STUDIES ON USE OF WILD SUGARCANE FOR PULPING AND PAPER MAKING COMMERCIAL AND TECHNICAL FEASIBILITY

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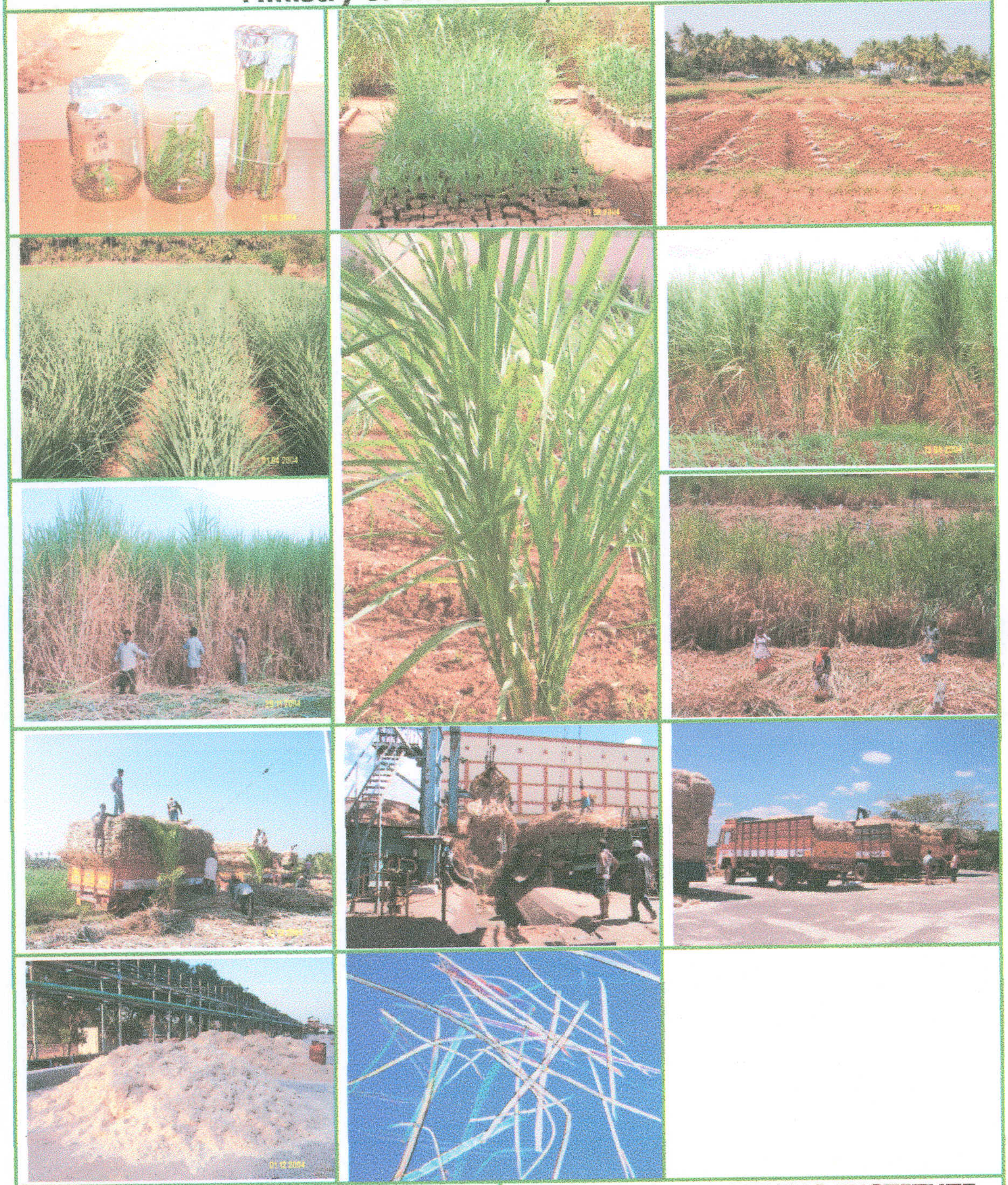

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STUDIES ON USE OF WILD SUGARCANE FOR PULPING AND PAPER MAKING: COMMERCIAL AND TECHNICAL FEASIBILITY'

1.	Broad area of technology	Raw Material Research
2.	Project Duration	36 Months
3.	Organisation	Tamil Nadu Newsprint and Papers Ltd., Kagithapuram, TN - 639 136
4.	Other interacting agencies	Sugarcane Breeding Institute, Coimbatore, TN – 641 007
5.	Actual location where the project is being carried out	Tamil Nadu Newsprint and Papers Ltd., Kagithapuram, TN - 639 136
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CONTENTS

1. INTRODUCTION

Increasing population, over exploitation of natural resources, shrinking forest cover, alternate use of agriculture and forest products leads to shortage of agro- based and forest based fibrous raw material for papermaking and forces the paper industry to look for alternate raw material resource. Shortage of fibrous raw material can be made-up by improving unit area productivity by introducing highly productive and improved pulpwood clones or by identifying and adopting new plant species having high biomass productivity. Annual and perennial grasses belong to non wood plant species and gives promising hope to work and develop them as new source of fibre for paper industry since from the ancient days. It is reported that non-wood fibre were used for papermaking form the ancient period, for example during 3000 BC in Egypt, pressed pith tissue of *Cyperus papyrus* L was used as printing material. Ts Ai Lun discovered the actual paper in China during 105 AD from Hemp rags and Mulberry. Straw was used as raw material for papermaking in 1800 and the first commercial operation of pulp mill started in the year 1927 in USA. After the invention of chemical pulping process, wood is being used increasingly in many part of the world as a paper making raw material in the 20th century. However in many regions of the wood is not sufficiently available for papermaking due to increase paper production [Atchison 1987a, Judt 1993] and also wood is being utilized for many other purposes including fuel and other value added products. The shortage of woody fibrous raw material for papermaking and growing demand for paper forced many papermakers to look for other alternate raw materials, such as, non-wood for papermaking. The world paper and board consumptions increased from 78 million tones per annum in 1961 to 335 million tones in 2004. Since ,1990 consumption in the developed regions as whole did not increased. In contrast growth in developing region especially in Asia is increasing at the rate of 6.5% per annum due to higher literacy and income [Adrian Whiteman, 2005]. Commercial non wood pulp production has been estimated to be around 6.5% of total global pulp production and it is expected to rise in the future.

China and India are the major users of non-wood fibre for papermaking. The main sources of non-wood raw materials are agricultural residues from the monocotyledons, such as, Rice Straw, Wheat Straw, Bagasse, Bamboo [Paavilainen *et al.,* 1998]. Other most common energy and fibre crops like *Mischanthus*, Giant Reed, Reed Canary Grass, Hemp, Kenaf, Sisal and Jute are also used to certain extent for papermaking.

The improved exploitation of agricultural residues and huge potential of nonfood crops can partially resolve the current dilemma between the increasing paper consumption and the diminishing forest resources. Beside agricultural residues, non-food plants offer a very attractive opportunity to utilise excess land for the cultivation of energy and fibre crops [Samson *et al.,* 2005]. However, utilization of fibre crops or agricultural residues for energy generation became popular in the post Kyoto regime especially bagasse in the sugar industry through co-generation for the production renewable energy. This offer additional benefit like carbon credits through Clean Development Mechanisms projects and created the new challenges for paper industry to look for other captive fibre sources for papermaking with improved productivity in the unit area.

Perennial grasses, such as, wild sugarcane [*Saccharum sp., Erianthus sp.]* Switchgrass [*Panicum virgatum*], *Miscanthus* [*Miscanthus sinensis*] are known for its high productivity due to its C_4 photosynthetic cycle, when compare to other C_3 plants and mainly used as bio-energy crop in many parts of the world [Klass, 1999, Mislevy *et al.,* 1995, Mislevy and Fluck, 1992, Fuentes and Taliaferro, 2002]. An ideal fibre crop should have a sustained capacity to capture and convert the available solar energy into harvestable biomass with maximal efficiency and with minimal inputs and environmental impacts [**Box 1**].

Biomass cropping systems must have a highly favorable resource balance, i.e. low resource input versus output, since resource input usually represents use of fossil fuel and emission of carbon to the atmosphere. Cultivation, harvest and especially nitrogen fertilization, represent large financial and fossil fuel inputs. Consideration of energy balances has driven a shift from annuals to perennials, primarily short rotation coppice like poplars, willows and perennial grasses, in particular *Phalaris, Miscanthus Erianthus* and *Panicum* [Venendaal *et al.,* 1997]. In contrast to annual crops, these perennials require only one cultivation activity, i.e. preparation for planting, over a 10- to 20-year duration, and minimal nitrogen inputs.

The economic yields and energy efficiency of biomass [fibre] crops will be determined predominantly by the amount of biomass that can be formed per unit area and per unit of investment of other resources, notably nitrogen. The potential limit on biomass yield will be set by the amount of light available, and the efficiency with which light is converted into biomass. Conversion efficiency depends on the duration, size and architecture of the canopy. A crop having closed canopy throughout the year or at least throughout crop season will clearly have highest productivity. C_4 photosynthesis is the most efficient form of photosynthesis known, largely due to the elimination of the wasteful process of photorespiration. Because of this, C_4 photosynthesis has the highest potential for converting sunlight energy into biomass energy and estimated to be 40% greater than that of C_3 photosynthesis [Long, 1999, Klass, 1999, McLaughlin, 1999]. C_4 photosynthesis also allows plants to have higher efficiencies of nitrogen and water use [Ehleringer and Monson, 1993]

BOX –1: Modified from Samson *et al.* [2005]

Objectives	Required characters
1. Efficient conversion of sunlight into plant material	1. There are two main photosynthetic pathways for converting solar energy into plant material: the C_3 and C_4 pathways. The C_4 pathway is approximately 40% more efficient than the C_3 pathway in accumulating carbon
2. Efficient water use moisture is one of the primary factors limiting biomass production in the world	2. C_4 species use approximately 1/2 the water of most C_3 species
3. Sunlight interception during as much of the growing season as possible	3. Perennial crops do not have annual establishment costs [seed, tillage, etc.] and some species of warm-season species and have excellent stand longevity
4. Minimal external inputs in the production and harvest cycle [i.e., seed, fertilizer, machine operations and crop drying].	4. C_4 species of grasses contain less nitrogen [N] thanC_3 species and can be more N-use efficient because N is cycled internally to the root system in the fall in temperate zones] and significant N fixation can occur in the tropics in some warm-season grasses

Utilization of these highly productive grasses as raw material for pulp and paper industry is a new concept developed recently to overcome raw material shortage in the developing countries like India where mostly on non-wood fibrous raw material are used to manufacture paper. Another major advantages of these perennial grasses are it contains less lignin when compared to woody plants. Lower lignin in raw material naturally consume less chemical during pulping, bleaching and give more yield, leading to less environmental impact to surrounding environment [Giouard and Samson, 1998, Elbensen, 2001, Goel *et al.*,1998]. In addition, to fibre supply to paper industry fibre crops would have added environmental benefits over current food crops [McLaughlin and Walsh 1998]. Perennials providing above ground structures throughout the year may provide refuge for wildlife [Giuliano and Daves, 2002]. Production and turnover of belowground storage organs will add organic matter and carbon to the soil [Zan *et al.*, 2001]. Perennials have more extensive root systems present throughout the year, so providing increased resistance to soil erosion and a more effective means of trapping nutrients and preventing nitrogen loss to drainage water. Because the crop is not used for food, the land could also be suitable for spreading sewage sludge and farm effluents that may represent health risks in areas sown with food crops [Visser and Pignatelli 2001]. Apart from the above these perennials can also be used for other purposes like generation of renewable energy like fuel alcohol or biogas from its juice in case if we use bagasse for paper making or in other wards the entire biomass can also be used for heat and electricity generation because biomass generally has energy value of around 4000 to 4500 kcal/ kg which is slightly less than the conventional fossil fuels like coal [5000 to 6000 kcal/kg]. However, perennial grasses have its own disadvantage like low bulk and short fibre length, presence of pith in the cortex region, relatively poor pulp quality and high handling and transportation cost.

India being a tropical country has many varieties of perennial grasses, one of them is *Erianthus arundinaceus* a wild relative of commercial sugarcane called Erianthus arundinaceus. *Erianthus arundinaceus* is the most widely distributed species and commonly found in the peninsular India and also in the North East India

Classification

Kingdom	: *Plantae*
Subkingdom	: *Tracheophyta*
Division	: *Spermatophyta*
Class	: *Liliopside*
Subclass	: *Commenlinidae*
Order	:*Cyperales*
Family	: *Poaceae*
Genus	:*Erianthus*
Species	: *arundinaceus*

Erianthus is an evergreen plant mostly found in the river banks in south India and in the north east India but adoptable to sub optimum moisture conditions. Species of *Erianthus* include small bushy type with narrow leaves without cane formation to those tall plants with broad leaves and long, thick canes resembling sugarcane plants. Propagation is by both seeds and by vegetative in the nature and it is possible to propagate artificially by clumps or setts.

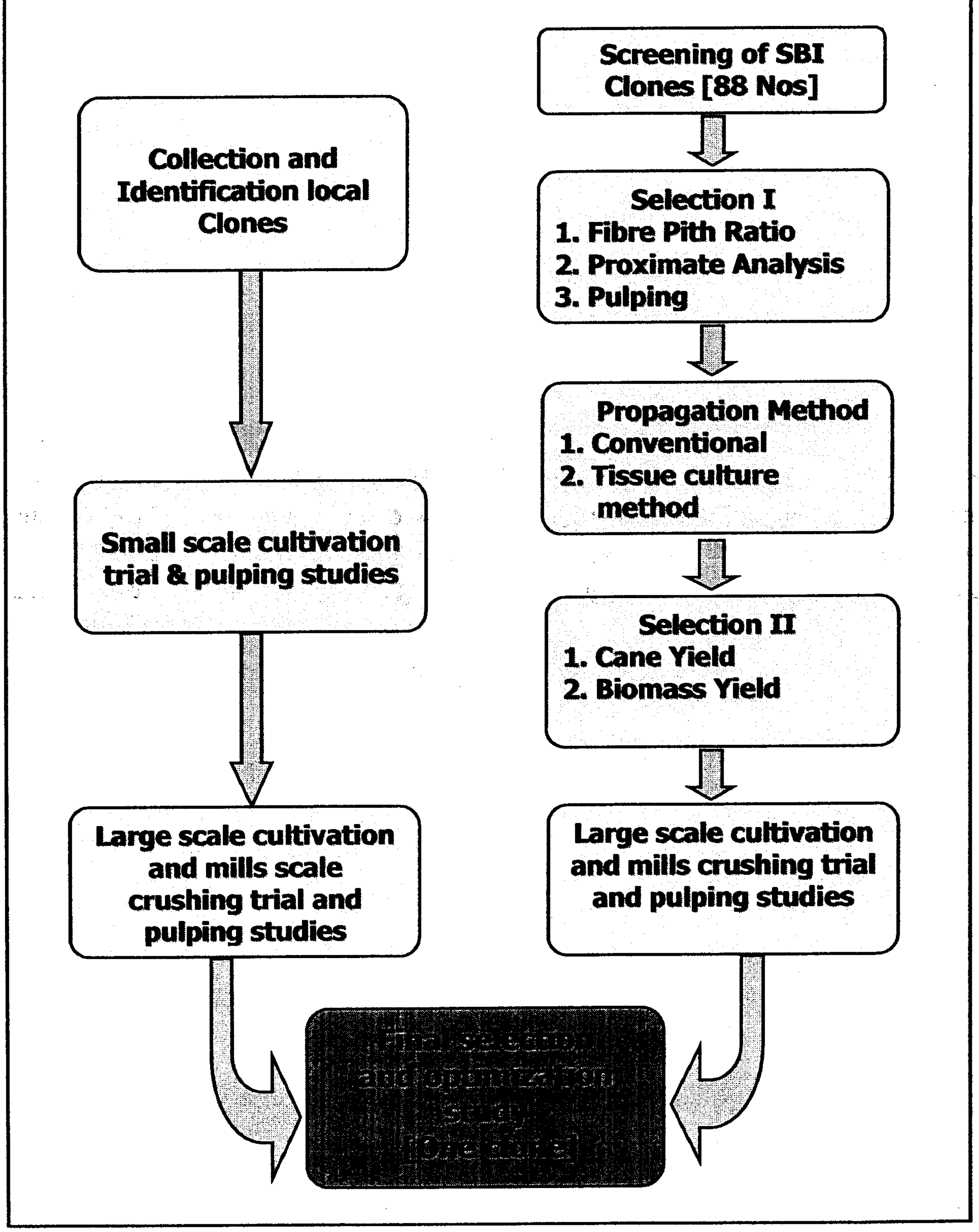
Morphology: Tall perennial, erect, gigantic grass with flowering clums [Except *Erianthus arundinaceus*]. The stems are pithy with out any juice or sucrose [Except *Erianthus arundinaceus*]. Leaves are flat, long narrow with stout midrib. Leaf insertion is finely bearded with hairs often extending up into the coloured [off- white, pale green, purple, brown or combinations of the above].

Anatomy: Stem epidermis contains solidary cork cell and absence of silica cells. Cork cells are always squarish, never pointed closely crowded. Presence of papillae on the lower surface, stomata distributed in the both surface randomly. Vascular bundles are of four type viz. primary, secondary, tertiary and quaternary. Sclerenchyma cell are generally well developed around the primary and secondary vascular bundles.

Cytology: *Erianthus* has mostly euploid series with lower chromosome numbers in multiples of 10. based on the chromosome numbers, Erianthus clones can classified in to four groups based on chromosome number i.e. 2n = 20, 30, 40 & 60. These variations indicate the occurrence of polyploidy in the *Erianthus* genus. Total seven species have been recorded in this genus. They are *Erianthus* arundinaceus [India, China, Myanmar, Thailand, Philippines, Malaysia, Indonesia, New Guinea], *Erianthus bengalense,* [India, China, Myanmar] Erianthus *ravennae* [India], *Erianthus elephantinus* [India], *Erianthus procerus* [India], *Erianthus longisetosus* [India] and *Erianthus hookeri* [India].

Considering the potential of high biomass productivity of Erianthus and raw material shortage, attempts were made to study the technical and commercial viability of *Erianthus arundinaceus* as fibrous raw material for papermaking under the CESS Fund through IPMA in TNPL Research and Development Division along with Sugarcane Breeding Institute. The studies are broadly classified as per the following work plan [**Box :2**]. Results of the study conducted are presented in this report.

Box 2 Work Plan



2. LOCAL CLONAL STUDY

2.1 COLLECTION AND IDENTIFICATION LOCAL CLONES

Six Erianthus arundinaceus clones [*Erianthus arundinaceus]* collected from Cauvery River banks were identified and screened based on their morphological characters such as, cane diameter, height, number of inter node, length of internodes etc. From the selected plants seed cane were colleted and used for small scale cultivation trial.

2.2 CULTIVATION TRIALS AND PULPING STUDIES OF LOCAL CLONES

To find out total biomass yield and cane yield, 10 M^2 trial plot was put-up and cultivation trial was carried out using selected local clones collected from Cauvery River banks. The cane was harvested after one year and the results are presented in the **Table 1.** The initial results indicate that the wild sugarcane can give around 50.6 tones of millable cane and 70 tones of green biomass [including leaf] per acre on as such basis [70%moisture]. The yield was relatively high due to scale and size of the plot. The results may not be true representative, because we found that the bordering effect was very high and made us to go for large scale trial to eliminate the bordering effect.

2.3 PULPING STUDIES

The harvested canes were fibrerised using the local small scale cane crusher commonly used for extracting sugarcane juice. The resulted bagasse was washed thoroughly to remove the sugars and used for pulping studies and results are presented in the **Table: 2.** The results indicate that bagasse quality and the pulp quality, such as, strength and optical properties are comparable to the conventional bagasse and in fact the quality of pulp made from Erianthus arundinaceus bagasse is slightly superior then conventional bagasse pulp.

2.4 LARGE SCALE CULTIVATION TRIAL

To find out the exact yield potential of the local clones of *Erianthus arundinaceus* in the much higher scale, two acres field trials were taken using seed canes collected from the Cauvery River banks. However, from the 10 M^2 trial plot study, we found that the rooting percentage was poor in the local variety due to the presence of only single row of root primordium in the nodal region leading to poor establishment in the field. The rooting percentage was increased by cane selection and hormone treatment using polybag method **[Plate 1 & 2].**

Treatment of seed cane by root initiation hormone like IBA and by using poly bag method, the plant establishment percentage was improved from 15% to 75%. Nearly 6000 seedlings were developed in this method and planted in two acres of farmer's land in Thirukkaduthuri, village near our factory using 6 feet by 2 feed spacing. The crop was harvested using the mechanical harvester hired from the M/s Sakthisugars, Appakkudal **[Plate – 3 & 4]**. The cane yield was found to be 28.9 MT/acre. The yield of the large scale trial was relatively less when compared to the previous study due to severe drought and water scarcity and also the impact of bordering effect was reduced substantially.

