COMPARISON OF PULPING STUDIES OF AUSTRALIAN SEED ROUTED *EUCALYPTUS* PLANTATIONS IN AMLAI REGION

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Introduction

The total landmass of Indian peninsula is 328.8 million hectares out of which 47% is used for agricultural purposes. Nearly 30% of land is uncultivated, barren and non-agricultural land. Forests and woodlands occupy 20% of landmass of which 38.6 million hectares in dense forest with a crown density of more than 40%. The rest of area amount to about 31 million hectares is considered as degraded forest land (Jain *et al*., 2005).

Plantation technology of fast growing, high pulp yielding and short rotation tree is of paramount national importance for India and other Asian countries to cope up with decreasing forest land, increasing population and requirement of paper and other forest based industries (Sahu and Patel, 1992). *Eucalyptus* is a very large genus of plants and includes around 700 species however, few (less than 1%) have been used for industrial forestry purpose. The *Eucalyptus* kraft pulp industry today is based largely on only two species *E. globulus* and *E. grandis* (including hybrid of *E. grandis* with *E. urophylla* and other species) *Eucalyptus* genus seems to offer considerable scope particularly in view of substantial world wide increase in *Eucalyptus* plantation is around 4 million ha over the past decade (Paul *et al*., 1999). The natural range of *E. grandis* is along east coast of Australia from North of New Castle to Bundaberg with scattered stands further North along Queensland coast (Cromer *et al*., 1998; Boland *et al*., 1984).

It is important to breed trees possessing high pulp yield and quality for management of pulp wood forests. The selection of elite species based on their quality has become increasingly significant from both environmental reasons and reduction of pulp cost especially for plantation with short rotation (Oshima *et al*., 2003; Ona and Sonoda, 1996). Orient Paper Mills, Amlai procured *Eucalyptus* seeds from Australian Tree Seeds Center CSIRO Division of forestry in the year 1996 for research & development programme. Seedlings of *E. camaldulensis, E. tereticornis, E. urophilla* and *E. saligna* were grown in central nursery at Amlai and planted in research plots during the same year (July 1996).

Raising of *Eucalyptus* plantation at amlai

Soil in the plantation area has been sandy loam with slightly acidic conditions. Soil depth varies between 1 to 3 m over-laying a continuous belt of hard rock. *Eucalyptus* hybrid seedlings were

planted at an espacement of 2.0 m x 2.0 m. The average rainfall in the Amlai region is around 1,200 mm/year where as temperature ranges between 5 to 45°C. The mean tree height, diameter at breast height and annual increment per hectare/ year after seven years of planting at Amlai region are given in Table 1. Height and DBH measurement were recorded once in a year before commencement of spring growth.

It was observed that seed routed plantations of *Eucalyptus* were not meeting the growth standards expected from fast growing species in semi-arid region of Madhya Pradesh, in which the mills have been promoting tree planting under farm-forestry programme. The quality of seeds has been deteriorating as it happens due in breeding in successive generation. The diverse quality of seeds also resulted in very high variation in their crops (Singh *et al*., 2004). The variation resulted in the mean annual increment variation between 6 to 12 m^3/ha/year.

Average diameter of *E. saligna* (over bark) was higher than other three *Euclalyptus* species but average height was more in *E. camaldulensis* (Table 1). The mean average incumbent (MAI) per hectare per year was more in *E. saligna* followed by *E. camaldulensis*, *E. urophylla* and *E. tereticornis*.

In Australia, majority of works carried out was for trees > 10 years (Anon., 1991). In Thailand harvesting age was 4 to 5 years but from forestry point of view the most economical harvesting age is believed between 9 to 14 years. However the harvesting age has dropped 2-3 years due to farming economics problem (Niskanen, 1997; Anon., 1999; Pisuttipiched *et al*., 2003). Therefore pulping studies of Australian seed routed *Eucalyptus* species of 7.0 years age were carried out at

