Technological forecasting on high pulp yielding plantation in India

PATEL M.* and SAHU A.K.**

ABSTRACT

Exigence for evolving high pulp yielding plantation technology in India has been forecasted in view of ever increasing requirements of paper. The world-wide scenario of paper consumption and raw materials are given Suitability of Eucalyptus plantation in different parts of the world and in India has been brought out. The different species of Eucalyptus have been reviewed alongwith the wood characteristics Comparative study on paper from Eucalyptus occuring in diiferent states in India has been made. Various products obtained from Eucalyptus tree are schematised.

Conditions for high pulp yielding plants namely, soil, climate, leaf index, silvicultural and species selection are defined. Intensive management, clonal technology and high density-short rotation plantation technologies are discussed. The environmental effects of Eucalyptus have been described. R & D imperatives on Eucalyptus and other high pulp yielding plantation have been made.

Introduction :

Technological forecasting is a proven technique[1-4] for evolving appropriate national policies and prioritising R & D imperatives. It encompasses enunciating the global scenario of the technology and reviewing relevant information so as to allow prioritisation of a technology. It had been successfully employed for a large number of resources and materials. While forecasting information on pulp and paper are amply available, rarely forecasting on high pulp yielding plantation technology has been made in the past.

The present review is basically informative on Eucalyptus and other high pulp yielding trees in India as well as other countries.

Global economical scenario :

India

Need for fast growing plantation technology in Indian pulp and paper mills, is existent and exhorts wide attention as it is intimately linked with per capita growth. The per capita paper consumption in India is 3 kg. while it is [5] more than 300 kg. in USA. As this consumption figure is bound to increase with the national development, the wood requirement will automatically shoot up and hence, need for technology for fast growing trees is expedient. This is more applicable to our country due to population growth which is causing limited land availability for plantation. The notion of forest resource development ought to come not simply as environmental protection but as an industry as it has abundant employment opportunity in India.

Australia

Eucalyptus plantation in Australia[37] has evolved over many thousands of years. It has 52 million trees in 50,000 hectares of native hardwood plantation area.

*Pulp and Paper Research Institute, Jaykaypur-765 017, Orissa.

The trees are harvesting after 20 years and the sawlogs in 50-100 years. It is felt now that it is uneconomical to wait for such long period for harvesting. Extensive research work has therefore started in Australia on Eucalyptus for pulp and paper as well as for timber needs.

Finland

Finland was semi-industrialised country before 1950 but agriculture and forestry have undergone considerable mechanisation. Its forest products account 20% of value added products of the country. Finland's total world share is 1% but in forest industry products, it accounts 10% of world's total trade.

South America

The South American countries have taken conscience of it in the last decade and they have come to the limelight recently in energy plantation. According to a recent forecast[6], South America is going to be the "Pulp basket" of the world by the year 2000 AD. Brazil has notably made remarkable progress on plantation technology of Eucalyptus and it has become one of the leading pulp exporters in the world. The policy of self-reliance on pulp and paper is so much so in Brazil that no paper industries commence without having enough raw materials. A new plant to be set up in Brazil[38] at a cost of US $ 1 billion has planned for plantation in 70,000 hectares of land. Venezuela claims[7] to be determined in exporting pulp by the end of this century though it is importing pulp presently. The Eucalyptus plantation in these countries represent a serious source of competition to the Scandinavian pulp wood industry.

Different species of Eucalyptus

More than 700 varieties of Eucalyptus are reported to be occuring[10] in the world out of which 138 are well recognised species. Names of species[11, 12, 13] are given in Table 1. The species identification should not be easy as differences from species to species are not much variable in most cases. The nature of plant may vary again in the same species based on the site conditions. Apart from the species, there are hybrid varieties also which may vary in properties from the parent species. The species are differentiated into three varieties (Table 1) according to the level of occurrence,

well known species — A
little less well known species — B
rarely occurring species — C.

Wood qualities according to species

Eucalyptus pulp is preferred for making writing, printing and tissue grade paper because its pulp imparts excellent properties like good formation, bulk, softness, flexibility, opacity and porosity[15]. They also tend to have lower fines content than other hard wood pulps, resulting in better drainage and drying properties.

E. grandis pulp has good strength properties in average while E. globulus pulp has good porosity and bulk. E. Cameldulensis and E. rostrata pulps have good bulk and opacity.

Laboratory studies conducted to determine the wood and kraft pulping characteristics of E. Torrelliana and E. grandis varieties showed that the wood fibres of the former are more rigid because of greater wall thickness and smaller lumen diameter in E. torrelliana species. It was higher content of extractive and pentosans; its holocellulose content was similar and its lignin content was lower. This implies that E. grandis fibre quality is better than that of E. torrelliana[16]. Eucalyptus species are characterised genetically which reflect on the fibre and vessel dimensions[14]. Some of the important properties[12, 13] of wood such as basic density, fibre length, lignin content, yield, pulpability and paper strength of 39 species are summarised in Table 2. The wood having low basic density, less lignin content, longer fibre and thin walled are the best criteria for giving good quality of paper. Out of all varieties of Eucalyptus, only two species; E. grandis and E diversicolor bear the "best" properties. Rarely paper industries produce pulp from 100% Eucalyptus wood. It is always used after blending with other wood pulp in different proportions to produce papers of different grades. The Gomphocephalla species has high tannin content (7%) which is serious drawback to be acceptable as a raw material in paper industry.

