Afforestation and Biomass Production of certain Fast Growing Pulp Wood Species under Agroclimatic Condition of Assam

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Abstract

Experiments were conducted to study the growth parameters like plant height, diameter and bio-mass yield alongwith paper making characteristics of certain fast growing plants viz. Acacia auriculiformis, Indigofera teysmanii and Azadirachta indica under the agroclimatic condition of Jorhat in Assam. Data obtained from agronomic trial revealed luxuriant growth of the plant with adequate bio-mass yield. The height of the plant recorded maximum in the five years old plants of Acacia auriculiformis (11.9 m) followed by Indigofera teysmanii (6.150 m) and Azadirachta indica (8.2 m). Similarly, plant diameter recorded 12.4, 9.0 and 8.5 cm respectively for A. auriculiformis, I Teysmanii and A.indica at the age of 5 years. The pulpable bio-mass yield was recorded maximum 226.860 t/ha/yr in A.auriculiformis followed by I teysmanii (152.75 t/ha/yr) and A. indica and (179.90 t/ha/yr) . The bleached pulp yield was recorded 42.7-45.0 % in A. auriculiformis followed by 41.2-42.7 % in 1 teysmanii and 41.7-42.5 % in A. indica. The physical characteristics and paper making properties of the pulp revealed that good quality paper can be produced trom these plants. Considering the luxuriant growth, adequate bio-mass yield and paper making properties, these plant species can be taken up for afforestation as well as commercial cultivation in various waste lands, degraded forests, cultivable waste lands, barren lands etc. for producing raw material for pulp and paper industry.

INTRODUCTION

In recent years attention has been given on afforestation for greening of the earth as well as to produce plant biomass to feed forest based industries (1,2). It is an established fact that plants remove the contaminants from the atmosphere and clean the environment (3,4). In some advance countries of the world extensive programmes have been undertaken for creation of green belt in and around the industrial belt to check the air pollution (5). In India air pollution is considered to be a major and serious problem affecting ecology as well as human health. Due to the rapid industrial growth and population, the natural forest areas of our country are gradually diminishing and also at the same time, the supply of plant materials from the forests to industry is decreasing alarmingly resulting in huge shortage of raw materials for various forest based industries.

Pulp and paper industry is considered to be one of the highest consumers of forest based raw materials throughout the globe. In India due to continuous use of cellulosic raw materials by the various forests based industries, the gap between the demand and supply of these materials is increasing at a faster rate (6). Therefore, to reduce the gap between the demand and supply of cellulosic raw materials, afforestation programmes have to be taken up either by public or private sector.

From last few decades, efforts are being made to produce plant biomass in different climatic conditions for various forest based industries (7,8). Due to the favourable agro climatic conditions, N E Region of India has been a reservour of a number of plant species.

Although experiments on biomass production of certain fast growing plants have been conducted earlier in the climatic conditions of Jorhat, (9,10) but the suitability of the species for plantation in waste lands have not been tried.

There are lot of waste lands, degraded forests, barren lands, cultivable waste lands available in Assam and other States of North Eastern Region. For proper utilization and for creation of forests in those waste land areas, an investigation was carried out at the experimental farm of RRL to develop suitable agro technologies for producing pulpable biomass from certain selected species of fast growing perennial plants.

EXPERIMENTAL

Three plant species viz; Acacia auriculiformis, Indigofera teysmanii and Azadirachta indica were selected for the present investigation on the basis of earlier study carried out in our laboratory (9).

The experiments on bio-mass production were conducted at the experimental farm of Regional Research Laboratory, Jorhat. The plant materials selected for the present investigations were originally brought from the Deptt. of Social Forestry, Govt. of Assam. These plants were raised from the seeds/clones from the original plantation. The soil of the experimental plot was initially tested and found 48% of sand, 36% of silt and 14% of clay and 2% of other inorganic matters. The available Nitrogen (N), Phosphorous

Table-1 Growth and yield of plant bio-mass at different maturity.