2.5 MILL SCALE BAGASSE PREPARATION AND DEPITHING STUDIES OF LOCALE Erianthus arundinaceus CLONES

Mill scale milling trials of *Erianthus arundinaceus* was taken in one of the associated off-site sugar mill using nearly 5 tones of fresh Erianthus arundinaceus harvested from the large scale trial at farmer's field. The results are presented in the **Table 3**. The results clearly indicate that the whole bagasse yield and fibre pith ratio of Erianthus arundinaceus is much higher when compared to conventional sugarcane. The whole bagasse yield was around 54.5% with 52% moisture. Pith removal and depithed bagasse fibre pith ratio was found to be 13.1% and 2.46:1 respectively.

2.6 KRAFT PULPING OF LOCAL *Erianthus arundinaceus* CLONE BAGASSE

The whole bagasse and depithed bagasse produced from the above trail was used to conduct the Kraft pulping studies in the laboratory. The kraft pulping results of mill trial local *Erianthus arundinaceus* bagasse is presented in the **Table 4** which indicates that the pulp properties are superior when compared to the conventional bagasse pulp and pulp yield is comparable to conventional sugarcane bagasse pulp. The results also confirm that the depithing improves the pulp properties similar to conventional bagasse. Though the pulp properties are superior when compared to conventional sugarcane bagasse pulp, the cane yield recorded was less and it is not economical to go for large-scale cultivation of *Erianthus arundinaceus* only for bagasse production alone. Therefore, further screening studies were carried out to find out a clone that can give higher biomass yield per unit area from the collections of Sugarcane Breeding Institute, Coimbatore.

3. SBI CLONAL STUDY

3.1 SCREENING OF SUGARCANE BREEDING INSTITUTE (SBI) *Erianthus arundinaceus* CLONES

Sugarcane Breeding Institute [SBI], Coimbatore is one of the premier institute function under the Indian Council of Agricultural Research and known throughout the world for its pioneers work in the sugarcane breeding and produced many commercial varieties and hybrids of sugarcane and introduced in India and world. SBI has good and largest collections of various wildcanes and sugarcanes such as, *Saccharum spontaneum, Saccharum officinarum Saccharum rubstrum Erianthus arundinaceus, Narenga*, and *Pennicitum* collected from south and south East Asia. The institute maintains this collections in the germplasm for it regular sugarcane breeding programs. Among the above wild species, *Erianthus arundinaceus* was selected for initial screening for our studies because it is found to be highly productive in terms of cane yield and biomass yield, fast growing, suitable for local agro-climatic conditions and comparatively resistant to pests and disease [Sreenivasan *et al.* 2001 Samson *et al.*, 2005]. Initially we have screened 88 clones obtained from the Sugarcane Breeding Institute based on fibre pith ratio and morphological characters. The results are presented in the **Table 5a and 5b.** Based on the above results we have selected 23 clones which has fibre pith ratio of 1.8:1 and above **Table 6.** All the 23 clones were screened further by proximate analysis. The results of the proximate analysis are presented in the **Table 7.** Among the 23 clones six clones were selected based on lignin content and also by using botanical characters such as rind and cortex ratio, number of tillers, number of inter-nodes, individual cane weight, inter-node length and flowering nature. All the selected Six clones viz. SES 159, SES 3, IMP 1536, EA Cutack, Mythan, A and IJ 342, are being multiplied in the trial plots of Sugarcane Breeding Institute for further studies, such as, biomass yield, cane yield, Juice quality and ratooning capacity.

3.2 JUICE AND FIBRE ANALYSIS OF SBI *Erianthus arundinaceus* CLONES

Juice extracted from all the six selected clones were analyzed for pH, Brix% , Pol% and COD. The results are presented in the **Table 8**. SES 159 found to be containing highest COD, [77,150 mg/lit]. Brix [9.2%] and Pol [0.8%] followed by SES 3, IJ 342, Mytahn A, EA Cutack and IMP 1536. After juice extraction the resulted bagasse was analyzed for fibre content and fibre pith ratio the results are presented in the **Table 9.** The results show that EA Cutack has highest fibre pith ratio [2.7:1] and fibre content [31%] followed by Mythan A, IJ 342, SES 159, IMP 1536 and SES 3.

3.3 PULPING STUDIES OF SELECTED SBI *Erianthus arundinaceus* CLONES

Krafts pulping studies of all the selected SBI clones were carried out after juice extraction and washing using 12% chemical charge, 20 Min. cooking time at 170°C. The results are presented in the **Table - 10**. The results shows that SES 3 gave the highest screen yield 55.7%] followed by IMP 1536 [53.2%], EA Cutack [53.1%], SES 159 [53.0 %], Mythan [51.6%] and IJ 342 [51.3%]. The pulp properties are comparable with conventional bagasse and all the clones are suitable for papermaking.

3.4 COMPUTATION OF YIELD POTENTIAL OF *Erianthus arundinaceus*

To estimate the yield potential and clump characters of sleeted *Erianthus arundinaceus* clone, the germplasm were monitored and the results are reported in the **Table 11**. Among the selected clones SES 159 was appeared to be comparatively superior with respect to total biomass productivity. It is estimated that SES 159 can give up to 74.2 kg of biomass per clump per year of which nearly 51.8 kg is contributed by the cane and remaining is by leaf. It also gave high number of cane per clump [71], long inter-node length and higher plant height than the other selected clones. Unfortunately the fibre percentage is relatively less than the E A Cuttack and Mythan

3.5. DEVELOPMENT OF TISSUE CULTURE PROTOCOL FOR MASS MULTIPLICATION *Erianthus arundinaceus*

As indicated earlier, during our field trials, we found that the survival percentage was very poor for the wild cane varieties due to poor rooting. This is because, in general the commercial cane varieties are having 3 to 4 rows of the root primordium, whereas the *Erianthus arundinaceus* has only one row of root primordium leading to poor rooting percentage. Also for large scale or pilot scale cultivation study we require quite large amount of seed cane or seedlings. In the SBI germplasm only limited clumps are maintained for breeding purpose that is not enough to take any cultivation trial. Use of the conventional setts method where maximum multiplication ratio achievable is 1:10 for this type of grass might take more than five years to get the required seed material to take any cultivation trial. Therefore, we have initiated in vitro propagation of the all the selected six clones using meristum culture [shoot tip] micro-propagation techniques to produce more seedlings in short time. Protocol for selected clones viz. SES 159, Mythan A, SES 3, IMP 1536, and EA Cuttack were developed except IJ 342 due to practical reasons **[Box 3]**. Among the above, SES 159 is found to respond well for in vitro multiplication and rooting **[Plate 5, 6,7]**.

Box – 3: Tissue culture protocol for Erianthus arundinaceus

1.	Surface sterilization of the explant by 70% ethanol treatment for one minute and 10% sodium hypochlorite treatment for 20 minutes.
2.	Then shoot tips were excised and inoculated with MS medium supplemented with Riboflavin, BAP and GA_3 for shoot initiation.
3.	Multiple shoots were developed by transferring culture to MS medium with BA.
4.	The well developed shoots were then placed in ½ MS medium with NAA for in vitro rooting.
5.	The in vitro regenerated plants were planted in polybag containing a mixture of sand, silt & compost (1:1:1) and covered with polythene sheet.
6.	After one month, they were exposed to sunlight and hardened plants were planted in field.

3.6 PLANTATION TRIAL OF SELECTED SBI *Erianthus arundinaceus* CLONES

Nearly 6500 seedlings of the above five clones produced using in-vitro propagation and by single bud polybag method were planted in the three acres of the farmer's field during the last week of November 2003. Among 3 acres of cultivation trial, 1.5 acres was under organic farming and another 1.5 acres was under conventional cultivation. After eleven month the crop was harvested and used for mill scale crushing trial in the sugar mill using two method one with conventional process and other with diffusion process. The results of crop yield are presented in the **Table 12.** The results indicate cane yield was higher in the organic farming when compared to conventional farming. Among all the selected clones the SES 159 give the highest yield [40.0 MT/Acre] followed by Mythan [32.0 MT/Acre] , EA Cuttack [25.6 MT/Acre] and IMP 1536 [23.3 MT/Acre].

To evolve suitable package of practices for commercial cultivation, experiments were taken up in two farmers fields near Pugalur in November 2003, to identify high yielding clone, planting material (viz., tissue cultured plants and polybag settlings); optimum spacing and fertilizer requirement. Two experimental trials laid out on 29.11.2003 in two farmers' fields of about 3 acres at Chatram and Velayuthapalayam near Pugalur to evolve package of management practices such as spacing, irrigation, manuring, fertilizer application and inter-cropping. Chemical fertilizers were used at Chatram and only organics and biofertilisers at Velayuthapalayam. About 6,500 seedlings raised by tissue culture and single bud setts were used for planting in these two fields with various combinations [**Box 4**] to study the impact on spacing , planting material and fertilizer application .

Box – 4: Field variables and purposes used in trial

S.NO	Variables and purpose
1.	Identification of suitable planting material – Treatments 6 : Combination of two planting materials (tissue cultured plants and polybag single bud settlings) with three treatments of organics (control, FYM & Vermicompos0t
2.	Spacing Trial – Treatments 6: Combination of two row–to-row spacing (6', 4.5') with three plant-to-plant spacing (2',3',4')
3.	Fertiliser Trial - Treatments 7: Control, 75%NPK, 100%NPK, 150%NPK, 50%NPK+BF, 75%NPK+BF, 150%NPK+BF (BF=biofertisers–Azospirillum & Phosphobacteria)
4.	Genotypes: Two namely SES 3 and SES 159

Results of fertilizer trials are presented in the **Table 13**. Highest yield of 112.16 MT/ hector was obtained with 100 % NPK [225, 62.5, 100 kg/h] and bio fertilizer [Azospirillum, and Phosphobacterium 10 kg each/h]. This indicates that there is a scope to increase the yield by optimizing the crop management practice especially with SES

159 **[Plate 8,9,10]**. Results of polybag seedlings developed using conventional single bud seed setts and with tissue culture plants with various combinations of organic fertilizers such as vermicompost [1 kg/ plant] and farm yard manure 1 kg/plant]. The results are presented in the **Table 14**. Poly bag seedlings developed with single bud setts planted with vermicompost showed highest yield of 128.65 MT/ hector over its control i.e. 105.53 MT/hector without any organic manure. In case of seedling developed by the plant tissue culture method again the yield was in vermicompost application [123.97 MT/ hector] over its control 107.75 MT/ hector] without any organic manure application. When compared between the polybag seedling and tissue culture seedling, polybag seedling yield was found to higher except in the control.

A spacing trial result are presented in the Table 15 and indicates that between the two clones, SES 159 recorded a higher mean cane yield [115.4 t/ha] than SES 3, which yielded 104.9 t/ha. It was observed that, in general, closer spacing gave higher yield. In particular, the spacing of 4.5' x 2.0' recorded the highest yield in both the clones [SES 3 115.5 t/ha & SES 159 127.6 t/ha]

Based on the initial field observation in the field and results SES 159 was selected for large-scale cultivation trial in the TNPL model farm. Nearly four acres of plantation was carried out using the tissue culture seeding of only SES 159 having different spacing such as 4 X 3, 4 X 2 and 4 X 1.5 feet during the month of June 2004 and results are discussed in this report latter.

3.7 PILOT SCALE MILL TRIALS OF SBI *Erianthus arundinaceus* CLONES

After harvesting, the canes of all the selected clones were used to conduct the pilot plant mill scale crushing trial **[Plate 11-14]** at sugar mill to find out bagasse yield, Bagasse quality, juice yield and juice quality. The results of the crushing study are presented in **Table 16**. Mythan gave the highest bagasse yield [60%] followed by EA Cuttack IMP 1536 [50.6%], SES 159 [50.0%] and SES 3 [44.5%]. All the clones of Erianthus arundinaceus gave higher bagasse yield than the conventional sugarcane [27- 30%] The results of the bagasse quality are presented in the **Table 17**. Though the whole bagasse fibre pith ratio of SES 159 is moderate, the depithed bagasse FPR ratio of SES 159 was found to be highest [3.13:1] among all the clones tested in the field including the conventional sugarcane bagasse [1.4 -1.5:1]. This indicates that SES 159 can be effectively depithed to improve the bagasse quality and pulp quality. The juice collected during the trial was analyzed for its quality and the results are presented in the **Table 18.** The COD [93974 mg/L] and BRIX [9.7%] content was highest in SES 159 followed by EA Cuttack [89155 mg/L, 7.0%], Mythan 81123 mg/L, 6.05] IMP 1536 [69075 mg/L, 7.2%] and SES 3 [60240 mg/L, 6.4%]. Surprisingly, COD and Brix, FPR and biomass yield of SES 159 is relatively high when compared all other selected clones. This indicate that SES 159 can be utilized as multifunctional crop for both for fibre and bio-energy i.e. bagasse for fibre source and juice as bio energy source such as biogas or alcohol.

3.8 PULPING STUDIES OF PILOT SCALE MILL TRIAL OF SBI *Erianthus arundinaceus* CLONE BAGASSE

Whole bagasse produced during pilot scale mill trial was used to carryout Kraft pulping studies in the laboratory. All results are presented in the **Table 19.** The results suggest that not much difference was found between various selected clones in terms of pulp yield, kappa number, brightness, TTA, RAA and Total Solids. In case of fiber classification, except +30 fraction where it was low in [6.3%] SES3 and high in SES 159 [18.1%] and all others or relatively equal.

3.9 UNBLEACHED PULP EVALUATION OF SBI *Erianthus arundinaceus* CLONE BAGASSE

All the pulps produced from the pilot plant mill scale bagasse [**Plate 15- 20**] were evaluated as such condition and after beating in the PFI mill to near 300 ml CSF. Both optical and strength properties are presented in the **Table 20.** The tear factor was found to be higher than sixty in both refined and unrefined pulp of SES 159, EA Cuttack and Mythan and less than sixty for all the remaining all other clones such as SES 3, and IMP 1536. Optical properties such, as brightness, Scattering coefficient, and opacity were found to be relatively similar in all the clones.

3.10 *Erianthus arundinaceus* CLONE SES 159 LARGE SCALE TRIAL BY CONVENTIONAL MILLING PROCESS

After conducting the pilot scale trial, the cane grown under the organic farming method was used for taking large scale mill trial at sugar mill [M/s Sakthi Sugars, Appakkudal], to find out the bagasse yield, Bagasse quality, juice yield and juice quality and the results are presented in the **Table 21 and 22.** The bagasse yield was found to be 53.4 % that is relatively high when compared to the pilot scale trial due to the drying and low cane moisture. The FPR of the SES159 wet whole bagasse was found to high [2.1:1] when compared to the conventional sugarcane bagasse [1.4 to 1.5:1]. The results of juice analysis indicate that *Erianthus arundinaceus* juice contains reasonable amount of sugars that can be utilized to dilute the molasses for the production of alcohol. All the juice generated during the trial period was sent to distillery for alcohol production.

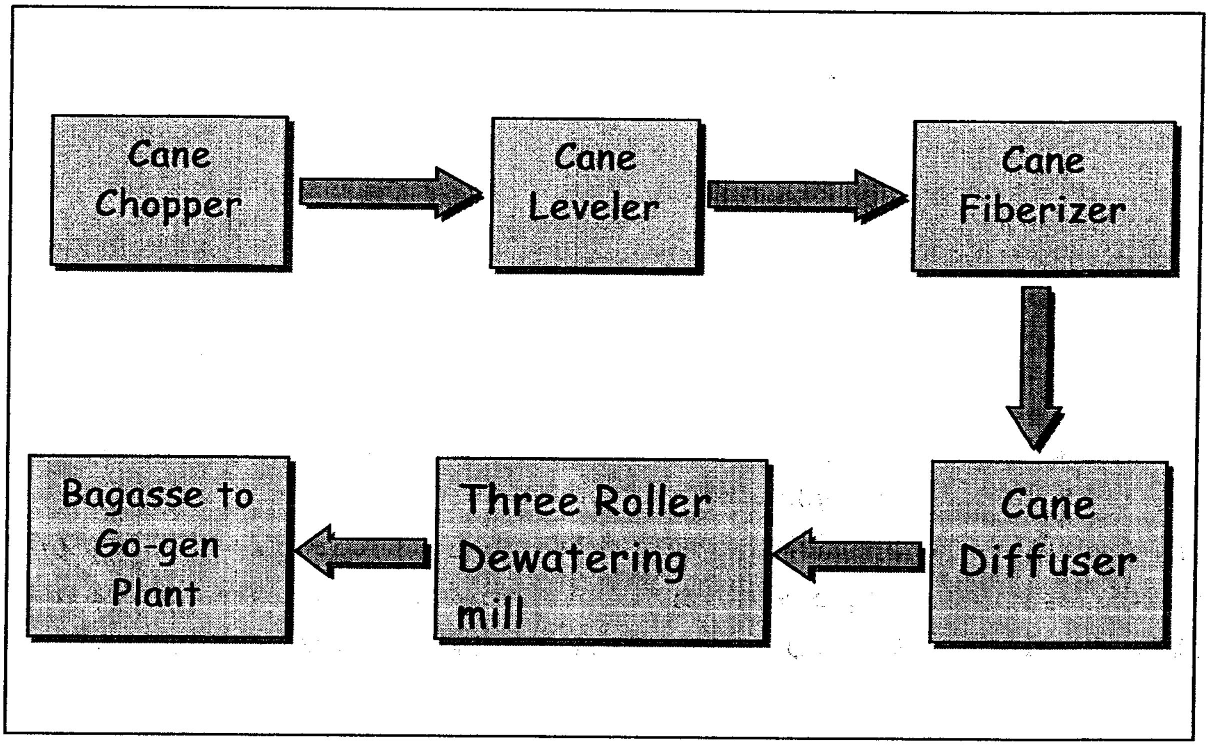
3.11 *Erianthus arundinaceus* SES 159 LARGE SCALE TRIAL BY DIFFUSION PROCESS

It is understood from our previous experience that during conventional sugarcane milling process, the fibres are getting damaged due to high force applied for improving juice extraction to increase the sugar recovery percentage. The damage caused to fibres during milling process reduces the FPR of the bagasse and also the quality of the pulp. Therefore, to reduce the fibre damage and improve the fibre and pulp quality we must reduce the number of milling and one such process is the diffusion process, not very commonly adopted in the sugar mill. We have identified mill having diffusion process [M/s Sagar Sugars Pvt. Chittor, 3000 TPD capacity] and trial have been taken to study the impact of the diffusion process on the bagasse and fibre quality.

Process description: The cane handling and preparation plant is equipped with a conventional cane chopper and cane leveler followed by fiberizer having 144 swing arm hammers with powered by 600 MW motor. The fibrized cane pass through the diffuser and juice extractor and finally dewatering mill for bagasse dewatering and then to cogen plant for use as fuel [**Box 5**].

Crushing trial: About twenty metric tons of SES 159 cane was used to carry out the trial and bagasse samples from fiberiser outlet, diffuser outlet and dewatering mill outlet were analyzed and results are presented in the **Table 23.** Juice samples collected during the trial also analyzed for its properties and presented in the **Table 24.** The whole bagasse yield was found to be 63.8 % which is relatively high when compared to the conventional milling trial taken earlier by using the same clone, main reason is that higher bagasse moisture content of the bagasse. However, not much difference was observed in the fibre pith ratio especially in dewatering mill outlet and conventional milling process bagasse. The quality of juice was found to be better in case of diffusion process then the conventional milling process and indicate the higher efficiency of juice recovery from the cane.

Box - 5 : Diffusion Process Flow Diagram of Diffusion Process



3.12 COMPARISON OF BLEACHED PULP PROPERTIES OF *Erianthus arundinaceus* SES 159 AND CONVENTIONAL SUGARCANE BAGASSE

The SES 159 bagasse pulp produced from large scale mill trial was bleached using the conventional bleaching sequence CEpH and compared with conventional sugarcane bagasse the properties are presented in the **Table 25.** The results indicate that the strength properties of both unrefined and refined pulp produced from the *Erianthus arundinaceus* bagasse was found to be higher than the conventional bagasse pulp especially in case of tear factor, around 10% was high in the *Erianthus arundinaceus* bagasse pulp when compared to conventional bagasse pulp. However, not much difference was observed in case of the optical properties and both *Erianthus arundinaceus* bagasse pulp and conventional bagasse pulp were the found to be similar to each another. In case of bleached pulp fibre classification +30 and +50 fraction were found to be higher and others were found be lower than the conventional bagasse pulp.

This may be one of the reasons for the higher tear factor in the Erianthus arundinaceus bagasse pulp.

4: LARGE SCALE TRIAL OF SELECTED *Erianthus arundinaceus* CLONE

Pilot plant cultivation trial bagasse, fibre, juice, pulping and bleaching studies reveled that among all the clones studied in details viz. Mythan, EA Cuttack, IMP 1536, SES 159, SES 3 and the local clones, SES 159 has relative high potential and selected as final clone to continue for further studies in the large scale.

