3	337	318	304	287	322
	4	450	354	328	309	383
Chiwengwa	1	409	357	347	370	375
	2	413	398	392	382	401
	3	432	411	370	391	408
	4	–	–	–	–	380
Nyangui	1	367	343	329	326	348
	2	416	359	366	394	387
	3	370	359	344	361	361
	4	354	376	327	378	358
Grasslands	1	432	374	346	329	385
	2	436	389	353	354	395
	3	478	428	399	370	436
	4	397	373	348	346	373

Table 4

Pinus patula progeny test: fibre dimensions by projection and McNett classification of sulphate pulps

Site	Tree identity	Fibre dimensions by projection: Length, mm: All fibres	Fibre dimensions by projection: Length, mm: Whole fibres	Fibre dimensions by projection: Width μm	Fibre dimensions by projection: Wall thickness μm	Fibre weight fractions by classification, %: Passed aperture, μm / Retained on aperture, μm: – 1,680	1,680 1,190	1,190 841	841 595	595 420	420 210	210 74	74* –	Calculated fibre length by classification, mm
Stapleford	1	1.87 (0.07)†	2.49 (0.08)	38.82 (0.99)	4.68 (0.13)	10.1	29.3	19.7	13.5	12.3	9.7	2.5	2.8	2.45
	2	1.94 (0.06)	2.62 (0.08)	36.74 (1.06)	4.02 (0.14)	16.8	26.1	20.8	10.8	10.5	9.2	2.5	3.4	2.54
	3	2.04 (0.07)	2.47 (0.09)	42.99 (1.11)	4.40 (0.15)	26.0	24.4	18.2	8.0	10.7	7.5	2.0	3.2	2.69
	4	1.82 (0.06)	2.37 (0.08)	39.07 (1.06)	4.38 (0.15)	23.8	27.1	18.5	8.4	8.6	8.0	2.0	3.7	2.68
Martin	1	1.81 (0.07)	3.11 (0.10)	38.86 (1.11)	3.92 (0.13)	39.2	18.9	14.9	7.1	7.6	7.0	2.0	3.4	2.86
	2	2.33 (0.07)	3.01 (0.10)	38.05 (0.94)	4.83 (0.15)	37.7	19.6	15.8	7.2	7.7	7.2	2.0	2.8	2.84
	3	2.38 (0.07)	2.97 (0.07)	40.46 (1.04)	4.18 (0.17)	33.8	21.9	16.9	7.2	8.5	6.5	2.0	3.3	2.80
	4	2.17 (0.06)	2.72 (0.08)	40.08 (0.83)	4.09 (0.14)	33.2	18.5	17.5	7.4	9.3	8.6	2.4	3.1	2.73
Chiwengwa	1	2.29 (0.08)	2.79 (0.07)	38.76 (0.92)	4.04 (0.09)	7.5	37.7	22.7	8.5	9.3	8.0	2.9	3.3	2.52
	2	1.41 (0.05)	2.36 (0.10)	29.43 (1.05)	4.01 (0.11)	37.1	21.8	14.0	7.5	7.7	6.8	2.1	3.0	2.85
	3	2.26 (0.07)	2.87 (0.08)	38.79 (0.87)	4.42 (0.15)	30.0	25.2	15.9	7.5	7.4	8.3	2.6	3.2	2.76
	4	2.12 (0.06)	2.70 (0.07)	41.80 (0.89)	3.80 (0.11)	8.8	33.6	21.6	9.4	10.7	8.9	3.1	3.9	2.47
Nyangui	1	1.74 (0.05)	2.48 (0.09)	39.21 (0.93)	4.04 (0.11)	14.1	29.7	20.3	11.3	10.9	8.0	1.9	3.8	2.54
	2	1.89 (0.06)	2.59 (0.08)	38.32 (1.16)	4.39 (0.12)	8.2	32.2	20.6	12.8	11.8	8.4	2.2	3.9	2.45
	3	2.08 (0.05)	2.56 (0.06)	44.65 (0.90)	3.89 (0.10)	8.5	31.8	22.2	12.1	12.0	8.7	2.1	2.6	2.48
	4	2.12 (0.06)	2.64 (0.08)	43.18 (0.89)	3.89 (0.11)	15.6	25.1	20.7	10.9	11.2	10.0	2.9	3.6	2.49
Grasslands	1	1.99 (0.06)	2.57 (0.09)	34.88 (0.94)	3.90 (0.10)	33.8	19.3	16.0	10.0	9.0	6.8	2.1	3.0	2.77
		2.23 (0.07)	2.93 (0.09)	35.01 (1.01)	4.81 (0.15)	43.4	19.6	12.6	5.5	7.2	6.1	1.9	3.7	2.93
	3	2.17 (0.07)	2.70 (0.09)	37.15 (0.83)	4.22 (0.15)	35.6	17.2	16.3	8.4	10.0	8.2	2.0	2.5	2.77
	4	2.05 (0.06)	2.64 (0.08)	44.39 (0.96)	4.09 (0.13)	23.8	22.6	17.9	10.7	11.3	8.2	2.0	3.6	2.62

Notes: * By difference

† Figures in brackets are the standard error of the mean determination

Table 5

Pinus patula progeny test: chemical analysis

Site	Tree identity	Cold water solubles	Hot water solubles	1% NaOH solubles	Ethanol-benzene solubles	Total solubles*	Lignin	Holo-cellulose	Alpha-cellulose
Stapleford	1	2.3	2.6	12.3	1.9	3.6	25.9	62.0	41.2
	2	3.1	3.2	13.7	2.5	4.5	26.5	60.1	40.4
	3	3.0	2.7	12.6	1.7	3.8	25.9	61.4	42.2
	4	3.0	3.0	14.7	2.1	4.1	26.3	61.2	40.7
Martin	1	3.0	2.8	12.7	1.4	3.5	26.6	63.5	40.7
	2	2.3	2.3	12.5	1.5	2.7	27.3	64.0	40.8
	3	2.4	2.5	13.0	1.6	2.9	27.0	62.2	40.9
	4	2.1	2.4	11.9	1.2	2.7	27.4	62.6	41.8
Chiwengwa	1	3.3	4.4	19.0	6.2	7.8	25.6	57.6	39.0
	2	3.9	4.0	17.2	6.4	8.1	25.1	59.4	40.6
	3	2.5	3.2	15.0	5.0	5.8	26.3	60.1	40.9
	4	2.8	3.1	15.3	3.4	4.6	26.7	59.9	41.8
Nyangui	1	2.7	3.0	13.0	1.4	3.4	26.5	61.5	40.9
	2	3.8	4.6	16.7	5.7	7.7	25.6	58.2	39.2
	3	3.4	3.7	14.8	1.8	4.3	26.6	59.2	40.5
	4	2.1	2.8	12.7	1.6	2.9	27.3	60.5	41.9
Grasslands	1	2.0	2.5	13.5	1.7	3.2	26.3	62.5	42.8
	2	2.0	2.5	12.4	1.6	3.1	26.2	63.2	42.8
	3	2.1	2.3	12.3	1.4	2.5	26.8	62.5	42.9
	4	2.3	2.8	13.4	2.1	3.2	27.7	60.5	41.2

Note: All values expressed as percentage oven-dry solubles or component on oven-dry unextracted sample

* Successive extractions in ethanol-benzene, ethanol and hot water to prepare an extractive-free sample for subsequent examination

Table 6

Pinus patula progeny test, site Stapleford: sulphate digestion conditions, pulp yield and evaluation

	Drainability CSF	Tree 1			Tree 2		
Cook number		MK861	MK869	MK885	MK863	MK871	MK887
Digestion conditions							
Active alkali as Na_2O on oven-dry wood, %		16.0	18.0	20.0	16.0	18.0	20.0
Sulphidity, %		25	25	25	25	25	25
Liquor to oven-dry wood ratio		5:1	5:1	5:1	5:1	5:1	5:1
Maximum temperature, °C		170	170	170	170	170	170
Time to reach maximum temperature, h		1	1	1	1	1	1
Time at maximum temperature, h		4	4	4	4	4	4
Chemical consumption							
Active alkali consumed as Na_2O on oven-dry wood, %		12.6	13.6	14.4	12.9	14.2	14.3
Yield of pulp							
Yield of oven-dry digested pulp on oven-dry wood, %		47.8	44.9	42.6	46.6	43.3	41.5
Yield of oven-dry screened pulp on oven-dry wood, %		45.4	44.4	42.6	43.5	42.5	41.3
Yield of oven-dry screenings on oven-dry digested pulp, %		5.1	1.0	0.2	6.6	1.8	0.4
Pulp evaluation							
Kappa number		43.9	34.0	25.0	47.7	36.7	27.0
Beating, revs	500	5,800	5,510	5,200	5,790	5,080	4,850
	300	9,560	8,760	8,210	10,350	9,520	8,780
Apparent density, g cm^{-3}	500	0.72	0.73	0.73	0.76	0.76	0.76
	300	0.75	0.75	0.76	0.79	0.80	0.79
Tensile index, N m g^{-1}	500	91.1	88.7	86.9	102	97.7	95.1
	300	95.0	97.2	93.9	103	104	103
Tensile energy absorption index, mJ g^{-1}	500	1,780	1,760	1,790	2,220	2,030	2,130
	300	1,910	1,840	1,850	2,390	2,330	2,270
Tear index, mN m^2 g^{-1}	500	10.2	10.6	10.8	9.00	9.03	9.66
	300	9.93	9.84	10.2	8.27	8.09	8.99
Burst index, kPa m^2 g^{-1}	500	5.91	5.80	5.53	6.77	6.51	6.29
	300	6.15	6.26	5.98	7.23	7.07	6.75
Folding endurance, $\log_{10}n$*	500	2.95	2.95	2.97	3.05	3.07	3.05
	300	2.96	2.99	2.97	3.14	3.10	3.08
Air resistance, s	500	12	14	16	23	30	34
	300	120	120	130	160	180	220

Table 6 *(continued)*

Pinus patula progeny test, site Stapleford: sulphate digestion conditions, pulp yield and evaluation