Species	Age Yr.	Plant height m	Plant dia at DBH cm	Pulpable green biomass Kg/Plant	Moisture %	Pulpable dry biomass t/ha/yr
Acacia auriculiformis	I	1.486	1.5	1.800	52.8	5.800
	2	3.421	3.2	3.200	51.6	12.500
	3	5.590	4.8	6.500	50.3	35.100
	4	9.850	12.0	37.500	50.7	202.500
	5	11.90	12.40	41.550	48.9	226.860
	6	12.25	12.58	41.720	48.8	227.50
Indigofera teysmanii	1	1.462	1.6	1.620	49.8	5.400
	2	2.826	2.6	3.780	49.5	25.650
	3	4.350	4.1	6.400	49.3	32.000
	4	5.150	7.5	24.540	48.7	122.700
	5	6.150	9.05	29.950	48.5	152.75
	6	6.710	9.85	30.125	49.0	153.00
Azardirachta indica	1	1.540	2.0	1.950	47.5	4.750
	2	2.569	4.8	4.625	47.8	27.470
	3	5.650	6.1	t 0.600	47.3	40.950
	4	6.350	6.5	26.500	47.5	97.400
	5	8.200	8.5	34.600	48.0	179.90
	6	8.500	9.8	35.825	48.5	182.80

Table 2 Currrent Annual Increment (CAI) and Mean Annual increment (MAI) of pulpable dry bio-mass (t/ha)

Crop	1st Year	2nd Year	3rd Year	CAI 4th Year	MAI 5th Year	MAI 6th Year	MAI
Acacia Auriculiformis	5.800	16.870	4.140	168.500	30.520	19.627	40.909
Indigofera Teysmanii	5.400	9.823	4.618	98.725	34.194	21.012	28.962
Azadirachta Indica	4.750	10.628	5.487	110.200	48.835	28.210	43.685

(P) and Potash (K) contents were 0.358, 0.009 and 0.005% respectively. The pH of the soil was recorded in between 5.2-5.8. The experiments were conducted in a randomized block design with four replications in the field. The size of the experimental plots was 6x6 m. Spacing was maintained 200x200 cm in all the three species. Uniform doses of fertilizers were applied @ N120,P50 and K50 Kg/ha/yr. Plant growth regulators i.e. $GA_{4+7}$of 250 ppm solution was sprayed on the leaves of the seedlings of 30 days to 240 days old plant at the interval of 30 days. A set of experiment was also conducted in the field without applying growth regulator in order to see the effect on growth characteristics of the plants. The plantation was done during monsoon in 1995 and the harvesting was done from one to six years old plants. The growth parameters such as plant height, diameter, distribution of aerial biomass, dry biomass yield etc were recorded at different stages of maturity. The height of the plants was measured with the help of a measuring tape from the tip of the leading shoot to the ground level without giving any allowance to minor curves of the stem and recorded in metres correct to the third decimal place. Diameter at breast height (DBH) was taken at 1.37 m and the measurements were taken from four samples of the bole and the average was recorded. DBH = (DI +D2+D3+D4)/4 where D1 to D4 are the four diameter measurements of the bole. Biomass of the over ground parts was measured with the help of spring balance of different capacities. The pulpable biomass

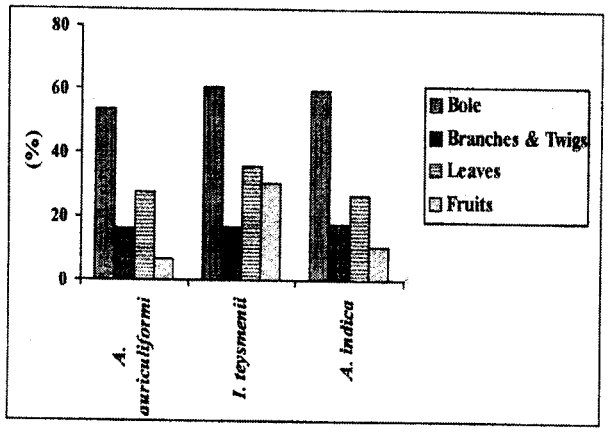

Fig. 1 Distribution of aerial biomass of the plant species

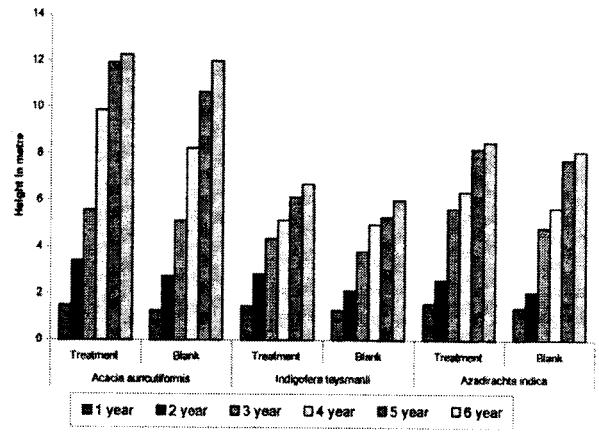

Fig. 2 (a) Effect of GA 4+7 on Height of the Plants

yield was calculated as per Chaturvedi and Khanna 1982, (11).