4.1 LARGE SCALE PLANTATION TRIAL OF *Erianthus arundinaceus* CLONE SES159

To develop a full-scale germplasm and field station to carry out various experiments an area of eight acres of land have been developed in TNPL as part of the project [**Plate 21-25**]. All the experiments related to cultivation trial will be carried out in the field station. Apart from the above TNPL is establishing its own Plant Tissue Culture and other related biotech research facility near the field station at the cost of RS 60.00 lakhs for plant tissue culture research and other fibre improvement program. In the mean time Nearly 18,000 seedlings of SES 159 produced by tissue culture method were planted in the TNPL filed station in an area of 4 acres to study the yield potential with various spacing. Also to study the possibility of utilizing the entire bio-mass including the leaf to produce the bagasse and utilize for papermaking. Because, in *Erianthus*, leaf contribute nearly 25% to 30% of total biomass and leaf also contains good amount of fibre that can be utilized for papermaking. The crop was harvested after one year. The results of harvesting trials are discussed below.

4.2 IMPACT OF SPACING ON *Erianthus arundinaceus* CLONE SES 159 ON TOTAL BIOMASS YIELD

In the present experiment total 3 spacing trails were undertaken. The space between rows was kept constant as 4 feet and the space between the plants were changed viz. 3, 2, and 1.5 feet. The results of total biomass production indicate that lowest spacing gave the highest yield [**Table 26** .] The maximum biomass production was recorded in the 1.5 [61.56 t/acre green weight] feet spacing between the plants followed by 2 [56.33 t/acre green weight] feet and finally in the 3 feet 48.85 t/ acre green weight]. This clearly indicates that the closer spacing is ideal for the higher biomass production. However, our field experience show that reducing the space less than 1.5 feet may not be possible to increase the yield further and also it is not economically and technically attractive.

4.3 FIBRE AND JUICE ANALYSIS OF *Erianthus arundinaceus* CLONE SES 159 [CANE]

Samples of 10 month, 11 month and 12 month canes of *Erianthus arundinaceus* were collected and analyzed for fibre and juice content and compared with commercial sugarcane. There results are presented in the **Table 27.** There is not much variation in the fibre percentage with respect to age of the *Erianthus arundinaceus* cane and it ranges around 22% against the total green weight of the cane. However, the fibre percentage of *Erianthus arundinaceus* was found to be relatively very high [22.5%] when compared to commercial cane [13.58%]. The juice extracted from the Erianthus arundinaceus cane during 10 month, 11 month and 12 month was analyzed for Total Solids, Total Dissolved Solids, pH, Biological Oxygen Demand and Chemical Oxygen Demand. The results are presented in the **Table 27**. The result indicates that there is no definite correlations occur in the juice characters with respect to the age of the cane. As expected solid contents, COD and BOD were relatively less in the *Erianthus arundinaceus* juice when compared to commercial cane.

4.4 FIBRE AND JUICE ANALYSIS OF *Erianthus arundinaceus* CLONE SES 159 [TOTAL BIOMASS]

Samples of whole plant collected during 9th month, 10th month, 11th month 12th month and 13th month were analyzed for fibre and juice characteristics. The results are presented in the **Table 28**. The fibre percentage ranges from 27.4% to 31.0%. The fibre percentage was found to be high in the whole plant biomass bagasse when compared to the bagasse extracted from only cane [**Table 27 & 28**]. The *Erianthus arundinaceus* leaf contains relatively less moisture and more fibre that may be one of the main reasons for high fibre percentage reported in bagasse extracted from whole plant. Juice characters like Total Solids, Total Dissolved Solids, pH, Biological Oxygen Demand and Chemical Oxygen Demand of *Erianthus arundinaceus* with respect to various age starting from 9th month to 13th month indicates that overall there is slight improvement in the juice characters with respect to age. Unlike fibre percentage, minor variation was observed between juice from only cane and juice from whole biomass of *Erianthus arundinaceus* [**Table 27 & 28**].

4.5 DEVELOPMENT OF CONVENTIONAL PROPAGATION FOR *Erianthus arundinaceus* CLONE SES 159

Cost of the tissue culture seedlings farm a major part of the cultivation cost of *Erianthus arundinaceus*. We are forced to adopt tissue culture technique due to the poor germination percentage of *Erianthus arundinaceus* clones and to produce large quantity of seed material. However, most of our germination percentage tests were based on the local clones collected from the Cauvery River bed. However, the performance of SBI clones in the field induced us to re-look the germination studies especially for SES 159. Therefore, we had taken large scale germination studies of SES 159 using the two bud seed cane collected from TNPL model farm. Total four plots were made in the TNPL model farm and the results are presented in the **Table 29.** From the trial it was found that the germination percentage of SES 159 is around 92.5, which is relatively good, and suggest that SES 159 can be propagated by conventional propagation method to reduce the cost of the seedlings. After one-year cultivation the entire above ground biomass was harvested to find out the above ground biomass yields and compared with results of tissue culture plants. The above ground biomass green yield was found to be 56.36 t/acre for *Erianthus arundinaceus* SES 159 cultivated by conventional setts propagation method against the 57.14 t/acre above ground green biomass yield of *Erianthus arundinaceus* clone SES 159 cultivated using plant tissue culture seedlings with the spacing of 4 X 1.5 feet [**Table 30**]

4.6 RATOON CROP STUDIES OF *Erianthus arundinaceus* CLONE SES 159

Cultivation studies were also taken up to study the cane yield in the first ratoon crop *of Erianthus arundinaceus* clone using Tissue culture seedlings and polybag seedlings with a spacing of 6 X 2 feet [**Table 31**]. The results indicate the tissue culture seedlings gave higher cane yield [41.60 t/acre] when compared to polybag seedlings [36.0 t/acre] and overall yield in the ratoon crop is lower than the first crop yield.

4.7 PULPING STUDIES OF VARIOUS FRACTIONS OF *Erianthus arundinaceus* CLONE SES 159

4.7.1 RESULTS OF FIBRE PITH ANALYSIS *Erianthus arundinaceus* CLONE 159 BAGASSE

Fibre pith analysis of *Erianthus arundinaceus* with leaf and without leaf and conventional sugarcane bagasse are presented in **Table 32**. As expected *Erianthus arundinaceus* showed higher fibre pith ratio for both with leaf and without leaf when compared conventional sugarcane bagasse. Age of the crop showed only marginal variations in the fibre pith ratio in all the samples

4.7.2 PULPING OF *Erianthus arundinaceus* CLONE SES 159 [CANE BAGASSE]

Cane samples of *Erianthus arundinaceus* clone SES 159 collected from the field during various month of cultivation viz. 10th month 11th month and 12th month were crushed and after crushing the bagasse was used for Kraft pulping in the laboratory. The results of the above study are presented in the **Table 33, 34, 35**. There is no significant difference in the pulp yield, kappa number, brightness and black liquor properties with respect to the age of the *Erianthus arundinaceus* cane.

4.7.3 PULPING OF *Erianthus arundinaceus* CLONE SES 159 [LEAF BAGASSE]

Erianthus arundinaceus plants were harvested from field during various month of cultivation viz. 10th month 11th month and 12th month and the leaf are separated from the cane and cut into small pieces to make bagasse and used for Kraft pulping in the laboratory. The results of the above study are presented in the **Table 36.** There is no increasing or decreasing trends observed in pulp yield, kappa number, brightness and black liquor properties of *Erianthus arundinaceus* leaf bagasse with respect to age of the crop. However when compare to conventional sugarcane bagasse pulp kappa number of *Erianthus arundinaceus* leaf bagasse found to be high. On the other hand the pulp yield was found to be less.

4.7.4 PULPING OF SUGARCANE BAGASSE [CANE BAGASSE]

To compare the Erianthus arundinaceus bagasse pulp quality with regular sugarcane bagasse pulp quality, pulping studies of sugarcane bagasse at various ages were undertaken simultaneously. The results are presented in the **Table 37, 38,39**. Similar to Erianthus arundinaceus there is no significant difference observed in pulp yield & kappa no with respect to crop age.

4.7.5 PULPING OF *Erianthus arundinaceus* CLONE SES 159 [WHOLE PLANT BAGASSE]

As indicated earlier, *Erianthus arundinaceus* above ground biomass contains nearly 25% to 30 % leaf, which is a significant percent and the pulping studies of *Erianthus arundinaceus* leaf suggests that the leaf of *Erianthus arundinaceus* can also give reasonable quality and quantity of pulp similar to paddy or wheat straw pulp. Therefore, to improve the economy and pulp yield per unit area it is proposed to utilize the entire above ground biomass including leaf to produce pulp. Initially, samples where collected during 8th month 9th month, 10th month, 11th month and 12th month of cultivation to study the impact of crop age on bagasse and pulp quality. The results of above study are presented in the [**Table 40, 41 42, 43, 44**]. There is slight increase in the pulp yield and kappa number with respect to increasing age of *Erianthus arundinaceus* and on the other hand there is a slight decrease in the brightness with respect to increase in age of the crop.

As expected the pulp yield was found to high for the bagasse produced from the cane alone [53.5% to 54.4 %] followed by whole biomass [48.6% to 50.0%] and then leaf 37.35 to 39.0%]. In case of unbleached pulp brightness the trend is almost similar to pulp yield. The kappa number was found to be high in leaf bagasse followed by the whole plant bagasse and then only cane bagasse.

4.7.6 EVALUATION OF UNBLEACHED PULP PROPERTIES BAGASSE OBTAINED FROM *Erianthus arundinaceus* CLONE SES 159 AND COMMERCIAL SUGARCANE

Pulp produced from all the above pulping studies were evaluated for its physical and optical properties in as such condition before refining and after refining and presented in the **Table 45, 46, 47, 48. 49, 50, 51, 52, 53, 54, 55, 56.** There is not much variation found in the properties of unrefined pulp produced from leaf bagasse of *Erianthus arundinaceus* clone 159 with respect to age. However in case of cane bagasse and whole biomass bagasse, the unbleached pulp strength properties are directly proportional to the age of the crop. Pulp properties also indicate that the crop age play important role and strength properties are directly proportional the age of the crop and it obvious that fibre get mature along with crop age especially in case of annual fibre crops. Overall when compared to conventional bagasse the pulp produced from the

Erianthus arundinaceus clone 159 is much superior in terms of strength properties **[Figure 1-11]**

4.8 EVALUATION OF BLEACHED PULPS PROPERTIES BAGASSE OBTAINED FROM *Erianthus arundinaceus* CLONE SES159

Pulp produced from all the above pulping studies were bleached using CEpH bleaching sequence. After bleaching, the bleached pulps were evaluated for its physical and optical properties in as such condition before refining and after refining and presented in the **Table 57, 58, 59, 60, 61, 62, 63, 64, 65, 67, 68**. Like unbleached pulp, crop age did not have any impact on the pulp produced from the leaf bagasse and played a positive role in physical properties of bleached pulp of both cane bagasse and whole biomass bagasse of *Erianthus arundinaceus* clone 159. For example strength properties, such as, tensile index, tear index and burst index of the pulp [from whole biomass] of 8 month old crop and 12 month old crop increased from 60.3 to 68.0, 5.6 to 6.6 and 3.8 to 4.3 respectively for unrefined pulps. In case of refined pulp, at 300 mL CSF, the increase is from 66.0 to 85.0, 5.4 to 6.5 and 4.1 to 5.2 respectively. The properties of the pulp produced from different component like leaf, cane and combined [whole biomass] differ significantly. For example, the strength properties and bleaching response were superior in the pulp produced from cane when compared to pulp produced from leaf. In refined pulp, again strength properties high in pulp produced from the cane bagasse when compared to the pulp produced from whole biomass bagasse. But overall when compared to conventional bagasse pulp the quality of the pulp produced from the whole biomass of *Erianthus arundinaceus* is much superior, except, in case of the pulp produced from the leaf. Fibre classifications of the bleached pulps indicate that the fine fraction is higher and +30 fraction is lower in the leaf bagasse pulp. The higher fine fraction of the leaf mainly contributed from the mesophyll cells of the leaf, which mainly contain parenchyma cell not fibres, and this may be the main reason for low tear index in the leaf bagasse pulp.

4.9 LARGE SCALE CRUSHING TRIAL OF *Erianthus arundinaceus* CLONE SES159

Large scale crushing and depithing trials of entire above ground biomass and respective bagasse of *Erianthus arundinaceus* clone 159 were conducted in the M/s Sakthi Sugars and in TNPL **[Plate 26 – 34]**. Total 37.5 tones of biomass [both leaf and cane] were used for the present trial. The results are presented in the **Table 69**. The results indicate that the fibre percentage on cane is slightly more when compared to lab scale trials due to drying of cane during transit time between the harvesting and crushing. The whole bagasse moisture was relative high when compared conventional bagasse and lab trials, because of high fibre content. During the crushing trial, especially in the milling stage, we are not able to increase load to improve liquid extraction due to frequent jamming and we are not able to extract any primary juice. We could get only the mixed juice and last mill juice with low brix and pol **Table 70**. The bagasse obtained from the crushing trial was transported to TNPL mill site and used for conducting the depithing trial and the results of depithing trial are presented in **Table 71**. The pith removal percentage is around 17.8% and fibre to pith ratio of whole bagasse, depithed bagasse and pith was found to be 2.11:1, 2.36:1 and 0.5:1 respectively. As expected the quality, in terms of fibre to pith ratio, of the bagasse obtained from *Erianthus arundinaceus* clone 159 [2.11:1] was found to be superior then the conventional bagasse [1.5 to 1.7:1] and required less pith removal percentage than the conventional sugarcane bagasse. The lower pith removal percentage indicates more value addition in terms of higher depithed bagasse yield per tone cane crushed. This would improve the overall fibre productivity.

4.10 PULPING AND BLEACHING STUDIES OF *Erianthus arundinaceus* CLONE SES 159 LARGE SCALE MILL TRIAL BAGASSE [WHOLE PLANT]

Pulping studies of large scale mill trial Erianthus arundinaceus bagasse [SES 159 with leaf], both whole bagasse and depithed bagasse, obtained from the large scale mill trial and depithing trial were carried out in the laboratory. The results are presented in the **Table 72 & 73**. Unbleached pulp produced from whole bagasse and depithed was found to be similar except brightness. The depithed bagasse pulp brightness was slightly high when compared to whole bagasse pulp. Both, pulp from whole bagasse and depithed bagasse were evaluated on as such basis without refining and after refining and results are presented in the **Table 74 and 75**. The results indicate that the strength and optical properties are superior in the depithed bagasse pulp than whole bagasse pulp similar to conventional sugarcane pulp. Same trend was observed in the fibre classification where +30 and +50 and +100 fractions were found to be high in the depithed bagasse pulp and as result +200 and –200 fractions found to be vise versa. Higher percentage of long fibre in depithed bagasse pulp is an additional evidence for high strength properties in the pulp.

Both whole bagasse pulp and depithed bagasse pulp were bleached in the laboratory using CEpH bleaching. The pulps were evaluated on as such basis and after refining. The results are presented in the **Table 76 and 77.** As expected, strength properties of depithed bagasse pulp were higher when compared to whole bagasse pulp.

5: DISCUSSION

Considering the low biomass yield and high fibre content and bagasse yield of local cauvery riverbed clones made us to look for other clones with better biomass productivity and fibre and bagasse yield. Obviously, SBI clones became natural choice because SBI has largest collection of germplasm collected from wide geographical regions. Initial screenings of clones were carried out based on the fiber content. [fiber pith ratio], morphological characters [plant height, cane length, cane diameter, numbers of internodes, length of internodes, cane weight] and biomass yield [can yield and biomass yield]. Out of 88 SBI clones six clones were found to be good and five short listed for further study based on seed material availability. Among the five clones, SES 159 was found to be comparatively superior with respect to biomass productively **[Table 11]** that is one of the main criteria for development of captive fiber source and bio-energy production [Klass, 1999, Mislevy *et al.,* 1989, Heaton *et al.,* 2004, Samson et al., 2005]. Fiber contents of clones that determine the pulp quality was found to be higher in EA Cuttack, unfortunately the EA Cuttack has low cane and biomass yield **[Table 11, 12]**

Based on initial observation and results obtained from germplasm characterization of the individual clones, cultivation trial were conducted using both organic and conventional method of cultivation for SES 159 and for others either one of the above method was adopted based on land availability. The results of large scale study confirm initial germplasm observation where SES 159 was found to be superior among all the clones viz. SES 159, SES 3, Mythan A, EA Cutack, and IMP 1536. Next to SES 159, SES 3 [35 t/acre] gave the highest cane yield followed by Mythan [32 t/acre], EA Cuttack [25.5 t/acre], IMP 1536 [23.3 t/acre] and CRI 1[22.7 t/acre]. *Erianthus arundinaceous* is proved to be one of the highest biomass producing perennial grass when compared to other grasses such as *Miscanthus giganteus*, Elephantgras, Sweet Sorghum and *Panicum virgatum* [Mislevy *et al.,* 1989, Price, *et al.*, 2004, Samson *et al.,* 2005]

The results of crushing trial show that bagasse yield and whole bagasse fibre pith ratio was high in Mythan when compared to other clones. The high yielding SES 159 gave the bagasse yield of 53% with fiber pith ratio of 2.2:1, which is higher than the conventional sugarcane varieties. [Rajesh and Mohan Rao, 1988]. All the clones studied have given more than 50% bagasse yield per tone of cane crushed, which is much more than the conventional sugarcane where the bagasse yield would be around 25-30%. Fibre pith ratio of *Erianthus arundinaceus* clones are in the range of 2.1:1 to 2.8:1 against 1.3: 1 to 1.7:1 of conventional sugarcane varieties. This indicates that *Erianthus arundinaceus* produce high fibre in the unit area with good quality. Higher fibre pith ratio of *Erianthus arundinaceus* open an opportunity to use the whole bagasse as such to produce pulp directly without depithing or mild depithing of 5 to 10% pith removal against the conventional depithing of around 30 to 35 % pith removal practiced for conventional bagasse.

There are no significant variations in pulp yield between *Erianthus arundinaceus* clones as well as conventional sugarcane. However, kappa number was relatively high in all *Erianthus arundinaceus* bagasse pulp against conventional bagasse pulp. One of the possible reason may be the presence of residual sugars present in bagasse would have consumed pulping chemicals. Our experience in plant suggests that one of the reason for higher kappa number or chemical consumption is use of fresh bagasse. Other parameters like pulp Brightness, freeness and Black Liquor analysis did not show any significant change and all are almost similar to conventional sugarcane bagasse pulp.

The fibre from kraft pulps of all the clones were classified in the Bauer-McNett fibre classification equipment. The fibre percentage of different fraction along with conventional sugarcane bagasse and switchgrass [Goel *et al.*, 1998] are summarized in the **Table 78.** The comparison shows that the *Erianthus arundinaceus* pulp contain less percentage of fines [-200] than the conventional sugarcane and switchgrass. It is interesting to note that the clone number SES159 has the highest +30 percentage among all clones studied that indicates the presence of longer fibre in the pulp. Photomicrograph of the SES 159 illustrate presence of vascular bundles, annular and spiral type vessel elements epidermal cells, ground tissue cells similar to conventional bagasse pulp [**Plate 35- 40**]. The Breaking length of refined pulp ranges from 6000-8000 m which is comparable with conventional sugarcane bagasse pulp. However in case of tear factor, SES159, EA Cuttack and Mythan bagasse pulp gave tear factor of more than 60 which is higher the commercial sugarcane bagasse pulp.

Among all the clones studied SES 159 was selected based on the biomass yield i.e. unit area fibre productivity and pulp properties. Also SES 159 respond well in micropropagation as well as in conventional two or single bud setts propagation when compared to other selected clones which an added advantage because, propagation is one of the major problem in perennial grasses. The percentage of plant establishment in the field was found to be more than 90%, which is almost comparable with other energy crops and sugarcane. The results of large-scale study are comparable with pilot scale trial, except bagasse yield, which is slightly higher. Comparative analysis of both refined and unrefined pulps of conventional bagasse pulp and *Erianthus arundinaceus* bagasse pulp indicates that strength and optical properties are similar except tear factor, which is higher in *Erianthus arundinaceus* bagasse pulp against the conventional sugarcane bagasse [Rajesh and Mohan Rao, 1998].

The Erianthus arundinaceus clone SES 159 was selected after the detail evaluation of the above screening and cultivation experimental results of one local clone from Cauvery riverbank and five from germplasm collections of Sugarcane Breeding Institute. Optimization of biomass productivity studies using various spacing trail suggest that closer spacing increased productivity [**Table 25**] The total above ground estimated annual biomass productivity was 44.28 tones per hectors on oven try basis which is slightly when compared to earlier study on the *Erianthus*. For example, the recent review on the C_4 annual grasses reported the biomass productivity of *Erianthus* ranges from 48.8 to 56.2 tones per hector on oven dry basis [Samson *et al.*, 2005]. The variations may be due to the environmental condition prevailing in the different experimental sites also the variation found in the different type *Erianthus* clones as well as species used for the studies. However, when compared to other perennial grasses, *Erianthus* was proved as highly productive grass because its tolerance to environmental stress, drought, pest and diseases [Sugimoto 2000]. *Erianthus* is also known for its thick canopy, large numbers of tillers production, extensive dense deep root system. These properties help in improving the biomass productivity by increased light absorption, reduced field drying leading to less irrigation requirements, drought resistance and improved and efficient nutrient uptake from soil [Sugimoto, 2000].