Table 1

MAI of Australian provenance Eucalyptus species

Species	Seed lot No. of Australian origin	Avg. height (m)	Avg. dia (cm)	Avg. vol. (m^3)	Vol / ha (m^3)	MAI / ha (m^3/ha/yr)
			Over-bark			
E. camaldulensis	18305	17.25	13.20	0.094	233.78	31.17
E. tereticornis	16348	14.70	13.00	0.077	193.18	25.76
E. urophilla	17565	14.50	13.57	0.083	207.65	27.69
E. saligna	19306	13.75	15.32	0.100	251.02	33.47
			Under-bark			
E. camaldulensis	18305	17.25	13.20	0.071	176.66	23.56
E. tereticornis	16348	14.70	13.00	0.058	145.37	19.38
E. urophilla	17565	14.50	13.57	0.063	156.52	20.87
E. saligna	19306	13.75	15.32	0.076	189.96	25.33

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Comparision of pulping characteristics of seed routed *Eucalyptus* plantation of various species

Proximate chemical analysis of *E. camaldulensis, E. urophylla, E. saligna* and *E. tereticornis* was carried out employing Tappi standard methods and results are tabulated in Table 2. Ash content in *E. camaldulensis* and *E. urophylla* was lower than *E. saligna* and *E. tereticornis*. Alcohol/Benzene solubility and Lignin percentage in *E. camaldulensis* was little on lower side than *E. urophylla, E. saligna* and *E. tereticornis*. Holocellulose content was observed to be little higher in *E. urophylla* and *E. tereticornis* than the other two *Eucalyptus* species. Comparison of proximate analysis of *Eucalyptus* species is projected in Fig. 1.

E. camaldulensis, E. urophylla, E. saligna and *E. tereticornis* wood screened chips (-29.0 mm + 3.0 mm) were cooked with different alkali percentage. *E. camaldulensis* and *E. tereticornis* require 16.0% and 17.0% alkali as Na_2O respectively under identical cooking condition where as *E. urophylla* and *E. saligna* need 18% alkali as Na_2O for attaining pulp kappa 24.5-27.0. *E. saligna* neede higher hold time at maximum cooking temperature (165°C) to produce bleached grade pulp. Unbleached pulp yield of *E. urophylla* was on higher side followed by *E. tereticornis*, *E. saligna* and *E. camaldulensis* respectively (Table 3). Black liquor °TW was higher in *E. urophylla* and *E. saligna* than other two *Eucalyptus* species. Comparison of alkali requirement of various *Eucalyptus* species versus their unbleached pulp yield %, rejects % and pulp kappa are projected in Fig. 2.

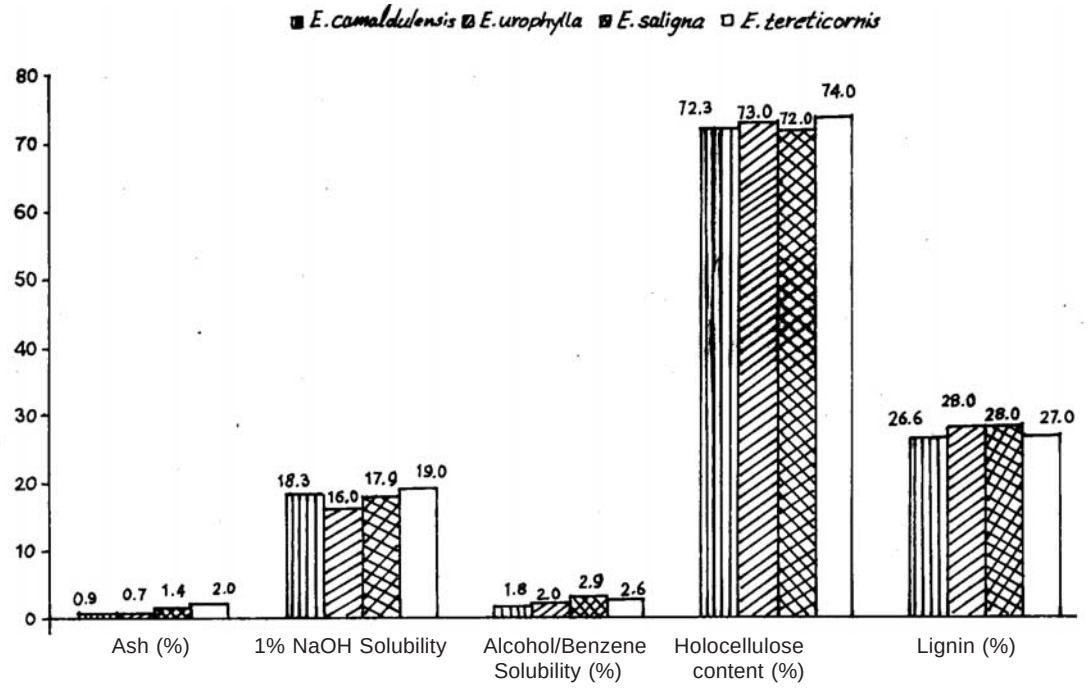
Fibre dimensional studies of various species of *Eucalyptus* pulps were carried out under a projective projection microscope and results are reported in Table 4. *E. urophylla* has higher slenderness ratio than *E. tereticornis* followed by *E. saligna* and *E.*