Occurrences

Occurrences of different Eucalyptus species are shown in Table 3. It can be seen that the E grandis grows both in Brazil and India. It prefers and fresh friable loams of good fertility and grows well near water

Table—1 : Name of different Eucalyptus Species

1.	Botryoides	—	A	38.	Fastigata	—	A
2.	Citriodora	—	A	39.	Niten	—	A
3.	Crebra	—	B	40.	Viminalis	—	A
4.	Behrima	—	C	41.	Regnanas	—	A
5.	Brook Wayii	—	C	42.	Decorticaus	—	B
6.	Tereticornis	—	A	43.	Saligna	—	A
7.	Cameldulensis	—	A	44.	Debrymploana	—	B
8.	Catadocalyx	—	A	45.	Sargentii	—	B
9.	Microcarpe	—	A	46.	Argophoea	—	A
10.	Gummifera	—	A	47.	Blesseri	—	B
11.	Punctata	—	A	48.	Rudis	—	A
12.	Transcentenentalis	—	C	49.	Lonsosera	—	B
13.	Salmonopholia	—	B	50.	Tetradonta	—	A
14.	Salubris	—	B	51.	Deanii	—	A
15.	Acameniodes	—	B	52.	Reesophylla	—	C
16.	Leucoxylon	—	B	53.	Delegatensis	—	B
17.	Mellidora	—	B	54.	Straiticalyx	—	C
18.	Maculata	—	A	55.	Dunnii	—	B
19.	Paniculata	—	A	56.	Microtheca	—	A
20.	Grandis	—	A	57.	Varmarocarna	—	C
21.	Cloeziana	—	B	58.	Rostrata	—	A
22.	Pilularis	—	A	59.	Robusta	—	A
23.	Populnea	—	A	60.	Globulus	—	A
24.	Ochrophoea	—	A	61.	Ficifolia	—	C
25.	Naudiana	—	B	62.	Resinifera	—	C
26.	Tesselaris	—	B	63.	Straigeriana	—	C
27.	Alba (Syn. E. Urophylla)	—	B	64.	Diversicolor	—	B
28.	Microcarpa	—	B	65.	Calophylla	—	B
29.	Rummerge	—	B	66.	Cypelbcarpa	—	B
30.	Odontocarpa	—	B	67.	Deglupta	—	A
31.	Umbranarnesis	—	B	68.	Macarthurii	—	C
32.	Socialis	—	B	69.	Maidenii	—	A
33.	Brew Folia	—	B	70.	Marginatta	—	B
34.	Pachyphylla	—	B	71.	Ovata	—	C
35.	Consideniana	—	C	72.	Sieberi	—	C
36.	Tasuranica	—	B	73.	Melanopholia	—	B
37.	St. Johnii	—	B				

A — Well known species

B — Little less well known species

C — Rarely occuring species

Table—2 Wood Characteristics of Different Eucalyptus Species

Eucalyptus species	Basic density	Fibre length	Lignin content	Yield	Pulpability	Paper strength
A	B	C	D	E	F	G
Cameldulensis	normal	average and thin	average	average	easier	average with good opacity
Citridora	high	normal, thin and thick walled	normal	low	difficult	poor
Doglupta	normal	short, wide and thick walled	high	low	easier	below average
Globulus (Blue gum)	normal	normal, thin and thin walled	average	average	easier	average
Grandis	low	normal and very thin	average	average	easiest	good
Maidenii	normal	average, thin and thick walled	normal	normal	easy	normal
Obliqua (Messmate)	normal	—	—	—	—	—
Regnan	normal	—	—	—	—	—
Robusta	high	average, wide and thick walled	high	low	not easy	below average
Saligna	normal	average, wide and thick walled	high	low	easy	below average
Tereticornis	very high	short, wide and thick walled	average	very low	difficult	below average
Viminalis	normal	average, thin thin walled	average	normal	easy	average
Torreliana	normal	short, thick walled	—	—	easy	below average
Cameldulensis (12 ABL)	high	average, wide thin walled	high	low	not easy	normal
Albens	very high	short, thin thick walled	average	low	difficult	normal
Amygdalina	normal	short, thin	normal	normal	easy	normal
Botryoides	normal	normal	normal	normal	easy	normal
Cloeziana	high	average, thin, thick walled	high	low	difficult	normal
Delegatensis	—	—	—	—	—	—
Gomphocephalla	high	short thin, thick walled	low	low	not easy	below average
Hemipholia	high	—	—	—	—	—

A	B	C	D	E	F	G
Leucoxylon	high	very short, thin, thick walled	normal	normal	not easy	poor
Occidentalis	high	very short thin, thick walled	low	low	difficult	poor
Ovata	normal	—	—	—	—	—
Trabutii	normal	average, thin thin walled	average	average	easy	average
Urophylla	medium to high range	short, wide, thick walled	average	normal	easy/ difficult	below average
Calophylla	high	longer	average	low	not easy	average
Cypellocarpa	high	—	—	—	—	—
Deanii	normal	average	high	low	easy	average
Diversicolor	slightly high	longer	normal	normal	easy	good
Dunii	average	average, thick walled	normal	normal	easy	poor
Fastigata	low	short	normal	normal	easy	poor
Macarthurii	normal	normal	normal	normal	easy	average
Maculata	high	below average, thin, thick walled	normal	low	not easy	poor
Marginata	normal	normal	—	—	—	—
Niten	normal	below average	normal	normal	easy	below average
Paniculata	high	below average	high	low	not easy	poor
Seiberi	normal	—	—	—	—	—
Tesselaris	normal	below average	high	low	easy	poor