	Drainability CSF	Tree 3			Tree 4		
Cook number		9	20	29	7	14	16
Digestion conditions							
Active alkali as Na_2O on oven-dry wood, %		16.0	18.0	20.0	16.0	18.0	20.0
Sulphidity, %		25	25	25	25	25	25
Liquor to oven-dry wood ratio		5:1	5:1	5:1	5:1	5:1	5:1
Maximum temperature, °C		170	170	170	170	170	170
Time to reach maximum temperature, h		1	1	1	1	1	1
Time at maximum temperature, h		4	4	4	4	4	4
Chemical consumption							
Active alkali consumed as Na_2O on oven-dry wood, %		13.2	13.9	14.1	13.2	13.8	14.4
Yield of pulp							
Yield of oven-dry digested pulp on oven-dry wood, %		48.0	45.9	43.1	48.3	45.2	43.3
Yield of oven-dry screened pulp on oven-dry wood, %		43.8	44.4	42.8	43.3	43.5	42.8
Yield of oven-dry screenings on oven-dry digested pulp, %		8.9	3.3	0.6	10.3	3.8	1.2
Pulp evaluation							
Kappa number		44.7	37.6	26.1	46.3	36.2	28.8
Beating, revs	500	6,470	5,760	6,150	5,900	5,510	5,010
	300	10,590	9,760	9,790	9,470	9,330	8,540
Apparent density, g cm^{-3}	500	0.74	0.72	0.74	0.72	0.72	0.72
	300	0.76	0.76	0.77	0.75	0.75	0.75
Tensile index, N m g^{-1}	500	102	100	94.2	101	101	98.8
	300	103	103	102	105	104	106
Tensile energy absorption index, mJ g^{-1}	500	2,100	2,000	1,850	2,140	1,950	1,860
	300	2,160	2,160	2,000	2,060	2,030	2,110
Tear index, mN m^2 g^{-1}	500	9.96	10.1	10.2	10.1	10.5	10.5
	300	9.19	9.51	9.36	9.29	9.97	9.76
Burst index, kPa m^2 g^{-1}	500	6.45	6.41	6.21	6.49	6.46	6.20
	300	6.77	6.61	6.55	6.81	6.86	6.59
Folding endurance, $\log_{10}n$*	500	3.01	2.99	3.03	2.98	2.98	2.99
	300	3.05	3.00	3.06	3.00	3.02	2.99
Air resistance, s	500	23	25	36	21	20	23
	300	190	190	250	180	170	180

Note: * n = number of double folds

Table 7

Pinus patula progeny test, site Martin: sulphate digestion conditions, pulp yield and evaluation

	Drainability CSF	Tree 1			Tree 2		
Cook number		MK865	MK873	MK889	MK867	MK875	MK891
Digestion conditions							
Active alkali as Na_2O on oven-dry wood, %		16.0	18.0	20.0	16.0	18.0	20.0
Sulphidity, %		25	25	25	25	25	25
Liquor to oven-dry wood ratio		5:1	5:1	5:1	5:1	5:1	5:1
Maximum temperature, °C		170	170	170	170	170	170
Time to reach maximum temperature, h		1	1	1	1	1	1
Time at maximum temperature, h		4	4	4	4	4	4
Chemical consumption							
Active alkali consumed as Na_2O on oven-dry wood, %		12.8	13.8	13.9	12.8	13.5	14.1
Yield of pulp							
Yield of oven-dry digested pulp on oven-dry wood, %		47.1	45.0	43.0	47.4	44.9	42.7
Yield of oven-dry screened pulp on oven-dry wood, %		45.9	44.8	43.0	46.2	44.6	42.6
Yield of oven-dry screenings on oven-dry digested pulp, %		2.7	0.6	0.1	2.4	0.5	0.1
Pulp evaluation							
Kappa number		37.6	30.6	22.6	39.7	30.1	22.9
Beating, revs	500	5,320	4,700	5,030	5,320	4,620	5,090
	300	9,490	8,730	8,750	8,970	8,670	8,280
Apparent density, g cm^{-3}	500	0.76	0.75	0.75	0.75	0.75	0.76
	300	0.78	0.77	0.77	0.78	0.78	0.78
Tensile index, N m g^{-1}	500	110	102	103	109	107	101
	300	113	110	106	115	112	108
Tensile energy absorption index, mJ g^{-1}	500	2,280	2,140	2,140	2,180	2,080	2,030
	300	2,420	2,360	2,170	2,370	2,120	2,090
Tear index, mN m^2 g^{-1}	500	9.70	10.2	10.3	9.68	9.69	9.02
	300	9.31	9.75	9.56	9.01	8.89	8.69
Burst index, kPa m^2 g^{-1}	500	7.40	7.19	6.80	7.37	6.97	6.67
	300	7.86	7.53	7.35	7.90	7.54	7.04
Folding endurance, $\log_{10}n$*	500	3.09	3.07	3.08	3.07	3.06	3.02
	300	3.14	3.12	3.14	3.11	3.08	3.06
Air resistance, s	500	32	31	34	29	28	30
	300	240	230	210	220	220	230

Table 7 *(continued)*

Pinus patula progeny test, site Martin: sulphate digestion conditions, pulp yield and evaluation

	Drainability CSF	Tree 3			Tree 4		
Cook number		22	24	26	31	33	35
Digestion conditions							
Active alkali as Na_2O on oven-dry wood, %		16.0	18.0	20.0	16.0	18.0	20.0
Sulphidity, %		25	25	25	25	25	25
Liquor to oven-dry wood ratio		5:1	5:1	5:1	5:1	5:1	5:1
Maximum temperature, °C		170	170	170	170	170	170
Time to reach maximum temperature, h		1	1	1	1	1	1
Time at maximum temperature, h		4	4	4	4	4	4
Chemical consumption							
Active alkali consumed as Na_2O on oven-dry wood, %		12.8	13.6	14.0	12.7	13.4	13.8
Yield of pulp							
Yield of oven-dry digested pulp on oven-dry wood, %		47.1	45.1	42.6	47.1	44.7	42.9
Yield of oven-dry screened pulp on oven-dry wood, %		45.6	44.9	42.5	45.4	44.4	42.9
Yield of oven-dry screenings on oven-dry digested pulp, %		3.1	0.6	0.1	3.7	0.6	0.1
Pulp evaluation							
Kappa number		39.8	32.5	23.0	39.6	28.7	23.7
Beating, revs	500	5,950	5,660	5,620	5,320	5,020	4,910
	300	10,480	9,970	9,710	9,420	8,520	7,750
Apparent density, g cm^{-3}	500	0.76	0.76	0.75	0.71	0.71	0.71
	300	0.79	0.79	0.78	0.74	0.74	0.74
Tensile index, N m g^{-1}	500	109	108	100	105	100	98.4
	300	112	113	110	108	103	106
Tensile energy absorption index, mJ g^{-1}	500	2,300	2,340	1,980	2,060	1,890	1,910
	300	2,560	2,520	2,210	2,300	2,150	2,090
Tear index, mN m^2 g^{-1}	500	9.87	9.64	10.0	12.1	12.6	12.4
	300	9.14	8.93	8.87	11.4	12.0	11.6
Burst index, kPa m^2 g^{-1}	500	7.31	7.06	6.76	6.92	6.59	6.48
	300	7.50	7.42	7.17	7.25	7.19	6.80
Folding endurance, $\log_{10}n$*	500	3.15	3.15	3.10	3.10	3.08	3.02
	300	3.23	3.20	3.15	3.13	3.05	3.07
Air resistance, s	500	37	36	31	17	23	23
	300	280	280	240	190	160	150

Note: * n = number of double folds

Table 8

Pinus patula progeny test, site Chiwengwa: sulphate digestion conditions, pulp yield and evaluation

	Drainability CSF	Tree 1			Tree 2		
Cook number		MK877	MK879	MK893	MK881	MK883	MK895
Digestion conditions							
Active alkali as Na_2O on oven-dry wood, %		16.0	18.0	20.0	16.0	18.0	20.0
Sulphidity, %		25	25	25	25	25	25
Liquor to oven-dry wood ratio		5:1	5:1	5:1	5:1	5:1	5:1
Maximum temperature, °C		170	170	170	170	170	170
Time to reach maximum temperature, h		1	1	1	1	1	1
Time at maximum temperature, h		4	4	4	4	4	4
Chemical consumption							
Active alkali consumed as Na_2O on oven-dry wood, %		13.0	13.6	14.0	12.9	13.5	13.8
Yield of pulp							
Yield of oven-dry digested pulp on oven-dry wood, %		44.1	41.6	40.1	43.6	41.4	39.2
Yield of oven-dry screened pulp on oven-dry wood, %		42.4	41.3	40.1	42.8	41.3	39.2
Yield of oven-dry screenings on oven-dry digested pulp, %		3.9	0.7	0.1	1.8	0.4	0.1
Pulp evaluation							
Kappa number		44.8	32.6	27.5	38.9	32.2	22.1
Beating, revs	500	5,320	4,940	4,630	5,060	5,040	5,240
	300	10,080	9,540	8,770	9,150	8,470	8,870
Apparent density, g cm^{-3}	500	0.79	0.79	0.80	0.74	0.76	0.75
	300	0.82	0.82	0.83	0.77	0.78	0.77
Tensile index, N m g^{-1}	500	101	96.3	92.2	97.5	92.2	91.7
	300	104	104	100	104	101	96.9
Tensile energy absorption index, mJ g^{-1}	500	2,450	2,260	2,110	1,960	1,890	1,850
	300	2,630	2,400	2,300	2,350	2,130	2,020
Tear index, mN m^2 g^{-1}	500	8.30	8.78	8.48	9.55	9.95	9.82
	300	8.11	7.89	7.59	9.20	9.43	9.45
Burst index, kPa m^2 g^{-1}	500	6.98	6.34	6.23	6.72	6.46	6.18
	300	7.11	7.01	6.61	7.00	6.89	6.71
Folding endurance, $\log_{10}n$*	500	3.14	3.06	3.03	3.03	2.98	2.95
	300	3.13	3.13	3.07	3.07	3.07	3.02
Air resistance, s	500	33	37	44	14	18	19
	300	260	260	300	130	150	170

Table 8 *(continued)*

Pinus patula progeny test, site Chiwengwa: sulphate digestion conditions, pulp yield and evaluation