Table 2

Proximate chemical analysis of Australian seed routed E. camaldulensis, E. urophylla, E. saligna and E. tereticornis.

Particulars	*Eucalyptus camaldulensis*	*Eucalyptus urophylla*	*Eucalyptus saligna*	*Eucalyptus tereticornis*
Ash (%)	0.9	0.7	1.4	2.0
Cold water Solubility (%)	3.9	4.2	5.5	3.6
Hot water Solubility (%)	6.4	5.6	7.9	7.2
1 % NaOH Solubility (%)	18.3	16.0	17.9	19.0
Alcohol / Benzene Solubility (%)	1.8	2.0	2.9	2.6
Holo cellulose (%)	72.3	73.0	72.0	74.0
Lignin (%)	26.6	28.0	28.0	27.0
Pentosans (%)	13.6	14.0	13.2	14.0

Fig. 1



Comparison of proximate analysis parameters of Australian species

camaldulensis. Fibre length of *E. camaldulensis* was on higher side compared to Australian and Thailand *E. camaldulensis*. This may be attributed due to environmental temperature (John and Abbott, 1983) that can influence its growth at the time of tissue formation under Indian climatic conditions and secondly the felling of the plants was conducted at the early age of 7 years of growth. As such physical strength properties are expected to be lower in *E. camaldulensis* compared to other *Eucalyptus* species.

Bleaching studies of *Eucalyptus* pulps were carried under C-Ep-H-D sequence for pulp brightness 87 1% P.V. Total bleach consumption was normal as per pulp Kappa of different *Eucalyptus* species and was lower in *E. urophylla* (Table 5). Bleached pulp viscosity was higher in *E. urophylla* than other *Eucalyptus* species. Bleached pulp yield in *E. urophylla* and *E. tereticornis* was 41.0% and 40.5% (Expt. No. 2) respectively and was higher than *E. saligna* and *E. camaldulensis*. Total bleach consumption of various *Eucalyptus* species, pulp brightness, bleached pulp yield and pulp viscosity are projected in Fig. 3.

Fibre classification of bleached pulps of different species was carried out in a Bauer Mcnett Classifier and results are tabulated in Table 6. Fibre retention percentage on 40 mesh was observed to be higher in *E. urophylla* than *E. saligna* and *E. tereticornis* and was lowest in *E. camaldulensis*. Comparison of fibre classification of bleached pulps

Table 3

Kraft cooking of Australian seed routed E. camaldulensis, E. urophylla, E. saligna and E. tereticornis.

