Evaluation Of *Erianthus Arundinaceus* As A Source Of Non-Conventinal Raw Material For Pulping And Papermaking

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ABSTRACT

Tamilnadu Newsprint and Papers Limited (TNPL) is India's largest bagasse based Integrated Pulp and Paper mill, having an installed capacity of 4,00,000 TPY Printing & Writing paper. TNPL is procuring one million tons of wet whole bagasse per annum from sugar mills. Till now bagasse is being used for papermaking. With the development of co-generation technology and increasing power demand, sugar industry would prefer to use bagasse for power generation with assured high returns. In future bagasse based pulp and paper industry may face shortage of fibrous raw material.

The present paper highlights the results of evaluation of Erianthus arundinaceus as an alternate captive fiber source of non-conventional raw material for pulping and papermaking. The following systematic studies were carried out. Field evaluation of clone SES 159 in farmer's field was studied and compared with conventional sugar cane Co 86032. Mill scale trials were conducted in sugar mill for bagasse yield determination, juice quality estimation along with conventional sugarcane Co 86032. Mill end wet whole bagasse of clone SES 159 and conventional sugarcane bagasse were depithed for pith removal and taken for storage studies. Kraft pulping and ECF bleaching of (Do EOP D_1) study was done for SES 159 clone depithed bagasse along with conventional sugarcane bagasse. Per hectare pulp production of clone SES 159 and Eucalyptus wood are compared. Economics of Erianthus arundinaceus clone SES 159 cultivation and bagasse production data was Tabulated.

Introduction

Pulp and paper Industry is one of the largest industries in the world and directly linked to the social and economical development of mankind. Indian pulp and paper Industry is the 15^{th} largest Industry in the world accounts for 1.6% world's production of paper and board. In India, it is an important sector, as it provides employment to nearly 1.5 million people and contributes 2500 Core's to the Government as revenue.

In the present scenario of open market economy, the challenges confronting the Indian pulp and paper Industry are multifold (Anon 2002). Indian paper Industry is facing shortage of raw material for sustainable growth. Developing countries like India, the forest-cover per capita is only 0.06 ha, compared to the world average of 0.62 ha and Asian average of 0.15 ha (Ravindranath *et al*; 2008). Forest resources are becoming scarce due to over exploitation and increase in population growth.

The increased usage of non-wood residues can partially meet the current demand for fiber source. Among agricultural residues, mainly bagasse is used for papermaking. However, with the development of co-generation technology and increasing power demand, the sugar industry prefers to use bagasse for power generation with assured high returns (Uppal *et al* ; 2006).

In future bagasse based pulp and paper industry may face shortage of fibrous raw material. One of the viable solutions for the above problem is to look for alternate sources of raw materials like wild species of Saccharum and its allied genera *Erianthus. E.arundinaceus* being a C_4 plant, it may serve as an ideal fiber crop with sustained capacity to capture and convert the available solar energy into biomass with maximum efficiency and with minimum input and environmental impact. (Girouard and Samson, 1998 and Goel *et al* ; 1998)

E.arunndinaceus can be grown in marginal and sub-marginal lands and has the ability to grow under adverse climatic conditions. Once established, it can be maintained with limited care and amenable for cyclical harvest with high ratoon potential. It is also less prone to biotic and abiotic stress (Matsuo *et al;* 2002). The main advantage of this perennial C_4 grass is that it produces more fiber per unit area of land per unit time than hardwood trees and can be harvested annually at any time.

Review of Literature

India is a tropical country which has many varieties of perennial grasses and one of them being *Erianthus arundinaceus,* a wild variety of commercial sugarcane. *Erianthus arundinaceus* is the most widely distributed species and commonly found in peninsular India and also in the north east India. Botanically, it is classified as below.

Classification

Kingdom	: Plantae
Subkingdom	: Tracheophyta
Division	: Supermatophyta
Class	: Lilliopside
Subclass	: Commenlinidase
Order	: Cyperales
Family	: Poaceae
Genus	: *Erianthus*
Species	: *arundinaceus*

Stricker *et al.* (1993) and Piperidis *et al.* (2000) have reported that *E.arundinaceus* is an evergreen plant mostly found on the river banks in south and north East India and adoptable to sub optimum moisture conditions. Species of *E.arundinaceus* include small busky type with narrow leaves without cane formation they are tall plants, with broad leaves and long, thick canes resembling conventional sugarcane plants. Propagation is by both seeds and vegetative means in nature and it is possible to propagate artificially by clumps or setts or tissue culture plants.