Table : 3 Occurrence of Different Species of Eucalyptus

Eucalyptus species	Country of occurrence
Cameldulensis	Spain, Siville, Cadic, Ruelva, Malga, Portugal, North Africa, turkey, Srilanka, Kenya, South Rhodesia, Malawi, Republic of South Africa, USA (California), Brazil, Argentina, Chile.
Citridora	Portugal, North Africa, Srilanka (at 1000–2000 mts), South, West, Central and East Africa, Brazil.
Doglupta	Philippines, Celebes, New Guinea, New Britain, New Ireland, Java, Cuba, Brazil, Srilanka, *India*, Malaysia, North Borneo, Solomon Island
Globulus (blue gum)	*India*, Italy, Portugal, Spain, Brazil.
Grandis	Brazil, *India*.
Maidenii	Italy. Portugal, Zaire, South Rhodesia, Malawi, Kenya, Brazil, Morocco, Newzealand.
Obliqua (Messmate)	Spain, North Africa, Brazil, Republic of South Africa, Newzealand.
Regnan	Newzealand, Republic of South Africa.
Robusta	Spain, South of Portugal, North Africa, Italy, Cyprus, Brazil, Mad-

	gascar, Mauritius, Malawi, *India*, Malaysia, Zaire.
Saligna	Brazil (Rio Claro), Republic of South Africa, Italy, Chile, Southern Rhodesia, Nigeria, Malawi, Srilanka, Kenya.
Tereticornis	Italy, Spain, *India*, Portugal, Cyprus, North Africa, Indonesia, Zaire.
Viminalis	South Portugal, California, Chile, Republic of South Africa, *India*, (high altitudes), Tanzania, Zaire.
Torreliana	Australia (North Queensland), Argentina, Brazil, Nigeria, Nyasaland Sudan, Congo, Cyprus, *India*, Malaysia, Solomon Island, Hawaii.
Camaldulensis (12 ABL)	Madagascar, Congo.
Albens	Easter Australia, Italy, Cyprus, West, East and South Africa.
Amygdalina	Tasmania, Australia, Italy.
Botryoides	Newzealand, South Rhodesia, Kenya, South Africa, USA (Coastal Zones of California), Rwanda, Burundi.
Cloeziana	Congo.
Delegatensis	Australia.
Gomphocephala	Republic of South Africa, California, Chile, Italy, *India*, Brazil Kenya, Zaire.
Hemipholia	*India*, Brazil.
Leucoxylon	Italy, North Africa, Republic of South Africa.
Occidentalis	Oran, Morocco.
Ovata	Algeria (Tell Atlas Mountains).
Trabutii	Algeria, North Africa, Italy.
Urophylla	Brazil.
Calophylla	Australia.
Cypellocarpa	Australia (New South Wales, Victoria).
Deanii	Brazil, Argentina.
Diversicolor (A typical tree which can each a height of 45 mts and girth 5 mts with good wood quality)	Australia (Western).
Dunni	Brazil.
Fastigata	Newzealand.
Macarthurii	Argentina.
Maculata	Brazil.
Marginata	Australia (Western).
Niten	Australia, Newzealand.
Paniculata	Brazil.
Seiberi	New South Wales, Australia.
Tesselaris	Brazil.

reservoirs but not in water logged area. Such types of lands being meant for crops and vegetables, suitable land availability for E. grandis plantation is restricted. Though E. grandis is one of the best among other Eucalyptus species, its plantation area is not so high as other species. E. tereticornis is less acclimatised at low altitude area. E. Camaldulensis fails to grow at low Indonesia and Kampuchea. E. botryoides cannot grow in Srilanka and Zaire while E. Maidinii does not grow in Brazil, Morocco and Newzealand[12, 13].

Eucalyptus in India

Eucalyptus was first introduced in India[17] during 1782 to 1802 at Nandi Hills of Bangalore and Sultanpet area in Deccan area. But the regular plantation was

started in 1856. Large scale trials were taken up in 1951 in Assam, Madhya Pradesh, Bihar, Maharastra, Uttar Pradesh and Kerala. Later on it was spread over to Andhra Pradesh, Karnataka, Tamilnadu, Punjab, Haryana and Orissa. In view of the expansion of existing paper industries, and starting of new ones, Eucalyptus plantation is spreading slowly all over the country. Even in Himalayan[19] region Eucalyptus plantation has been started. It is reported that in Andaman Island, it has been grown. It is possible to grow Eucalyptus even in desert area of Rajasthan. The Eucalyptus species which grow well in India are E. cameldulensis, E. tereticornis, E. grandis, E. citridora, and Globulus. The different varieties of Eucalyptus reported to be occuring in different states are shown in the Map(Figl) The species shown in the map need not be applicable