Particulars	*Eucalyptus camaldulensis*	*Eucalyptus urophylla*	*Eucalyptus saligna*	*Eucalyptus tereticornis*	
				Expt. No. 1	Expt. No. 2
Chips taken, on O.D. chips (kg)	2.0	2.0	2.0	2.0	2.0
Initial moisture in chips (%)	15.0	10.5	10.5	14.5	14.5
Alkali used (% as Na_2O)	16.0	18.0	18.0	16.0	17.0
Sulphidity (%)	17.2	17.2	17.2	17.2	17.2
Bath Ratio	1 : 3	1 : 3	1 : 3	1 : 3	1 : 3
Cooking Cycle :					
(i) 0 to 135°C. min.	120	120	120	120	120
(ii) 135 to 165°C. min.	60	60	60	60	60
(iii) At 165°C. min.	60	60	60	60	60
(iv) Total cooking time hr.	4.0	4.0	4.5	4.0	4.0
Kappa No.	25.5	25.0	26.8	27.3	24.5
K No.	16.5	16.3	17.0	17.3	16.3
Unbleached pulp yield (%) (on o.d. chips)	43.6	46.0	44.3	45.3	46.6
Rejects (%) (on o.d. chips)	1.0	0.8	0.6	1.05	0.5
Black Liquor Analysis:					
(i) °TW at 60°C	26.0	28.0	28.0	26.0	27.0
(ii) R.A.A, g/l as Na_2O	18.6	22.0	21.70	18.60	20.15

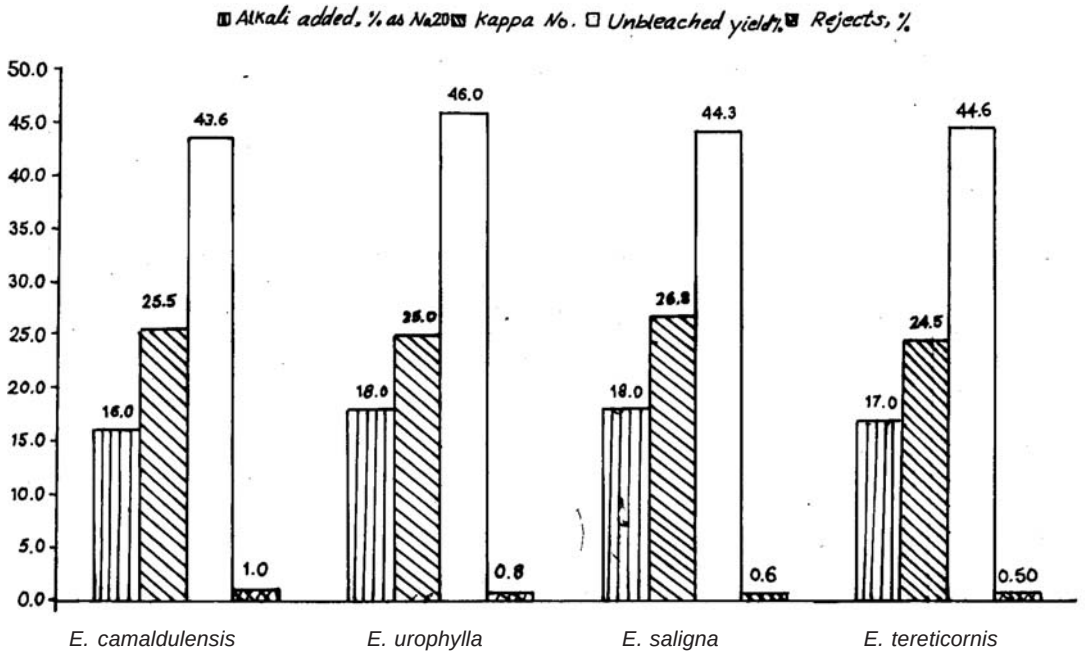
of *Eucalyptus* species are projected in Fig. 4.

All the four *Eucalyptus* bleached pulps were beaten in a P.F.I. mill at 30°SR freeness and evaluated for physical strength properties (Table 7). *E. camaldulensis* require lower beating revolution to achieve 30°SR freeness and has lowest physical strength properties than other *Eucalyptus* species. *E. camaldulensis* and *E. urophylla* pulps have higher bulk than *E. tereticornis* and *E. saligna*. Comparison of strength properties of bleached pulps of different *Eucalyptus* species are projected in Fig. 5.