Morphology

Piperidis *et al*.(2000) studied that tall, perennial, erect, gigantic grass with a flowering clumps (except *E.arundinaceus*). The stems are pithy without any juice or sucrose (except *E.arundinaceus*) leaves are flat long narrow with stout midrib. Leaf insertion is finely bearded with hairs often extending up into the coloured of white pale green, Purple, brown combinations of the above.

Anatomy

Stem epidermis contains solitary cork cells and absence of silica cells. Papillae are present on the lower surface, stomata distributed in both the surface randomly. Vascular bundles are of four types viz., Primary, secondary, tertiary and quaternary. Sclerenchyma cells are generally well developed around the primary and secondary vascular bundles.Piperidis *et al.*(2000) reported that *E.arundinaceus* is a species related to sugarcane with desirable characteristics, excellent vigor and ratooning adaptability to environment stresses. Numerous attempts have been made to cross *E.arundinaceus* with sugarcane to introduce these characters into modern cultivators. Till date no conclusive results have been achieved. Though *Erianthus* and related grasses were available in the collection of germplasms all over the world, very little or no work on utilization of *Erianthus* as an alternate raw material for pulping and papermaking has been reported. However several other grasses being evaluated for the cane yield point of view only.

1. Study Materials

1.1. Erianthus arundinaceus clones

The clones available in the germplasm collection of Sugarcane Breeding Institute, Coimbatore were used as study materials.

1.2. Sugarcane Bagasse

Sugarcane bagasse of the popular variety Co 86032 was collected from M/s Sakthi sugars Ltd., Appakudal and the Salem Co-operative Sugar mills Ltd, Mohanur. Tamilnadu, both tie up sugar mills of TNPL.

2. Experimental methods

2.1. Screening of SBI Erianthus *arundinaceus* clones

SBI has the germplasm with largest collections of both cultivable and wild canes. *Erianthus arundinaceus* clones of 88 were selected for the study of their potential in terms of cane yield and total biomass. Finally the clone SES 159 were selected for multiplication and planted in TNPL model farm for further studies.

2.2. Big mill test of SES 159 clone

After 12th month, the cane was harvested and subjected to big mill test at one of the TNPL tie up sugar mills. During milling trial, juice, mill end bagasse was collected, from cane weight and bagasse weight, bagasse yield was calculated. Mill end bagasse fiber pith ratio was determined. The above big mill test was repeated using conventional sugarcane Co 86032.

2.3. Depithing Study

Wet whole bagasse of the clone SES 159 along with sugarcane bagasse were taken for depithing directly from the last mill tandern of sugar mill. During depithing trial, whole bagasse, depithed bagasse and pith samples were collected across the depither for the clone SES 159 and conventional cane Co 86032. Fiber pith analysis was done for the above collected samples. Percentage of pith separation was calculated.

2.4. Bagasse storage study

Wet bulk storage methods was adopted to study the quality of SES159 clone depithed bagasse and conventional sugarcane bagasse. Piles of about five tonnes of SES159 clone depithed bagasse and conventional sugarcane bagasse were made fresh depithed bagasse was used. Brightness was studied for fresh bagasse and storage bagasse from three and nine months old piles. Impact of storage on quality of bagasse / pulp was studied.

2.5. Pulping study

Pulping was done for the clone SES159 depithed bagasse and conventional clone depithed bagasse Co 86032. For pulping 12% chemical at 170°C temperature, 20 minutes cooking time with H- factor of 450. Pulp yield was calculated. Pulps were evaluated using PFI mill.

2.6. Bleaching studies

D-E_{OP}-D_1 bleaching of clone SES 159 bagasse pulp along with conventional bagasse pulp were carried out, results of bleaching were given in Tables. Bleaching experiments were performed with 200g OD pulp. E_{OP} stage was performed in laboratory digester with 2 kg/cm^2 oxygen pressure at 85°C and peroxide charge of 0.4% on unbleached pulp. The pulp evaluation of unbleached and bleached pulps was carried out after refining in PFI mill.

3. Results and Discussion

Studies were carried out to evaluate *Erianthus arundinaceus* as a source of non conventional raw material for pulping and papermaking. The clone SES 159 was selected from the germplasm collections of Sugarcane Breeding Institute, Coimbatore. The clone was cultivated in farmer's field and evaluated for cane yield, bagasse yield and pulp and paper properties. The bagasse pulp and paper properties of these clone SES 159 were compared with that of sugarcane popular variety Co 86032.