The age of the plant may have influence on content and quality of fibre used for producing bagasse and then pulp. This evidenced on the fibre content of the bagasse produced from SES 159 whole plant bagasse. It get optimized at the age of 9-10 month and after that there is no significant change in the fibre quantity in all the samples studied [**Table 32**]. This clearly indicates that the crop can be cultivated at the age of 9 to 10 month but need further study. The *Erianthus arundinaceus* is primarily cultivated for fibre and not for sugar like sugarcane. This is an added advantage because the final product yield i.e. fibre generally do not get affected due to aging of crop like sugars where sugar yield is more depend on the age. This will give more flexibility in harvest and transport operation of cane, which is major constrain in the sugar industry.

Significant difference was observed in the pulp yield between the *Erianthus arundinaceus* whole plant, cane and leaf bagasse. Presence of high water soluble content and parenchema cells and less fibres are attributed to the poor pulp yield of leaf bagasse then the cane and whole plant bagasse. Pulp strength properties at 300 mL of both unbleached and bleached pulp show upward trend with respect to age of the crop. Invariably in all the samples tested, strength properties are directly proportional to the crop age. [**Figure 23, 24, 24**]. This indicate the maturity of the fibre in terms of quality. When compared to conventional sugarcane bagasse pulp, both pulp from whole plant bagasse and from cane showed significant improvement in strength properties. It suggests that *Erianthus arundinaceus* bagasse contains high quality bagasse than the conventional sugarcane bagasse, which is evidenced by the higher fibre pith ratio in the *Erianthus arundinaceus* bagasse [**Table 32**]. It is reported that *Erianthus* has high fibre content than the other perennial grass studied for the pulp production [**Table 78**].

The properties of the pulp produced from the large-scale mill trial bagasse from the *Erianthus arundinaceus* whole plant is compared with the conventional sugarcane bagasse [**Table 79, 80**]. The pulp produced from both whole bagasse and depithed bagasse is found to be superior in terms of strength properties than conventional sugarcane bagasse pulp. Bagasse yield was also found to be high in the *Erianthus arundinaceus* due to higher fibre percentage in the *Erianthus arundinaceus*. In general one tone of sugarcane crushed yield around 250 to 300 kg bagasse whereas *Erianthus arundinaceus* the bagasse yield will be around 500 to 560 kg per tone of Erianthus arundinaceus crushed [including leaf]. Therefore, for 60 tones of *Erianthus arundinaceus* biomass produced in one acre would generate around 36.27 tones of bagasse valued at RS 45,330 at the rate RS 1250 per tone of bagasse. Naturally the high fibre yield would reduce the sugar production in the *Erianthus arundinaceus* resulting low sugar content in the Erianthus arundinaceus juice i.e. Pol % and Brix % [**Table 22, 24**]. This makes it un-economical to go for sugar extraction from *Erianthus arundinaceus* juice and reduce economical viability of *Erianthus arundinaceus* cultivation only for bagasse production. One option to improve the economic viability is to improve the biomass productivity to improve the unit area bagasse yield or effective resource uitilization by reducing the waste generation, value addition and converting the waste into useful products. Including leaf along with cane to produce bagasse is one of the attractive option to increase the bagasse yield. This will increase the bagasse yield by 25 to 30 % and subsequent pulp yield per unit area. For example, 60 tones of above ground biomass produced annually per acre of *Erianthus arundinaceus* plantation will give roughly 8.16 tones of pulp whereas if use only cane to produce bagasse and pulp, the pulp yield will be 25 to 30 % less than above i.e. 6.12 to 5.76 tones per acre.

As indicated earlier, the annual estimated pulp yield per acres would be around 8.16 tones for *Erianthus arundinaceus* which is higher than one of the highly productive hardwood pulp species like *Eucalyptus* where maximum unit area pulp yield per acre in an year would be around 2.484 tones if we get 60 tones wood per acre in five year rotation period [**Table 81**]. This indicate that the Erianthus arundinaceus has potential to produce three times more pulp when compared to dominant hardwood pulp species like *Eucalyptus*.

As expected the quality of juice i.e. brix% pol% and total reducing sugars was found to be poor in all clones studied when compared to conventional sugarcane. This is mainly due to higher fiber content in *Erianthus* sp. as reported elsewhere [Matsuo *et al.*, 2003] and considered as draw back for forage crop because of poor digestibility associated with high fibre content. *Erianthus arundinaceus* juice analysis indicates that it contain reasonable amount of dissolved organic content and it is estimated that the Chemical Oxygen Demand (COD) was around 1,00,000 mg/lit and it is a new raw material resource for producing renewable energy like biogas that can be utilized as in-house energy to save fossil fuel. For 60 tones of annual *Erianthus arundinaceus* yield in an acre would approximately generate around 3360 kg COD of juice and for 85% COD reduction with 0.5 m^3 biogas factor, the gas generation potential for the juice generated from one acre of *Erianthus arundinaceus* plantation would be around 1428 m^3 which roughly equivalent 714 Lit. of furnace oil [Chinnaraj *et al.*, 2003, Chinnaraj and Venkoba Rao, 2006]. Furnace oil is one of the major fossil fuel used in many industrial process which is non renewable and CO_2 emission from the fossil fuel burning has negative effect on the global climate change and contributes to net raise in CO_2 level in the atmosphere and classified as non renewable carbon in global carbon cycle. Today fossil fuel consumption in the world stands around 6 Gtc/year [Giga tone of carbon] and contributes as largest source CO_2 emission from manmade activities, leading to net increase of 2.1 Gtc/year in atmosphere after neutralizing carbon sequestration potential [3.9 Gtc/ year] of natural resource such as forest and ocean ecosystems [Reicher, 1999]. In the post Kyoto Protocol era reduction of Greenhouse gas emission gets major priority in many countries and in many industrial process due to the predicted adverse effects of climate change like global warming and sea level rise because of increasing greenhouse gas level in atmosphere. As a greenhouse gas CO_2 contributes to global warming and sea level rise [Climate Change Information Kit, 2001]. It is learned that one barrel of furnace oil [160 litters] use result in 487 kg of CO_2 emission to atmosphere [Energyprobe.org.]. Saving 714 liters of furnace oil from one acre *Erianthus arundinaceus* plantation would reduce 2.18 tones of CO_2 emission to atmosphere and generate revenue of around RS 14280. Apart from the above, CO_2 reduction may also get qualify for carbon credit under the Clean Development Mechanism of United Nation Framework Convention on Climate Change and generate additional revenue.

The total value of juice [RS 14,280] and bagasse [RS 45,330] would be RS 59,610 and net value will be around RS 19,610 after deducting other expenses like cultivation, harvesting, transportation and processing. The computed return per ton of biomass would be around RS 660, which can be paid to farmers. This will generate net annual revenue of RS 19,610 per acre to farmer.

6. CONCLUSION

1. Utilization of fibrus raw material for other purpose, such as, fuel in bioenergy generation system due to increase in oil price and pressure to reduce the greenhouse gas emission under Kyoto protocol coupled with increasing demand

for paper and paper product leads to increase in fibrous raw material cost and demand. The concept of growing perennial C_4 grass for bioenergy purpose has been a focus in the past few decades because of its high unit area biomass productivity.

2. *Erianthus arundinaceus* has been identified as excellent biomass producing species in tropical belt and known for its high fibre content. Traditionally *Erianthus arundinaceus* has been used in breeding to genetically improve sugarcane especially for productivity and environmental stress improvement. In this present study the unique grass has been identified as alternate source of fibre to conventional sugarcane bagasse.

3. Total six *Erianthus arundinaceus* clones collected from Cauvery Riverbank and eighty eight clones collected from germplasm collections of Sugarcane Breeding Institute were screened to find out the paper making potential of this unique grass based on the fibre pith ratio, biological characters, biochemical composition and pulping. Among all the clones studied six clones were selected for pilot scale field trial, Out of six *Erianthus arundinaceus* clones, SES159 was found to be promising captive fibre source and alternate for sugarcane bagasse due its high unit area productivity and its amicability for propagation and establishment in the field and used for large scale trial.

4. The bagasse produced from SES 159 has high fibre pith ratio and bagasse yield was almost twice when compared to conventional sugarcane bagasse. SES 159 juice has little sugars in the juice and not suitable for sugar extraction but can be used to generate in-house bioenergy like biogas.

5. The green biomass productivity of SES 159 is estimated to be more than 60 t acre^{-1} y^{-1} and this can yield 8.16 t acre^{-1} y^{-1} pulp against 2.484 t acre^{-1} y^{-1} pulp yield of dominant hardwood like *Eucalyptus* which is more than three times.

6. The strength properties of pulp produced from SES 159 are superior at least minimum 10% when compared to pulp produced from conventional bagasse pulp.

7. Our field experience indicates that harvesting and transportation is the major bottleneck converting this unique grass into captive fibre source for paper industry because high fibre content and robust growth create many practical problems in the field. This needs further study especially development of suitable technology for harvesting and production of hybrids with high biomass productivity and optimized cultivation practice.

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Table – 1:Yield results of 10 m^2 plot wildcane (local clone collected from Cauvery river bank)

S. NO	PARAMETERS	YIELD IN 10 M^2 PLOT	YIELD PER ACRE
1	Cane weight	126.5kgs	50.6 T
2	Leaf weight	48.5 kgs	19.4 T
3	Total biomass	175 kgs	70 .0 T
4	Cane moisture	65%	—

Table – 2: Results of wildcane pulping study (local clone collected from Cauvery river bank)

S.NO	PARAMETERS	UNITS	WILDCANE WHOLE BAGASSE	CONVENTIONAL SUGARCANE WHOLE BAGASSE
1	Fibre pith ratio		2.14:1	1.3-1.5:1
2	Chemical applied	%	12	12
3	Pulp yield	%	53.0	51.5-52
4	Kappa Number		15.0	17 –18.5
5	Brightness	%	35.5	32-34
Pulp Evaluation @ 300 ml CSF				
6	Breaking length	M	8650	8000 - 8200
7	Tear Factor		54.7	51 – 52
8	Burst Factor		51.0	47 - 48
Pulping Conditions				
Sulphidity		%	18 - 20	
Bath Ratio			1 : 4.0	
Cooking Temp		°C	170	
Cooking Time		mts.	20	
H - Factor			450	

Table –3: Results of wild cane milling trial (local clone collected from Cauvery river bank)

S. NO	PARAMETERS	RESULTS
1.	Whole bagasse yield	54.5 %
2.	Whole bagsse moisture	52.0%
3.	Whole bagasse Fibre pith ratio	2.14:1
4.	Depithed bagasse fibre pith ratio	2.46:1
5.	Depithed bagasse moisture	49.8%
6.	Pith removal	13.1%

Table- 4: Results of wildcane bagasse pulping study (local clone collected from Cauvery river bank)

S. NO	PARAMETERS	UNITS	WILDCANE WHOLE BAGASSE	WILDCANE DEPITHED BAGASSE
1	Fibre pith ratio		2.13:1	2.46:1
2	Chemical applied	%	12	12
3	Total pulp yield	%	53.2	54.6
4	Kappa Number		17.5	15.5
5	Brightness	%	37.0	41.5
Pulp Evaluation @ 300 ml CSF				
6	Breaking length	M	8000	8200
7	Tear Factor		55.5	60
8	Burst Factor		51.0	52.5
Pulping Conditions				
Sulphidity		%	18 - 20	
Bath Ratio			1 : 4.0	
Cooking Temp		° C	170	
Cooking Time		mts.	20	
H - Factor			450	

Table – 5:Results of fibre pith analysis of *Erianthus arundinaceus* SBI clones

S. NO	CLONE NO	USEFUL FIBRE %	PITH %	FINES & WATER SOLUBLE %	FIBRE PITH RATIO
1	57	53.60	36.30	10.10	1.48:1
2	49	55.40	34.80	9.81	1.59:1
3	81	52.00	36.80	11.2	1.41:1
4	32	56.00	31.20	12.8	1.79:1
5	34	56.50	32.10	11.4	1.76:1
6	21	54.40	23.90	11.8	2.69:1
7	43	62.20	26.80	11.00	2.32:1
8	55	54.60	33.30	12.20	1.64:1
9	76	53.50	35.60	10.80	1.50:1
10	18	53.90	31.90	14.10	1.69:1
11	35	59.00	30.60	10.40	1.93:1
12	37	53.40	33.30	13.30	1.60:1
13	54	55.80	33.60	10.60	1.66:1
14	22	55.50	31.90	12.50	1.74:1
15	15	56.20	30.10	13.60	1.87:1
16	8	53.40	33.20	13.40	1.61:1
17	24	52.70	36.50	10.70	1.44:1
18	29	55.10	32.90	12.00	1.67:1
19	87	52.60	36.70	10.50	1.43:1
20	30	56.26	32.86	10.87	1.71:1
21	48	60.24	29.59	10.20	2.04:1
22	4	53.55	34.03	12.49	1.57:1
23	11	58.15	31.24	10.92	1.86:1
24	56	53.60	34.37	12.01	1.56:1
25	44	57.18	31.31	11.50	1.83:1
26	19	53.95	34.66	11.38	1.56:1
27	77	55.61	33.87	10.51	1.64:1
28	12	59.03	29.75	11.21	1.98:1
29	52	56.58	33.31	10.09	1.70:1
30	36	58.92	30.87	10.20	1.90:1
31	10	52.15	35.96	11.90	1.45:1
32	28	56.10	31.34	12.54	1.79:1
33	6	59.21	31.00	9.78	1.91:1
34	69	52.27	37.22	10.50	1.40:1
35	78	53.60	35.50	11.42	1.49:1
36	31	55.17	35.11	9.71	1.57:1
37	9	57.05	30.39	12.54	1.88:1
38	27	55.89	32.32	11.78	1.73:1
39	82	51.24	36.49	12.27	1.40:1
40	17	54.24	37.82	7.92	1.43:1
41	26	58.62	30.45	10.93	1.92:1
42	20	53.40	35.25	11.34	1.51:1

Table 5 Continuation......

S. NO	CLONE NO	USEFUL FIBRE %	PITH %	FINES & WATER SOLUBLE %	FIBRE PITH RATIO
43	83	54.96	34.46	10.55	1.59:1
44	7	51.81	36.78	11.39	1.41:1
45	86	49.58	38.12	12.28	1.30:1
46	1	54.47	34.06	11.46	1.60:1
47	5	58.97	29.36	11.65	2.0:1
48	50	55.24	32.59	12.21	1.69:1
49	51	60.45	28.11	10.92	2.1:1
50	47	57.61	31.91	10.45	1.8:1
51	67	52.91	35.80	11.26	1.48:1
52	71	55.21	33.13	11.65	1.66:1
53	80	57.11	32.23	10.64	1.77:1
54	85	55.95	36.64	11.40	1.42;1
55	14	54.43	33.61	11.95	1.62:1
56	16	59.47	29.42	11.09	2.02:1
57	53	55.61	33.32	11.06	1.67:1
58	46	52.21	36.34	11.43	1.44:1
59	65	52.94	36.01	11.04	1.47:1
60	70	54.28	33.98	11.73	1.60:1
61	73	57.65	31.20	11.12	1.85:1
62	74	53.82	34.17	11.99	1.57:1
63	79	56.19	32.32	11.48	1.74:1
64	72	56.99	30.92	12.07	1.84:1
65	45	55.50	33.19	11.31	1.67:1
66	58	54.47	36.80	8.74	1.48:1
67	59	56.52	32.12	11.36	1.76:1
68	60	49.80	40.25	9.94	1.24:1
69	33	55.59	35.56	8.85	1.56:1
70	38	60.66	30.44	8.93	1.99:1
71	39	56.94	33.28	9.78	1.71:1
72	41	60.97	29.44	9.58	2.07:1
73	61	57.92	31.43	10.66	1.84:1
74	62	56.98	30.45	12.57	1.87:1
75	63	58.32	31.14	10.54	1.87:1
76	64	60.82	27.11	12.07	2.24:1
77	2	56.18	32.23	11.59	1.74:1
78	13	54.73	33.39	11.88	1.64:1
79	23	54.57	34.21	11.21	1.59:1
80	25	53.69	34.53	12.02	1.55:1
81	40	58.96	30.72	10.31	1.92:1
82	66	55.41	32.02	12.56	1.76:1
83	68	57.74	30.62	11.64	1.88:1
84	84	53.22	35.20	11.58	1.51:1
85	75	50.84	35.82	12.8	1.42:1
86	3	55.27	32.85	11.88	1.68:1
87	42	57.34	32.49	10.16	1.76:1
88	88	55.41	32.02	12.56	1.76:1

Table- 6: *Erianthus arundinaceus* clones having fibre pith ratio more than 1.8:1

S. NO	CLONE NO	USEFUL FIBRE %	PITH %	FINES & WATER SOLUBLE %	FIBRE PITH RATIO
1	5	60.22	28.38	11.40	2.12:1
2	6	58.81	30.62	10.57	1.92:1
3	9	57.23	30.92	11.84	1.85:1
4	11	57.89	31.57	10.52	1.83:1
5	12	59.00	29.75	11.25	1.98:1
6	15	56.51	30.24	13.25	1.87:1
7	16	60.04	28.65	11.30	2.09:1
8	21	62.57	25.33	12.09	2.47:1
9	26	57.41	31.39	11.19	1.83:1
10	35	58.92	31.20	9.88	1.89:1
11	36	59.43	29.83	10.74	1.99:1
12	38	59.78	28.73	11.48	2.08:1
13	40	60.65	29.68	9.74	2.04:1
14	41	60.60	29.51	9.89	2.05:1
15	43	62.34	28.57	9.09	2.18:1
16	44	58.41	28.92	12.66	2.02:1
17	47	57.89	30.72	11.39	1.88:1
18	48	58.72	30.14	11.20	1.95:1
19	51	59.49	29.78	10.73	2.00:1
20	62	58.18	30.12	11.62	1.93:1
21	64	60.85	27.55	11.59	2.21:1
22	68	56.83	30.58	12.59	1.86:1
23	73	56.88	31.37	11.75	1.81:1

Table – 7: Results of Proximate analysis of 23 selected *Erianthus arundinaceus* clones

S NO	CLONE NAME	ASH %	HOT WATER SOLUBLES %	1% NA OH SOLUBLES %	AB EXTR-ACTIVES %	PENTOSANS %	HOLO-CELLULOSE %	ACID IN-SOLUBLES %
1	SES 003	2.0	9.8	33.1	3.4	21.5	66.6	18.2
2	SES 079	1.9	9.9	32.4	3.3	21.1	65.2	19.7
3	SES 136	2.2	10	33.2	3.5	23.3	63.2	21.1
4	SES153	1.8	8.8	30.6	2.8	21.4	67.0	19.6
5	SES 159	2.2	9.9	33.7	3.0	22.2	63.3	21.6
6	SES 228	2.1	10.2	32.4	3.0	22.7	63.4	21.3
7	SES 293	2.2	9.6	33.6	2.8	22.3	64.0	21.4
8	IK76-027	2.8	9.7	32.7	2.6	21.8	63.9	21.0
9	IK76-081	2.8	9.9	32.3	2.1	21.9	65.5	19.7
10	IS76-142	2.5	8.5	27.3	2.8	22.9	66.1	20.1
11	IS76-134	2.4	8.0	31.4	3.3	23.3	65.1	21.2
12	IS76-145	2.4	7.6	25.1	2.9	22.8	66.6	20.5
13	IS76-163	2.5	9.3	30.6	2.8	21.4	66.3	19.1
14	IS76-169	2.6	7.9	29.8	2.8	21.9	66.9	19.8
15	IS76-178	2.9	9.7	29.8	2.4	22.6	63.6	21.4
16	IS76-202	2.6	9.0	28.6	2.5	21.8	65.3	20.6
17	IJ76-327	2.8	9.7	30.5	2.5	20.5	66.2	18.8
18	IJ76-332	3.8	8.1	31.0	2.7	22.1	65.0	20.4
19	IJ76-342	3.1	10	31.4	2.3	21.3	63.3	21.3
20	IJ76-408	3.3	9.8	33.5	3.0	21.4	64.3	19.6
21	IMP1536	2.4	8.6	32.7	3.3	22.0	65.9	19.8
22	EA CUTTACK	2.7	10.2	32.3	3.0	22.6	63.3	21.1
23	MYTHAN	3.2	10.5	34.0	3.2	23.0	63.9	19.2