Conclusion

Australian seed-routed *Eucalyptus* plantations were raised at Amlai (M.P). The M.A.I. of *E. saligna* (over bark and

Fig. 2



Alkali required as Na_2O (%) by different Australian species and its impact on unbleached pulp yield (%), rejects (%) and pulp kappa

Table 4

Fibre dimensions of Australian seed routed E. camaldulensis, E. urophylla, E. saligna and E. tereticornis bleached pulps

Particulars	*Eucalyptus camaldulensis*	*Eucalyptus urophylla*	*Eucalyptus saligna*	*Eucalyptus tereticornis*
Fibre length (mm)				
Min.	0.70	0.80	0.80	0.70
Max.	1.50	1.40	1.50	1.50
Avg.	1.10	1.18	1.15	1.10
Fibre diameter (mm)				
Min.	0.010	0.010	0.010	0.010
Max.	0.025	0.025	0.030	0.030
Avg.	0.017	0.015	0.016	0.015
Slenderness ratio				
L / D	64.7 : 1	78.7 : 1	71.9 : 1	73.3 : 1

Table 5

Bleaching of Australian seed routed E. camaldulensis, E. urophylla, E. saligna and E. tereticornis pulps under C-Ep-H-D sequence.

Particulars	*Eucalyptus camaldulensis*	*Eucalyptus urophylla*	*Eucalyptus saligna*	*Eucalyptus tereticornis*	
	Kappa No. 25.5	Kappa No. 25.0	Kappa 26.8	Kappa No. 27.3 Expt. No.1	Kappa No. 24.5 Expt. No. 2
1	2	3	4	5	6
Chlorination Stage :					
(i) Chlorine applied (%)	4.0	3.6	4.5	4.5	3.5
(ii) Chlorine consumed (%)	3.94	3.55	4.45	4.47	3.55
(iii) End pH.	1.9	2.0	2.1	1.9	1.8
(iv) Consistency (%)	3.0	3.0	3.0	3.0	3.0
(v) Temp. °C	Room	Room	Room	Room	Room
(vi) Time, min	60	60	60	60	60
Alkali Extraction Stage :					
(i) Caustic applied (%)	1.4	1.3	1.5	1.5	1.3
(ii) H_2O_2 applied (%)	0.4	0.4	0.4	0.4	0.4
(iii) End pH	10.3	10.2	10.5	10.3	10.4
(iv) Consistency (%)	10.0	10.0	10.0	10.0	10.0
(v) Temp. °C	65 ± 1	65 ± 1	65 ± 1	65 ± 1	65 ± 1
(vi) Time, min	60	60	60	60	60
Calcium Hypo chlorite Stage :					
(i) Hypo chlorite applied (%)	2.5	2.4	2.5	2.5	2.5
(ii) Hypo chlorite consumed (%)	2.4	2.3	2.43	2.39	2.27
(iii) Sulphamic Acid added (%)	0.1	0.1	0.1	0.1	0.1
(iv) Buffer added (%)	0.80	0.75	0.70	0.65	0.60
(v) End pH	8.8	8.7	8.3	8.1	8.2
(vi) Consistency (%)	10.0	10.0	10.0	10.0	10.0
(vii) Temp. °C	40 ± 1	40 ± 1	40 ± 1	40 ± 1	40 ± 1
(viii) Time, min	120	120	120	120	120
Chlorine dioxide Stage :					
(i) Chlorine dioxide applied (%)	0.6	0.6	0.5	0.5	0.5

