Young Eucalyptus (Tereticornis) And Gmelina Arborea: Silviculture, High Wood Yield And Low Kappa Number

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ABSTRACT:-- Plantation of eucalyptus tereticornis and gmelina arborea with silvicultural application based on composted sludge has been carried out and the growth pattern as well as pulping and bleaching characteristics are compared with plantation eucalyptus having no silvicultural treatment. The wood yields from silvicultural plantation after four and half years are shown to be 3 times more than that in ordinary plantation. 41-42% of pulp yield, fairly good strength properties, marked by low kappa number (14.5 in eucalyptus) are other characteristics of the present wood samples. Possibility of 3 crops in 10 years and wood pulp generating effluent with low TOCl has been conceived as one of the practical solutions to raw material and environmental problems of pulp and paper mills.

INTRODUCTION

Plantation technology for fast growing, high pulp yielding and short rotation trees is of paramount national importance for India and other Asian countries to cope with decreasing forest land, increasing population and wood requirement of paper and other forest based industries as well as illegal felling of trees (1). In our earlier work (2) rotation of eucalyptus and subabul in every 5 years was advocated not only because of demographic problems but because of superiority in strength properties of 5 years old tree over 3 or 7 years old trees. For example, the breaking length of 5 years old eucalyptus was 7050 m at 40°SR, compared to 5860 m at 7 years at same freeness level; the corresponding burst factors were found to be 52 and 38.6 and tear factors as 45 and 37.5.

These results encouraged us to carry out further work to bring in improvement in the plantation strategy preserving the 5 years rotation period, namely (3-5) by:

- more careful seedling in nursery.
- proper planting with fertilizer and insecticide
- occasional treatment of trees with water and insecticide to stop termite attack
- application of composted paper mill fibrous sludge.

Worldwide attempts are going on (6-13) for increasing wood yield with technologies of faster growth, and short rotation mostly with eucalyptus. Silvicultural applications have also been made (14-16) and pulping as well as bleaching characteristics have been reported on young trees from 2 to 10 years. The results presented here will show that the silvicultural application helps not only in faster growth and higher pulp yield of the trees but also the additional benefit of wood with low kappa number, vital for low TOCl generating effluent.

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EXPERIMENTAL

Plantation

The plantation site is situated at altitude of ~800 ft above sea level, having annual rainfall of ~500 mm. The soil is slightly acidic with pH of 6.8. The seedling was carried out with due care from selected seeds. The seedlings were of 8 months old when planted and before plantation, the soil pit was treated with urea, cowdung and gamaxene exposed for one month. The plantation was made during rainy season with spacing of 1.5m X 1.5m. Gamaxene treatment was made intermittently to avoid termite attack.

The composted sludge was applied at the rate of 15 kg/tree in October-92, April-93, September-93 and November-94. Apart from the water in rainy season, the trees were irrigated occasionally with effluent water. The average growth rate of trees have been measured time to time (Table 1A). The faster growth period is the first two years. The biomass of gmelina arborea as well as eucalyptus were measured while felling. The leaves of gmelina arborea have fodder value.

Table-1

Physical Characteristics

Property		E-I	E-II	G.A.
Species		Tereticornis	Tereticornis	--
Age	(year)	4.1\2	4.1\2	4.1\2
Bark content	(%) w/w	12	18	17
Height	(m)	5.7	9	6.8
Average dbh	(cm)	8	25	25
Wood yield (OD basis)	(t/acre)	9.3	25	24
Basic density	(kg/m³)	494	513	521
Bulk density	(kg/m³)	313	324	318

E Eucalyptus
G.A. Gmelina Arborea
dbh diameter at breast height

Table-1A

Growth of (E-II) Eucalyptus

Year	Height (cm)	% Increase of growth
August-91	77	--
February-92	167	116.9
August-92	304	82.0
April-93	478	57.2
December-93	660	38.0
June-94	730	10.6
December-94	820	12.3

Pulping and Bleaching

The logs were debarked manually and then chipping was carried out in the mill chipper. For proximate chemical analysis, chips were powdered in the laboratory grinder and +60 mesh was taken for analysis. Chips of -32 and +3 mesh fractions have been taken for cooking in a Rotary digester of 25 l capacity.