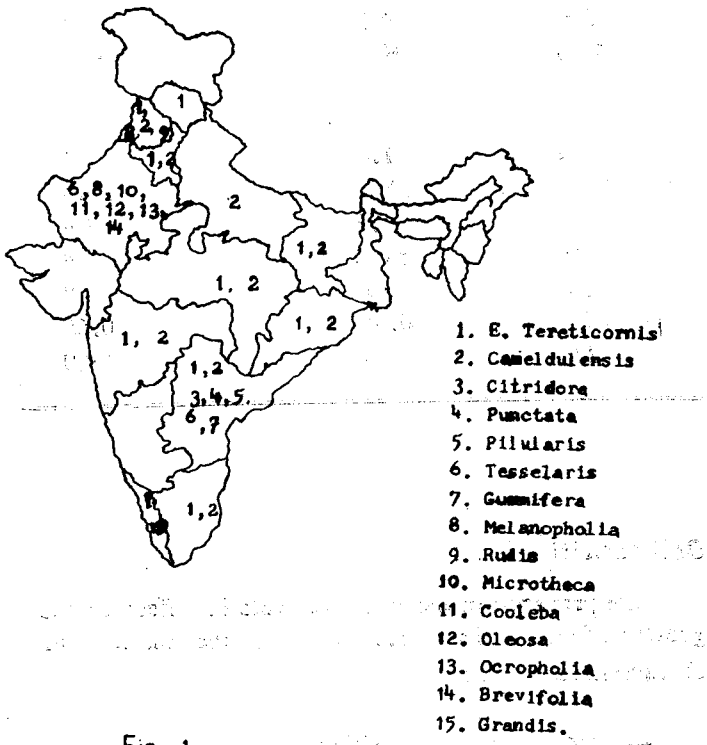

Fig - 1

Eucalyptus species in different states

to the whole state because of varying soil and climatic conditions within the state. However, this map gives an idea for selection of a species when new plantation is desired. Species may be selected based on the soil and climatic conditions also.

There are some Australian species like E.dundasi and E. occidentalis that can grow well in India where the rain fall is 260 mm (with every month 15 mm rain fall) and other species like E. bicolor, E. ochropholia, E. botryoides, E. microtheca, E. fasciculosa, E. populifolia, E. pilligaris can grow in areas where rain fall is 380 mm per annum. In salt affected area and in drier zones E. microtheca is found to grow well[18]. Thus the meteorological data of a site where certain species grow better, is one of the factors which can be correlated to select the species.

Analysis results of samples from five states in India carried out in the same conditions, are shown in Teble-4. It can be observed that the strength properties of sheets from Haryana are better than other samples[19]. As far as bleach yield is concerned, samples from Punjab and Tamilnadu are better than others. However strength properties of paper producted from the wood available from various states are in the acceptable range.

Comparison with other hardwoods :

From economic point of view Eucaly ptuspulp is cheaper than other hardwoods. Because of straightness of Eucalyptus tree, more number of trees can be planted in a given area as compared to other trees. Its harvesting and transportation handling are also easier.

Casuarina another hardwood which is extensively grown in India and used by the paper mills, are a competitor for Eucalyptus. Casuarina can grow in the coastal region also. It has been seen in our laboratory[19] that Subabul can give higher pulp yield than even Eucalyptus.

Other plants which are considered suitable for pulp making and are fast growing are : Enterolobium[24] Gmelina arboria[25], Poplar[26], Acacia[27], Subabul[47] Siris (C. Siamea), Simamba (Simarubaceae), Simal (Bombax) Bixa (Orellana, L).

Improved plantation technology :

Objective of any improvement in plantation technology should be to produce high volume of wood with acceptable quality in a fixed land area. Factors responsible for such improvement can be due to[11] :

Table–4

Comparative Study on Paper from Eucalyptus Occuring in Different States

Particulars		Orissa	Haryana	Punjab	Tamil Nadu	Karnataka
Basic density, (Kg/m^3)		612	527	619	628	571
Chips bulk density (Kg/m^3)		225	215	298	245	286
Pulping						
Kappa no.		22	16	17	18.9	116.7
Screened pulp yield,	(%)	46.0	45.1	46.2	43.1	44.2
Bleaching (CEH)						
Total chlorine added/ consumed,	(%)	7.5/6.1	7.0/5.71	7.2/7.0	6.3/6.0	7.0/5.9
Brightness	(%El)	79.3	80.5	79.4	81.0	80.5
Viscosity,	(cp)	5.4	5.3	5.6	4.5	4.4
Bleached pulp yield	(%)	38.0	36.5	40.3	39.5	38.1
Strength properties						
Bulk	(cc/g)	1.4	1.3	1.5	1.4	1.4
Burst factor		39.2	41.8	29.2	38.6	26.4
Tear factor		42.2	44.3	38.5	45.0	32.6
Breaking length	(m)	5839	6115	4821	5960	3915
Double fold		15	36	10	14	8
Fibre length	(mm)	0.8	0.9	0.73	0.86	0.65
Fibre diameter	(μm)	18	16	22	18	20.0

a. Soil condition
b. climatic conditions specially rain fall
c. meteorological parameters
d. availability of sunlight
e. leaf index of a tree
f. tree species
g. silvicultural preparation.

These factors are so important that whatsoever may be findings made in research level for planting density, high productive tree or maximum growth treatment alone may not bring in any improvement. These factors are therefore discussed in details below, with special reference to Eucalyptus plantation.

Soil conditioning :

Site preparation has a major role in affecting the growth of plant. The basic nature of the soil is to be characterised by its :

— mechanical composition,
— texture class,
— water holding capacity,
— field capacity,
— organic matter content,
— nutrient content and
— soil pH.

For hard soil, severe operations like bull dozing,

stump removal, heavy disc ploughing and disc harrowing are required[24].

Soils having pH of 8 to 11, impart poor drainage. Addition of gypsum and farm yard manure can improve the drainage property of the soil for better growth of Eucalyptus. Pyrite and acid forming agents can also be added beneficially for the same purpose. However, there are certain species like, E. dundasi and Occidentalis which prefer alkaline soil condition. Cameldulensis from Kuwait origin exhibit faster growth on saline site. In Punjab area where the soil is sandy, saline and arid, species like E. malanopholia, E. cameldulensis, E. tereticornis and E. Rudis have been tried with success with irrigation facility in the first three years. In calcareous soil, E. tesselaris shows better performance[18]. The paper mill effluent, already treated with urea and supper phosphate, can be well utilized in plantation site. Depending upon the soil condition, quantification of effluent treatment and species selection are important parameter that is to be seen.