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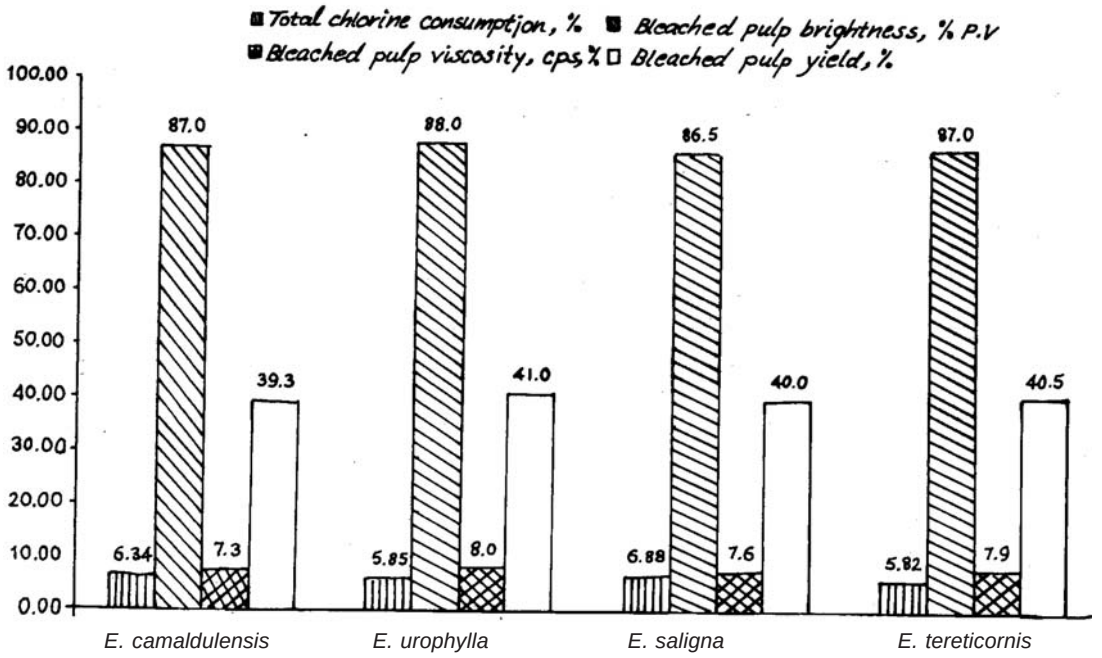
1	2	3	4	5	6
(ii) Chlorine dioxide consumed (%)	0.51	0.52	0.41	0.40	0.43
(iii) End pH	5.7	5.8	5.2	5.4	5.5
(iv) Consistency (%)	10.0	10.0	10.0	10.0	10.0
(v) Temp. °C	70 ± 1	70 ± 1	70 ± 1	70 ± 1	70 ± 1
(vi) Time, min	120	120	120	120	120
Final Results :					
(i) Total chlorine applied (%)	6.5	6.0	7.0	7.0	6.0
(ii) Total chlorine consumed (%)	6.34	5.85	6.88	6.86	5.82
(iii) Pulp Brightness, % P.V	87.0	88.0	86.5	87.	87.0
(iv) Bleached pulp yield (%) (on O.D. chips)	39.3	41.0	40.0	41.2	40.5
(v) Pulp Viscosity (0.5%C.E.D), Cps	7.3	8.0	7.6	7.6	7.9

Fig. 3



Comparison of total chlorine consumption (%), pulp brightness (%), P.V. viscosity, cps and bleached pulp yield (%) of Australian species

Table 6

Fibre classification of Australian seed routed E. camaldulensis, E. urophylla, E. saligna and E. tereticornis bleached pulps.

Mesh Size	*Eucalyptus camaldulensis*	*Eucalyptus urophylla*	*Eucalyptus saligna*	*Eucalyptus tereticornis*	
				Expt. No.1	Expt. No. 2
			Retention %		
+ 40	25.10	39.18	37.57	35.78	37.00
- 40 + 70	36.20	35.42	30.84	33.58	32.60
- 70 + 100	25.80	13.25	18.75	17.19	18.19
- 100 + 140	3.70	2.50	2.82	2.62	2.32
- 140	9.20	9.65	10.02	10.83	9.89
Total	100.00	100.00	100.00	100.00	100.00