Table 1
Harvested cane yield

S.No	Clone	Cane yield t ha^{-1}
1	SES 159	100.1
2	Sugarcane Co 86032	110

Table 2
Depithed bagasse quality

S.No	Clone	Whole bagasse			Depithed bagasse			Pith			Pith Removal %
		Yield at 50% moisture	Moisture as such	FPR	Yield %	Mois %	FPR	Yield %	Mois %	FPR	
1.	SES159	51.8	53.1	2.60:1	45.3	50.4	3.10:1	6.5	59.4	0.26:1	12.5
2.	Sugarcane Co 86032	28	53.5	1.32:1	19.6	52.0	2.52:1	8.4	60.2	0.37:1	30.0

Table 3
Juice quality

S.No	Parameter	Clone SES 159	Sugarcane Co 86032
1	pH	2.0	3.0
2	COD mgl^{-1}	93,974	3,50,000
3	Brix (%)	7.9	18.0
4	Pol (%)	2.8	15.1
5	Purity (%)	30.0	83.2
6	TRS (%)	2.5	45

Table 4
Fresh depithed bagasse fiber pith ratio

S.No	Parameter	Clone SES 159	Sugarcane Co 86032
1	Moisture %	50.4	52.0
2	Useful fiber %	70.0	64.2
3	Pith %	22.5	25.6
4	Water solubles %	7.5	10.2
5	FPR %	3.11 : 1	2.50 : 1
6	Brightness %	40.1	39.2
7	Yellowness %	27.6	28.8

Table 5
Proximate analysis of bagasse of E.*arundinaceus* clone SES 159 and sugarcane Co 86032.

S.No	Clone	Ash %	Hot water Solublity %	AB Extractives %	Acid Insoluble lignin %	Holo cellulars %	Pentosans	NaOH solubles %
1	SES 159	5.0	7.3	1.9	21.2	69	22.8	30.5
2	Sugarcane Co 86032	1.8	3.7	2.7	20.4	68.5	23.5	29.1

3.1. Field evaluation of clone SES 159

Yield and yield attributes of clone SES 159 in farmer's field. It was observed that the germination and survival percentage was very poor for the wild cane varieties due to poor rooting. It is because *Erianthus arundinaceus* had only one row of root primordium in the internode. Through tissue culture SES 159 clone multiplication was done and planted in 1.2 hectares in farmer's field. The crop was harvested after 12 months and the yield data presented in Table 1. Clone SES 159 recorded the cane yield of 100 t ha^{-1} and did not flower. The conventional sugarcane Co 86032 harvested cane yield was 110 t ha^{-1}.

3.2. Big Mill Test

The canes of SES 159 clone along with sugarcane Co 86032 were subjected to Big Mill Test (BMT) at Salem Co-Operative Sugar Mills Ltd., Mohanur and the results are presented in Table 2. Bagasse yield (calculated at 50 % moisture) for SES 159 clone was 51.8 % whereas for conventional sugarcane, it was only 28 %. This higher bagasse yield of 50.4 % is due to higher fiber percent in the cane of clone *Erianthus arundinaceus than sugarcane* Co 86032.

3.3. Depithing Bagasse

Whole bagasse of the clone SES 159 and sugarcane bagasse Co 86032 were subjected to depithing. Results are furnished in Table 2. SES 159 clone pith removal was 12.6 % whereas for conventional sugarcane pith removal was 30 %. In clone SES 159 whole bagasse pith content is less (FPR 2.60:1) against conventional sugarcane FPR (1.32:1). During depithing in conventional bagasse useful fiber also get fragmented and separated along with pith.

3.4. Juice Quality

Juice collected during the Big Mill Test was analyzed for quality parameters and results are presented in Table 3. Quality of juice was found to be poor for the clone SES 159 when compared to sugarcane Co 86032. Clone SES 159 had COD value of 93,974 mg L^{-1}. Chinnaraj *et al*., (2003) reported that high COD juice exploited for the production of biogas using anaerobic digestion process. Clone SES 159 juice suitable for producing alcohol, methane gas.

3.5. Storage of Bagasse

Fresh depithed bagasse was taken for storage study. FPR results are given in Table 4. Bagasse storage studies revealed that for both clone SES 159, conventional sugarcane bagasse Co 86032 loss of useful fiber in top layer (60 cm) at third month was not much pronounced, while at ninth month considerable loss of useful fiber was observed Table 6. In case of bottom layer of bagasse, three months storage resulted in fiber marginal degradation and availability of useful fiber content is maintained. Clone SES 159 bagasse was better or comparable with that of sugarcane bagasse even after nine months of storage..