Climate :

Tropical climate with uniform rain fall throughout the year is suitable for Eucalyptus as in Brazil and Venezuela Climate in Australia and Spain are also favourable. Based on the climate[25], South America, SouthAfrica and Maditeranean region can be favourable for growing Eucalyptus. E. saligna and E. grandis grow in South Africa and South America, while E. globulus in Northern Spain, Portugal and Italy. It is reported that growth of E. saligna variety in the rich soil in Brazil, where climate is hot and wet, is excellent; the yield was 625 m^3/ha. after 7 years. On the other hand, in poor quality of soil as in South Africa, (sandy loam granites and dolomites), the average annual yield is very low, 15-35 m^3/ha.

It is previously discussed that Eucalyptus can grow in extreme climates like in desert area of Rajasthan, and near Himalayas. It is reported that E. tereticornis variety occurs easily in India in regions where rain fall is 400 to 4000 mm, and in climate from tropical to warm temperature and provinances coastal to 2000 meters altitudes[17].

Meterological parameters :

Apart from the temperature and rain fall, wind velocity can play some role in growth of Eucalyptus. August to September are the ideal months for plantation because of rain fall. In the initial period, water logging can cause elimination of the plant. Once, succumbed to a climate, the plant adapts to the local weather quickly but the overall yield may be effected.

Availability of sunlight :

It is one of the most important criteria for fast growing Eucalyptus, specially in the western countries. Higher the sunlight, better is the photosynthetic process and helps in proper growth of plant. Areas where shadow of big trees are found, Eucalyptus may not grow suitably. This has repercussion of the spacings adapted for plantation.

Leaf index of tree :

If the plant contains lot of leaves, the sunlight can not fall on the lower region of the tree and thereby the growth is retarded. These factors become very important as the growth period required for pulp and paper industry is 7 to 8 years. It is reported that the size of photosynthetic canopy rather than any difference in the efficiency of the photosynthetic process results in the faster volume growth of symphomyrtus compared to monocalyptus species[24]. The early investment in leaf area index (M^2 of leaf area/M^2 ground area) by the symphomyrtus will lead to a rapid increase in canopy photosythesis compared to the ashes. Thus if the leaf index is high, maximum light interception will be achieved at earlier stage in the growth of crop and higher rate of production or shorter rotation will be realised.

Tree species :

Eucalyptus can grow from both coppice and seedling. However it has been experimented that coppice grown in mist chamber can produce uniform quality of plants. The hybrid variety is one of the most preferred species for raising plantation in India. Its fast growth character accompanied by adaptability to edaphic and arid climatic conditions become attractive and it is used extensively in most social forestry pro-

gramme in India. Normally 5-6 months of old seedlings. are used. E. tereticornis is again the variety which is most used in India.

Silvicultural preparation :

Proper fertilizer and insecticide treatment are very important for fast growing plantation mainly because mostly unused or waste lands are alone made available for Eucalyptus. In Indian condition the sequence of treatment of fertilizer is shown in Table-5 which should be continued for 4 to 5 consecutive years in order to have good growth rate. Ammonium sulfate, super phosphate and potash are required to be added. It is reported that urea (5 gms.) should be added[27] in a pit of volume of 30 cm^3 at the time of plantation. One has to be very careful in application of urea. It may be easier to add after about two weeks of plantation. Fig. 2 indicates growth of E. globulus with and without fertilizer[28]. The growth is 10 times more on application of fertilizer. The amount of fertilizer used is 565 kg/hectare. Relationship between wood colour,silvicultural treatment, and rate of growth in Eucalyptus grandis Hill (Maiden), has been studied by Wilkin and Stamp recently[37].

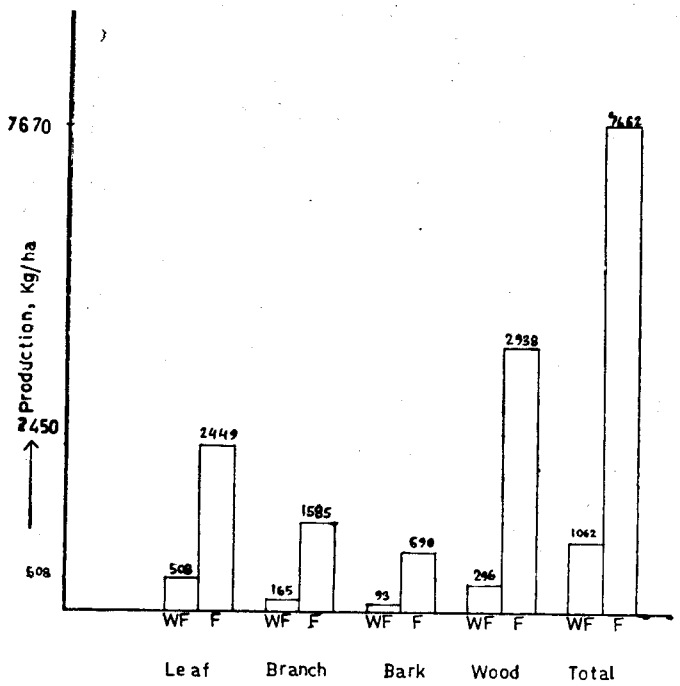

Fig2.Dry weight Production of Eucalyptus - globulus, 2 yrs.

WF → without fertilizer.