Table – 8: Results of SBI clones Juice analysis

S. NO	CLONE NAME	PH	COD MG/LIT	BRIX %	POL %
1.	SES 159	5.3	77,150	9.2	0.8
2.	SES 3	5.2	62,200	7.5	0.5
3.	IMP 1536	5.6	38,400	5.3	0.4
4.	EA Cutack	5.4	44,630	7.0	0.5
5.	Mytahn A	5.3	46,850	7.0	0.5
6.	IJ 342	5.5	54,260	7.0	0.4

Table- 9: Results of SBI clones fibre analysis

S. NO	CLONE NAME	FIBRE PITH RATIO	FIBRE % ON CANE
1.	SES 159	2.5:1	24.0
2.	SES 3	2.3:1	21.2
3.	IMP 1536	2.6:1	21.4
4.	EA Cutack	2.7:1	31.0
5.	Mytahn A	2.5:1	25.4
6.	IJ 342	2.4:1	25.3

Table -10:Results of selected SBI clones pulping study

S. NO	PARAMETERS	SES 159	IJ 342	SES 3	IMP 1536	MYTHAN	EA CUTACK
1	Chemical %	12	12	12	12	12	12
2	Total Yield %	53.60	55.95	52.4	54.15	52.45	53.90
3	Screen rejects %	0.60	1.27	0.90	0.99	0.88	0.85
4	Screen yield %	53.0	54.7	51.5	53.2	51.6	53.1
5	Kappa No	18.7	20.8	21.0	17.5	20.0	20.9
6	Brightness % ISO	39.1	33.9	34.2	36.2	38.2	38.9
7	WBL pH	10.5	11.2	11.4	11.3	11.9	11.9
8	TTA gpl	24.4	23.6	19.6	23.1	24.5	23.5
9	RAA gpl	6.5	7.8	7.7	7.6	8.4	8.9
10	Total solids gpl	169	180	182	173	181	189

Pulping Conditions	
Sulphidity	18 – 20 %
Bath Ratio	1 : 4.0
Cooking Temp	170 ° C
Cooking Time	20 mts
H - Factor	450

Table - 11 : Yield per plant and quality parameter of selected *Erianthus arundinaceus* clones

S. NO.	PARAMETERS	UNITS	SES -003	IMP 1536	MYTHANE	EA CUTTACK	SES 159
1	Plant height	cm	528	575	530	436.7	547
2	Biomass yield	kg	55.5	62	58.2	37.2	74.2
3	Cane yield	Kg	29.17	40.5	34.3	25.8	51.8
4	Number of cane	nos	39	52	47	35	71
5	Cane length	cm	353	329	346	250	333
6	Cane diameter	mm	23.5	20	20.2	20.6	20.8
7	Number of internodes	no	35	29	30	28	27
8	Internode length	cm	14.3	16.2	13.7	10.9	16.8
9	Single cane weight	g	650	400	600	600	560
10	Fibre content	%	21.2	21.4	25.4	31.0	25.0

Table – 12: Results of *Erianthus arundinaceus* SBI clones cultivation trial

S. NO	CLONE NAME	CONVENTIONAL FARMING	ORGANIC FARMING
1	SES 159	40 .0 T/Acre	45. 0 T/Acre
2	SES 3	—	35. 0T/Acre
3	Mythan	32. 0 T/Acre	—
4	E.A. Cuttack	25. 6 T/Acre	—
5	IMP 1536	23. 3 T/Acre	—

Table – 13: Effect of fertilizers on stalk yield of *Erianthus arundinaceus* - Clone SES 159

S. NO.	TREATMENTS	STALK YIELD T/HA
1	Control - No fertilizer	53.75
2	50% NPK	67.06
3	75% NPK	80.10
4	100% NPK	98.60
5	50% NPK + BF	78.16
6	75% NPK + BF	96.96
7	100% NPK + BF	112.16

100 % NPK Recommended dose: 225, 62.5, 100 kg NPK/ha
P applied as Basal dose before planting
N & K applied in two equal splits i.e. at 45^{th} day 90^{th} day after planting.
BF: Biofertilizers (Azospirillum, Phosphobacterium) applied in two equal splits each @ 10 kg/ha
Spacing: 180 cm X 90 cm (row to row – 180 cm and with in the row – 90 cm)

Table - 14: Effect of planting material and organics on cane yield of *Erianthus arundinaceus* Clone SES 159

S. NO.	TREATMENTS	MEAN CANE YIELD T/HA
1	Control – No organics	107.75
2	TC + FYM	122.72
3	TC + VC	123.97
4	PBS control	105.53
5	PBS + FYM	123.48
6	PBS + VC	128.65

Mean yield of TC : 118.15 t/ha
Mean yield of polybag settlings : 119.22 t/ha
Mean yield of control : 106.64 t/ha
FYM : 123.10 t/ha
VC : 126.31 t/ha
TC : Tissue culture plants
PBS : Polybag settlings
FYM : Farm yard manure – 1kg/plant
VC : Vermi compost – 1 kg/plant
Spacing: 180 cm X 90 cm (row to row – 180 cm and with in the row – 90 cm)

Table - 15: Effect of spacing on cane yield of Erianthus arundinaceus clones (SES 3 & SES 159)

S. NO.	TREATMENT SPACING	CANE YIELD T/HA	
		SES 3	SES 159
1	4.5' X 2.0'	115.5	127.6
2	4.5' X 3.0'	105.3	116.7
3	4.5' X 4.0'	99.5	107.7
4	6.0' X 2.0'	113.0	123.6
5	6.0' X 3.0'	101.2	112.4
6	6.0' X 4.0'	94.9	104.3
	Mean	104.9	115.4

Table – 16: Results of SBI *Erianthus arundinaceus* clones mill trial

S.NO	PARAMETERS	SES 3	SES159	EA CUTTACK	MYTHAN	IMP 1536
1.	Cane weight MT	3.35	4.63	3.78	3.98	3.45
2.	Hydraulic load kg/cm^2	100	100	100	100	100
3.	Wet whole bagasse weight MT	1.48	2.32	2.10	2.54	1.75
4.	Bagasse yield %	44.5	50.0	55.6	60.0	50.7
5.	De-pithed bagasse weight MT	1.37	2.03	1.94	2.26	1.53
6.	Pith weight MT	0.11	0.29	0.16	0.28	0.22
7.	Pith removal %	7.4	12.5	7.6	11.0	12.6
8.	Trial duration min.	10	15	15	15	10
9.	No of De-pithers used	2	3	3	3	3

Table – 17: Pilot scale Mill trial Bagasse quality of SBI *Erianthus arundinaceus* clones

S. NO	CLONE NAME	WHOLE BAG.		DE-PITHED BAG		PITH	
		MOISTURE	FPR	MOISTURE	FPR	MOISTURE	FPR
1	SES 3	49.3	2.5:1	50.2	2.72:1	56.1	0.29:1
2	SES 159	53.1	2.25:1	50.4	3.13:1	59.4	0.26:1
3	E.A. Cuttack	54.1	2.83:1	56.3	3.01:1	60.4	0.28:1
4	Mythan	56.9	2.5:1	54.6	2.98:1	61.2	0.18:1
5	IMP 1536	54.9	2.2:1	56.8	2.73:1	62.7	0.22:1

Table –18: Results of Pilot Scale Mill trial Juice Analysis of SBI *Erianthus arundinaceus* clones

S.NO	CLONE NAME	PH	COD PPM	BRIX %	POL %	PURITY %	TRS %
1	SES 3	2.1	60240	6.4	2.24	35.2	4.5
2	SES 159	2.0	93974	7.9	2.1	26.5	2.5
3	E.A. Cuttack	1.9	89155	7.0	1.5	17.1	2.5
4	Mythan	1.8	81123	6.0	1.02	17.1	3.5
5	IMP 1536	2.1	69075	8.2	1.4	17.2	2.9

Table –19: Pulping results of SBI *Erianthus arundinaceus* clones

S. NO	PARAMETERS	SES 159	SES -003	IMP 1536	MYTHANE	EA CUTTACK
1	Chemical %	12	12	12	12	12
2	Total Yield %	54.4	55.4	55.0	54.5	54.5
3	Screen rejects %	1.00	1.30	0.50	0.80	0.90
4	Screen yield %	53.4	54.1	54.5	53.7	53.6
5	Kappa No	17.5	18.4	17.0	19.7	21.0
6	Brightness % ISO	38.0	35.0	39.0	39.0	37.0
7	WBL pH	12.0	11.6	11.8	12.1	12.4
8	TTA gpl	21.0	22.4	23.0	23.9	21.4
9	RAA gpl	7.4	6.6	7.5	8.1	8.6
10	Total solids gpl	169	187	172	181	182
11	FPR	2.25:1	2.5:1	2.2:1	2.5:1	2.83:1
12	CSF ml	460	450	440	460	470
13	Fibre Classification +30 +50 +100 +200 -200	 18.1 25.5 20.6 18.3 17.5	 6.3 30.7 25.5 22.5 15.0	 12.4 30.2 18.9 16.8 21.7	 10.6 29.4 21.5 18.8 19.7	 14.4 30.7 20.3 17.4 17.2

Pulping Conditions	
Sulphidity %	18 – 20 %
Bath Ratio	1 : 4.0
Cooking Temp ° C	170
Cooking Time mts.	20
H - Factor	450

Table - 20:Unbleached pulp evaluation of SBI *Erianthus arundinaceus* clones

S.NO	PARAMETERS	CLONE NAME					
		SES 159		EA Cuttack		Mythan	
		UR	Refined	UR	Refined	UR	Refined
1	CSF	460	340	470	340	460	330
2	Bulk cc/g	1.6	1.49	1.63	1.54	1.58	1.48
3	Breaking length m	6380	7280	5100	6510	6090	6580
4	Tear Factor	66	64.2	66.2	63.8	65.8	63.8
5	Burst Factor	42.2	47.8	27.5	45.8	39.8	44.4
6	Brightness %	36.2	35.9	37.3	36.8	39	38
7	Opacity %	94	93.2	93.9	92.8	94.6	93.4
8	Sc. Coeffi. m^2/kg	27	26.2	26.5	25.8	28.2	22.5
9	Yellowness	32.1	32.8	34.8	35.2	31.6	34
10	Fibre Classification						
	(+30)	18.1		14.4		10.6	
	(-30, +50)	25.5		30.7		29.4	
	(-50, +100)	20.6		20.3		21.5	
	(-100, +200)	18.3		17.4		18.8	
	(-200)	17.5		17.2		19.7	

Table – 20: Unbleached pulp evaluation of SBI *Erianthus arundinaceus* clones

S.NO	PARAMETERS	CLONE NAME			
		SES 3		IMP 1536	
		UR	Refined	UR	Refined
1	CSF	500	315	400	305
2	Bulk cc/g	1.67	1.55	1.4	1.35
3	Breaking length m	5900	7100	7030	8230
4	Tear Factor	52.4	56.4	50.8	52.8
5	Burst Factor	41.3	47.5	53.2	58.5
6	Brightness %	33.6	33.1	35.4	33.6
7	Opacity %	95.8	94.8	91.9	95.8
8	Sc. Coeffi m^2/kg	25.8	24.2	25.5	21.4
9	Yellowness	31.5	32.5	31.5	32
10	Fibre Classification				
	(+30)	6.3		12.4	
	(-30, +50)	30.7		30.2	
	(-50, +100)	25.5		18.9	
	(-100, +200)	22.5		16.8	
	(-200)	15.0		21.7	

Table - 21:Large scale Mill Trial Results *Erianthus arundinaceus* clones SES 159

S. NO	PARAMETERS	SES 159
1.	Cane weight MT	28.8
2.	Hydraulic load kg/cm^2	180-190
3.	Wet whole bagasse weight MT	15.4
4.	Bagasse yield %	53.4
5.	Fibre % on cane	25.4
6.	Juice % on cane	45.6
7.	Total reducing sugars %	3.72
8.	Whole bagasse moisture	48.3
9.	Whole bagasse FPR	2.1:1

Table – 22: Large Scale Mill Trial Juice Analysis Results *Erianthus arundinaceus* clones SES 159.

S. NO	PARAMETERS	PH	BRIX %	POL %	PURITY %
1	Primary Juice	6.62	8.94	0.95	10.63
2	Mixed Juice	6.54	4.59	0.44	9.60
3	Last mill Juice	—	1.14	0.08	5.67
4	Bagasse	—	3.88	0.22	—
5	Molasses Quantity	1.06 MT			

Table – 23: Results of Mill scale diffusion process trial of *Erianthus arundinaceus* clones SES 159

S.NO	PARAMETERS	SES 159
1	Cane weight MT	20.0
2	Hydraulic load kg/cm^2	150
3	Wet whole bagasse weight MT	12.8
4	Bagasse yield %	63.8
5	Whole bagasse moisture	66.5
6	Fibre % on cane	29.03
7	FPR fiberizer outlet	2.4:1
8	FPR Diffuser outlet	2.3:1
9	FPR dewatering mill outlet	2.1:1
10	Bagasse Pol% before dewatering mill	1.2
11	Bagasse Pol% after dewatering mill	1.0

Table - 24: Results of Large Scale Mill Trial Juice Analysis of *Erianthus arundinaceus* clones SES 159

S.NO	PARAMETERS	BRIX %	POL %	PURITY %
1	Fiberizer outlet	10.27	1.87	18.0
2	Screened Juice	6.24	2.75	44.0
3	Dewatering mill discharge	1.25	0.42	33.6

Table - 25: Comparison of conventional sugarcane bagasse bleached pulp and wildcane (SES 159) bleached pulp

S.NO	PARAMETERS	WILDCANE (SES 159) BAGASSE		CONVENTIONAL SUGARCANE BAGASSE	
		UR	Refined	UR	Refined
1	CSF	440	280	420	300
2	Bulk cc/g	1.50	1.38	1.4	1.35
3	Breaking length m	6680	7320	6900	7600
4	Tear Factor	64.8	62.4	57.0	55.0
5	Burst Factor	40.0	45.0	43.0	48.0
6	Brightness %	85.0	83.5	85.0	83.8
7	Opacity %	72.5	71.6	73.5	71.5
8	Sc. Coeffi m^2/kg	27.7	25.2	28.5	26.0
9	Yellowness	5.4	5.8	3.2	3.5
10	Fibre Classification				
	(+30)	17.2		12.0	
	(-30, +50)	23.2		21.0	
	(-50, +100)	21.4		26.0	
	(-100, +200)	19.2		19.0	
	(-200)	19.0		22.0	

Bleaching conditions (CEpH)				
Parameters	Units	Chlorination	Extraction*	Hypo
Consistency	%	3	8	8
Temperature	°C	Ambient	60	40
pH	–	2	>10.5	8.5-9.5
Time	Mts	30	60	120
*0.5 % H_2O_2				

Table – 26: Results of Impact on planting space yield on *Erianthus arundinaceus* clones SES 159

S.NO.	PARAMETERS	PLANTING SPACE IN FEET		
		3 X 4	2 X 4	1.5 X 4
1	Area	0.4 acres	0.45 acres	0.31 acres
2	Biomass yield in mt	19.54	25.35	19.09
3	Biomass yield/acre in mt	48.85	56.33	61.56

Table - 27: Results of *Erianthus arundinaceus* clones SES 159 fibre and juice characterization [only cane]

S.NO.	SAMPLE	UNITS	WILDCANE			SUGARCANE
			10 MONTH	11 MONTH	12 MONTH	10 MONTH
1	Total weight	kg	22	20	10	27
2	Juice wight	kg	9.5	7.5	4.774	16
3	Bagasse weight	kg	12.5	12.5	5.18	11
4	Bag. Moisture	%	58.04	61.8	54.83	58.76
5	OD bag weight	kg	5.25	4.77	2.34	4.54
6	Juice solids	%	5.70	4.70	4.80	19.20
7	Fibre weight	kg	4.95	4.55	2.23	3.67
8	Fibre weight	%	22.48	22.75	22.27	13.58
	Juice analysis					
9	pH		4.1	4.6	5.3	5
10	TS	mg L^{-1}	60500	53004	52694	158027
11	TDS	mg L^{-1}	57860	47616	48468	155292
12	BOD_5	mg L^{-1}	86969	71670	73750	178000
13	COD	mg L^{-1}	117676	98500	101968	210600

Table - 28: Results of *Erianthus arundinaceus* clones SES 159 fibre and juice characterization [whole plant]

S.NO.	SAMPLE	UNIT	AGE				
			9 MONTH	10 MONTH	11 MONTH	12 MONTH	13 MONTH
1	Total weight	kg	49	24	21	37570	50
2	Juice wight	kg	16.25	8	6	8320	14.5
3	Bagasse weight	kg	30.75	16	14	29250	35.5
4	Bag. Moisture	%	51.68	56.8	55.3	56.8	52.5
5	OD bag weight	kg	14.86	6.91	6.25	12928.5	16.86
6	Juice solids	%	5.50	5.40	4.30	7.7	7.70
7	Fibre weight	kg	14.04	6.54	5.98	11649.2	15.43
8	Fibre weight	%	28.66	27.24	28.50	31.0	30.85
	Juice analysis						
9	pH		4.3	5.6	5.1	5.2	5.4
10	TS	mg L^{-1}	62170	57066	51740	85610	89130
11	TDS	mg L^{-1}	55298	54660	43690	77100	77016
12	BOD_5	mg L^{-1}	79264	83425	73750	78540	87337
13	COD	mg L^{-1}	102641	110825	96000	104620	116450

Table – 29: Results of *Erianthus arundinaceus* clones SES 159 two bud setts germination trial

S.NO	PLOT ID	NUMBER OF SETTS PLANTED	NUMBER OF SETTS GERMINATED
1	RI	4860	4290
2	R2	4636	4462
3	R3	3328	3147
4	R4	3026	2682
5	Total	15850	14581

Table – 30: First year crop yield results of *Erianthus arundinaceus* clones SES 159

S.NO.	PARAMETERS	SPACING	
		4 X 1.5 SES 159	Setts (4 feet) SES 159
1	Sample plot	182 m^2	220 m^2
2	Area in acres	0.0455	0.055
3	Biomass yield in mt	2.60	3.10
4	Biomass yield/ mt/acre	57.14	56.36

Table – 31 : First ratoon crop yield results of *Erianthus arundinaceus* clones SES 159

S.NO.	PARAMETERS	SPACING	
		6X 2 poly Bag SES 159	6X 2 TC Plant SES 159
1	Sample plot	200 m^2	200 m^2
2	Area in acres	0.05	0.05
3	Biomass yield	1.80	2.08
4	Biomass yield/acre	36.00	41.60

Table- 33: Results of bagasse fibre pith analysis of *Erianthus arundinaceus* clones SES 159 and commercial sugarcane

S.NO	PARAMETERS	USEFUL FIBRE % (+14)	PITH % (+30)	PITH % (+200)	DUST AND WATER SOLUBLES %	FPR
1	10 month wildcane without leaf	62.8	12.3	17.3	7.6	2.12:1
2	11 month wildcane without leaf	64.2	12	17.6	6.2	2.17:1
3	12 month wildcane without leaf	63.5	11.5	18.2	6.8	2.14:1
4	10 month sugarcane without leaf	58.5	13.7	18.3	9.5	1.83:1
5	11 month sugarcane without leaf	58.5	14.3	18	9.2	1.82:1
6	12 month sugarcane without leaf	58.6	13.6	18.2	9.6	1.84:1
7	8 month wildcane with leaf	63.8	11	18.4	6.8	2.17:1
8	9 month wildcane with leaf	64.6	10.6	18	6.8	2.26:1
9	10 month wildcane with leaf	65	11.1	17.5	6.4	2.27:1
10	11 month wildcane with leaf	65.5	10.7	18	5.8	2.28:1
11	12 month wildcane with leaf	65	11.5	17.3	6.2	2.26:1

Table – 33 : Pulping results of 10 month old *Erianthus arundinaceus* clones SES 159 [cane Bagasse]

S. NO	PARAMETERS	UNITS	(1)	(2)	AVG
1	Chemical addition	%	12	12	12
2	Un-screened pulp yield	%	54.6	54.25	54.4
3	Screen rejects	%	0.87	0.92	0.9
4	Screened pulp yield	%	53.7	53.3	53.5
5	Kappa Number		13.1	12.6	12.9
6	Brightness	% ISO	41.2	42.2	41.7
	Black liquor				
7	pH	--	12.7	12.7	12.7
8	Total solids	gpl	183	186	185
9	TTA as Na2O at 200 gpl TS	gpl	32.4	32.1	32.3
10	RAA as Na2O at 200 gpl TS	gpl	5.73	5.82	5.8
Pulping Conditions					
Sulphidity		%	18 - 20		
Bath Ratio			1 : 4.0		
Cooking Temp		° C	170		
Cooking Time		mts.	20		
H - Factor			450		

Table – 34: Pulping results of 11 month old *Erianthus arundinaceus* clones SES 159 [cane bagasse]