Growth, Aerial biomass distribution and pulpable biomass yield

Data on growth characteristics such as plant height, diameter and green and dry bio mass yield of A. auriculiformis, I teysmanii and A. indica of 1-6 years maturity were recorded and presented in Table-1. The current annual increment (CAI) and the mean annual increment (MAI) of pulpable biomass were calculated and recorded in Table 2. The distribution of aerial biomass of the plants are represented in Fig 1.

Evaluation of raw material, pulp and Paper

Proximate analysis

Wood samples of the above three plants viz A. auriculiformis, It eysmanii and A indica of 5 years maturity were collected from the field. After debarking manually the wood samples were chipped and then converted to dust with the help of a Wiley mill. The proximate chemical analyses of 5 years plants were carried out and recorded in Table 3.

Wood and fibre properties

Wood properties like moisture content, specific gravity, wood bark ratio and pulp properties such as kappa number, pulp viscosity and brightness, fibre dimensions etc. of the above three plants at different maturity were carried out as per Tappi test methods (12) and the results obtained are recorded in Table 4. The length and diameter of the pulp fibres of A. auriculiformis. I teysmanii, and A. indica were determined with the help of a Docuval photomicroscope, Jeol, Japan. The fractionation of pulp fibres was measured by Baur Mc Nett classifier for the above three plants and the percentage of different length of fibre present in the pulp furnish are recorded in Table 5.

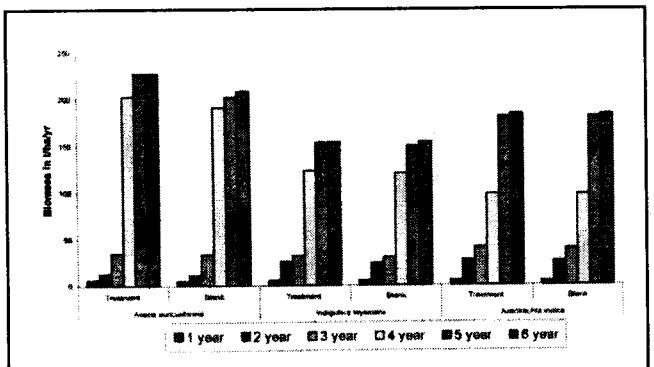

Fig. 2 (b) Effect of GA 4+7 on pulpable biomass

Scanning electron microscopy

Fibres in the pulp samples were prepared and mounted on specimen holders with the help of electroconductive tape. The Samples were coated with gold in an ion-sputter coater (JFC 100, JEOL, Japan) in low vacuum with a layer 150-200 μm thick. The observation was made in a JEOL, JSM-35 m-35CF electron microscope at an accelerating potential of I5KV. Micrographs were taken at this potential.

Physical properties of paper sheets

The physical strength properties of the paper sheets made from these three plants were tested as per TAPPI Test methods and recorded in Table 6.

RESULTS AND DISCUSSION

Table-1 represents the growth characteristics and biomass yield of A. auriculiformis, I teysmanii and A. indica of one to six years maturity. It has been observed that the growth parameters i.e. plant height, diameter, pulpable green (dry biomass) yield increased along with the ages. Among the three plants, A. auriculiformis showed better growth characteristics and biomass yield. The height of the plant (11.2 m), diameter (12.4 cm) and Dry pulpable biomass (226.860 t/ha/ha) were recorded for A. auriculiformis at 5 years. There was no significant increase in the above properties after 5 years. Similarly, I teysmanii also showed a gradual increasing trend in growth characteristics with the maturity of the plant. The data recorded for growth characteristics and biomass yield of A. indica showed a uniformly increasing trend up to the age of six years. The plant height (8.5 m), diameter (9.8 cm) and dry

Table 3 Proximate chemical analyses of the plant materials

Particulars	Plant species		
	A. auriculiformis	1 teysmanii	A. indic
Solubility in (%)			
Cold water	4.25	3.52	2.75
Hot water	8.00	9.32	6.50
1 % NaOH	17.0	34.75	19.25
Alcohol benzene	5.25	5.75	3.50
Lignin %	22.0	21.5	21.2
Pentosan %	16.0	16.5	17.1
Cellulose %	55.2	52.5	53.2
Ash %	1.28	0.90	0.93

pulpable biomass (182.80 t/ha/yr) were recorded at that maturity. Among the three plant species I teysmanii showed minimum growth and biomass yield.