Pulping and bleaching experiments have been carried out according to standard procedures of Tappi (1991) using laboratory Valley beater and British hand sheet maker. The hand sheets were conditioned at temperature of 25°C and humidity of 65% for 4 hours before measuring the strength properties. The FS and bond factors were determined in Pulmac trouble shooter and the brightness was measured in Elrepho bringhtness tester.

RESULTS AND DISCUSSION

Representative plantation eucalyptus of poor growth (E-I) and good growth (E-II) and gmelina arborea trees (G.A.) (3) were selected for the present study. The eucalyptus trees were 4 1/2 years old while gmelina arborea was four years old at the time of felling. This includes time of seedling also. The physical characteristics of the three trees are given in Table-1. The height of E-I was 5.7 m with 8 cm of dbh while E-II was of 9 m height with 25 cm of dbh. E-I would represent poor wood yield/acre, 9.3 t while E-II represents 25 t/acre which is quite appreciable. Gmelina arborea had height of

Table-2

Proximate Chemical Analysis

Property		E-I	E-II	G.A.
Cold water solubility	(%)	7.2	5.9	15.9
Hot water solubility	(%)	6.0	6.4	8.5
1% NaOH solubility	(%)	17.5	18.2	19.6
Alcohol-Benzene solubility	(%)	3.2	2.8	6.0
Klason-lignin	(%)	25.0	24.5	23.8
Holocellulose	(%)	71.4	73.1	68.4
Pentosan	(%)	16.0	15.7	16.5
Ash content	(%)	1.0	0.8	1.3

6.8 m with dbh of 25cm having yield of 24 t/acre. The wood yield is higher in the present study than previously reported (2) for eucalyptus and subabul. The bark content in E-II and G.A. are comparatively (17) high (18 and 17%). The basic density of E-I, E-II and G.A. are quite close and on the higher side. However, these are quite acceptable (494, 513 and 521 kg/m^3). The bulk densities of the 3 woods studied are also practically same (313, 324 and 318 kg/m^3).

The results of proximate chemical analysis in Table-2 show normal values for cold and hot water solubilities for all the 3 samples. The 1% NaOH solubility values for the three are on the higher side (2). The A-B extractives of both E-I and E-II are similar to mature tree (3.2 and 2.8% respectively) but G.A. has very high A-B extractive (6%). The Klason lignin value of G.A. is lower than in eucalyptus (23.8 and 24.5% in G.A. and E-II respectively). However, all are on the lower side. The holocellulose contents in E-I is 71.4, 73.1 in E-II and 68.4% in G.A. with pentosan values of around 16% in the 3 cases. The holocellulose content of G.A. is comparatively lower than in eucalyptus. Ash contents of 1, 0.8 and 1.3% have been found in the 3 trees respectively. G.A. has thus higher ash content than eucalyptus. The results of proximate chemical analysis are comparable to the previously reported values (2) for eucalyptus and subabul, excepting high A-B extractive in G.A. and marginally higher holocellulose content in E-II.

The chip classification data in Table-3, reported between +32 to -3mm sizes indicate the eucalyptus wood to be normal and correspond to that in mature trees. However, the +32 mesh fraction in G.A. is very high resulting in more of rejects. The chipping should have been different in G.A. from eucalyptus to avoid such high rejects. However, it is obvious that the wood characteristics of the two trees are quite different from each other.

The pulping characteristics in Table-4 corresponding to the cooking conditions mentioned at AA of 17% show screened pulp yield of 31.4% for E-I, 38% for E-II and 38.4% for G.A., the total unbleached pulp yield for E-I being 32%, 41.8% in E-II and 42.4% in G.A. Yield of 32% (E-I) represents very inferior quality of trees while 42.4% is fairly in the acceptable range and comparable to mature trees (2). The kappa number obtained for E-I is 10.2 and 14.5 for E-II which are quite remarkable and attractive both from economical and environmental points of views. However in G.A. the kappa number is 18 which is also fairly on lower side. Such values are normally obtained after oxygen delignification (13). On varying AA during pulping of E-II from 15 to 18%, the kappa number decreases from 17.1 to 13.0 (Fig.-1) with corresponding pulp yield decrease from 41.8 to 35% (Fig.-2). From the yield point of view 15% of AA could be tolerable with kappa number of ~17. Such low alkali consumption is also of significance to the mill. The highest total unbleached pulp yield is in G.A. (42.4%). For achieving low kappa number of 15-16, the yield can be reduced similar to that in E-II i.e., 40-41%. The total pulp yields in eucalyptus and