F → with fertilizer

TABLE—5

FERTILISER APPLICATION

Year*	Ammonium sulphate (N_2) Kg/ha	Super phosphate (P), Kg/ha	Muriate of Potash (K), Kg/ha
1	47	21	—
2	79	35	—
3	79	35	—
4 (I)	63	27	75
(II)	79	35	—
(III)	63	27	75
TOTAL	410	180	150

*1, 2 and 3 in October

I - January, II - October, III - January.

Termite control in soil

Termite attack can be very severe at the early stage as it was observed in our experimental plantation stage. Application of BHC is a must to avoid termite effect.

Chlorpyrifos[26] is an effective soil insecticide that can be used by spray or pit treatment methods with 0.2% water emulsion of chlorpyrifos in the soil for termite control.

The mixture of two herbicides can be used as follows :

(8l/ha) 25% ammonium thiocyanate + (6l/ha) 50% amitrole (contact herbicide) and (6l/hac) 50% atrazine (a per-emergence herbicide).

These chemicals kill small grasses and some time save the plant from various poisonous chemicals produced by the grasses apart from the termites.

Carbaryl and metasystox in combination is used as an insecticide that minimises the browsing from insects[26] There are other chemicals for controlling the termite and weeds available in the market. In choosing the chemicals, the effectiveness as well as cost should be taken into account.

Advanced plantation technology

No systematic methods are followed previously for plantation of Eucalyptus. Based on the literature

survey, the following three methods can be suggested for large scale propagation of Eucalyptus in India :

i. Intensive management technique.
ii. Clonal technology.
iii. High density - short rotation method.

Combination of the two or three is imperative for high pulp yielding plantation.

Intensive management technique

This is Australian method[24] according to which Eucalyptus plantation should be carried out sequentially as follows :

Site preparation including soil conditioning, treatment with manures and insecticide. By adopting intensive management of plantation, it was observed that the current annual increment became significant (Table 6) at the age of 4 years. The species tried were Niten, Globulus, Delegatensis and Regnan. Four sites had been selected at altitudes of 60, 240, 449 and 650 metres. The results shown are the standing volume at 4 years of age at 60 meters of altitudes (Table 7).

TABLE—6

ANNUAL INCREMENT OF VARIOUS SPECIES OF EUCALYPTUS

Eucalyptus species	Current annual increment, m^3/ha/yr	
year	*2-3*	*3-4*
Niten	23.0	39.4
Globulus	21.4	23.8
Delegatensis	13.1	23.6
Regnan	15.5	16.1

TABLE—7

STANDING VOLUME OF VARIOUS SPECIES OF EUCALYPTUS

Eucalyptus species	Standing Volume (4 yrs) in m^3/ha
Niten	65.6
Globulus	50.2
Delegatensis	38.2
Regnan	35.0

Clonal technology

This is a Brazilian technology for making large scale plantation. The trees grown by this techonology have farely uniform growth and at a faster rate. The properties of wood are farely of the tree (7—8 years), coppice are grown. These are then grown in polythene pots inside mist chamber. The soil and admixtures etc used inside the pots and the conditions in the mist chamber are considered to be quite important.

A comparative growth[29] data from seedling origin and from coppice are shown in Fig. 3. The diameter is more than double and the height is more then 50% when the plant is from coppice origin than from seedling. However, disadvantage with plant grown in coppice origin is that the bark content is four times more than that of the seedling method.

High density, short rotation method :

The spacings for Eucalyptus plantation followed in social forestry in the country are :

a) 1 5 m X 1.5 m
b) 2 m X 2 m
c) 3 m X 1.5 m
d) 5 m X 5 m (for bamboo).

In the agro-forestry, the space maintained is 4 m X 5 m

Critical examination of such space fixation does not appear to be based on experimental Works. It is required to experiment the growth pattern regionwise at varying spaces and then fix the spacing. In view of the future land demand for housing and limitation in land availability for plantation, all research efforts should be directed to have higher yield per unit area. Recently, the spacings tried at Forest Research Institute was 1 m X 1 m though it was reported the yield might increase marginally when the spacing is 1.2 mX1.2m[30]

Farm and Agro Forestry

Many paper mills in the country are investing huge amount of money since few years to propagate Eucalyptus and Subabul trees to become self-reliant. Inboth the forestry, the germination/seedlings are to be made in the nursery.