S. NO	PARAMETERS	UNITS	(1)	(2)	AVG
1	Chemical addition	%	12	12	12
2	Un screened pulp yield	%	54.65	55.4	55.0
3	Screen rejects	%	0.60	0.70	0.7
4	Screened pulp yield	%	54.1	54.7	54.3
5	Kappa Number		12.8	12.6	12.7
6	Brightness	% ISO	40.2	40.6	40.4
	Black liquor				
7	pH		12.9	12.8	12.8
8	Total solids	gpl	190	187	189
9	TTA as Na2O at 200 gpl TS	gpl	32.1	32.8	32.4
10	RAA as Na2O at 200 gpl TS	gpl	6.20	5.90	6.1
Pulping Conditions					
Sulphidity		%	18 – 20		
Bath Ratio			1 : 4.0		
Cooking Temp		° C	170		
Cooking Time		mts.	20		
H - Factor			450		

Table – 35: Pulping results of 12 month old *Erianthus arundinaceus* clones SES 159 [cane bagasse]

S.NO.	PARAMETERS	UNITS	(1)	(2)	AVG
1	Chemical addition	%	12	12	12.0
2	Un screened pulp yield	%	54.8	55.2	55.0
3	Screen rejects	%	0.48	0.53	0.51
4	Screened pulp yield	%	54.3	54.7	54.5
5	Kappa Number		13	12.6	12.8
6	Brightness	% ISO	40.3	39.6	40.0
	Black liquor				
7	pH		12.8	12.7	12.8
8	Total solids	gpl	176	174	175
9	TTA as Na2O at 200 gpl TS	gpl	31.2	32.0	31.6
10	RAA as Na2O at 200 gpl TS	gpl	5.84	6.12	6.0
Pulping Conditions					
Sulphidity		%	18 – 20		
Bath Ratio			1 : 4.0		
Cooking Temp		° C	170		
Cooking Time		mts.	20		
H - Factor			450		

Table- 36:Pulping results of *Erianthus arundinaceus* clones SES 159 [leaf bagasse]

S.NO	PARAMETERS	10 MONTH	11 MONTH	12 MONTH
1	Chemical addition %	12	12	12
2	Un screened pulp yield -%	37.8	38.9	39.3
3	Screen rejects - %	0.50	0.19	0.2
4	Screened pulp yield - %	37.3	38.7	39.0
5	Kappa Number	16.7	18	17.7
6	Brightness %	29.5	31.9	31.9
	Black liquor			
7	pH	11.3	11.1	11.3
8	Total solids gpl	200	204	201
9	TTA as Na2O at 200 gpl	26.8	25.34	28.6
10	TAA as Na2O at 200 gpl	2.80	4.31	3.2
Pulping Conditions				
Sulphidity %		18 – 20		
Bath Ratio		1 : 4.0		
Cooking Temp ° C		170		
Cooking Time mts.		20		
H - Factor		450		

Table - 37: Pulping results of 10 month old commercial sugarcane [Cane bagasse]

S.NO.	PARAMETERS	UNITS	(1)	(2)	AVG
1	Chemical addition	%	12	12	12.0
2	Un screened pulp yield	%	53.4	53.85	53.6
3	Screen rejects	%	0.52	0.42	0.5
4	Screened pulp yield	%	52.9	53.4	53.2
5	Kappa Number		13.2	12.9	13.1
6	Brightness	% ISO	39.6	40	39.8
	Black liquor				
7	pH		12.4	12.6	12.5
8	Total solids	gpl	184	188	186
9	TTA as Na_2O at 200 gpl TS	gpl	31.5	32.6	32.0
10	RAA as Na_2O at 200 gpl TS	gpl	5.10	4.85	5.0
Pulping Conditions					
Sulphidity		%	18 – 20		
Bath Ratio			1 : 4.0		
Cooking Temp		° C	170		
Cooking Time		mts.	20		
H - Factor			450		

Table- 38: Pulping results of 11 month old commercial sugarcane [Cane bagasse]

S. NO.	PARAMETERS	UNITS	(1)	(2)	AVG
1	Chemical addition	%	12	12	12
2	Un screened pulp yield	%	54.1	53.7	53.9
3	Screen rejects	%	0.50	0.50	0.5
4	Screened pulp yield	%	53.6	53.2	53.4
5	Kappa Number		13.2	13.5	13.4
6	Brightness	% ISO	39.2	39.6	39.4
	Black liquor				
7	pH		12.7	12.6	12.65
8	Total solids	gpl	185	187	186
9	TTA as Na_2O at 200 gpl TS	gpl	31.9	32.3	32.1
10	RAA as Na_2O at 200 gpl TS	gpl	5.10	5.32	5.21

Pulping Conditions		
Sulphidity	%	18 – 20
Bath Ratio		1 : 4.0
Cooking Temp	° C	170
Cooking Time	mts.	20
H - Factor		450

Table - 39 : Pulping results of 12 month old commercial sugarcane [Cane bagasse]

S.NO.	PARAMETERS	UNITS	(1)	(2)	AVG
1	Chemical addition	%	12	12	12
2	Un screened pulp yield	%	53.3	53.72	53.5
3	Screen rejects	%	0.50	0.70	0.6
4	Screened pulp yield	%	52.8	53.0	52.9
5	Kappa Number		14.0	13.6	13.8
6	Brightness	% ISO	38.5	39.4	39.0
	Black liquor				
7	pH		12.6	12.6	12.6
8	Total solids	gpl	183	187	185.0
9	TTA as Na2O at 200 gpl TS	gpl	32.2	31.6	31.9
10	RAA as Na2O at 200 gpl TS	gpl	4.48	4.65	4.6
Pulping Conditions					
Sulphidity		%	18 – 20		
Bath Ratio		-	1 : 4.0		
Cooking Temp		° C	170		
Cooking Time		mts.	20		
H - Factor		-	450		

Table - 40: Pulping results of 8 month old Erianthus *arundinaceus* clone SES 159 [whole plant bagasse]

S. NO	PARAMETERS	UNITS	(1)	(2)	AVG
1	Chemical addition	%	12	12	12
2	Un screened pulp yield	%	48.8	49.3	49.1
3	Screen rejects	%	0.43	0.52	0.5
4	Screened pulp yield	%	48.4	48.8	48.6
5	Kappa Number		11.4	11.6	11.5
6	Brightness	% ISO	41.0	40.6	40.8
	Black liquor				
7	pH		11.8	11.9	11.9
8	Total solids	gpl	180	186	183
9	TTA as Na_2O at 200 gpl TS	gpl	31.9	30.46	31.2
10	RAA as Na_2O at 200 gpl TS	gpl	5.25	5.4	5.3
Pulping Conditions					
Sulphidity		%	18 – 20		
Bath Ratio			1 : 4.0		
Cooking Temp		° C	170		
Cooking Time		mts.	20		
H - Factor			450		

Table - 41: Pulping results of 9 month old Erianthus *arundinaceus* clone SES 159 [whole plant bagasse]

S.NO	PARAMETERS	UNITS	(1)	(2)	AVG
1	Chemical addition	%	12	12	12.0
2	Un screened pulp yield	%	49.4	50	49.7
3	Screen rejects	%	0.47	0.52	0.50
4	Screened pulp yield	%	48.9	49.5	49.2
5	Kappa Number		12.0	12.2	12.1
6	Brightness	% ISO	39.6	40.4	40.0
	Black liquor				
7	PH		12.2	12.0	12.1
8	Total solids	gpl	187	184	186
9	TTA as Na2O at 200 gpl TS	gpl	30.02	29.56	29.8
10	RAA as Na2O at 200 gpl TS	gpl	4.88	4.72	4.80
Pulping Conditions					
Sulphidity		%	18 – 20		
Bath Ratio			1 : 4.0		
Cooking Temp		° C	170		
Cooking Time		mts.	20		
H - Factor			450		

Table - 42: Pulping results of 10 month old Erianthus *arundinaceus* clone SES 159 [whole plant bagasse]

S. NO	PARAMETERS	UNITS	(1)	(2)	AVG
1	Chemical addition	%	12	12	12
2	Un screened pulp yield	%	49.7	50.26	50.0
3	Screen rejects	%	0.72	0.66	0.7
4	Screened pulp yield	%	49.0	49.6	49.3
5	Kappa Number		12.5	12.9	12.7
6	Brightness	% ISO	39.6	38.8	39.2
	Black liquor				
7	pH		11.8	11.8	11.8
8	Total solids	gpl	186	181	184
9	TTA as Na2O at 200 gpl TS	gpl	29.65	29.46	29.6
10	RAA as Na2O at 200 gpl TS	gpl	4.62	4.52	4.6
Pulping Conditions					
Sulphidity		%	18 – 20		
Bath Ratio			1 : 4.0		
Cooking Temp		° C	170		
Cooking Time		mts.	20		
H - Factor			450		

Table - 43: Pulping results of 11 month old Erianthus *arundinaceus* clone SES 159 [whole plant bagasse]

S. NO.	PARAMETERS	UNITS	(1)	(2)	AVG
1	Chemical addition	%	12	12	12
2	Un screened pulp yield	%	50.29	50.48	50.4
3	Screen rejects	%	0.62	0.57	0.6
4	Screened pulp yield	%	49.7	49.9	49.8
5	Kappa Number		13.2	12.7	13.0
6	Brightness	% ISO	38.8	38.2	38.5
	Black liquor				
7	PH		11.9	11.8	11.9
8	Total solids	gpl	183	179	181
9	TTA as Na2O at 200 gpl TS	gpl	29.38	29.78	29.6
10	RAA as Na2O at 200 gpl TS	gpl	4.46	4.36	4.4
Pulping Conditions					
Sulphidity		%	18 – 20		
Bath Ratio			1 : 4.0		
Cooking Temp		° C	170		
Cooking Time		mts.	20		
H - Factor			450		

Table - 44: Pulping results of12 month old Erianthus *arundinaceus* clone SES 159 [whole plant bagasse]

S.NO.	PARAMETERS	UNITS	(1)	(2)	AVG
1	Chemical addition	%	12	12	12
2	Un screened pulp yield	%	50.2	50.4	50.3
3	Screen rejects	%	0.72	0.66	0.7
4	Screened pulp yield	%	49.5	49.7	49.6
5	Kappa Number		13.1	13.5	13.3
6	Brightness	% ISO	38.2	37.7	38.0
	Black liquor				
7	pH		11.9	11.9	11.9
8	Total solids	gpl	184	181	183
9	TTA as Na2O at 200 gpl TS	gpl	30.12	28.96	29.5
10	RAA as Na2O at 200 gpl TS	gpl	4.32	4.18	4.3
Pulping Conditions					
Sulphidity		%	18 – 20		
Bath Ratio			1 : 4.0		
Cooking Temp		° C	170		
Cooking Time		mts.	20		
H - Factor			450		

Table - 45: Unbleached pulp evaluation results of 10 month old Erianthus *arundinaceus* clone SES 159 [cane bagasse]

S.NO.	PARAMETERS	UNITS	PFI REVOLUTIONS			
			0	250	500	750
1	Freeness	ml CSF	490	400	330	280
2	Bulk	cc/g	1.59	1.55	1.52	1.50
3	Tensile index	Nm/g	64.00	74.5	79.50	82.30
4	Breaking length	m	6528	7599	8109	8395
5	Tear index	mN.m^2/g	7.20	7.10	7.02	6.90
6	Tear factor	-	73.4	72.4	71.6	70.4
7	Burst index	kPa.m^2/g	3.92	4.4	4.7	4.9
8	Burst factor	-	40.0	44.9	47.9	50
9	Brightness	% ISO	39.5	40.3	40.9	40.1
10	Yellowness	%	30.7	30.9	30.0	31.0
11	Fiber classification					
	(+30)	%	16.6			
	(-30, +50)	%	25.7			
	(-50, +100)	%	24.6			
	(-100, +200)	%	19.8			
	(-200)	%	13.3			

Table- 46: Un-bleached pulp evaluation results of 10 month old commercial sugarcane [cane bagasse]

S.NO.	PARAMETERS	UNITS	PFI REVOLUTIONS			
			0	250	500	750
1	Freeness	ml CSF	450	370	310	260
2	Bulk	cc/g	1.54	1.51	1.48	1.45
3	Tensile index	Nm/g	54.80	66.80	72.20	74.30
4	Breaking length	m	5590	6814	7364	7579
5	Tear index	$mN.m^2/g$	5.80	5.72	5.60	5.53
6	Tear factor	-	59.2	58.3	57.1	56.4
7	Burst index	$kPa.m^2/g$	3.56	4.00	4.18	4.35
8	Burst factor	-	36.3	40.8	42.6	44.4
9	Brightness	% ISO	39.2	38.5	37.4	36.8
10	Yellowness	%	31.2	32.5	33.2	33.8
14	Fiber classification					
	(+30)	%	15.2			
	(-30, +50)	%	26.1			
	(-50, +100)	%	24.6			
	(-100, +200)	%	19.8			
	(-200)	%	14.3			

Table - 47: Unbleached pulp evaluation results of 11 month old Erianthus *arundinaceus* clone SES 159 [cane bagasse]

S.NO	PARAMETERS	UNITS	PFI REVOLUTIONS				
			0	250	500	750	1000
1	Freeness	ml CSF	510	380	340	300	270
2	Bulk	cc/g	1.62	1.59	1.56	1.53	1.51
3	Tensile index	Nm/g	68.6	80.6	83.2	85.0	86.6
4	Breaking length	m	6997	8221	8486	8670	88.33
5	Tear index	$mN.m^2/g$	7.3	7.2	7.15	7.1	7.05
6	Tear factor	-	74.5	73.4	72.9	72.4	71.9
7	Burst index	$kPa.m^2/g$	4.3	5.0	5.2	5.3	5.4
8	Burst factor	-	43.9	51.0	53.0	54.1	55.1
9	Brightness	% ISO	40.8	40.0	39.7	39.4	39.0
10	Yellowness	%	29.5	29.7	29.9	30.5	30.7
14	Fiber classification						
	(+30)	%	14.6				
	(-30, +50)	%	28.3				
	(-50, +100)	%	27.6				
	(-100, +200)	%	14.8				
	(-200)	%	14.7				

Table - 48: Un-bleached pulp evaluation results of 11 month old commercial sugarcane [cane bagasse]

S.NO.	PARAMETERS	UNITS	PFI REVOLUTIONS			
			0	250	500	750
1	Freeness	ml CSF	460	380	320	270
2	Bulk	cc/g	1.58	1.52	1.49	1.47
3	Tensile index	Nm/g	61.0	72.0	76.5	78.2
4	Breaking length	m	6222	7344	7803	7976
5	Tear index	mN.m^2/g	6.10	6.00	5.90	5.82
6	Tear factor	-	62.2	61.2	60.2	59.4
7	Burst index	kPa.m^2/g	3.9	4.4	4.6	4.7
8	Burst factor	-	39.8	44.9	46.9	47.9
9	Brightness	% ISO	39.0	38.4	37.8	37.4
10	Yellowness	%	30.7	31.2	31.8	32.2
11	Fiber classification					
	(+30)	%	13.5			
	(-30, +50)	%	27.2			
	(-50, +100)	%	26.5			
	(-100, +200)	%	19.6			
	(-200)	%	13.2			

Table - 49: Unbleached pulp evaluation results of 12 month old *Erianthus arundinaceus* clone SES 159 [cane bagasse]

S.NO.	PARAMETERS	UNITS	PFI REVOLUTIONS			
			0	250	500	750
1	Freeness	ml CSF	500	380	320	270
2	Bulk	cc/g	1.59	1.56	1.53	1.51
3	Tensile index	Nm/g	65.70	78.00	83.20	85.60
4	Breaking length	m	6701	7956	8486	8731
5	Tear index	$mN.m^2/g$	7.40	7.28	7.15	7.06
6	Tear factor	-	75.5	74.3	72.9	72.0
7	Burst index	$kPa.m^2/g$	4.30	4.90	5.20	5.40
8	Burst factor	-	43.9	50.0	53.0	55.1
9	Brightness	% ISO	40.6	39.7	39.4	38.9
10	Yellowness	%	31.6	32.0	32.3	32.7
11	Fiber classification					
	(+30)	%	15.8			
	(-30, +50)	%	28.2			
	(-50, +100)	%	25.6			
	(-100, +200)	%	16.2			
	(-200)	%	14.2			

Table - 50: Un-bleached pulp evaluation results of 12 month old commercial sugarcane [cane bagasse]

S. NO.	PARAMETERS	UNITS	PFI REVOLUTIONS			
			0	250	500	750
1	Freeness	ml CSF	480	400	330	270
2	Bulk	cc/g	1.60	1.54	1.50	1.48
3	Tensile index	Nm/g	61.00	74.50	79.60	82.10
4	Breaking length	m	6222	7599	8119	8374
5	Tear index	$mN.m^2/g$	6.25	6.15	6.08	5.90
6	Tear factor	-	63.8	62.7	62.0	60.2
7	Burst index	$kPa.m^2/g$	3.85	4.30	4.50	4.70
8	Burst factor	-	39.3	43.9	45.9	47.9
9	Brightness	% ISO	38.4	38.2	37.5	37.1
10	Yellowness	%	30.2	31.4	32.0	32.7
11	Fiber classification					
	(+30)	%	14.2			
	(-30, +50)	%	27.6			
	(-50, +100)	%	26.9			
	(-100, +200)	%	17.5			
	(-200)	%	13.8			

Table- 51: Un-bleached pulp evaluation results of *Erianthus arundinaceus* clone SES 159 [leaf bagasse]

S. NO.	PARAMETERS	UNITS	AGE		
			10 month	11 month	12 month
1	Freeness	ml CSF	240	220	230
2	Bulk	cc/g	1.40	1.38	1.37
3	Tensile index	Nm/g	63.50	65.70	64.60
4	Breaking length	m	6477	6701	6589
5	Tear index	$mN.m^2/g$	4.42	4.60	4.50
6	Tear factor	-	45.1	46.9	45.9
7	Burst index	$kPa.m^2/g$	3.60	3.70	3.80
8	Burst factor	-	36.7	37.7	38.8
9	Brightness	% ISO	27.3	25.3	26.8
10	Yellowness	%	36.5	38.5	37.6

Table - 52: Unbleached pulp evaluation results of 8 month old *Erianthus arundinaceus* clone SES 159 [whole plant bagasse]

S. NO	PARAMETERS	UNITS	PFI REVOLUTIONS		
			0	250	500
1	Freeness	ml CSF	430	350	300
2	Bulk	cc/g	1.50	1.46	1.42
3	Tensile index	Nm/g	56.20	66.60	69.30
4	Breaking length	m	5732	6793	7069
5	Tear index	$mN.m^2/g$	6.30	6.10	6.00
6	Tear factor	-	64.3	62.2	61.2
7	Burst index	$kPa.m^2/g$	3.70	4.30	4.50
8	Burst factor	-	37.7	43.9	45.9
9	Brightness	% ISO	41.0	39.2	38.3
10	Yellowness	%	32.4	33.6	33.8
11	Fiber classification				
	(+30)	%	7.8		
	(-30, +50)	%	23.3		
	(-50, +100)	%	21.6		
	(-100, +200)	%	27.2		
	(-200)	%	20.1		

Table - 53: Unbleached pulp evaluation results of 9 month old *Erianthus arundinaceus* clone SES 159 [whole plant bagasse]

S.NO.	PARAMETERS	UNITS	PFI REVOLUTIONS			
			0	250	500	750
1	Freeness	ml CSF	440	340	300	260
2	Bulk	cc/g	1.56	1.46	1.43	1.38
3	Tensile index	Nm/g	62.30	70.50	72.60	74.30
4	Breaking length	m	6355	7191	7405	7579
5	Tear index	$mN.m^2/g$	6.60	6.48	6.40	6.30
6	Tear factor	-	67.3	66.1	65.3	64.3
7	Burst index	$kPa.m^2/g$	3.90	4.45	4.60	4.75
8	Burst factor	-	39.8	45.4	46.9	48.5
9	Brightness	% ISO	40.8	40.0	39.4	38.8
10	Yellowness	%	31.2	32.0	33.1	33.5
11	Fiber classification					
	(+30)	%	8.6			
	(-30, +50)	%	23.2			
	(-50, +100)	%	21.8			
	(-100, +200)	%	28.3			
	(-200)	%	18.1			

Table - 54: Unbleached pulp evaluation results of 10 month old *Erianthus arundinaceus* clone SES 159 [whole plant bagasse]

S.NO.	PARAMETERS	UNITS	PFI REVOLUTIONS			
			0	250	500	750
1	Freeness	ml CSF	450	350	300	250
2	Bulk	cc/g	1.57	1.52	1.45	1.43
3	Tensile index	Nm/g	64.00	72.50	76.00	79.20
4	Breaking length	m	6528	7395	7752	8078
5	Tear index	mN.m^2/g	6.80	6.73	6.62	6.55
6	Tear factor	-	69.4	68.6	67.5	66.8
7	Burst index	kPa.m^2/g	3.80	4.47	4.70	4.90
8	Burst factor	-	38.8	45.6	47.9	50.0
9	Brightness	% ISO	37.5	37.0	37.0	36.7
10	Yellowness	%	29.2	29.9	30.5	31.0
11	Fiber classification					
	(+30)	%	11.7			
	(-30, +50)	%	25.8			
	(-50, +100)	%	24.6			
	(-100, +200)	%	18.4			
	(-200)	%	19.5			