Table-3

Chips classification

Screen size, mm	% Retained E-I	% Retained E-II	% Retained G.A.
+ 32	2.1	1.7	15.6
- 32, + 25	10.6	9.5	19.6
- 25, + 22	17.3	9.4	13.5
- 22, + 19	8.6	11.3	12.0
- 19, + 16	15.4	16.3	12.8
- 16, + 13	15.5	17.6	9.8
- 13, + 6	24.4	27.9	11.8
- 6, + 3	3.7	4.9	2.9
- 3,	2.4	1.4	2.0

Table-4

Pulping Characteristics

Property		E-I	E-II	G.A.
Active alkali as Na_2O	(%)	17	17	17
Screened pulp yield	(%)	31.4	38	38.4
Rejects	(%)	0.6	2.8	4.0
Total pulp Yield,	(%)	32.0	40.8	42.4
Kappa number		10.2	14.5	18.0
Residual active alkali	(gpl)	3.5	4.6	6.8

Cooking conditions:

Sulphidity of white liquor	(%)	:	17
Bath ratio		:	1 : 2.7

Cooking schedule:

50°C to 165°C	(hr)	:	2
At 165°C	(hr)	:	1.5

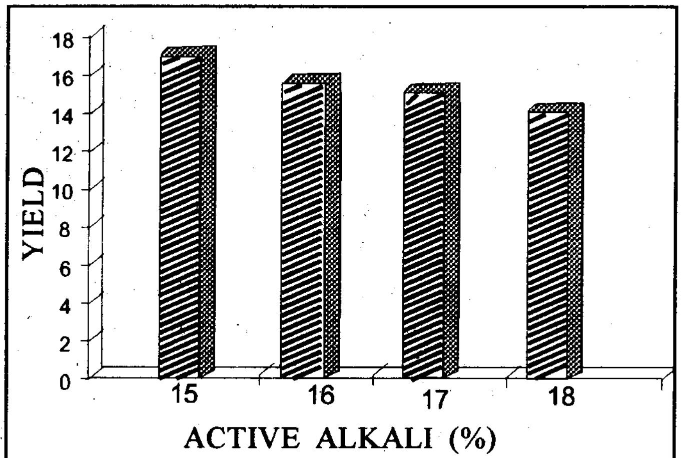

Fig. 1: Active alkali Vs Kappa Number

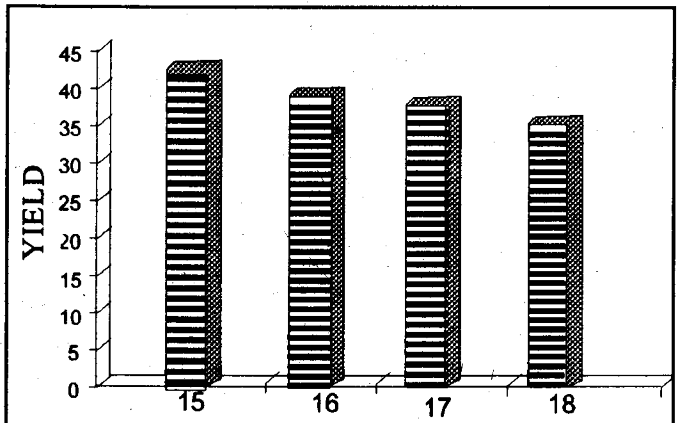

Fig. 2: Active alkali Vs Yield

subabul (2) were, however higher (48-50%) than the present pulps.

In our previous work (15) the kappa numbers obtained for eucalyptus were 27, 22 and 22.8 after 3, 5 and 7 years in eucalyptus tereticornis. The improvement in pulp kappa number here is essentially due to the silvicultural applications unlike in the previous study where the tree grew in wild condition (2).