Table 7

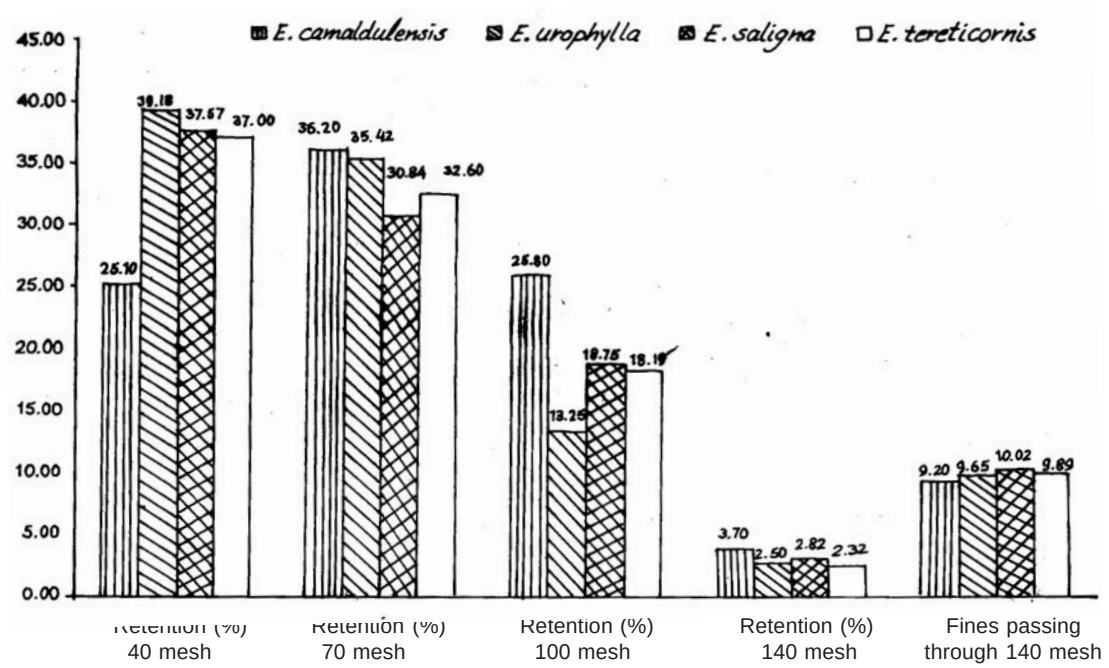
Physical strength properties of Australian seed routed E. camaldulensis, E. urophylla, E. saligna and E. tereticornis bleached pulps.

Particulars	*Eucalyptus camaldulensis*	*Eucalyptus urophylla*	*Eucalyptus saligna*	*Eucalyptus tereticornis*	
				Expt. No. 1	Expt. No. 2
Final freeness °SR of pulp.	30	30	30	30	30
Beating revolution in P.F.I. mill (rpm)	4750	5000	5400	5200	5250
Bulk (cc/gram)	1.41	1.40	1.38	1.36	1.36
Tensile Index (N.m/g)	51.71	52.85	67.23	65.01	66.32
Bursting Index (KPa. m^2/g)	4.51	4.72	5.59	6.15	6.05
Tearing Index (m N m^2/g)	6.81	8.86	7.97	7.37	7.50
Double fold	236	392	486	442	462

under bark) was highest followed by *E. camaldulensis*, *E. urophylla* and *E. tereticornis*.

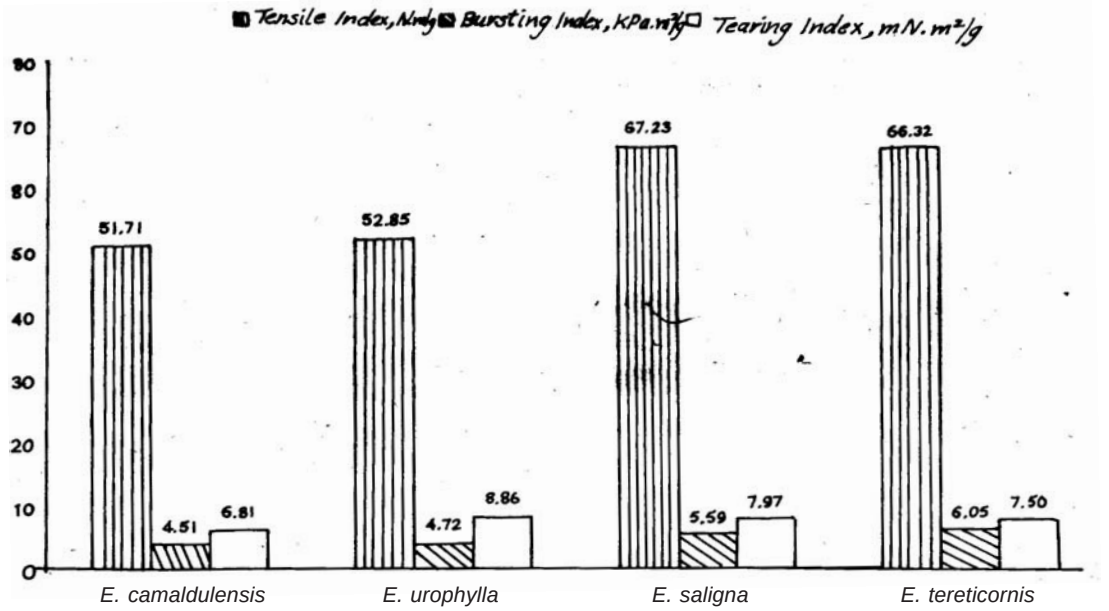
Alkali requirement in cooking operation was higher by 2.0% in *E. urophylla* and *E. saligna* than *E. camaldulensis* and 1.0 % than *E. tereticornis* to produce bleached grade pulp of Kappa 24.5-27.0.