	Drainability CSF	Tree 3			Tree 4		
Cook number		37	48	46	5	12	18
Digestion conditions							
Active alkali as Na_2O on oven-dry wood, %		16.0	18.0	20.0	16.0	18.0	20.0
Sulphidity, %		25	25	25	25	25	25
Liquor to oven-dry wood ratio		5:1	5:1	5:1	5:1	5:1	5:1
Maximum temperature, °C		170	170	170	170	170	170
Time to reach maximum temperature, h		1	1	1	1	1	1
Time at maximum temperature, h		4	4	4	4	4	4
Chemical consumption							
Active alkali consumed as Na_2O on oven-dry wood, %		12.8	13.3	13.9	13.2	14.1	14.5
Yield of pulp							
Yield of oven-dry digested pulp on oven-dry wood, %		44.3	41.6	39.5	45.3	43.0	41.0
Yield of oven-dry screened pulp on oven-dry wood, %		43.0	41.3	39.5	43.1	42.5	40.9
Yield of oven-dry screenings on oven-dry digested pulp, %		3.0	0.6	0.1	5.0	1.2	0.2
Pulp evaluation							
Kappa number		43.1	30.6	24.9	47.5	35.9	28.9
Beating, revs	500	5,940	5,680	4,990	6,340	5,440	5,330
	300	9,710	9,370	8,740	11,590	10,330	9,560
Apparent density, g cm^{-3}	500	0.74	0.72	0.73	0.78	0.79	0.79
	300	0.76	0.76	0.76	0.80	0.82	0.82
Tensile index, N m g^{-1}	500	106	99.4	96.9	100	94.1	93.4
	300	109	104	103	105	101	97.5
Tensile energy absorption index, mJ g^{-1}	500	2,100	2,060	1,930	2,530	2,470	2,520
	300	2,230	2,240	2,140	2,710	2,690	2,460
Tear index, N m^2 g^{-1}	500	10.3	10.2	10.3	9.65	10.2	9.48
	300	9.89	9.66	9.50	9.00	9.10	8.98
Burst index, kPa m^2 g^{-1}	500	6.95	6.54	5.91	6.65	6.11	5.99
	300	7.10	6.97	6.75	6.90	6.58	6.48
Folding endurance, $\log_{10}n$*	500	3.07	3.07	3.04	3.10	3.15	3.09
	300	3.08	3.09	3.08	3.12	3.20	3.13
Air resistance, s	500	19	15	16	23	33	39
	300	140	130	150	160	190	250

Note: * n = number of double folds

Table 9

Pinus patula progeny test, site Nyangui: sulphate digestion conditions, pulp yield and evaluation

	Drainability CSF	Tree 1			Tree 2		
Cook number		MK897	MK899	MK901	MK903	MK905	MK907
Digestion conditions							
Active alkali as Na_2O on oven-dry wood, %		16.0	18.0	20.0	16.0	18.0	20.0
Sulphidity, %		25	25	25	25	25	25
Liquor to oven-dry wood ratio		5:1	5:1	5:1	5:1	5:1	5:1
Maximum temperature, °C		170	170	170	170	170	170
Time to reach maximum temperature, h		1	1	1	1	1	1
Time at maximum temperature, h		4	4	4	4	4	4
Chemical consumption							
Active alkali consumed as Na_2O on oven-dry wood, %		12.9	13.6	14.0	12.5	13.6	14.9
Yield of pulp							
Yield of oven-dry digested pulp on oven-dry wood, %		47.0	44.4	42.8	45.6	42.2	40.5
Yield of oven-dry screened pulp on oven-dry wood, %		44.9	44.1	42.8	43.7	41.9	40.4
Yield of oven-dry screenings on oven-dry digested pulp, %		4.5	0.6	0.1	4.2	0.7	0.2
Pulp evaluation							
Kappa number		43.3	31.6	26.8	46.4	33.3	26.4
Beating, revs	500	5,550	5,100	5,110	5,780	5,340	4,860
	300	9,220	8,760	8,140	9,470	9,100	8,100
Apparent density, g cm^{-3}	500	0.74	0.77	0.76	0.74	0.75	0.75
	300	0.77	0.80	0.78	0.77	0.78	0.78
Tensile index, N m g^{-1}	500	101	102	96.6	98.9	95.6	94.1
	300	104	108	105	103	101	99.5
Tensile energy absorption index, mJ g^{-1}	500	2,070	2,200	2,030	2,060	1,930	1,790
	300	2,180	2,250	2,150	2,190	2,100	2,050
Tear index, mN m^2 g^{-1}	500	9.84	9.06	9.39	8.87	9.12	8.90
	300	9.25	8.44	8.88	8.27	8.66	8.42
Burst index, kPa m^2 g^{-1}	500	6.86	6.83	6.41	6.66	6.33	6.04
	300	7.18	7.31	6.98	6.25	6.61	6.47
Folding endurance, $log_{10}n$*	500	3.02	2.98	3.03	2.76	2.97	2.92
	300	3.02	3.08	3.07	3.05	3.02	2.94
Air resistance, s	500	20	36	24	16	21	20
	300	170	280	190	130	150	170

Table 9 *(continued)*

Pinus patula progeny test, site Nyangui: sulphate digestion conditions, pulp yield and evaluation

	Drainability CSF	Tree 3			Tree 4		
Cook number		50	52	54	63	65	67
Digestion conditions							
Active alkali as Na_2O on oven-dry wood, %		16.0	18.0	20.0	16.0	18.0	20.0
Sulphidity, %		25	25	25	25	25	25
Liquor to oven-dry wood ratio		5:1	5:1	5:1	5:1	5:1	5:1
Maximum temperature, °C		170	170	170	170	170	170
Time to reach maximum temperature, h		1	1	1	1	1	1
Time at maximum temperature, h		4	4	4	4	4	4
Chemical consumption							
Active alkali consumed as Na_2O on oven-dry wood, %		13.1	14.0	14.7	13.2	14.0	14.6
Yield of pulp							
Yield of oven-dry digested pulp on oven-dry wood, %		46.5	43.9	41.5	46.1	43.6	41.4
Yield of oven-dry screened pulp on oven-dry wood, %		43.6	43.2	41.4	44.2	43.0	41.2
Yield of oven-dry screenings on oven-dry digested pulp, %		6.2	1.5	0.2	4.2	1.3	0.5
Pulp evaluation							
Kappa number		47.2	36.9	25.9	44.4	34.6	26.6
Beating, revs	500	6,870	6,310	5,360	5,950	5,370	5,000
	300	11,020	10,140	9,730	10,310	9,460	8,640
Apparent density, g cm^{-3}	500	0.77	0.77	0.78	0.76	0.77	0.77
	300	0.80	0.80	0.80	0.78	0.79	0.80
Tensile index, N m g^{-1}	500	96.0	99.9	98.0	103	103	100
	300	104	103	101	111	108	107
Tensile energy absorption index, mJ g^{-1}	500	2,310	2,350	2,120	2,260	2,150	2,180
	300	2,390	2,450	2,260	2,380	2,410	2,320
Tear index, mN m^2 g^{-1}	500	8.91	8.66	8.92	8.64	9.01	8.79
	300	8.56	8.50	8.71	8.43	8.50	8.29
Burst index, kPa m^2 g^{-1}	500	6.52	6.48	6.17	6.83	6.78	6.38
	300	6.92	6.76	6.61	7.30	7.09	6.69
Folding endurance, $\log_{10}n$*	500	3.13	3.12	3.08	3.11	3.13	3.07
	300	3.15	3.16	3.14	3.12	3.18	3.10
Air resistance, s	500	26	32	33	31	33	40
	300	230	260	240	210	250	290

Note: * n = number of double folds

Table 10

Pinus patula progeny test, site Grasslands: sulphate digestion conditions, pulp yield and evaluation

	Drainability CSF	Tree 1			Tree 2		
Cook number		MK909	MK911	MK913	MK915	MK917	MK919
Digestion conditions							
Active alkali as Na_2O on oven-dry wood, %		16.0	18.0	20.0	16.0	18.0	20.0
Sulphidity, %		25	25	25	25	25	25
Liquor to oven-dry wood ratio		5:1	5:1	5:1	5:1	5:1	5:1
Maximum temperature, °C		170	170	170	170	170	170
Time to reach maximum temperature, h		1	1	1	1	1	1
Time at maximum temperature, h		4	4	4	4	4	4
Chemical consumption							
Active alkali consumed as Na_2O on oven-dry wood, %		13.0	13.7	14.1	12.9	13.7	14.0
Yield of pulp							
Yield of oven-dry digested pulp on oven-dry wood, %		47.3	45.0	42.7	47.9	45.2	43.7
Yield of oven-dry screened pulp on oven-dry wood, %		44.9	44.4	42.6	45.2	44.5	43.6
Yield of oven-dry screenings on oven-dry digested pulp, %		5.1	1.4	0.1	5.8	1.5	0.2
Pulp evaluation							
Kappa number		43.0	31.7	23.9	41.3	30.5	24.8
Beating, revs	500	5,580	5,230	5,140	5,530	5,160	5,340
	300	9,170	8,760	7,910	8,780	8,260	7,940
Apparent density, g cm^{-3}	500	0.70	0.71	0.71	0.70	0.70	0.70
	300	0.73	0.74	0.74	0.72	0.73	0.72
Tensile index, N m g^{-1}	500	94.2	94.1	91.6	97.9	93.4	92.7
	300	98.0	98.4	95.5	99.8	97.1	97.5
Tensile energy absorption index, mJ g^{-1}	500	1,800	1,820	1,720	1,900	1,790	1,790
	300	2,010	1,960	1,870	1,930	1,960	1,870
Tear index, mN m^2 g^{-1}	500	11.8	12.3	12.2	12.0	12.9	12.7
	300	11.0	11.2	11.0	11.8	12.1	11.9
Burst index, kPa m^2 g^{-1}	500	6.58	6.25	6.12	6.67	6.38	6.25
	300	6.75	6.67	6.40	6.90	6.71	6.59
Folding endurance, $\log_{10}n$*	500	3.01	2.99	2.97	2.99	3.00	3.00
	300	3.03	3.05	3.02	3.01	3.01	3.02
Air resistance, s	500	12	15	13	10	12	13
	300	96	120	120	87	100	110