The bleaching results are given in Table-5. Because of low kappa number, the Cl_2 dosing has been also quite low i.e. 3.06 and 3.9% in the two eucalyptus and 5.6% in gmelina arborea. The Cl_2 consumed in E-I is 2.84% and 3.8% in E-II while it is 5.1% in G.A. The hypo addition is also minimum compared to $\geq$ 3% in matured trees. The total Cl_2 consumed in the 3 samples are thus:

E-I	:	3.74%
E-II	:	5.70%
G.A.	:	6.8%

for brightness values of 78.5, 79.8 and 77% El respectively. The TOCl calculated (22) for the 3 trees are:

E-I	:	3	kg/t
E-II	:	3.8	kg/t
G.A.	:	4.7	kg/t.

Table-5

Bleaching Characteristics

Property		E-I	E-II	G.A.
Kappa no.		10.2	14.5	18
CHLORINATION:				
a) Cl_2 added	(%)	3.06	3.9	5.6
b) Cl_2 consumed	(%)	2.84	3.8	5.1
c) Final pH		2.5	2.3	2.0
ALKALI EXTRACTION:				
a) NaOH added	(%)	1.02	1.3	1.8
b) Final pH		10.5	11.0	11.7
HYPO STAGE:				
a) Hypo (available Cl_2) added	(%)	1	1.9	1.9
b) Buffer added	(%)	0.2	0.2	0.2
c) Final pH		8.8	8.5	9.5
d) Cl_2 (as available) consumed	(%)	0.9	1.9	1.7
Brightness	(% El)	78.5	79.8	77

Constant conditions:		Chlorination	Extraction	Hypo stage
Temperature	(°C)	Ambient	55	Ambient
Retention time	(hr)	0.75	1.5	4
Consistency	(%)	3	10	10

Table-6

Physical strength properties of bleached pulp at different °SR

Properties	E-I			E-II			G.A.		
	Initial 20	30	40	Initial 22	30	40	Initial 18	30	40
Bulk (cc/g)	1.9	1.5	1.4	1.9	1.49	1.40	1.86	1.3	1.25
Burst factor	19	41.3	43.1	19	41.3	46.5	12	35	39.6
Tear factor	51.1	49.2	47.0	51.2	49.2	46.9	36.4	40	44
Breaking length (m)	3390	6077	6803	3389	5640	6077	2525	5695	6336
Double fold (no)	5	25	42	5	25	32	2	23	43

Table-7

Bauer McNett Fibre classification of bleached pulp

Mesh size no.	Fibres retained, %					
	E-I		E-II		G.A.	
	Initial	40°SR	Initial	40°SR	Initial	40°SR
+ 16	0.2	0.5	0.75	0.3	0.7	0.3
- 16, + 30	2.5	1.6	1.7	3.5	3.3	2.7
- 30, + 50	73.9	62.4	66.4	58.9	53.4	47.6
- 50, +100	2.9	4.9	8.4	5.8	14.8	14.5
- 100,	20.5	30.7	22.75	30.7	27.8	34.9

The kappa number of normal matured hard wood kraft pulp is in the range of 21-23 where the Cl_2 consumption will naturally be higher with higher TOCl generation in the effluent than the present low kappa number pulp in CEH bleaching sequence. Such reduction in TOCl generation using young trees can be practised easily and pollution load can be reduced.

The physical strength properties of the bleached pulp samples at initial, 30 and 40°SR are given in Table-6. Compared to eucalyptus, gmelina arborea possesses low bulk in the hand sheet prepared (1.25 cc/g at 40°SR for G.A. and 1.49 cc/g for E-II). The burst factor for E-II at 40°SR is 46.5 and 39.6 in G.A. which are in the acceptable range. Tear factor of E-II is similarly higher than that of G.A. (46.9 and 44), both being in normal range. The breaking length of E-I is as high as 5803m at 40°SR, 6077m for E-II and 6336m for G.A. The double fold values at the same freeness level for the 3 samples are 42, 32 and 43 no. It can be inferred therefore that E-II has good strength properties with lower Cl_2 demand during bleaching as its kappa number before bleaching was 14.5. It appears to be very attractive though G.A. has also comparatively appreciable properties.