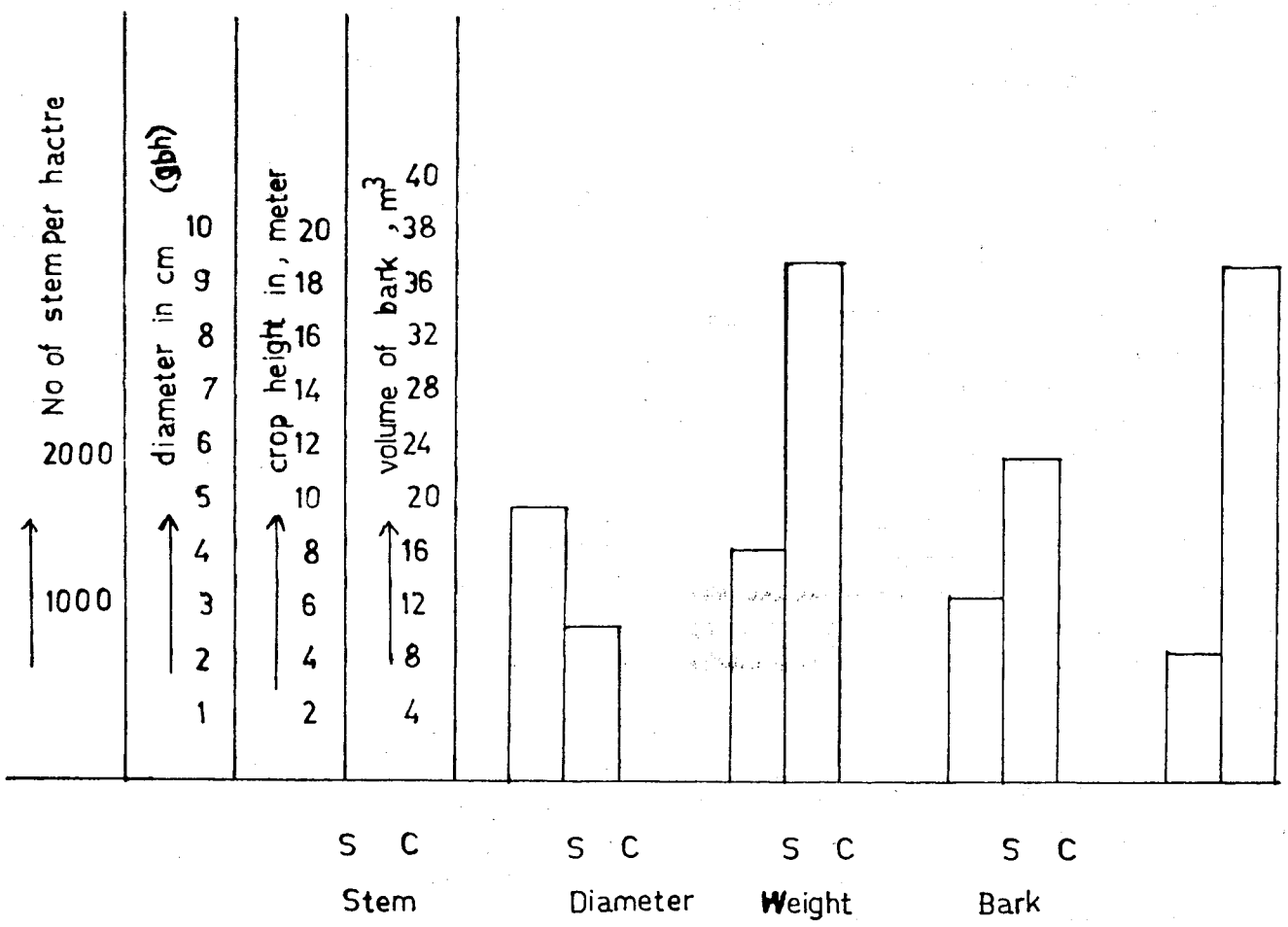

Fig-3 Comparative growth & yield of seedling origin crop & first coppice in $5\frac{1}{2}$ yrs. (E. hybrid)
S—From seedling origin
C—From coppice

Nursery technique :

a. Soil bed is to be prepared with soil : sand : organic manure (farm yard manure) 50 : 30 : 20 along with insecticide.
b. The seeds should be sown after mixing with sand in the bed of 5' X 4' size. About 57 gm consisting of 2500-3000 seeds are required.
c. Best time of sowing is November-December.
d. The seed-bed should be covered with straw to protect against brids etc.
e. Seedlings are ready for pricking out when the second pair of leaves above cotyledon appear (after 45 days of sowing).
f. The seedlings are kept in polythene bags (suitable size 10 X 17.5 cm and 10 X 20 cm) having local soil (50) : Sand (30) : Compost (20).
g. After 6-8 months the seedlings are ready for planting

Cultivators are being supplied seedlings and fertilizers etc. freely under these schemes so that the

return can be benefitted by the farmers and the trees can go the paper mill.

Environmental effect :

There are some controversies on luxury consumption[36] of water by Eucalyptus plant. It is reported that it can affect the growth of other crops in the Eucalyptus plantation site as the water level goes down. The restrictions against growing Eucalyptus now being promoted by some environmentalists are however, not well founded. The experiments carried out in one place can not be generalised because of varying soil conditions, specially percolation, seepage and various civil engineering factors.

It was found in our experimental plantation area that other plants like Subabul, Casuarina etc. grow quite well in nearby Eucalyptus plantation area. In the rainyseason, on the other hand, the area becomes quite wild because of growth of shrubs.

Its leaves are known to have medicinal value. As it grows without much of difficulty and it is straight, it is grown in gardens as ornamental plants. It is presumed that Eucalyptus may be suitable for biomanagement and it can consume effluent water from pulp and paper mill. As its root goes quite deep, soil erosion is avoided in areas having Eucalyptus plantation.

Recently it is reported that (i) Eucalyptus tereticornis is more effective in controlling soil erosion than many other plants according to a recent study in Himachal Pradesh. (ii) Eucalyptus is reported to grow over waste material from alumina industry[16]. (iii) Topinambour plants can grow well with effluent from pulp and paper mill in Siberia region.