Table 10 *(continued)*

Pinus patula progeny test, site Grasslands: sulphate digestion conditions, pulp yield and evaluation

	Drainability CSF	Tree 3			Tree 4		
Cook number		56	58	60	39	41	44
Digestion conditions							
Active alkali as Na_2O on oven-dry wood, %		16.0	18.0	20.0	16.0	18.0	20.0
Sulphidity, %		25	25	25	25	25	25
Liquor to oven-dry wood ratio		5:1	5:1	5:1	5:1	5:1	5:1
Maximum temperature, °C		170	170	170	170	170	170
Time to reach maximum temperature, h		1	1	1	1	1	1
Time at maximum temperature, h		4	4	4	4	4	4
Chemical consumption							
Active alkali consumed as Na_2O on oven-dry wood, %		12.9	13.7	14.4	13.1	13.5	14.3
Yield of pulp							
Yield of oven-dry digested pulp on oven-dry wood, %		47.5	44.8	43.1	47.8	44.5	42.2
Yield of oven-dry screened pulp on oven-dry wood, %		45.1	44.5	43.0	43.9	43.7	42.1
Yield of oven-dry screenings on oven-dry digested pulp, %		5.0	0.7	0.3	8.0	1.7	0.4
Pulp evaluation							
Kappa number		42.6	29.8	26.2	46.8	35.7	28.2
Beating, revs	500	5,860	5,510	4,920	6,220	5,360	5,120
	300	9,100	8,700	8,400	9,850	8,890	8,130
Apparent density, g cm^{-3}	500	0.68	0.68	0.68	0.72	0.72	0.73
	300	0.71	0.71	0.73	0.75	0.75	0.76
Tensile index, N m g^{-1}	500	97.2	93.8	90.6	97.3	99.4	94.0
	300	98.7	96.4	96.4	102	104	96.9
Tensile energy absorption index, mJ g^{-1}	500	1,800	1,760	1,630	2,010	2,050	1,880
	300	1,970	1,890	1,990	2,230	2,180	2,030
Tear index, mN m^2 g^{-1}	500	13.0	13.7	13.4	11.3	11.2	10.4
	300	11.9	13.0	12.6	10.3	10.5	10.2
Burst index, kPa m^2 g^{-1}	500	6.37	6.12	5.88	6.40	6.43	6.16
	300	6.75	6.42	6.34	6.71	6.73	6.38
Folding endurance, $\log_{10}n$*	500	3.01	3.06	2.97	3.07	3.09	3.04
	300	3.04	3.06	3.05	3.11	3.13	3.04
Air resistance, s	500	7.6	7.2	8.1	17	14	20
	300	60	59	77	140	120	160

Note: * n = number of double folds

Table 11

Pinus patula progeny test, site Stapleford: sulphate pulp evaluation

Cook number	Kappa number	Beating	Drainability	Drainage time	Moisture content	Apparent density	Tensile index	Stretch	Tensile energy absorption index	Tear index	Burst index	Folding endurance	Air resistance	ISO brightness
		revs	CSF	s	%	g cm^{-3}	N m g^{-1}	%	mJ g^{-1}	mN m^2 g^{-1}	kPa m^2 g^{-1}	$log_{10}n$*	s	%
Tree 1														
MK861	43.9	0	730	4.4	7.7	0.45	37.0	1.8	341	17.9	1.73	1.72	0.5	20.0
		1,500	695	4.4	7.7	0.64	72.3	2.5	1,160	14.0	4.30	2.85	1.7	14.5
		4,500	575	4.5	7.8	0.70	86.0	3.1	1,680	10.9	5.58	2.94	7.0	13.0
		7,500	395	4.9	7.8	0.73	94.4	2.9	1,800	10.1	6.04	2.94	33	12.0
		10,500	260	6.2	7.8	0.75	94.9	3.3	1,980	9.85	6.21	2.98	200	12.0
MK869	34.0	0	725	4.4	7.6	0.48	39.2	1.9	391	18.3	1.94	1.89	0.7	21.0
		1,500	680	4.5	7.8	0.65	75.7	2.4	1,200	13.4	4.35	2.82	2.1	16.0
		4,500	560	4.7	7.8	0.72	85.0	3.1	1,670	11.1	5.46	2.93	8.3	14.0
		7,500	360	5.3	7.7	0.74	94.9	3.1	1,790	10.2	6.16	2.96	55	13.0
		10,500	228	6.8	7.8	0.77	99.8	3.0	1,930	9.28	6.37	3.03	280	13.0
MK885	25.0	0	725	4.5	7.4	0.48	38.1	2.0	381	17.1	1.85	1.82	0.8	23.0
		1,500	685	4.5	7.5	0.66	67.8	2.6	1,120	14.4	4.00	2.81	2.4	18.0
		4,500	545	4.8	7.7	0.72	83.6	3.2	1,710	11.3	5.29	2.96	12	15.5
		7,500	335	5.6	7.7	0.76	92.9	3.2	1,820	10.3	5.91	2.96	78	15.0
		10,500	202	8.1	7.7	0.78	96.7	3.1	1,990	9.70	6.23	3.02	440	14.5
Tree 2														
MK863	47.7	0	715	4.4	7.8	0.51	55.4	2.4	778	16.7	3.29	2.85	1.4	19.0
		1,500	665	4.6	8.0	0.69	82.1	3.4	1,710	12.1	5.38	3.01	5.4	14.0
		4,500	560	4.7	8.0	0.74	98.2	3.4	2,140	9.54	6.54	3.04	13	12.5
		7,500	410	5.0	8.0	0.77	103	3.5	2,250	8.85	6.84	3.07	53	11.5
		10,500	295	5.5	8.0	0.79	103	3.7	2,400	8.23	7.26	3.14	170	11.0
MK871	36.7	0	700	4.5	7.7	0.53	60.0	2.6	898	16.9	3.59	2.93	2.1	20.5
		1,500	645	4.5	7.7	0.71	83.5	3.2	1,700	11.1	5.49	3.03	9.5	15.0
		4,500	525	4.8	7.7	0.76	96.2	3.3	1,970	9.28	6.36	3.06	21	13.5
		7,500	385	5.2	7.7	0.78	101	3.6	2,260	8.44	6.94	3.09	92	12.5
		10,500	260	6.0	7.7	0.80	105	3.6	2,340	7.92	7.11	3.10	260	12.0
MK887	27.0	0	700	4.5	7.6	0.53	51.5	2.5	820	18.8	3.15	2.89	2.4	22.5
		1,500	640	4.5	7.7	0.71	78.8	3.4	1,710	12.5	5.29	3.02	10	17.5
		4,500	520	4.8	7.8	0.76	93.5	3.6	2,100	9.88	6.21	3.05	31	15.5
		7,500	355	5.6	7.7	0.78	102	3.5	2,250	9.11	6.62	3.06	120	14.5
		10,500	238	7.0	7.7	0.80	103	3.5	2,300	8.78	6.93	3.11	410	14.0

Table 11 *(continued)*

Pinus patula progeny test, site Stapleford: sulphate pulp evaluation

Cook number	Kappa number	Beating	Drainability	Drainage time	Moisture content	Apparent density	Tensile index	Stretch	Tensile energy absorption index	Tear index	Burst index	Folding endurance	Air resistance	ISO brightness
		revs	CSF	s	%	g cm^{-3}	N m g^{-1}	%	mJ g^{-1}	mN m^2 g^{-1}	kPa m^2 g^{-1}	$log_{10}n$*	s	%
Tree 3														
9	44.7	0	725	4.5	8.0	0.46	41.5	1.6	482	21.2	2.03	2.10	0.9	18.5
		1,500	685	4.6	8.2	0.65	77.7	2.4	1,350	13.8	4.64	2.91	3.1	14.0
		4,500	595	4.7	8.0	0.71	94.3	2.8	1,860	10.9	5.93	3.00	11	12.5
		7,500	440	5.0	8.1	0.74	102	3.0	2,130	9.85	6.52	3.00	41	11.5
		10,500	305	5.7	8.3	0.76	103	3.0	2,160	9.20	6.76	3.05	170	11.0
		13,500	206	7.3	8.4	0.77	106	3.1	2,290	9.26	7.04	3.06	580	11.5
20	37.6	0	715	4.5	8.0	0.47	41.5	1.4	437	22.9	2.15	2.21	1.2	20.0
		1,500	675	4.6	7.9	0.65	77.5	2.4	1,300	13.7	4.90	2.88	4.8	15.0
		4,500	565	4.8	8.1	0.71	97.8	2.8	1,930	10.8	6.15	2.97	15	13.0
		7,500	405	5.2	8.1	0.74	98.9	2.8	1,970	9.82	6.45	2.99	63	12.0
		10,500	270	6.1	8.0	0.76	106	2.9	2,250	9.40	6.68	3.01	280	12.0
29	26.1	0	720	4.5	7.6	0.47	38.7	1.5	426	21.6	2.09	2.02	1.1	23.5
		1,500	675	4.6	7.6	0.66	75.4	2.3	1,240	13.4	4.53	2.90	4.8	18.0
		4,500	580	4.7	7.7	0.72	87.7	2.7	1,670	11.2	5.74	2.99	15	16.0
		7,500	420	5.4	8.0	0.75	98.3	2.8	1,920	9.71	6.37	3.05	83	15.0
		10,500	285	6.7	7.8	0.77	103	2.8	2,020	9.28	6.61	3.06	340	15.5
Tree 4														
7	46.3	0	715	4.5	8.0	0.47	44.7	1.5	492	20.0	2.34	2.35	0.9	17.5
		1,500	670	4.6	8.2	0.64	82.5	2.3	1,350	13.7	4.90	2.89	2.6	13.5
		4,500	570	4.6	8.3	0.70	97.7	2.9	1,980	11.0	6.11	2.96	11	11.5
		7,500	400	5.1	8.1	0.74	101	3.0	2,090	9.68	6.63	2.99	57	11.0
		10,500	255	6.3	8.1	0.76	108	2.7	2,060	9.07	6.93	3.01	290	11.0
14	36.2	0	710	4.5	7.9	0.47	44.7	1.5	497	22.8	2.24	2.28	0.9	20.0
		1,500	870	4.6	8.0	0.64	81.2	2.4	1,380	14.1	4.70	2.96	3.7	15.5
		4,500	550	4.7	7.9	0.70	99.0	2.7	1,860	11.1	6.17	2.98	12	13.5
		7,500	395	5.3	8.1	0.73	101	2.8	1,980	10.2	6.68	2.99	60	13.0
		10,500	242	6.8	8.0	0.76	106	2.8	2,070	9.76	6.99	3.04	330	12.5
16	28.8	0	710	4.5	7.5	0.47	42.7	1.4	426	21.9	2.12	2.13	1.0	22.0
		1,500	670	4.5	7.5	0.66	80.2	2.4	1,330	13.6	4.62	2.87	4.4	16.5
		4,500	530	4.8	7.6	0.72	96.6	2.7	1,790	10.8	6.03	2.98	18	14.5
		7,500	355	5.6	7.6	0.74	105	2.8	2,060	9.96	6.54	2.98	97	14.0
		10,500	206	8.0	7.6	0.77	107	2.9	2,190	9.27	6.67	3.02	520	13.5