Table- 55: Unbleached pulp evaluation results of 11 month old *Erianthus arundinaceus* clone SES 159 [whole plant bagasse]

S.NO.	PARAMETERS	UNITS	PFI REVOLUTIONS			
			0	250	500	750
1	Freeness	ml CSF	450	360	300	250
2	Bulk	cc/g	1.58	1.52	1.46	1.44
3	Tensile index	Nm/g	67.50	79.50	83.20	85.20
4	Breaking length	m	6885	8109	8486	8690
5	Tear index	$mN.m^2/g$	6.90	6.80	6.68	6.60
6	Tear factor	-	70.4	69.4	68.1	67.3
7	Burst index	$kPa.m^2/g$	4.00	4.90	5.20	5.30
8	Burst factor	-	40.8	50.0	53.0	54.1
9	Brightness	% ISO	38.4	37.8	37.7	36.5
10	Yellowness	%	30.9	31.5	31.7	32.9
11	Fiber classification					
	(+30)	%	12.7			
	(-30, +50)	%	21.6			
	(-50, +100)	%	25.6			
	(-100, +200)	%	22.0			
	(-200)	%	18.1			

Table- 56: Unbleached pulp evaluation results of 12 month old *Erianthus arundinaceus* clone SES 159 [whole plant bagasse]

S.NO.	PARAMETERS	UNITS	PFI REVOLUTIONS			
			0	250	500	750
1	Freeness	ml CSF	450	350	310	270
2	Bulk	cc/g	1.58	1.52	1.46	1.43
3	Tensile index	Nm/g	68.00	78.50	84.00	85.60
4	Breaking length	m	6936	8007	8568	8731
5	Tear index	$mN.m^2/g$	6.90	6.80	6.72	6.65
6	Tear factor	-	70.4	69.4	68.5	67.8
7	Burst index	$kPa.m^2/g$	4.10	4.90	5.30	5.40
8	Burst factor	-	41.8	50.0	54.1	55.1
9	Brightness	% ISO	38.4	37.8	37.7	36.5
10	Yellowness	%	30.9	31.5	31.7	32.9
11	Fiber classification					
	(+30)	%	12.8			
	(-30, +50)	%	23.7			
	(-50, +100)	%	25.2			
	(-100, +200)	%	19.5			
	(-200)	%	18.8			

Table- 57: Bleached pulp evaluation results of 10 month old *Erianthus arundinaceus* clone SES 159 [cane bagasse]

S.NO.	PARAMETERS	UNITS	PFI REVOLUTIONS			
			0	250	500	750
1	Freeness	ml CSF	480	390	320	260
2	Bulk	cc/g	1.57	1.52	1.47	1.45
3	Tensile index	Nm/g	66.20	74.6	77.2	79.0
4	Breaking length	m	6752	7609	7874	8658
5	Tear index	$mN.m^2/g$	6.90	6.80	6.72	6.55
6	Tear factor	-	70.4	69.4	68.5	66.8
7	Burst index	$kPa.m^2/g$	4.0	4.4	4.6	4.8
8	Burst factor	-	40.8	44.9	46.9	49.0
9	Brightness	% ISO	85.7	84.9	84.2	83.7
10	Opacity	%	72.2	71.0	69.7	68.8
11	Sc.Coeff.	m^2/kg	27.4	25.4	24.3	23.3
12	Yellowness	%	30.7	30.9	30.0	31.0
13	Fiber classification					
	(+30)	%	14.6			
	(-30, +50)	%	26.8			
	(-50, +100)	%	28.3			
	(-100, +200)	%	15.8			
	(-200)	%	14.5			

Bleaching conditions (CEpH)				
Parameters	Units	Chlorination	Extraction*	Hypo
Consistency	%	3	8	8
Temperature	°C	Ambient	60	40
pH	--	2	>10.5	8.5-9.5
Time	Mts	30	60	120
*0.5 % H_2O_2				

Table- 58: Bleached pulp evaluation results of 10 month old commercial sugarcane [cane bagasse]

S.NO.	PARAMETERS	UNITS	PFI REVOLUTIONS			
			0	250	500	750
1	Freeness	ml CSF	440	360	310	260
2	Bulk	cc/g	1.53	1.47	1.44	1.42
3	Tensile index	Nm/g	57.40	66.00	69.50	71.50
4	Breaking length	m	5855	6732	7089	7293
5	Tear index	mN.m^2/g	5.50	5.40	5.35	5.25
6	Tear factor	-	56.1	55.1	54.6	53.6
7	Burst index	kPa.m^2/g	3.70	4.10	4.42	4.60
8	Burst factor	-	37.7	41.8	45.1	46.9
9	Brightness	% ISO	85.7	84.6	83.9	83.3
10	Opacity	%	73.6	71.2	69.6	68.5
11	Sc. Coeff.	m^2/kg	27.8	25.4	24.6	23.8
10	Yellowness	%	7.7	8.0	8.2	8.3
11	Fiber classification					
	(+30)	%	13.2			
	(-30, +50)	%	25.2			
	(-50, +100)	%	28.8			
	(-100, +200)	%	17.5			
	(-200)	%	15.3			

Bleaching conditions (CEpH)				
Parameters	Units	Chlorination	Extraction*	Hypo
Consistency	%	3	8	8
Temperature	°C	Ambient	60	40
pH	–	2	>10.5	8.5-9.5
Time	Mts	30	60	120
*0.5 % H_2O_2				

Table- 59: Bleached pulp evaluation results of 11 month old *Erianthus arundinaceus* clone SES 159 [cane bagasse]

S.NO.	PARAMETERS	UNITS	PFI REVOLUTIONS			
			0	250	500	750
1	Freeness	ml CSF	500	400	330	270
2	Bulk	cc/g	1.58	1.48	1.44	1.42
3	Tensile index	Nm/g	67.0	76.5	81.0	83.6
4	Breaking length	m	6834	7803	8262	8527
5	Tear index	$mN.m^2/g$	7.1	7.0	6.9	6.75
6	Tear factor	-	72.4	71.4	70.4	68.9
7	Burst index	$kPa.m^2/g$	4.2	4.8	5.1	5.2
8	Burst factor	-	42.8	49.0	52.0	53.0
9	Brightness	% ISO	85.5	84.8	84.3	83.8
10	Opacity (ptg)	%	72.6	70.6	68.5	67.5
11	Sc.coefficient	m^2/g	27.6	25.4	23.6	22.7
12	Yellowness	%	7.8	8.1	8.3	8.4
14	Fiber classification					
	(+30)	%	16.8			
	(-30, +50)	%	27.5			
	(-50, +100)	%	26.8			
	(-100, +200)	%	15.1			
	(-200)	%	13.8			

Bleaching conditions (CEpH)				
Parameters	Units	Chlorination	Extraction*	Hypo
Consistency	%	3	8	8
Temperature	°C	Ambient	60	40
pH	--	2	>10.5	8.5-9.5
Time	Mts	30	60	120
*0.5 % H_2O_2				

Table- 60: Bleached pulp evaluation results of 11 month old commercial sugarcane [cane bagasse]

S.NO.	PARAMETERS	UNITS	PFI REVOLUTIONS			
			0	250	500	750
1	Freeness	ml CSF	450	380	320	260
2	Bulk	cc/g	1.55	1.46	1.43	1.40
3	Tensile index	Nm/g	61.60	70.00	74.3	76.1
4	Breaking length	m	6283	7140	7579	7762
5	Tear index	$mN.m^2/g$	5.75	5.60	5.46	5.30
6	Tear factor	-	58.7	57.1	55.7	54.1
7	Burst index	$kPa.m^2/g$	3.80	4.2	4.4	4.5
8	Burst factor	-	38.8	42.8	44.9	45.9
9	Brightness	% ISO	85.6	84.2	83.4	82.7
10	Opacity	%	72.9	70.8	69.3	68.5
11	Sc.Coefficient	m^2/kg	28.2	26.6	25.3	24.7
12	Yellowness	%	7.7	8.1	8.3	8.4
13	Fiber classification					
	(+30)	%	13.2			
	(-30, +50)	%	27.3			
	(-50, +100)	%	27.6			
	(-100, +200)	%	17.7			
	(-200)	%	14.2			

Bleaching conditions (CEpH)				
Parameters	Units	Chlorination	Extraction*	Hypo
Consistency	%	3	8	8
Temperature	°C	Ambient	60	40
pH	—	2	>10.5	8.5-9.5
Time	Mts	30	60	120
*0.5 % $H_2 O_2$				

Table- 61: Bleached pulp evaluation results of 12 month old *Erianthus arundinaceus* clone SES 159 [cane bagasse]

S.NO.	PARAMETERS	UNITS	PFI REVOLUTIONS			
			0	250	500	750
1	Freeness	ml CSF	490	400	330	270
2	Bulk	cc/g	1.59	1.48	1.44	1.42
3	Tensile index	Nm/g	68.30	77.60	82.50	84.50
4	Breaking length	m	6967	7915	8415	8619
5	Tear index	mN.m^2/g	7.20	7.10	7.00	6.86
6	Tear factor	-	73.4	72.4	71.4	70.0
7	Burst index	kPa.m^2/g	4.30	4.90	5.20	5.40
8	Burst factor	-	43.9	50.0	53.0	55.1
9	Brightness	% ISO	85.5	84.8	84.3	83.8
10	Opacity (ptg)	%	72.6	70.6	68.5	67.5
11	Sc.coefficient	m^2/g	27.6	25.4	23.6	22.7
12	Yellowness	%	7.8	8.1	8.3	8.4
14	Fiber classification					
	(+30)	%	16.8			
	(-30, +50)	%	27.5			
	(-50, +100)	%	26.8			
	(-100, +200)	%	15.1			
	(-200)	%	13.8			

Bleaching conditions (CEpH)				
Parameters	Units	Chlorination	Extraction*	Hypo
Consistency	%	3	8	8
Temperature	°C	Ambient	60	40
pH	--	2	>10.5	8.5-9.5
Time	Mts	30	60	120
*0.5 % H_2O_2				

Table- 62: Bleached pulp evaluation results of 12 month old commercial sugarcane [cane bagasse]

S.NO.	PARAMETERS	UNITS	PFI REVOLUTIONS			
			0	250	500	750
1	Freeness	ml CSF	460	380	320	260
2	Bulk	cc/g	1.56	1.47	1.44	1.42
3	Tensile index	Nm/g	64.20	73.60	79.00	81.60
4	Breaking length	m	6548	7507	8058	8323
5	Tear index	mN.m^2/g	5.80	5.70	5.65	5.55
6	Tear factor	-	59.2	58.1	57.6	56.6
7	Burst index	kPa.m^2/g	3.96	4.50	4.70	4.80
8	Burst factor	-	40.4	45.9	47.9	49.0
9	Brightness	% ISO	86.0	85.3	84.7	84.0
10	Opacity	%	72.8	71.4	70.0	69.2
11	Sc.Coefficient	m^2/kg	27.9	26.8	25.3	24.5
12	Yellowness	%	8.0	8.2	8.1	8.4
13	Fiber classification					
	(+30)	%	15.2			
	(-30, +50)	%	28.8			
	(-50, +100)	%	27.6			
	(-100, +200)	%	14.7			
	(-200)	%	13.7			

Bleaching conditions (CEpH)				
Parameters	Units	Chlorination	Extraction*	Hypo
Consistency	%	3	8	8
Temperature	°C	Ambient	60	40
pH	–	2	>10.5	8.5-9.5
Time	Mts	30	60	120
*0.5 % H_2O_2				

Table- 63: Bleached pulp evaluation results of *Erianthus arundinaceus* clone SES 159 [leaf bagasse]

S. NO.	PARAMETERS	UNITS	AGE		
			10 month	11 month	12 month
1	Freeness	ml CSF	260	240	250
2	Bulk	cc/g	1.33	1.34	1.34
3	Tensile index	Nm/g	66.60	68.20	68.40
4	Breaking length	m	6793	6956	6977
5	Tear index	$mN.m^2/g$	4.50	4.38	4.58
6	Tear factor	-	45.9	44.7	46.7
7	Burst index	$kPa.m^2/g$	3.80	3.96	4.00
8	Burst factor	-	38.6	40.4	40.8
9	Brightness	% ISO	82.8	82.0	81.8
10	Opacity	%	76.8	77.4	78.0
11	Sc.Coefficient	m^2/kg	22.6	23.8	22.7
10	Yellowness	%	8.7	9.2	9.3
12	Fiber classification				
	(+30)	%	7.2	7.8	9.0
	(-30, +50)	%	19.6	22.5	22.0
	(-50, +100)	%	19.2	18.6	15.0
	(-100, +200)	%	17.2	16.5	15.8
	(-200)	%	36.8	34.6	38.2

Bleaching conditions (CEpH)				
Parameters	Units	Chlorination	Extraction*	Hypo
Consistency	%	3	8	8
Temperature	°C	Ambient	60	40
pH	–	2	>10.5	8.5-9.5
Time	Mts	30	60	120
*0.5 % H_2O_2				

Table - 64: Bleached pulp evaluation results of 8 month old *Erianthus arundinaceus* clone SES 159 [whole plant bagasse]

S.NO.	PARAMETERS	UNITS	PFI REVOLUTIONS		
			0	250	500
1	Freeness	ml CSF	370	290	220
2	Bulk	cc/g	1.48	1.44	1.39
3	Tensile index	Nm/g	60.30	66.50	68.60
4	Breaking length	m	6331	7018	7489
5	Tear index	$mN.m^2/g$	5.60	5.40	5.20
6	Tear factor	-	58.6	53.8	50.0
7	Burst index	$kPa.m^2/g$	3.84	4.13	4.36
8	Burst factor	-	39.1	41.1	44.5
9	Brightness	% ISO	85.6	85.0	84.0
10	Opacity (ptg)	%	72.0	69.8	65.9
11	Sc.coefficient	m^2/g	27.7	24.4	21.4
12	Yellowness	%	7.1	7.2	7.2
13	Fiber classification				
	(+30)	%	13.2		
	(-30, +50)	%	25.3		
	(-50, +100)	%	10.5		
	(-100, +200)	%	32.0		
	(-200)	%	19.0		

Bleaching conditions (CEpH)				
Parameters	Units	Chlorination	Extraction*	Hypo
Consistency	%	3	8	8
Temperature	°C	Ambient	60	40
pH	--	2	>10.5	8.5-9.5
Time	Mts	30	60	120
*0.5 % H_2O_2				

Table- 65: Bleached pulp evaluation results of 9 month old *Erianthus arundinaceus* clone SES 159 [whole plant bagasse]

S. NO	PARAMETERS	UNITS	PFI REVOLUTIONS		
			0	250	500
1	Freeness	ml CSF	430	310	250
2	Bulk	cc/g	1.53	1.42	1.40
3	Tensile index	Nm/g	62.5	71.0	73.8
4	Breaking length	m	6375	7242	7528
5	Tear index	$mN.m^2/g$	6.37	6.15	6.00
6	Tear factor	-	65.0	62.7	61.2
7	Burst index	$kPa.m^2/g$	4.10	4.60	4.80
8	Burst factor	-	41.8	46.9	49.0
9	Brightness	% ISO	85.3	84.3	82.8
10	Opacity (ptg)	%	78.5	68.7	64.6
11	Sc.coefficient	m^2/g	27.9	24.9	22.3
12	Yellowness	%	7.0	7.3	7.5
14	Fiber classification				
	(+30)	%	14.1		
	(-30, +50)	%	18.5		
	(-50, +100)	%	24.1		
	(-100, +200)	%	22.4		
	(-200)	%	20.9		

Bleaching conditions (CEpH)				
Parameters	Units	Chlorination	Extraction*	Hypo
Consistency	%	3	8	8
Temperature	°C	Ambient	60	40
pH	–	2	>10.5	8.5-9.5
Time	Mts	30	60	120
*0.5 % H_2O_2				

Table- 66: Bleached pulp evaluation results of 10 month old *Erianthus arundinaceus* clone SES 159 [whole plant bagasse]

S.NO.	PARAMETERS	UNITS	PFI REVOLUTIONS		
			0	250	500
1	Freeness	ml CSF	440	310	250
2	Bulk	cc/g	1.55	1.52	1.45
3	Tensile index	Nm/g	65.0	73.5	76.5
4	Breaking length	m	6630	7497	7803
5	Tear index	$mN.m^2/g$	6.50	6.30	6.20
6	Tear factor	-	66.3	64.3	63.2
7	Burst index	$kPa.m^2/g$	4.1	4.5	4.7
8	Burst factor	-	41.8	45.9	47.9
9	Brightness	% ISO	85.4	85.0	84.4
10	Opacity	%	70.5	68.2	66.3
11	Sc. Coefficient.	m^2/kg	27.2	25.2	22.3
12	Yellowness	%	7.4	7.6	7.8
13	Fiber classification				
	(+30)	%	12.3		
	(-30, +50)	%	25.8		
	(-50, +100)	%	24.6		
	(-100, +200)	%	18.4		
	(-200)	%	18.9		

Bleaching conditions (CEpH)				
Parameters	Units	Chlorination	Extraction*	Hypo
Consistency	%	3	8	8
Temperature	°C	Ambient	60	40
pH	--	2	>10.5	8.5-9.5
Time	Mts	30	60	120
*0.5 % H_2O_2				

Table - 67: Bleached pulp evaluation results of 11 month old *Erianthus arundinaceus* clone SES 159 [whole plant bagasse]

S.NO.	PARAMETERS	UNITS	PFI REVOLUTIONS		
			0	250	500
1	Freeness	ml CSF	450	320	260
2	Bulk	cc/g	1.56	1.46	1.42
3	Tensile index	Nm/g	67.5	78.6	81.0
4	Breaking length	m	6885	8017	8262
5	Tear index	$mN.m^2/g$	6.60	6.50	6.35
6	Tear factor	-	67.3	66.3	64.8
7	Burst index	$kPa.m^2/g$	4.1	4.8	5.1
8	Burst factor	-	41.8	49.0	52.0
9	Brightness	% ISO	85.7	84.9	84.2
10	Yellowness	%	8.0	8.2	8.4
11	Fiber classification				
	(+30)	%	13.1		
	(-30, +50)	%	25.1		
	(-50, +100)	%	23.4		
	(-100, +200)	%	20.4		
	(-200)	%	18.0		

Bleaching conditions (CEpH)				
Parameters	Units	Chlorination	Extraction*	Hypo
Consistency	%	3	8	8
Temperature	°C	Ambient	60	40
pH	--	2	>10.5	8.5-9.5
Time	Mts	30	60	120
*0.5 % H_2O_2				

Table - 68: Bleached pulp evaluation results of 12 month old *Erianthus arundinaceus* clone SES 159 [whole plant bagasse]

S.NO.	PARAMETERS	UNITS	PFI REVOLUTIONS			
			0	250	500	750
1	Freeness	ml CSF	450	350	300	260
2	Bulk	cc/g	1.55	1.51	1.48	1.44
3	Tensile index	Nm/g	67.6	78.0	81.5	84.2
4	Breaking length	m	6895	7956	8313	8588
5	Tear index	$mN.m^2/g$	6.60	6.50	6.42	6.35
6	Tear factor	-	67.3	66.3	65.5	64.8
7	Burst index	$kPa.m^2/g$	4.1	4.7	5.0	5.2
8	Burst factor	-	41.8	47.9	51.0	53.0
9	Brightness	% ISO	85.3	84.7	84.3	83.7
10	Opacity (ptg)	%	71.3	69.8	67.5	66.4
11	Sc.coefficient	m^2/g	27.6	25.8	24.3	22.7
12	Yellowness	%	7.7	7.9	8.1	8.2
13	Fiber classification					
	(+30)	%	13.6			
	(-30, +50)	%	25.3			
	(-50, +100)	%	24.2			
	(-100, +200)	%	17.7			
	(-200)	%	19.2			

Bleaching conditions (CEpH)				
Parameters	Units	Chlorination	Extraction*	Hypo
Consistency	%	3	8	8
Temperature	°C	Ambient	60	40
pH	--	2	>10.5	8.5-9.5
Time	Mts	30	60	120
*0.5 % H_2O_2				

Table – 69: Large scale mill trial results of *Erianthus arundinaceus* clone SES 159 [whole plant]

S.NO.	PARAMETERS	UNITS	RESULTS
1	Quantity of cane	Tone	37.57
2	Quantity of water added	Tone	89.2
3	Quantity of mixed juice	Tone	97.52
4	Quantity of Bagasse	Tone	29.25
5	Bagasse % on cane	%	77.85
6	Fibre % on cane	%	33.01
7	TRS % on cane	%	2.54

Table – 70: Large scale mill trial juice analysis results *Erianthus arundinaceus* clone SES 159 [whole plant]