3.6. Morphological study

Morphological investigations revealed that clone SES 159 fiber length was 0.97 mm which was higher than the sugarcane bagasse pulp (0.84 mm). Clone SES 159 had the desired fiber length 0.97 mm slenderness and good dimensional stability for papermaking and quality was comparable to that of sugarcane bagasse. The clone SES 159 had higher ash content 5 % when compared sugarcane bagasse (Table 7). Both SES 159 clone and conventional sugarcane have higher holocellulose content and is a factor for suitability of fibrous raw material for papermaking.

3.7. Pulping and bleaching study

Clone SES 159 screened pulp yield was 0.7 % higher than sugarcane Co 86032 pulp. Strength properties at 300 ml CSF clone SES 159 had tear index of 0.8 mNm^2g^{-1} higher than sugarcane bagasse pulp (Table 8). In ECF bleaching 4.2 % 4.3 % of ClO_2 as Cl_2 was added to bleach the pulp to final brightness 89.4 % ISO. Bleachability of clone SES 159 pulp was as good as sugarcane bagasse pulp. Clone SES 159 bleached pulp strength properties were good. Results are given in Table 9 and 10.

Comparison of per hectare pulp production of Erianthus arundinaceus SES 159 and Eucalyptus wood.

The per hectare bio mass and pulp yields obtainable from Erianthus arundinaceus clone SES 159 was compared with Eucalyptus, which is now widely cultivated for pulp and paper production (Table 11). The green yield per hectare per year of Eucalyptus (30 t ha^{-1} $year^{-1}$) was for below that of Erianthus arundinaceus clone SES 159 (125 t $ha^{-1}year^{-1}$).

Economics of E. arundinaceus clone SES 159 cultivation and bagasse production

The economics of E. arundinaceus clone SES 159 cultivation and mill level bagasse, pulp and fiber production was worked out and the results are furnished in Table 12. Considering a maximum attainable biomass yield at 50 % moisture was 64.8 tons. The furnace oil equivalent of the predicted biogas production from the COD yield was estimated to be Rs. 83,700 ha^{-1}. Net revenue to the farmer was Rs.1,42,460 ha^{-1} $year^{-1}$. Hence, cultivation of E. arundinaceus clone SES 159 as a

Table 6

Changes in brightness and useful fiber of bottom layer depithed bagasse clone SES 159 and Sugarcane Co 86032 during storage.

S.No	Clone	Fresh bagasse		Three months after storage		Nine months after storage	
		Brightness %	Useful fiber %	Reduction in Brightness %	Reduction in Useful fiber %	Reduction in Brightness %	Reduction in Useful fiber %
1	SES 159	40.1	70.0	12.2	7.1	22.6	11.4
2	Sugarcane Co 86032	39.2	64.2	11.5	3.4	19.9	6.9

Table 7

Morphological properties of depithed bagasse fiber of clone SES 159 and sugarcane Co 86032

S.No	Clone	Mean fiber length (mm)	Mean fiber width (mm)	Length to width ratio
1	SES 159	0.97	18.3	53.1
2	Sugarcane Co 86032	0.84	19.2	43.9

Table 8

Depithed bagasse pulp properties of clone SES 159 and sugarcane Co 86032.

S.No	Clone	Total yield %	Screen rejects % (0.25mm)	Screen Yield %	Kappa number	Brightness %	Pulp strength at 300 ml		
							Tensile Index ($Nm\ g^{-1}$)	Tear Index ($mN\ m^2\ g^{-1}$)	Burst Index ($kpa\ m^2\ g^{-1}$)
1	SES 159	56	0.5	55.5	10.5	43.4	72.3	6.9	4.3
2	Sugarcane Co 86032	56.1	1.3	54.8	11.0	42.8	74.9	6.1	4.9

Chemical applied: 12%

TAA, RAA values are calculated at total solide $200gl^{-1}$ solids.