The Bauer McNett classification results of bleached pulp (Table-7) indicate -100 mesh fraction to be comparatively high; specially for G.A. where it is 34.9% at 40°SR. As in the chip classification +32 mesh fraction for G.A. was high and rejected, on bleaching the pulp has produced more of fines than in eucalyptus. The fibre dimensions (Table-8) of the 3 wood samples are in the normal range for hard wood (length = 0.78-0.93mm). The longer fibre length of G.A. corresponds to comparatively its higher strength than eucalyptus. The fibre and bonding characteristics given in Table-9 show that both G.A. and E-II have good bond and FS factor with high zero span breaking length. E-II possesses better bonding characteristic than gmelina arborea with higher F.S. factor and therefore, the zero span breaking length in E-II is more than in G.A. The

Table-8

Fibre dimensions of bleached pulp

Property		E-I	E-II	G.A.
Fibre length (Average)	(mm)	0.78	0.93	0.85
Fibre diameter	(μm)	12	16	16

Table-9

Fibre and Bonding Characteristics

Properties	E-I			E-II			G.A.		
	Initial	30	40	Initial	30	40	Initial	30	40
Bond factor	3.23	4.17	4.21	3.18	4	4.43	2.12	3.52	4.1
FS factor	21.83	21.54	19.03	17.64	17.63	17.42	17.5	17.6	16.0
Zerospan breaking length (m)	10986	11304	11924	10819	11951	12214	11511	11603	11840