Note: * n = number of double folds

Table 12

Pinus patula progeny test, site Martin: sulphate pulp evaluation

Cook number	Kappa number	Beating	Drainability	Drainage time	Moisture content	Apparent density	Tensile index	Stretch	Tensile energy absorption index	Tear index	Burst index	Folding endurance	Air resistance	ISO brightness
		revs	CSF	s	%	g cm^{-3}	N m g^{-1}	%	mJ g^{-1}	mN m^2 g^{-1}	kPa m^2 g^{-1}	$log_{10}n$*	s	%
Tree 1														
MK865	37.6	0	705	4.4	7.7	0.52	59.1	2.3	750	20.5	3.52	2.93	1.7	20.0
		1,500	650	4.6	7.8	0.69	95.1	3.0	1,770	12.2	6.16	3.05	7.5	15.5
		4,500	535	4.8	7.8	0.75	108	3.3	2,180	9.94	7.22	3.07	23	13.5
		7,500	390	5.3	7.8	0.76	111	3.5	2,430	9.77	7.61	3.16	94	12.5
		10,500	255	6.6	7.7	0.79	114	3.4	2,400	8.94	8.01	3.11	370	12.0
MK873	30.6	0	705	4.4	7.3	0.53	58.6	2.4	835	20.7	3.56	2.95	2.4	22.0
		1,500	640	4.6	7.6	0.69	90.4	3.2	1,740	12.7	5.89	3.04	8.3	17.0
		4,500	510	4.9	7.6	0.74	101	3.3	2,120	10.3	7.14	3.07	32	14.5
		7,500	355	5.6	7.6	0.77	107	3.4	2,290	9.96	7.45	3.10	120	14.0
		10,500	224	7.4	7.6	0.79	116	3.4	2,470	9.25	7.70	3.14	560	13.5
MK889	22.6	0	705	4.5	7.4	0.52	53.1	2.3	667	24.1	3.12	2.90	1.9	24.5
		1,500	655	4.6	8.0	0.69	84.1	2.8	1,490	13.3	5.64	3.02	6.7	19.5
		4,500	525	4.9	7.5	0.74	101	3.5	2,090	10.6	6.65	3.06	27	17.0
		7,500	360	5.8	7.6	0.77	105	3.4	2,170	9.63	7.23	3.15	130	16.0
		10,500	224	7.8	7.5	0.79	109	3.3	2,210	9.48	7.49	3.11	390	16.0
Tree 2														
MK867	39.7	0	715	4.4	7.6	0.53	57.9	2.3	712	18.6	3.37	2.88	1.6	20.0
		1,500	655	4.6	7.8	0.69	90.9	2.7	1,590	11.4	6.11	3.04	6.4	15.0
		4,500	545	4.8	7.8	0.74	106	3.3	2,100	9.99	7.11	3.06	21	13.0
		7,500	365	5.5	7.9	0.77	113	3.2	2,250	9.24	7.81	3.11	100	12.5
		10,500	240	6.9	7.9	0.79	118	3.4	2,550	8.77	7.95	3.11	430	12.0
MK875	30.1	0	705	4.5	7.5	0.54	59.3	2.4	760	18.4	3.39	2.92	2.2	21.5
		1,500	645	4.5	7.5	0.70	89.3	3.0	1,560	11.6	5.79	3.02	7.1	16.5
		4,500	505	5.0	7.6	0.75	106	3.2	2,070	9.74	6.94	3.06	28	14.5
		7,500	360	5.8	7.7	0.77	111	3.1	2,060	9.03	7.44	3.06	110	14.0
		10,500	210	8.2	7.8	0.80	113	3.3	2,300	8.69	7.68	3.12	650	13.5
MK891	22.9	0	710	4.5	7.4	0.53	53.0	2.3	645	19.9	3.02	2.81	1.9	24.0
		1,500	660	4.5	7.5	0.70	84.6	2.6	1,400	12.0	5.35	2.97	5.8	18.5
		4,500	535	4.9	7.5	0.75	98.5	3.3	1,960	9.38	6.51	3.01	23	16.5
		7,500	340	6.0	7.7	0.78	107	3.2	2,060	8.72	6.94	3.05	150	15.5
		10,500	210	8.9	7.7	0.80	112	3.3	2,230	8.50	7.37	3.11	620	15.5

Table 12 *(continued)*

Pinus patula progeny test, site Martin: sulphate pulp evaluation

Cook number	Kappa number	Beating	Drainability	Drainage time	Moisture content	Apparent density	Tensile index	Stretch	Tensile energy absorption index	Tear index	Burst index	Folding endurance	Air resistance	ISO brightness
		revs	CSF	s	%	g cm^{-3}	N m g^{-1}	%	mJ g^{-1}	mN m^2 g^{-1}	kPa m^2 g^{-1}	$log_{10}n$*	s	%
Tree 3														
22	39.8	0	705	4.5	8.1	0.51	55.0	1.9	745	22.6	3.23	3.02	1.8	19.0
		1,500	670	4.5	7.7	0.68	87.2	2.8	1,680	12.7	5.76	3.14	6.0	15.0
		4,500	565	4.7	7.8	0.74	103	3.0	2,130	10.5	6.89	3.16	21	13.0
		7,500	420	5.1	8.1	0.77	113	3.1	2,420	9.64	7.51	3.15	75	12.0
		10.500	300	5.9	8.0	0.79	112	3.3	2,560	9.14	7.50	3.23	290	11.5
24	32.5	0	705	4.4	7.6	0.52	53.7	1.9	743	24.0	3.13	2.99	2.1	21.0
		1,500	660	4.5	7.9	0.69	90.2	2.7	1,720	12.6	5.68	3.09	7.2	16.0
		4,500	550	4.7	7.8	0.74	104	3.0	2,190	10.1	6.76	3.15	24	14.0
		7,500	410	5.2	7.7	0.77	113	3.2	2,480	9.48	7.31	3.15	82	13.0
		10,500	280	6.2	7.6	0.79	113	3.2	2,520	8.77	7.43	3.21	370	12.5
26	23.0	0	710	4.4	7.9	0.51	48.6	1.7	614	26.4	2.79	2.82	1.9	24.0
		1,500	670	4.5	7.5	0.68	85.1	2.6	1,530	13.8	5.27	3.09	7.4	19.0
		4,500	560	4.7	7.8	0.74	95.8	2.8	1,890	10.7	6.42	3.10	16	16.5
		7,500	390	5.4	7.9	0.77	106	2.8	2,060	9.52	7.01	3.12	96	16.0
		10,500	270	6.4	7.5	0.79	110	2.9	2,270	8.61	7.22	3.16	330	15.5
Tree 4														
31	39.6	0	720	4.4	7.9	0.47	48.0	1.6	525	24.4	2.73	2.62	0.9	20.0
		1,500	665	4.6	8.0	0.63	82.6	2.6	1,450	16.0	5.42	3.01	2.9	15.5
		4,500	550	4.8	8.1	0.70	99.1	2.8	1,930	12.8	6.60	3.08	13	13.5
		7,500	360	5.5	8.0	0.72	110	3.0	2,240	11.6	7.23	3.12	70	13.0
		10,500	270	6.9	8.1	0.75	107	3.2	2,340	11.2	7.26	3.14	300	12.5
33	28.7	0	710	4.4	7.8	0.47	46.8	1.6	521	25.3	2.54	2.64	1.0	22.0
		1,500	670	4.5	7.8	0.64	84.0	2.6	1,510	16.5	5.27	3.01	3.6	17.0
		4,500	530	4.9	7.8	0.70	99.1	2.7	1,840	12.9	6.42	3.08	18	15.5
		7,500	355	5.8	7.7	0.73	101	3.0	2,090	12.2	7.13	3.04	94	14.5
		10,500	200	8.8	7.9	0.75	110	2.9	2,240	11.4	7.20	3.11	400	14.5
35	23.9	0	705	4.4	7.8	0.48	47.0	1.6	552	24.2	2.51	2.55	1.3	24.5
		1,500	650	4.6	7.8	0.66	82.7	2.6	1,480	15.0	5.28	3.05	6.1	19.0
		4,500	525	5.0	7.7	0.71	96.6	2.8	1,860	12.7	6.36	3.02	21	17.5
		7,500	310	6.2	7.8	0.74	105	2.9	2,080	11.7	6.77	3.07	120	17.0
		10,500	190	9.9	7.7	0.76	108	3.0	2,240	10.7	7.20	3.12	520	16.5