R & D Imperatives :

The merit of Eucalyptus lies in its expansion i.e. genetic improvement and growing pattern depending upon the end use. Its main uses are in pulp and paper mill, timber industries and for energy. The social forestry works for Eucalyptus plantation are already carried out with innovative efforts. But there is no significant development in laboratory scale experimentation on selection of species with respect to the soil and other criteria for fast growing. Some of the R & D imperatives[17] that can be made are as follows :

1. Suitability of Eucalyptus for afforestation of difficult sites, waste lands and in salt affected areas is to be evaluated.
2. Selection of particular species for a given environmental conditions and site is to be made.
3. Research on genetic and plant breeding techniques including tissue culture and biotechnology for fast growing trees is to be initiated.
4. Energy plantation technique for higher biomass production at short rotation is to be found out.
5. Study on the effect of Eucalyptus on cropping pattern of important agricultural areas and pattern of choice of crops by the farmer are highly essential.
6. Because of various uses of Eucalyptus, research on the commercially exploitable properties of the wood should be intensified.
7. Taxonomical research should be carried out for high level of genetic diversity.
8. It is also further needed to study the effect of different species of Eucalyptus on wood quality, organic matter, nutrient status, surface water runoff, ground water and water conservation under varying edaphic and climatic conditions.
9. As pulp and paper industries discharge effluents, having manure value, Eucalyptus plantation using this effluent should be made and the growth pattern should be studied. Other fast growing trees like casuarina, subabul and non-wood fibres like bamboo may also be grown with irrigation of effluent water.
10. In view of the problems of import for soft-wood pulp, plantation of soft wood trees like pine etc. should be introduced in the non-tropical part of India. These are limited to mostly Himalayan regions now.
11. Not much of fundamental works have been done on fibre morphology, lignin and other constituents using sophisticated techniques like scanning and electron microscopy, mass spectrometry etc which can impart original findings.

12. Though huge social forestry works have been accomplished in the country, very little research outputs have been employed for high pulp-yielding and fast growing trees. It is considered that no more research efforts are required to be contributed. However, it is not appropriate like in many other fields. Many recent[17, 28, 34, 41] research reports are certainly worth-while applying in field.

13. The economical aspect is also to be studied thoroughly specially in agro and farm forestry.

Acknowledgement

The authors are grateful to the management of Pulp and Paper Research Institute, Jaykaypur for encouragements.

References :

1. Rohatgi, P.K., and Vyas, B.J., *Indian Foundry J., 24* (2) 1978) 1.
2. Patel, M., Gopakumar, K. and Rohatgi, P.K., *Proc, Int Symp Reson Engg Technol*, IIT. Bombay, *2* (1979) 5 (ii) C6.
3. Rohatgi, P.K., Rohatgi. K. and Bowonder B., *Technological forecasting* (Tata-MecGraw Hills Co. New Delhi) 1979.
4. Patel. M., Dan, T.K. and Rohatgi, P.K., *J Sci Ind Res. 40* (8) (1981) 475-486.
5. Editorial, *Les Echa Ind*, 13 March, 1991.
6. Jackson, M., Falk, B., Moldenius, S. and Edstrom A. *Pulp and paper Can., 89* (10) (1988) 79.
7. Ladrach, W., *Tappi J. 74* (3) (1991) 65.
8. Rao, D.V.. *Indian Forester* J, *110* (1) (1984) 28.
9. Rao, D.v., *Indian Forester, 110* (1984) 28.
10. Rao., A.L., *Indian Forester, 110* (1) (1984) 1. *Pulping and Paper Making Properties of Fast growing Plantation wood Species.*
11. Food and Agri. Org., United Nation, 19/1, (1980) 105 *Pulping and Paper making Properties of fast growing Plantation wood species*
12. Food and Agri. Org., United Nation, *19/2,* (1980)
13. ABIPC, *IAWA* 9 (1) (1988) 13
14. Sidaway, S., *Tappi J, 71.* (12) (1988) 47
15. *Papel,* J., *48* (8) (1987) 56.
16. Bhatia, C.L., *Indian Forester, 110* (2) (1984) 91.
17. Mathur, N.K. and Sharma, A.K., *Indian Forester 110* (1) (1984) 9.
18. Pulp and Paper Res. Inst., Jaykaypur (1989) Orissa unpublished work.
19. Brahman, R., RRL Bhubaneswar (1991), Orissa Pvt. Communication.
20. Zobel, B., *Tappi J 71* (12) 1988) 42.
21. Sharma, S. K., *Indian Forester, 117* (4) (1988) 42.
22. D.F.O., Rayagada (1991), Orissa Pvt. Communication.
23. Turnbull, C.R.A., Bendle, C.L., Bird, T. and McLeod, D.E., *APPITA J., 41* (6) (1988) 447.
24. Mandal, M., *Tropical wood symp. Singapore* (19 8) 26.
25. Thakur, M.L., Kumar, S., Negi, A. and Rawat, D.S , *Indian Forester, 115* (10) (1989) 733.
26. Pal, M., and Raturi, D.P., *Indian Forester, 117* (3) (1991) 187.
27. Chromer, R.N. and Hansen, N. W., *APPITA J., 26* (3) (1972) 189.
28. Prasad, R., *Indian Forester, 115* (5) (1989) 281.
29. Rai, A.K., Sharma, K.K. and Sharma, Y.K. *Indian Forester, 117* (3) (1991) 213.
30. Aldokhin, N.A., Goncharov, A.I., Grachev, M.A. and Suturn N.A., *UNEP Ind Environ, 13* (3-4) (1990) 21.
31. Lal, S., *Indian Forester J., 117* (6) (1991) 454.
32. News *APPITA* J., *44* (2) (1991) 70.
33. Sagarra, A.F , *Tappi J., 74* (6) (1991) 42.
34. Jha, M.N. and Pande, P., *Indian Forester J. 110* (1), (1984) 16.
35. Tiwari, K.M. and Mathur, R.S., *Indian Forester J 109* (12, (1983) 1.
    wilkin, A.P. and Stamp C.M.
36. Wood Science and Technology, 24 (1990) 297.