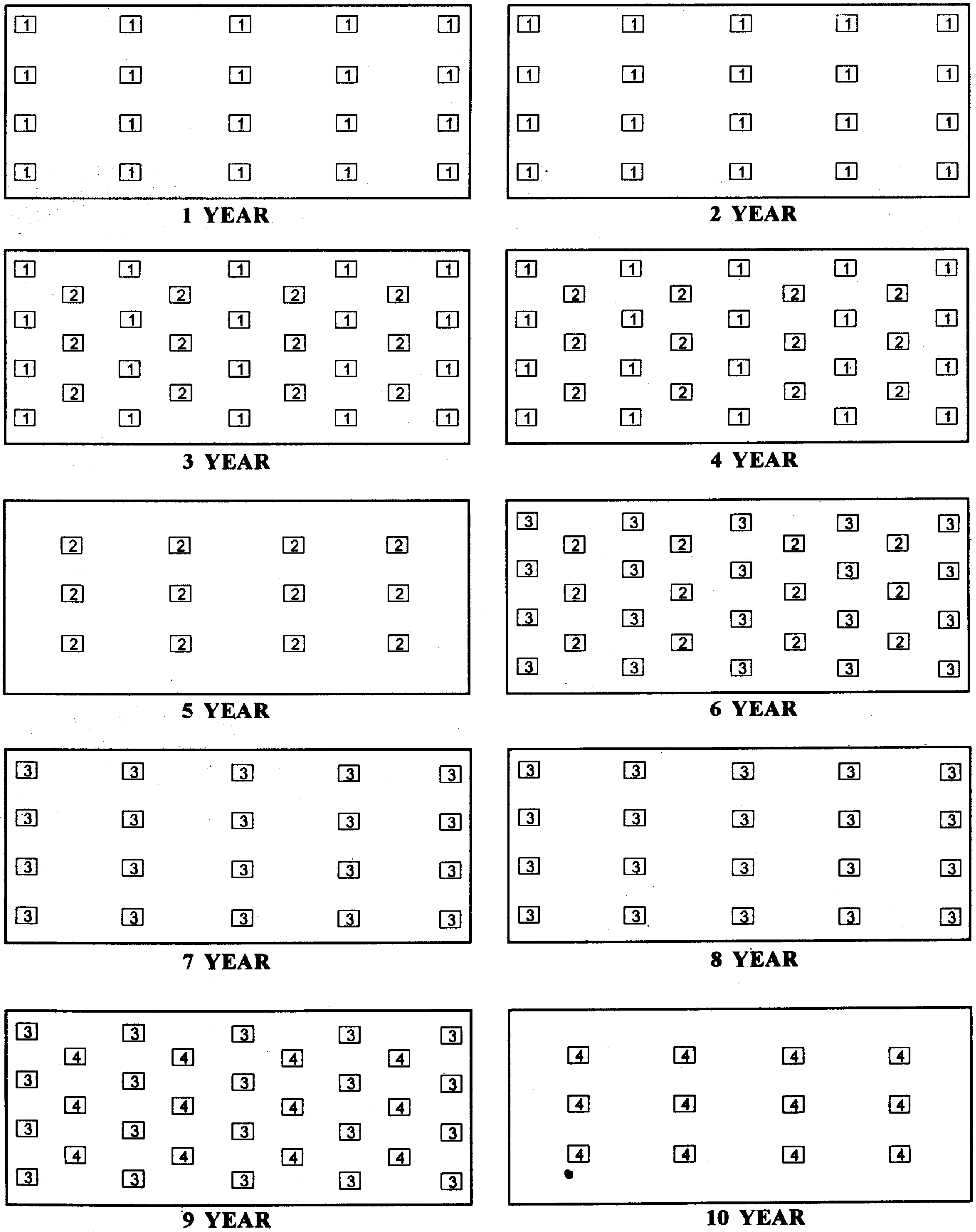

Fig. 3: Schema for short rotation Eucalyptus Plantation

better bonding characteristic of E-II is reflected in higher burst and tear factors in E-II than in G.A. (Table-6).

From the overall properties, E-II appears to be more promising than G.A. E-II has a kappa number of 14.5 which is quite low and rarely achievable in matured trees. Kappa number values of 16-18 are often found in matured eucalyptus also (1). In E-I, kappa number is 10.2 but the wood and pulp yields are very poor. As in our previous work (2), kappa number of 21-23 was obtained for eucalyptus after 3, 5 and 7 years, the silvicultural application appears to have effected the genetic character of the trees. More works need to be carried out to establish the change in genetic character of the tree due to the composted sludge. It is obvious that in early age, bonding of lignin with cellulose is not firm and therefore, delignification mechanism should be easier but then it is difficult to understand as to why the same was not observed when silvicultural application was not made (2). Normally, silviculture helps in increasing the wood yield and for faster growth of tree but here, we tend to infer that it effects the lignin structure and formation mechanism in the plant.

Kappa number of 19-27 is reported in eucalyptus globulus (7) after six years and 11-15 in other woods in 9-13 years (10). Perusal of literature shows that plantation with the objective of bringing down kappa number from environmental point of view (11) has rarely been carried out which is conceived to be achievable in this work.

Because of short rotation (4-5 years), the felling and transportation cost will no doubt increase compared to felling of trees once in every 8-10 years but as the wood yield is appreciable in the present trees, this negative factor carries little meaning. Rather, plantation can be carried out three times in 10 years. An idealistic approach for obtaining optimum wood in a plot is shown in Fig.-3 where new plants can be planted on the 3rd year so that after felling the trees after 4 years, these trees grow in another three years. Thus, in average in 10 years, there can be 3 crops (Table-10) compared to eucalyptus grown wildly and without silvicultural treatment which is usually felled in 10 years (2) thus wood yield of 6 times is theoretically achievable. Such wood yield accompanied by pulp of low kappa number can be considered one of the ideal future plantation technologies.

Table-10

Felling and plantation time

1st felling	:	In the middle of 5th year
2nd felling	:	In the middle of 7th year
3rd felling	:	In the middle of 10th year
1st plantation (Seedling)	:	In 1st year
2nd plantation (Coppice)	:	In middle of 3rd year
3rd plantation (Coppice)	:	In middle of 6th year

CONCLUSIONS

4 – $4^1/_2$ years old eucalyptus tereticornis and gmelina arborea planted using silvicultural treatment, produce kappa number of 10-18 in the kraft process. The strength properties of the wood are quite appreciable (breaking length > 6000 m). The pulp yields are ~40%. These pulps are likely to produce low TOCl. Eucalyptus is comparatively better than gmelina arborea in pulping, bleaching and strength properties. However, both these trees are promising for fast growing, short rotation and low kappa number pulp. Because of silvicultural applications, the wood yield in eucalyptus is 3 times more than in eucalyptus grown wildly after $4^1/_2$ years (7.8 t/acre after 5 years without treatment and 25 t/acre with silvicultural treatment after $4^1/_2$ years). Wood yield of gmelina arborea is also equally good (24 t/acre) because of silvicultural application.

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