Fig. 1 represents the distribution of aerial biomass produced by A. auriculiformis, I teysmanii and A. indica. Among the three plants, I teysmanii produced maximum percentage of bole and leaves.

Table - 4 Wood and Pulp properties of plants at different maturity

Name of the species						
Particular	A. auriculiformis		I. teysmanii		Azadirachta indica	
	3 Yrs.	5 Yrs.	3 Yrs.	5 Yrs.	3 Yrs.	5 Yrs.
Wood specific Gravity	0.29	0.47	0.32	0.51	0.34	0.48
Bark to wood Ratio						
By mass	20.6	17.7	18.8	16.2	17.0	20.2
By volume	22.8	19.3	20.7	18.2	19.3	22.0
Pulp yield						
Unbleached (%)	48.8	50.5	46.5	47.5	45.3	46.8
Bleached (%)	42.7	45.0	41.2	42.5	41.7	42.5
Kappa Number	25	28	23	27	26	29
Pulp brightness (%)	70.5	72.8	70.6	71.4	69.5	70.2
Pulp viscosity, Cp	18.5	18.0	17.6	17.2	15.8	16.0
Fibry length, (mm) Average	0.98	1.00	0.75	0.90	0.9	0.98
Fibre diameter (um)	17.0	18.0	14.8	16.0	16.0	17.0
Lumen diametre (um)	10.0	9.5	9.0	9.5	10.0	9.6
Cellwall thickness (um)	4.5	5.0	5.1	5.3	5.0	5.3

Table 5 Baur Mc Nett classification of pulp fibres 5 Years maturity

Mesh No.	Opening mm	Fibre retained %		
		A. auriculiformis	I.teysmanii	A. indica
+ 14	1.18	46.0	42.2	40.6
-14+30	0.595	15.6	17.3	18.8
- 30 + 50	0.295	9.2	8.3	7.9
-50+100	0.50	8.4	7.8	8.6
-100	-	20.8	24.4	24.1

However, there was no much variation in percentage of branches and twings produced by these plants

Table - 2 shows the CAI and MAI of A. auriculiformis, I teysmanii and A. indica. Among the three plant species CAI recorded maximum 168.5 t/ha in A. auriculiformis while I teysmanii and A. indica showed 98.725 and 110.200 t/ha respectively in fourth year.

Fig. 2 (a) represents the effect of GA_{4+7} on plant height of A. auriculiformis, I teysmanii and A. indica. It has been observed that with the application of gibberlic acid the height of the plant is increased in comparison to the control plant. In A. auriculiformis at the age of 6 years, the height recorded for treated plants was 12.95 m while 11.98 m for control one, which was found highest among the three plants. Fig. 2(b) shows the effect of GA_{4+7} on pulpable biomass yield of the plants. It has been observed that with the application of Gibberlic acid treatment

Table 6 Physical strength properties of paper sheets

Particulars	Plant species (5 years maturity)		
	A. auriculiformis	I. teysmanii	A. indica
Initial pulp freeness °SR	17	16	15
Final pulp frteeness °SR	40	40	40
Time of beating, hrs	1.30	1.20	1.20
Burst index (Kpm^2jg)	2.55	2.65	2.84
Tear index (Nm^2jg)	8.82	8.33	8.43
Tensile index Nm/g	39.91	38.22	37.24
Double fold	70+	68	82