Note: * n = number of double folds

Table 13

Pinus patula progeny test, site Chiwengwa: sulphate pulp evaluation

Cook number	Kappa number	Beating	Drainability	Drainage time	Moisture content	Apparent density	Tensile index	Stretch	Tensile energy absorption index	Tear index	Burst index	Folding endurance	Air resistance	ISO brightness
		revs	CSF	s	%	g cm^{-3}	N m g^{-1}	%	mJ g^{-1}	mN m^2 g^{-1}	kPa m^2 g^{-1}	$log_{10}n$*	s	%
Tree 1														
MK877	44.8	0	705	4.5	8.0	0.55	57.6	2.9	1,070	17.1	3.75	3.13	2.5	20.0
		1,500	630	4.6	8.1	0.75	88.0	3.5	2,000	10.1	6.04	3.10	12	14.5
		4,500	535	4.7	8.1	0.79	99.6	3.6	2,400	8.57	6.85	3.13	24	12.5
		7,500	395	5.1	8.2	0.81	101	3.8	2,470	8.15	7.03	3.15	90	11.5
		10,500	285	5.7	8.0	0.83	105	3.8	2,670	8.10	7.13	3.13	300	11.5
MK879	32.6	0	710	4.5	7.9	0.57	56.3	3.0	1,050	18.0	3.79	3.12	3.2	22.0
		1,500	630	4.6	8.2	0.75	83.5	3.5	1,890	10.5	5.69	3.10	12	16.5
		4,500	520	4.8	7.9	0.79	95.0	3.7	2,240	8.97	6.24	3.07	41	14.0
		7,500	375	5.2	7.8	0.81	101	3.3	2,230	8.12	6.89	3.07	93	13.5
		10,500	265	6.1	7.9	0.82	105	3.8	2,510	7.80	7.03	3.17	400	13.0
MK893	27.5	0	695	4.5	7.5	0.57	55.4	2.6	984	16.4	3.61	3.02	3.7	23.5
		1,500	615	4.6	7.7	0.76	82.8	3.4	1,850	9.89	5.51	3.05	17	18.0
		4,500	505	4.9	7.7	0.80	91.8	3.7	2,100	8.54	6.20	3.03	41	15.5
		7,500	350	5.6	7.6	0.82	99.1	3.4	2,260	7.68	6.64	3.07	190	14.5
		10,500	244	6.3	7.7	0.84	101	3.3	2,340	7.52	6.51	3.07	570	14.0
Tree 2														
MK881	38.9	0	725	4.5	8.0	0.49	48.3	2.0	613	23.8	2.76	2.75	0.7	20.0
		1,500	680	4.5	8.0	0.68	80.7	3.0	1,520	12.9	5.31	3.01	3.0	15.0
		4,500	530	4.7	8.2	0.74	95.2	3.1	1,860	9.76	6.59	3.03	11	13.0
		7,500	375	5.0	8.2	0.76	104	3.5	2,340	9.53	6.93	3.05	50	12.0
		10,500	242	6.0	8.1	0.78	103	3.4	2,300	8.76	7.07	3.09	280	11.5
MK883	32.2	0	725	4.5	7.6	0.51	47.9	2.2	668	23.3	2.78	2.70	1.0	22.0
		1,500	665	4.6	7.8	0.70	77.3	3.1	1,540	12.9	5.31	3.02	4.5	16.5
		4,500	530	4.7	7.7	0.75	89.7	3.1	1,830	10.3	6.32	2.97	16	14.5
		7,500	350	5.4	7.8	0.77	100	3.3	2,090	9.55	6.80	3.07	78	13.5
		10,500	214	7.0	7.8	0.79	100	3.6	2,190	9.09	7.10	3.04	530	13.0
MK895	22.1	0	730	4.4	7.6	0.49	40.1	2.1	514	23.6	2.29	2.25	0.9	25.0
		1,500	660	4.6	7.5	0.69	72.0	2.5	1,210	13.8	4.49	2.98	3.2	19.5
		4,500	535	4.7	7.6	0.74	89.5	3.0	1,770	10.3	5.95	2.94	15	17.0
		7,500	380	5.3	7.6	0.77	93.8	3.3	1,960	9.62	6.53	3.02	63	16.0
		10,500	198	8.0	7.7	0.79	103	3.4	2,120	8.94	6.97	2.97	540	15.5

Table 13 *(continued)*

Pinus patula progeny test, site Chiwengwa: sulphate pulp evaluation

Cook number	Kappa number	Beating revs	Drainability CSF	Drainage time s	Moisture content %	Apparent density g cm^{-3}	Tensile index N m g^{-1}	Stretch %	Tensile energy absorption index mJ g^{-1}	Tear index mN m^2 g^{-1}	Burst index kPa m^2 g^{-1}	Folding endurance log$_{10}$n*	Air resistance s	ISO brightness %
Tree 3														
37	43.1	0	730	4.4	7.8	0.44	45.1	1.6	501	23.2	2.36	2.48	0.6	19.0
		1,500	690	4.5	8.1	0.65	82.0	2.7	1,530	14.0	5.12	3.01	2.7	14.5
		4,500	570	4.6	8.4	0.71	101	2.8	1,980	11.0	6.71	3.03	10	12.5
		7,500	415	5.0	8.0	0.75	107	3.0	2,150	10.2	6.89	3.10	42	11.5
		10,500	260	5.9	8.2	0.76	110	3.0	2,260	9.74	7.23	3.06	210	11.5
48	30.6	0	735	4.5	8.2	0.46	43.7	1.5	475	24.6	3.18	2.42	0.7	22.0
		1,500	690	4.5	8.1	0.66	77.5	2.5	1,350	14.9	4.85	3.01	2.6	17.0
		4,500	565	4.6	8.1	0.71	96.0	2.9	1,920	11.0	6.24	3.06	8.3	15.0
		7,500	390	5.2	8.1	0.74	100	3.1	2,150	10.0	6.70	3.08	46	14.0
		10,500	250	6.5	8.3	0.77	107	3.1	2,300	9.33	7.18	3.10	250	13.5
46	24.9	0	720	4.5	7.8	0.49	43.6	1.7	530	25.6	2.50	2.50	1.0	24.0
		1,500	675	4.6	7.8	0.66	74.5	2.5	1,290	14.3	4.63	2.94	3.0	18.5
		4,500	525	4.8	8.0	0.73	94.6	2.8	1,860	10.6	5.74	3.03	13	16.5
		7,500	360	5.5	8.0	0.75	102	2.9	2,100	9.66	6.57	3.07	66	15.5
		10,500	218	7.8	8.1	0.78	105	3.0	2,190	9.21	6.94	3.08	470	15.0
Tree 4														
5	47.5	0	715	4.4	8.3	0.49	51.3	2.6	1,030	22.7	3.43	3.04	1.3	18.0
		1,500	675	4.5	8.4	0.72	80.0	3.3	1,960	12.3	5.56	3.09	5.6	13.0
		4,500	590	4.6	8.2	0.76	94.4	3.6	2,480	10.4	6.29	3.08	10	11.5
		7,500	440	4.8	8.4	0.79	102	3.4	2,510	9.48	6.76	3.11	41	10.5
		10,500	335	5.1	8.4	0.80	104	3.5	2,680	9.11	6.90	3.12	110	10.0
		13,500	238	5.6	8.3	0.82	105	3.5	2,710	8.85	6.87	3.13	350	10.0
12	35.9	0	710	4.5	7.7	0.53	50.1	2.9	1,100	21.5	3.37	3.04	2.2	20.5
		1,500	650	4.5	8.3	0.73	77.4	3.4	1,990	13.1	5.21	3.11	9.9	15.0
		4,500	535	4.7	8.0	0.78	91.4	3.5	2,390	10.8	5.92	3.16	25	13.0
		7,500	420	4.9	8.1	0.80	97.6	3.6	2,590	9.37	6.44	3.13	62	12.0
		10,500	295	5.3	8.1	0.82	101	3.6	2,690	9.10	6.58	3.21	210	11.5
18	28.9	0	705	4.4	7.8	0.52	49.4	2.7	1,040	23.0	3.29	3.06	2.5	22.0
		1,500	645	4.6	7.9	0.73	77.1	3.4	1,940	13.2	5.15	3.09	10	16.5
		4,500	540	4.7	8.0	0.78	90.8	3.6	2,460	10.0	5.80	3.09	30	14.0
		7,500	385	5.0	8.0	0.81	95.7	3.5	2,450	9.16	6.36	3.10	110	13.0
		10,500	265	5.8	8.0	0.83	98.4	3.4	2,480	8.86	6.51	3.14	370	12.5

Note: * n = number of double folds

Table 14

Pinus patula progeny test, site Nyangui: sulphate pulp evaluation

Cook number	Kappa number	Beating	Drainability	Drainage time	Moisture content	Apparent density	Tensile index	Stretch	Tensile energy absorption index	Tear index	Burst index	Folding endurance	Air resistance	ISO brightness
		revs	CSF	s	%	g cm^{-3}	N m g^{-1}	%	mJ g^{-1}	mN m^2 g^{-1}	kPa m^2 g^{-1}	$log_{10}n$*	s	%
Tree 1														
MK897	43.3	0	720	4.5	8.1	0.49	49.9	2.1	545	18.8	2.81	2.56	0.8	18.5
		1,500	685	4.5	8.2	0.66	84.3	2.7	1,450	12.8	5.17	2.95	3.0	14.0
		4,500	555	4.8	8.2	0.73	99.1	3.1	1,980	10.3	6.59	3.02	14	12.0
		7,500	390	5.2	8.2	0.76	102	3.3	2,120	9.52	7.03	3.00	55	11.5
		10,500	236	6.9	8.3	0.78	107	3.4	2,260	9.00	7.32	3.05	370	11.0
MK899	31.6	0	705	4.5	7.7	0.54	53.7	2.1	637	17.2	3.11	2.68	1.9	21.0
		1,500	650	4.6	7.9	0.71	88.8	2.7	1,530	11.4	5.68	3.00	6.7	16.0
		4,500	530	4.9	8.1	0.76	100	3.5	2,130	9.34	6.68	2.97	30	14.0
		7,500	355	5.7	8.1	0.79	106	3.3	2,250	8.65	7.13	3.07	130	13.0
		10,500	230	7.3	8.0	0.80	112	3.2	2,280	8.09	7.60	3.07	570	13.0
MK901	26.8	0	710	4.5	7.6	0.51	49.2	2.3	599	19.3	2.76	2.53	1.6	22.5
		1,500	655	4.6	7.9	0.70	82.7	2.8	1,520	12.2	5.08	2.99	6.1	17.0
		4,500	535	4.9	7.8	0.75	94.1	3.3	1,970	9.78	6.19	3.02	20	15.0
		7,500	330	5.7	7.9	0.78	104	3.3	2,120	8.94	6.92	3.06	120	14.5
		10,500	206	8.7	8.1	0.81	106	3.5	2,320	8.55	7.17	3.09	730	14.0
Tree 2														
MK903	46.4	0	725	4.5	8.3	0.50	49.1	2.2	588	18.3	2.63	2.55	0.9	18.5
		1,500	685	4.6	8.4	0.67	83.5	2.7	1,490	11.3	5.20	2.91	2.8	14.0
		4,500	560	4.7	8.4	0.73	96.5	3.2	1,970	9.36	6.44	2.66	9.1	12.0
		7,500	405	5.1	8.4	0.76	99.8	3.2	2,100	8.55	6.56	3.00	41	11.5
		10,500	246	6.2	8.4	0.78	105	3.4	2,250	8.11	6.06	3.01	240	11.5
MK905	33.3	0	710	4.5	8.4	0.51	49.4	2.2	567	20.5	2.65	2.55	1.1	21.0
		1,500	670	4.6	8.2	0.68	80.7	2.6	1,360	11.8	4.95	2.90	3.4	16.5
		4,500	545	4.7	8.5	0.73	92.2	3.2	1,840	9.54	6.08	2.95	15	14.0
		7,500	370	6.0	8.3	0.76	101	3.4	2,040	8.83	6.59	3.02	70	13.5
		10,500	246	6.5	8.1	0.79	101	3.5	2,170	8.48	6.62	3.02	260	13.0
MK907	26.4	0	715	4.5	8.1	0.51	48.5	2.0	557	20.3	2.69	2.46	1.3	23.0
		1,500	660	4.6	8.1	0.69	80.4	2.6	1,370	11.5	4.87	2.87	4.4	17.5
		4,500	520	4.9	7.8	0.74	92.9	3.1	1,750	9.10	5.94	2.92	18	15.0
		7,500	330	5.2	8.0	0.77	98.9	3.5	2,020	8.47	6.43	2.93	110	14.0
		10,500	188	8.9	8.2	0.80	102	3.3	2,130	8.06	6.59	3.01	670	14.0