Table 9

ECF bleaching of clone SES159 and sugarcane Co 86032

S.NO.	Parameters	Clone SES 159	Sugarcane Co 86032
1	Kappa number	10.5	11
2	Brightness (%)	43.4	42.8
	DO stage		
3	ClO_2 as Cl_2 applied / consumed (%)	2.20 / 2.20	2.30 / 2.30
4	pH initial / final	3.7 / 3.5	3.8 / 3.7
5	Brightness (%)	55.4	54.8
	EOP stage		
6	Alkali as NaOH applied / consumed (%)	1.50 / 0.98	1.60 / 1.10
7	Peroxide applied / consumed (%)	0.4 / 0.39	0.5 / 0.42
8	pH initial / final	11.9 / 11.1	12.2 / 11.3
9	Kappa number	2.48	2.20
10	Brightness (%)	80.0	78.0
	D1 stage		
11	ClO_2 as Cl_2 applied / consumed (%)	2.0 / 1.82	2.1 / 1.9
12	pH initial / final	4.5 / 5.0	4.6 / 5.2
13	Brightness (%)	89.4	88.8

Table 10
ECF bleached pulp strength at 3300 ml CSF clone SES 159 and sugarcane Co 86032

S.NO.	Clone	Tensile Index ($Nm\ g^{-1}$)	Tear Index ($mN\ m^2\ g^{-1}$)	Burst Index ($kpa\ m^2\ g^{-1}$)
1	SES 159	68.2	6.6	4.0
2	Sugarcane Co 86032	70.1	5.8	4.3

Table 11
Comparison the pulp production of clone SES 159 and Eucalyptus wood.

S.NO.	Parameter	Clone SES 159	Eucalyptus
1	Crop duration (years)	1	5
2	Total green yield ($t\ ha^{-1}$)	125	150
3	Green yield per year ($t\ ha^{-1}$)	125	30
4	OD bagasse yield at 26 % fiber OD wood yield at 45 % moisture	32.3	16.5
5	Yield for bagasse pulp at 54.5 % ($t\ ha^{-1}$) Wood pulp yield at 44 % ($t\ ha^{-1}$)	17.6	7.26

Table 12
Economics of clone SES 159 cultivation and bagasse production.

S.NO.	Parameter	
1	Green yield ($t\ ha^{-1}\ year^{-1}$)	125
2	Bagasse yield (51.8 %) at 50 % moisture	64.8
3	Value of depithed bagasse @ Rs `2450 t^{-1}	Rs. 1,58,760
4	Juice COD value ($mg\ L^{-1}$)	93,974
5	Juice yield at 80 % extraction efficiency ($L\ t^{-1}$)	560
6	COD yield of biomass ($kg\ t^{-1}$)	70
7	COD yield of SES 159 clone ($kg\ ha^{-1}\ year^{-1}$)	8750
8	Biogas generation at 85 % efficiency ($kg\ ha^{-1}\ year^{-1}$)	7438
9	Biogas generation potential at 0.5 factor ($m^3\ ha^{-1}$)	3719
10	Furnace oil equivalent to biogas ($L\ m^{-3}$)	1860
11	Furnace oil saved @ Rs. 45 L^{-1}	Rs. 83,700
12	Total revenue for SES 159 clone plantation (` $ha^{-1}\ year^{-1}$)	Rs. 2,42,460
13	Cost of cultivation (` $ha^{-1}\ year^{-1}$)	Rs. 50,000
14	Cost of harvesting & transportation (` $ha^{-1}\ year^{-1}$)	Rs. 35,000
15	Cost of processing (` $ha^{-1}\ year^{-1}$)	Rs. 15,000
16	Net revenue to farmer (` $ha^{-1}\ year^{-1}$)	Rs. 1,42,460

captive fiber source will be economical and viable as a fiber and energy crop.

Conclusions

- High fiber pith ratio of E. arundinaceus indicates that the whole bagasse can be used as such to produce pulp directly without depithing or with mild depithing of 5 to 10 % pith removal as against 30 % pith removal practiced for sugarcane bagasse from sugar mills
- E. arundinaceus had the potential of producing higher biomass with more bagasse and pulp yield.
- The quality of bagasse and pulp are comparable to that of sugarcane Co 86032. E. arundinaceus was found to be suitable raw material for pulp and papermaking.
- Commercial exploitation of E. arundinaceus as a potential captive fiber can meet the raw material requirement of bagasse based industry.
- Processing is easy at paper mill without much alteration in infrastructure facilities except establishment of a mill scale crusher to obtain bagasse.
- The juice from the E. arundinaceus clone can be utilized for ethanol and methane production, which will save as an alternate fuel to meet out the energy demand at factory level.
- The existing sugar mills can also crush the canes and supply the bagasse to paper industries.
- The juice can be used for diluting the molasses in the distillery for production of alcohol.

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