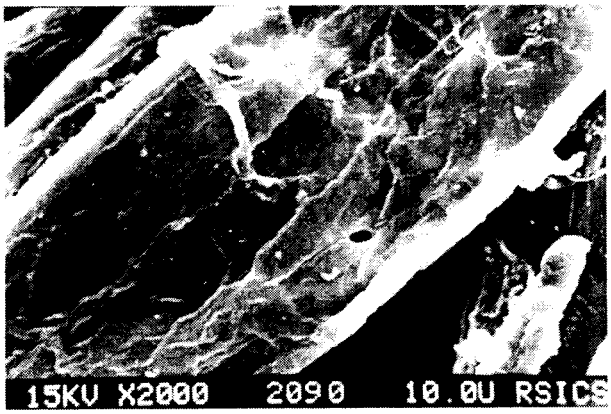

Fig.3 : Scanning electron micrograph of pulp fibre of acacia auriculiformis

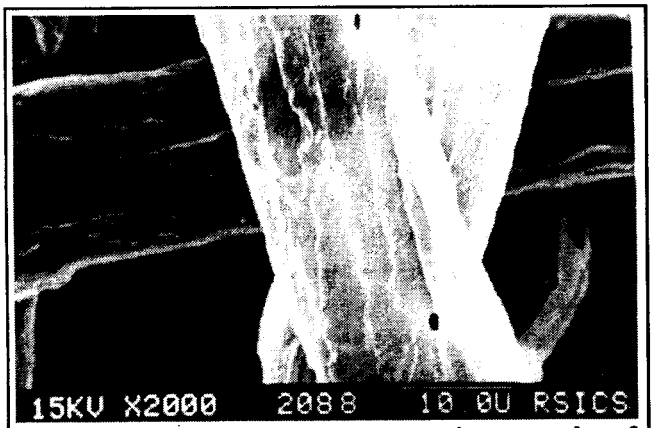

Fig.4 : Scanning electron micrograph of pulp fibre of indigofera teysmanii

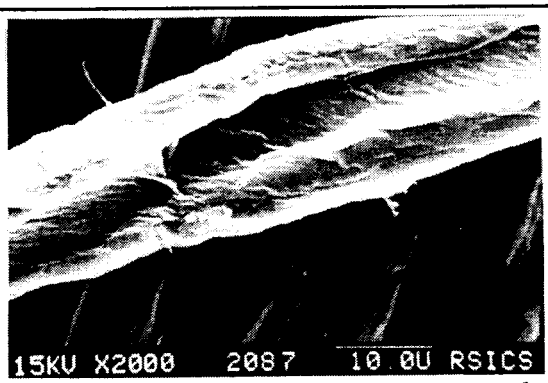

Fig.5 : Scanning electron micrograph of pulp fibre of Azadirachta indica

the yield of pulpable biomass recorded for A. auriculiformis was 227.00 and 221.30 t/ha/yr respectively for treated and control plants, which was found to be highest among the three plant species.

Table-3 shows the proximate chemical analyses ofthe three plants. The data for wood constituents and soluble matters in the wood samples of these plants are comparable to conventional paper making raw materials like bamboo mixed hardwood etc. (13,14). There was no much variation in percentage of Lignin, Cellulose and Pentosan content among these species. Lignin content ranges from 21.2-22.01, pentosan 16.0-17.1 % and cellulose 52.2-53.2%.

Table-4 represents the data for wood and pulp properties of the plants. Wood properties viz. specific gravity varies from 0.47-0.51 and wood bark ratio from 16.2-20.6%. kappa number ranges from 23-29, pulp brightness 70.2-72.8% and pulp viscosity 16-18 cp. The morphological characteristics of the pulp fibre of these three plant species were found similar. The fibre length recorded maximum 1.00 mm in A. auriculiformis and minimum (.90 mm) in A. indica. Likewise, fibre diameter, lumen diameter and fibre wall thickness varied within a narrow range.

Fig.3-5 show the scanning electron micrographs of the pulp fibres extracted from five years old plants of Acacia auriculiformis, Indigofera teysmanii and Azadirachta indica. Fig.3 represents a single fibre of Acacia auriculiformis which is larger in diameter with a few pores on the surface. The fibre seems to be matured with irregularly arranged fibrils on the surface. Occasional cracks are also visible on the surface of the fibre. Fig.4 represents fibres of I. teysmanii. Like A. auriculiformis pores are distinctly visible on the fibre surface. The fibriler arrangements are found similar to that of A.auriculiformis pulp fibre. Fig.5 represents the fibre of Azardirachta indica, where the fibrils are regular with horizontal cracks.

Table-5 represents the fibre fractionation datas of all the three species. There is no much variation in data obtained from Baur Mc Nett classification of pulp fibre of A. auriculiformis, I teysmanii and A. indica.

Table-6 shows the data for physical strength properties of paper sheets made from A. auriculiformis, I teysmanii and A. indica. The paper sheets made under identical conditions give

burst index value ranging from 2.55-2.84 (Kpm^2/g), Tear index 8.33-8.82 Nm^2/g. Tensile index 37.24-39.91 Nm/g and double fold 68-82 in all the three species.

CONCLUSION

It has been observed from the present investigation that A. auriculiformis, I teysmanii and A. indica are found suitable for cultivation in the agroclimatic condition of Jorhat, Assam. Luxuriant growth of these plants are recorded for all the three species grown under identical conditions in the field. The biomass was recorded highest in case of A. auriculiformis among the three plants. Based on the growth characteristics and biomass yield produced by these plants, the economic harvesting of these plants is suggested at the age of 5 years. Considering their faster growth and development these plants can be taken up for commercial cultivation as well as afforestation in various waste land areas.

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