Table 14 *(continued)*

Pinus patula progeny test, site Nyangui: sulphate pulp evaluation

Cook number	Kappa number	Beating	Drainability	Drainage time	Moisture content	Apparent density	Tensile index	Stretch	Tensile energy absorption index	Tear index	Burst index	Folding endurance	Air resistance	ISO brightness
		revs	CSF	s	%	g cm^{-3}	N m g^{-1}	%	mJ g^{-1}	mN m^2 g^{-1}	kPa m^2 g^{-1}	$log_{10}n$*	s	%
Tree 3														
50	47.2	0	730	4.4	8.4	0.47	44.9	1.9	618	20.8	2.51	2.61	1.0	18.0
		1,500	690	4.5	8.3	0.68	80.4	3.0	1,700	11.3	5.27	3.08	4.3	13.5
		4,500	610	4.6	8.5	0.74	92.9	3.3	2,170	9.66	6.17	3.07	9.5	11.5
		7,500	465	4.9	8.4	0.77	96.1	3.3	2,310	8.87	6.55	3.15	37	10.5
		10,500	320	5.4	8.4	0.79	103	3.2	2,370	8.62	6.88	3.15	180	10.5
		13,500	214	6.7	8.6	0.81	109	3.2	2,490	8.26	7.01	3.17	680	10.5
52	36.9	0	720	4.4	8.1	0.51	48.7	2.1	732	20.2	2.93	2.82	1.6	19.5
		1,500	685	4.5	8.3	0.70	76.8	3.0	1,650	12.0	4.98	3.07	5.7	14.5
		4,500	585	4.7	8.3	0.76	94.0	3.2	2,180	9.34	6.14	3.12	18	12.5
		7,500	435	5.0	8.3	0.78	101	3.3	2,380	8.69	6.53	3.12	56	11.5
		10,500	285	5.9	8.3	0.80	103	3.3	2,460	8.45	6.80	3.17	330	11.5
54	25.9	0	720	4.4	7.9	0.52	46.7	2.0	690	21.1	2.77	2.78	1.8	22.5
		1,500	670	4.5	7.9	0.72	78.6	2.9	1,620	11.4	4.92	3.01	7.5	17.0
		4,500	550	4.8	8.0	0.77	94.2	3.1	2,060	9.33	5.96	3.07	21	14.5
		7,500	380	5.3	8.2	0.79	101	3.0	2,160	8.70	6.39	3.10	110	13.5
		10,500	275	5.9	8.1	0.81	101	3.2	2,300	8.72	6.69	3.15	300	12.0
Tree 4														
63	44.4	0	720	4.4	8.4	0.51	53.4	1.8	674	19.0	2.95	2.80	1.5	18.5
		1,500	685	4.6	8.3	0.68	86.4	2.7	1,650	11.2	5.58	3.06	4.8	14.0
		4,500	565	4.7	8.5	0.74	101	3.0	2,110	9.04	6.60	3.11	16	12.5
		7,500	425	5.1	8.3	0.78	104	3.2	2,350	8.62	6.93	3.11	66	12.0
		10,500	290	6.0	8.4	0.79	112	3.0	2,380	8.41	7.33	3.12	230	11.0
65	34.6	0	710	4.5	8.2	0.51	51.2	1.8	661	20.2	2.83	2.75	1.6	20.0
		1,500	670	4.6	8.2	0.69	84.5	2.6	1,580	11.6	5.40	3.02	6.9	15.0
		4,500	545	4.8	8.1	0.75	101	2.9	2,040	9.32	6.59	3.11	26	13.5
		7,500	390	5.3	8.3	0.78	105	3.1	2,330	8.83	6.93	3.17	85	12.5
		10,500	255	6.8	8.3	0.80	110	3.1	2,440	8.26	7.19	3.18	450	12.0
67	26.6	0	715	4.5	7.8	0.52	50.7	1.8	660	20.5	2.87	2.70	2.1	22.5
		1,500	655	4.6	8.0	0.71	85.1	2.8	1,700	11.2	5.31	3.05	8.1	17.0
		4,500	525	5.0	8.0	0.76	98.1	3.1	2,130	9.05	6.26	3.07	31	15.0
		7,500	355	5.6	8.1	0.79	106	3.1	2,290	8.32	6.63	3.08	170	14.0
		10,500	224	7.6	8.1	0.81	109	3.1	2,380	8.24	6.80	3.15	620	14.0

Note: * n = number of double folds

Table 15

Pinus patula progeny test, site Grasslands: sulphate pulp evaluation

Cook number	Kappa number	Beating	Drainability	Drainage time	Moisture content	Apparent density	Tensile index	Stretch	Tensile energy absorption index	Tear index	Burst index	Folding endurance	Air resistance	ISO brightness
		revs	CSF	s	%	g cm^{-3}	N m g^{-1}	%	mJ g^{-1}	mN m^2 g^{-1}	kPa m^2 g^{-1}	$log_{10}n$*	s	%
Tree 1														
MK909	43.0	0	730	4.4	7.8	0.47	44.9	2.1	474	23.3	2.43	2.44	0.7	18.5
		1,500	695	4.5	8.3	0.63	76.1	2.7	1,270	15.9	4.74	2.94	1.7	14.0
		4,500	560	4.7	8.2	0.69	90.9	3.0	1,680	12.5	6.30	3.00	7.7	12.5
		7,500	390	5.1	8.3	0.71	96.9	3.3	1,940	11.4	6.69	3.01	32	12.0
		10,500	232	6.5	8.1	0.74	98.8	3.4	2,050	10.7	6.83	3.06	220	11.5
MK911	31.7	0	725	4.5	7.8	0.47	43.4	1.9	426	25.9	2.41	3.39	0.7	21.0
		1,500	680	4.5	7.6	0.64	76.8	2.6	1,270	16.3	4.86	2.90	2.0	16.0
		4,500	540	4.8	8.0	0.70	92.0	3.2	1,750	12.9	6.05	2.97	10	14.0
		7,500	365	5.3	7.7	0.73	96.7	3.3	1,930	11.4	6.57	3.04	60	13.5
		10,500	214	7.1	7.9	0.75	102	3.2	2,000	11.0	6.81	3.06	290	13.0
MK913	23.9	0	725	4.4	7.4	0.47	42.6	2.1	438	22.6	2.24	2.13	0.7	23.5
		1,500	680	4.5	7.4	0.65	76.0	2.4	1,180	16.0	4.64	2.84	2.3	18.0
		4,500	540	4.8	7.6	0.70	89.3	2.9	1,640	12.8	5.92	2.95	9.4	16.0
		7,500	320	5.6	7.5	0.74	95.2	3.2	1,870	11.1	6.36	3.01	83	15.0
		10,500	184	8.3	7.7	0.77	98.1	3.1	1,900	10.5	6.71	3.05	530	15.0
Tree 2														
MK915	41.3	0	735	4.4	7.7	0.44	40.0	2.0	354	23.5	1.90	1.92	0.4	19.0
		1,500	695	4.5	8.0	0.63	76.5	2.7	1,320	15.9	4.82	2.90	1.5	14.5
		4,500	560	4.7	8.1	0.68	94.8	3.1	1,810	12.6	6.37	2.98	6.6	12.5
		7,500	370	5.3	7.9	0.71	98.4	3.2	1,920	12.0	6.79	3.00	37	12.5
		10,500	218	6.7	8.0	0.74	103	3.2	1,980	11.3	7.10	3.03	230	12.0
MK917	30.5	0	725	4.4	7.6	0.48	40.0	1.9	387	23.7	2.09	2.00	0.6	21.5
		1,500	675	4.6	7.7	0.64	75.0	2.9	1,270	15.9	4.73	2.89	2.0	16.5
		4,500	540	4.7	7.8	0.69	91.2	2.9	1,710	13.3	6.19	2.99	8.5	14.5
		7,500	345	5.5	7.7	0.72	96.0	3.3	1,940	12.3	6.60	3.01	59	14.5
		10,500	176	8.1	7.7	0.75	102	3.2	2,010	11.0	7.22	3.01	470	14.0
MK919	24.8	0	730	4.4	7.4	0.47	42.1	1.9	376	22.9	2.08	2.05	0.6	24.0
		1,500	685	4.5	7.6	0.64	73.5	2.6	1,240	16.7	4.62	2.95	1.8	18.5
		4,500	555	4.8	7.6	0.69	89.2	3.1	1,700	13.4	5.94	2.99	7.7	16.5
		7,500	325	5.7	7.6	0.72	96.8	3.2	1,850	12.0	6.57	3.02	78	16.0
		10,500	176	8.7	7.5	0.74	102	3.1	1,980	11.2	6.70	3.05	480	16.0