Fig. 4



Fibre retention of Australian *Eucalyptus* bleached pulps on different mesh

Fig. 5



Physical strength properties of Australian *Eucalyptus* bleached pulps

Unbleached and bleached pulp yield and physical strength of *E. urophylla*, *E. saligna* and *E. tereticornis* were higher than *E. camaldulensis*. Although alkali requirement of *E. saligna* was on higher side but is better in respect of M.A.I. and physical strength properties than other *Eucalyptus* species.

SUMMARY

***E. camaldulensis, E. urophylla, E. saligna* and *E. tereticornis* plantations in Amlai region of Madhya Pradesh through seed route were raised from Australian seeds procured from Australian Tree Seeds Centre CSIRO Division. MAI achieved after seven years of growth was maximum in *E. saligna* followed by *E. camaldulensis*, *E. urophylla* and *E. tereticornis*. *E. urophylla* and *E. saligna* wood of seven years of age need 2.0% more alkali than *E. camadulensis* and 1.0% than *E. tereticornis* in cooking operation to produce bleachable grade pulp. *E. saligna* is better in MAI and bleached pulp strength properties than other *Eucalyptus* species. *E. camadulensis* was observed to be inferior in respect of unbleached and bleached pulp yield and various physical strength properties than other *Eucalyptus* species.**

अम्लई क्षेत्र में आस्ट्रेलियाई बीज मार्ग से लगाए हुए *युकेलिप्टस* रोपवनों के लुगदीकरण अध्ययनों की तुलना

आलोक खरे, के०एन० मिश्र, जी०जी० भार्गव, एम०सी० पाण्डे व एन०के० थुसू

सारांश

मध्यप्रदेश के अम्लई क्षेत्र में आस्ट्रेलियाई वृक्ष बीज केन्द्र, सीएसआईआरओ डिवीजन से मंगाए आस्ट्रेलियाई बीजों से *यु० कैमेलड्युलेसिंस, यु० उरोफायला, यु० सैलिग्ना* और *यु० टेरेटिकार्निस* के रोपवन उगाए गए। सात वर्षो की बढ़वार होते रहने के बाद *यु० सैलिग्ना* की माध्य वार्षिक संवृद्धि सबसे ज्यादा रही, उसके उपरान्त *यु० कैमेलड्युलेसिंस, यु० उरोफायला* और *यु० टेरेटिकार्निस* की रही। श्वेतन करने योग्य लुगदी तैयार करने के लिए सात वर्ष की उम्र वाले वृक्ष की लकड़ी को पकाने की क्रिया में *यु० उरोफायला* और *यु० सैलिग्ना* 2% सामाक्षार (एल्केली) की जरूरत *यु० कैमेलड्युलेसिंस* की तुलना में और 1% सामाक्षार की जरूरत *यु० टेरेटिकार्निस* की लकड़ी की तुलना में ज्यादा होती है। अन्य *युकेलिप्टस* जातियों की तुलना में *यु० सैलिग्ना* माध्य वार्षिक संवृद्धि और श्वेतित या विरंजित लुगदी विशेषताओं में ज्यादा अच्छा है। अविरंजित और विरंजित लुगदी की प्राप्ति तथा अन्य भौतिक शक्ति विशेषताओं की दृष्टि से *यु० कैमेलड्युलेसिंस* अन्य युकेलिप्टस जातियों की तुलना में घटिया पाया गया।

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