Table 15 *(continued)*

Pinus patula progeny test, site Grasslands: sulphate pulp evaluation

Cook number	Kappa number	Beating	Drainability	Drainage time	Moisture content	Apparent density	Tensile index	Stretch	Tensile energy absorption index	Tear index	Burst index	Folding endurance	Air resistance	ISO brightness
		revs	CSF	s	%	g cm^{-3}	N m g^{-1}	%	mJ g^{-1}	mN m^2 g^{-1}	kPa m^2 g^{-1}	$log_{10}n$*	s	%
Tree 3														
56	42.6	0	725	4.4	8.5	0.42	39.7	1.4	392	24.2	1.97	2.06	0.4	18.5
		1,500	695	4.5	8.4	0.60	74.2	2.4	1,210	16.9	4.74	2.98	1.2	14.0
		4,500	575	4.6	8.5	0.66	93.7	2.6	1,690	13.9	5.99	3.00	3.9	12.5
		7,500	395	5.1	8.5	0.70	96.6	2.8	1,850	12.3	6.58	3.02	22	12.0
		10,500	226	6.3	8.4	0.73	102	3.0	2,110	11.6	6.91	3.06	140	11.5
58	29.8	0	730	4.4	8.0	0.43	38.4	1.4	370	25.6	1.91	2.00	0.4	21.0
		1,500	690	4.5	8.1	0.61	72.6	2.1	1,080	19.0	4.46	2.93	1.3	16.5
		4,500	555	4.6	8.2	0.67	90.5	2.6	1,630	14.5	5.84	3.05	4.5	14.5
		7,500	370	5.2	8.0	0.70	95.3	2.8	1,860	13.3	6.31	3.05	26	14.0
		10,500	200	7.2	8.2	0.73	99.3	2.8	1,930	12.2	6.63	3.10	210	14.0
60	26.2	0	725	4.4	8.1	0.45	39.8	1.4	403	26.2	1.94	2.02	0.5	22.5
		1,500	685	4.5	8.0	0.62	72.7	2.3	1,150	19.5	4.38	2.95	1.3	17.5
		4,500	525	4.7	8.0	0.67	89.2	2.5	1,570	13.8	5.76	2.96	5.6	16.0
		7,500	350	5.4	8.1	0.72	95.2	2.9	1,940	12.8	6.26	3.04	46	15.0
		10,500	184	8.9	8.1	0.74	99.8	2.9	2,040	11.9	6.55	3.05	340	15.0
Tree 4														
39	46.8	0	730	4.4	8.3	0.46	44.0	1.7	531	22.6	2.20	2.40	0.7	18.0
		1,500	690	4.4	8.5	0.64	78.9	2.5	1,370	13.5	5.07	3.01	2.3	13.5
		4,500	580	4.6	8.5	0.70	92.2	2.9	1,870	12.0	6.18	3.03	8.1	12.0
		7,500	435	4.9	8.5	0.73	99.7	2.9	2,060	10.8	6.42	3.10	34	11.5
		10,500	260	6.0	8.4	0.76	103	3.1	2,290	10.2	6.83	3.11	220	11.0
41	35.7	0	730	4.4	8.2	0.48	45.5	1.6	515	24.7	2.41	2.52	0.8	20.0
		1,500	690	4.5	8.0	0.64	79.5	2.5	1,420	14.7	4.84	2.97	2.5	15.5
		4,500	550	4.7	8.2	0.70	96.6	2.9	1,970	11.8	6.20	3.07	8.8	13.0
		7,500	375	5.2	8.3	0.74	102	2.9	2,120	10.6	6.65	3.11	54	12.5
		10,500	220	6.9	8.3	0.77	107	3.0	2,270	10.5	6.83	3.16	330	12.0
44	28.2	0	725	4.5	7.9	0.47	43.1	1.5	467	23.0	2.34	2.34	0.9	22.0
		1,500	675	4.6	7.9	0.66	75.5	2.5	1,370	14.4	4.78	3.00	3.3	17.0
		4,500	540	4.8	8.1	0.72	91.8	2.8	1,800	10.9	5.98	3.04	13	15.0
		7,500	335	5.7	8.1	0.75	96.2	3.0	2,030	10.2	6.37	3.03	110	13.5
		10,500	192	8.4	8.2	0.78	101	2.8	2,030	9.70	6.46	3.11	550	14.0

Note: * n = number of double folds

Figure 1

Site means, 18% active alkali sulphate digestion: influence of site on tear index

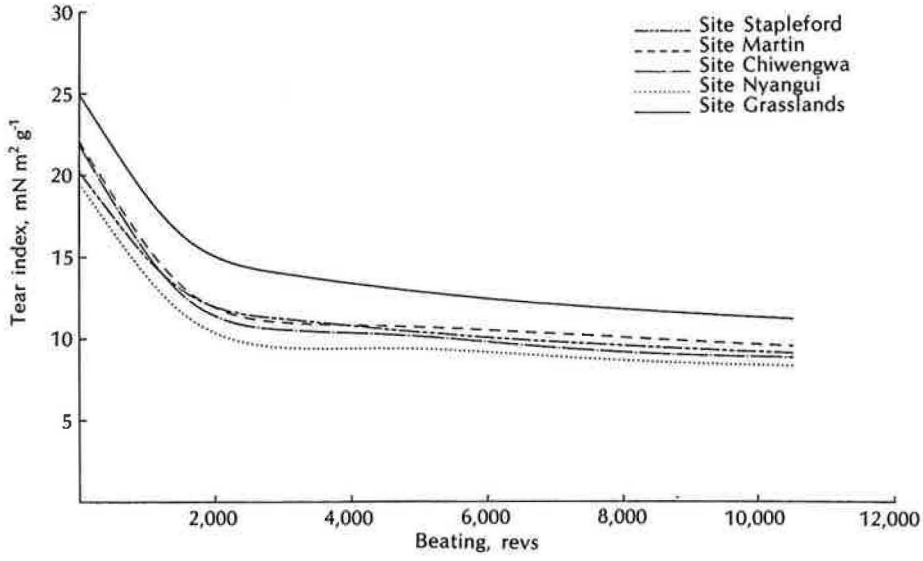


Figure 2

Site Grasslands, 18% active alkali sulphate digestion: influence of tree on tear index

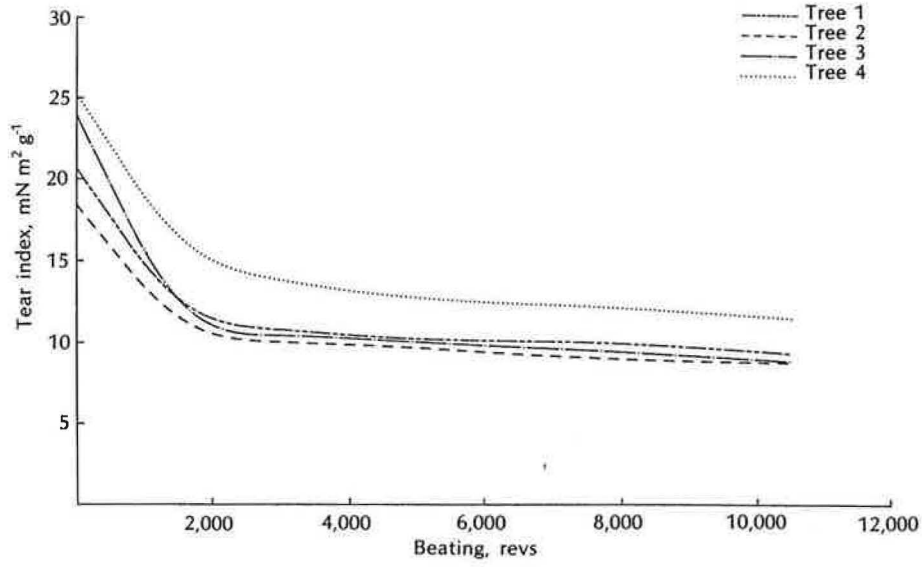
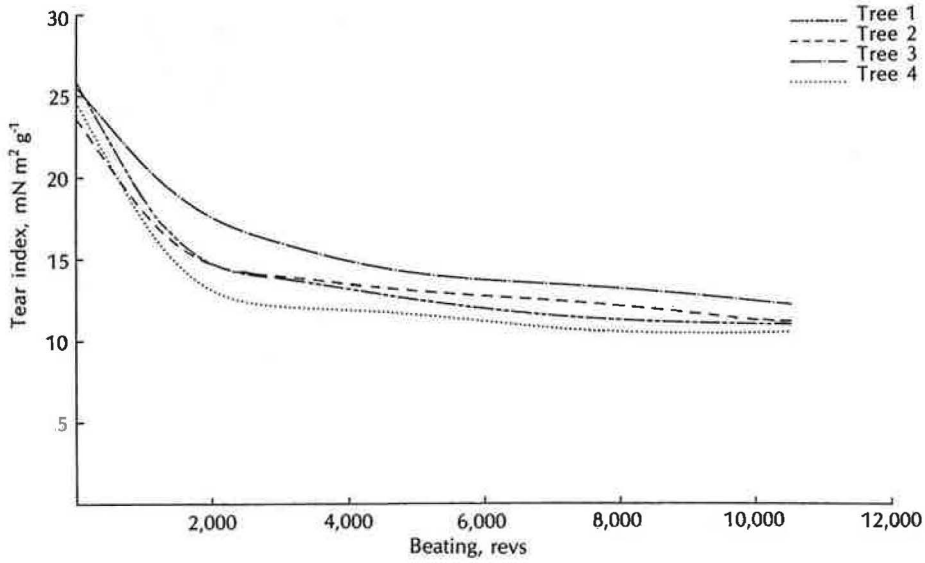


Figure 3

Site Martin, 18% active alkali sulphate digestion: influence of tree on tear index



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