S.NO	PARAMETERS	PH	BRIX %	POL %	PURITY %
1	Mixed Juice	4.80	1.88	0.31	16.49
2	Last mill Juice	—	1.43	0.21	13.99
3	Bagasse	—	0.79	0.11	—
4	Molasses Quantity	0.96 MT			

Table – 71: Results of the depithing trial of *Erianthus arundinaceus* clone SES 159 [whole plant bagasse]

S.NO.	PARAMETERS	UNITS	RESULT
1	Bagasse weight	Tone	20.430
2	No. of de-pithers	Nos	6
3	Time of trial	Min	0.30
4	Pit weight	Tone	3.654
5	Pith removal %	%	17.8

Table - 72 : Large sale mill trial whole bagasse pulping results of *Erianthus arundinaceus* clone SES 159 [whole plant]

S. NO.	PARAMETERS	UNIT	I	II	III	AVG.
1	Fibre to Pith Ratio	-	1.94 : 1	-	-	1.94 : 1
2	Chemical as Na2O applied	%	12	12	12	12
3	Total yield	%	53.78	53.19	53.81	53.59
4	Screen Rejects	%	1.79	1.65	1.26	1.57
5	Screened Yield	%	51.99	51.54	52.55	52.02
6	Kappa No.		14.9	14.8	15.0	14.9
7	Brightness	%ISO	38.9	39.18	37.47	38.51
	Black Liquor					
8	pH	-	11.7	11.5	11.8	11.7
9	Total Solids	Gpl	193	200	191	195
10	TTA as Na2O at 200gpl T.S.	Gpl	29.81	28.52	28.56	28.96
11	RAA as Na2O at 200gpl T.S.	Gpl	4.94	4.34	4	4.42
Pulping Conditions						
Sulphidity		%	18 - 20			
Bath Ratio			1 : 4.0			
Cooking Temp		° C	170			
Cooking Time		mts.	20			
H - Factor			450			

Table - 73 : Large sale mill trial depithed bagasse pulping results of *Erianthus arundinaceus* clone SES 159 [whole plant]

S. NO.	PARAMETERS	UNIT	I	II	III	AVG.
1	Fibre to Pith Ratio	-	2.36 : 1	-	-	2.36 : 1
2	Chemical as Na2O applied	%	12	12	12	12
3	Total yield	%	53.70	52.87	52.87	53.14
4	Screen Rejects	%	1.3	0.84	1.55	1.23
5	Screened Yield	%	52.4	52.03	51.32	51.91
6	Kappa No.		13.8	13.5	13.8	13.7
7	Brightness	%ISO	41.8	42.3	40.1	41.4
	Black Liquor					
8	pH	-	12.1	12.2	12.4	12.2
9	Total Solids	Gpl	188	182	192	187
10	TTA as Na2O at 200gpl T.S.	Gpl	29.68	30.53	32.29	30.83
11	RAA as Na2O at 200gpl T.S.	Gpl	5.14	5.45	4.84	5.14
Pulping Conditions						
Sulphidity		%	18 - 20			
Bath Ratio			1 : 4.0			
Cooking Temp		° C	170			
Cooking Time		mts.	20			
H - Factor			450			

Table - 74 : Unbleached pulp evaluation results of whole plant large sale mill trial of *Erianthus arundinaceus* clone SES 159 [whole bagasse]

S.NO.	PARAMETERS	UNITS	PFI REVOLUTIONS			
			0	250	500	1000
1	Freeness	ml CSF	510	370	300	250
2	Bulk	cc/g	1.67	1.59	1.55	1.48
3	Tensile index	Nm/g	59.00	74.00	78.90	80.20
4	Breaking length	m	6020	7250	7850	8070
5	Tear index	$mN.m^2/g$	7.05	6.85	6.70	6.56
6	Tear factor	-	71.9	69.9	68.3	66.9
7	Burst index	$kPa.m^2/g$	3.60	4.60	4.96	5.00
8	Burst factor	-	36.7	46.9	50.6	51.0
9	Brightness	% ISO	37.0	36.6	35.4	34.5
10	Yellowness	%	32.6	32.8	33.0	34.2
	Fiber classification					
	(+30)	%	18.4			
	(-30, +50)	%	21.4			
	(-50, +100)	%	16.7			
	(-100, +200)	%	26.8			
	(-200)	%	16.7			

Table - 75 : Unbleached pulp evaluation results of whole plant large sale mill trial of *Erianthus arundinaceus* clone SES 159 [depithed bagasse]

S.NO.	PARAMETERS	UNITS	PFI REVOLUTIONS			
			0	1000	1500	2000
1	Freeness	ml CSF	600	380	310	250
2	Bulk	cc/g	1.71	1.60	1.52	1.48
3	Tensile index	Nm/g	42.94	74.47	79.20	81.96
4	Breaking length	m	4380	7596	8078	8360
5	Tear index	$mN.m^2/g$	7.60	7.30	7.15	7.00
6	Tear factor	-	77.5	74.5	72.9	71.4
7	Burst index	$kPa.m^2/g$	2.52	4.81	5.15	5.42
8	Burst factor	-	25.7	49.1	52.5	55.3
9	Brightness	% ISO	40.3	40.3	39.3	38.5
10	Yellowness	%	31.9	32.7	33.3	34.0
11	Fiber classification					
	(+30)	%	27.3			
	(-30, +50)	%	26.8			
	(-50, +100)	%	17.6			
	(-100, +200)	%	19.7			
	(-200)	%	8.6			

Table - 76 : Bleached pulp evaluation results of whole plant large sale mill trial of *Erianthus arundinaceus* clone SES 159 [whole bagasse]

S.NO.	PARAMETERS	UNITS	PFI REVOLUTIONS		
			0	250	500
1	Freeness	ml CSF	470	320	260
2	Bulk	cc/g	1.56	1.46	1.41
3	Tensile index	Nm/g	59.80	75.30	78.40
4	Breaking length	m	6100	7681	7997
5	Tear index	$mN.m^2/g$	6.40	6.28	6.10
6	Tear factor	-	65.3	64.1	62.2
7	Burst index	$kPa.m^2/g$	3.79	4.65	5.04
8	Burst factor	-	38.7	47.4	51.4
9	Brightness	% ISO	85.0	84.3	84.0
10	Opacity (ptg)	%	71.2	69.9	68.4
11	Sc.coefficient	m^2/g	26.8	25.0	23.9
12	Yellowness	%	8.2	8.5	8.6
13	Fiber classification				
	(+30)	%	11.2		
	(-30, +50)	%	26.1		
	(-50, +100)	%	15.4		
	(-100, +200)	%	30.1		
	(-200)	%	17.2		

Bleaching conditions (CEpH)				
Parameters	Units	Chlorination	Extraction*	Hypo
Consistency	%	3	8	8
Temperature	°C	Ambient	60	40
pH	–	2	>10.5	8.5-9.5
Time	Mts	30	60	120
*0.5 % H_2O_2				

Table - 77 : Bleached pulp evaluation results of whole plant large sale mill trial of *Erianthus arundinaceus* clone SES 159 [depithed bagasse]

S.NO	PARAMETERS	UNITS	PFI REVOLUTIONS		
			0	1000	1500
1	Freeness	ml CSF	540	310	240
2	Bulk	cc/g	1.65	1.55	1.49
3	Tensile index	Nm/g	56.40	77.80	82.00
4	Breaking length	m	5753	7936	8364
5	Tear index	$mN.m^2/g$	7.20	6.85	6.78
6	Tear factor	-	73.4	69.9	69.2
7	Burst index	$kPa.m^2/g$	3.29	4.88	5.21
8	Burst factor	-	33.6	49.8	53.2
9	Brightness	% ISO	83.5	82.4	82.0
10	Opacity (ptg)	%	72.5	69.2	67.6
11	Sc.coefficient	m^2/g	29.6	24.7	23.4
12	Yellowness	%	3.4	3.8	3.9
13	Fiber classification				
	(+30)	%	23.2		
	(-30, +50)	%	22.7		
	(-50, +100)	%	16.0		
	(-100, +200)	%	24.4		
	(-200)	%	13.7		

Bleaching conditions (CEpH)				
Parameters	Units	Chlorination	Extraction*	Hypo
Consistency	%	3	8	8
Temperature	°C	Ambient	60	40
pH	--	2	>10.5	8.5-9.5
Time	Mts	30	60	120
*0.5 % H_2O_2				

Table - 78 : Comparison of *Erianthus arundinaceus* fibre classification results with others

S.NO	CLONE NAME	BAUER MCNETT FRACTIONS %				
		+30	+50	+100	+200	-200
1	SES 159	18.1	25.5	20.6	18.3	17.5
2	SES 3	11..3	25.7	25.5	22.5	15.0
3	E.A. Cuttack	14.4	30.7	20.3	17.4	17.2
4	Mythan	10.6	29.4	21.5	18.8	19.7
5	IMP 1536	12.4	30.2	18.9	16.8	21.7
6	CR 1	8.8	25.7	27.4	22.0	16.1
7	Conventional	12.0	21.0	26.0	19.0	22.0
8	Switchgrass	11.1	24.3	19.8	19.3	25.8

Table - 79: Comparison of unbleached pulp properties of *Erianthus arundinaceus* whole plant bagasse and commercial sugarcane bagasse

S. NO	PARAMETERS	UNIT	WILD CANE PULP	COMMERCIAL CANE PULP
1	Freeness	ml CSF	510	460
2	Bulk	cc/g	1.62	1.58
3	Tensile index	Nm/g	68.6	61.00
4	Breaking length	m	6997	6222
5	Tear index	$mN.m^2/g$	7.3	6.10
6	Tear factor	-	74.5	62.2
7	Burst index	$kPa.m^2/g$	4.3	3.90
8	Burst factor	-	43.9	39.8
9	Brightness	% ISO	40.8	39.0
10	Yellowness	%	29.5	30.7
11	Strength at 300 mL CSF			
	Tensile index	Nm/g	85.0	77.0
	Tear index	$mN.m^2/g$	7.1	5.9
	Burst index	$kPa.m^2/g$	5.3	4.6

Table - 80: Comparison of bleached pulp properties of *Erianthus arundinaceus* whole plant bagasse and commercial sugarcane bagasse

S. NO	PARAMETERS	UNIT	E.ARUNDINACEUS	COMMERCIAL CANE
1	Freeness	ml CSF	500	450
2	Bulk	cc/g	1.58	1.55
3	Tensile index	Nm/g	67.00	61.6
4	Breaking length	m	6834	6283
5	Tear index	$mN.m^2/g$	7.10	5.75
6	Tear factor	-	72.4	58.7
7	Burst index	$kPa.m^2/g$	4.20	3.8
8	Burst factor	-	42.8	38.8
9	Brightness	% ISO	85.5	85.6
10	Opacity	%	72.6	72.9
11	Sc. Coefficient	m^2/kg	27.6	28.2
12	Yellowness	%	7.8	7.7
13	Strength at 300ml CSF			
	Tensile index	Nm/g	82.0	75.0
	Tear index	$mN.m^2/g$	6.8	5.4
	Burst index	$kPa.m^2/g$	5.1	4.5

Table- 81: Comparison of unit area pulp production of *Erianthus arundinaceus* clone SES 159 and *Eucalyptus*

S. NO	PARAMETERS	UNITS	VALUES
Wildcane SES 159			
1	Total Green yield	T/acre	60
2	Green yield per year	T/acre	60
3	OD bagasse yield @ 27.2 % fibre	T/acre	16.32
4	Pulp yield	T/acre	8.16
Eucalyptus			
1	Total Green yield for 5 year rotation	T/acre	60
2	Green yield per year	T/acre	12
3	OD wood yield @ 45%	T/acre	5.4
4	Pulp yield	T/acre	2.484

Table- 82: Economics of Erianthus arundinaceus (wildcane) SES 159 as captive fibre crop for paper industry

S. NO	PARAMETERS	UNITS	VALUES
1	Green yield per year	T/acre	60
2	OD fibre or bagasse yield @ 27.2	T/acre	16.32
3	Bagasse yield on as such basis @ 55 % Moisture	T/acre	36.27
4	Value of the bagasse @ RS 1250/T	RS/acre	45333
6	Juice COD Value	mg/lit	100000
7	Juice yield @ 80% extraction efficiency	Lit/T	560
8	COD yield per Ton of biomass	kg/T	56
9	COD yield per acre of wildcane plantation	kg/T	3360
10	Estimated Biogas generation potential	m3/acre	1428
11	Furnace oil equivalent to biogas	lit/m3	714
12	Value furnace oil saved	RS 20/lit	14280
13	Total Revenue from wildcane plantation	RS/acre	59613
14	Cost of cultivation	RS/acre	20,000
15	Cost of harvesting & transport	RS/acre	14,000
16	Cost of processing	RS/acre	6,000
17	Net revenue	RS/acre	19,613
18	Computed return per ton of biomass	RS/T	660
19	Revenue to Farmer	RS/acre	39,613
20	Net revenue to Farmer per annum	RS/acre	19,613

Table- 82: Economics of Erianthus arundinaceus (wildcane) SES 159 as captive fibre crop for paper industry

S. NO	PARAMETERS	UNITS	VALUES
1	Green yield per year	T/acre	60
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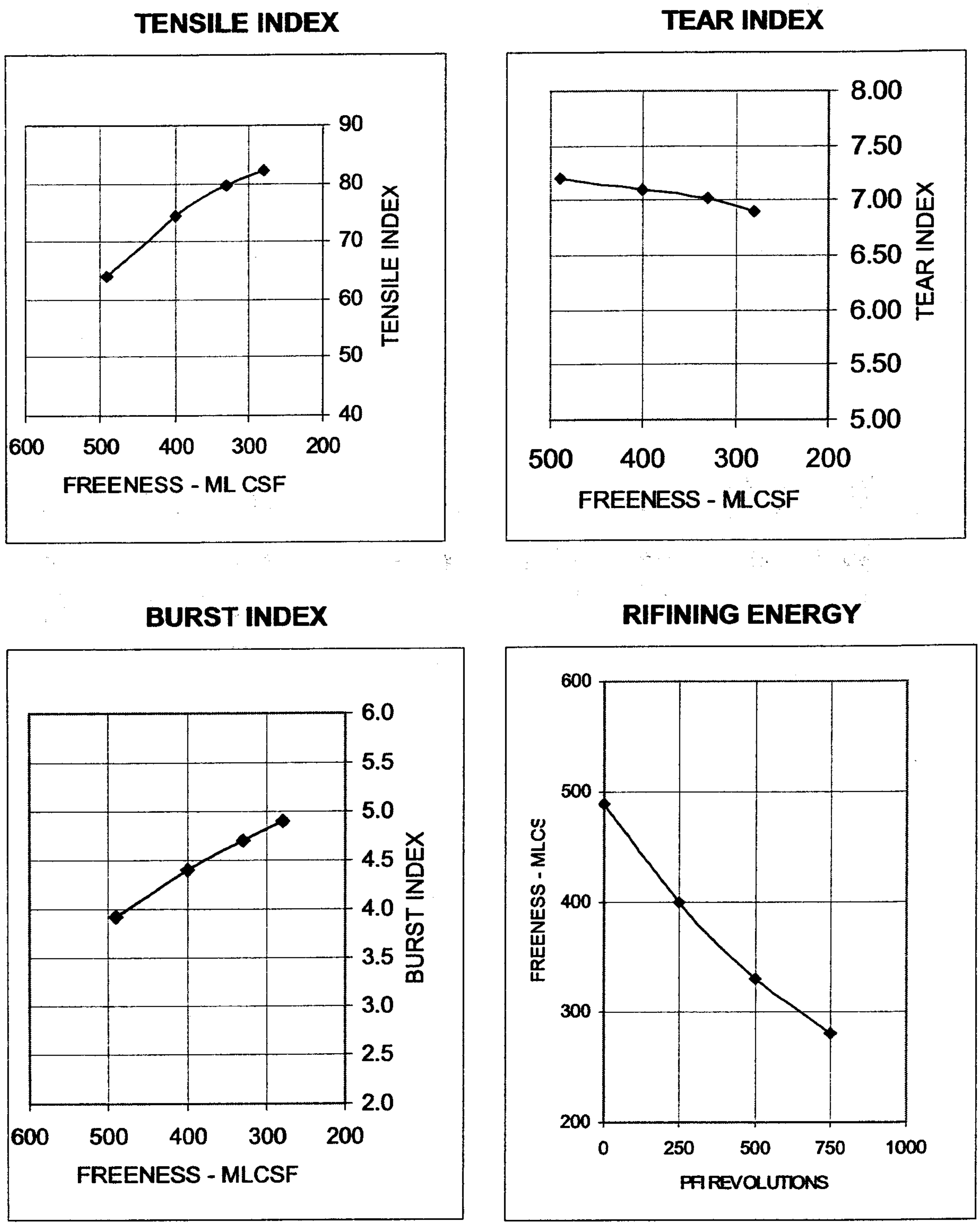


Figure: 2 Unbleached strength properties of 11 month old *Erianthus arundinaceus* clone SES 159 [cane bagasse] at various freeness levels

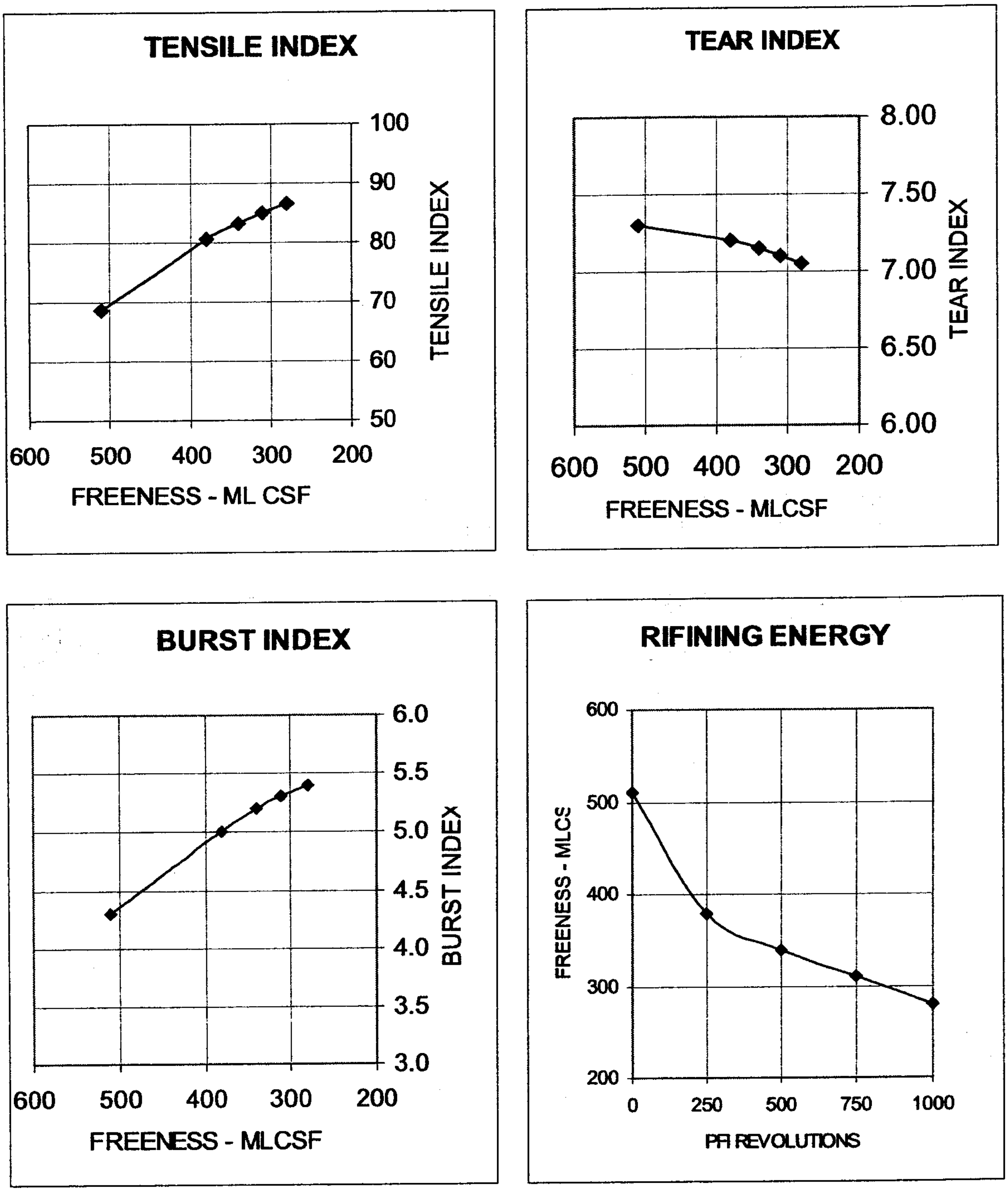


Figure: 3 Unbleached strength properties of 12 month old *Erianthus arundinaceus* clone SES 159 [cane bagasse] at various freeness levels

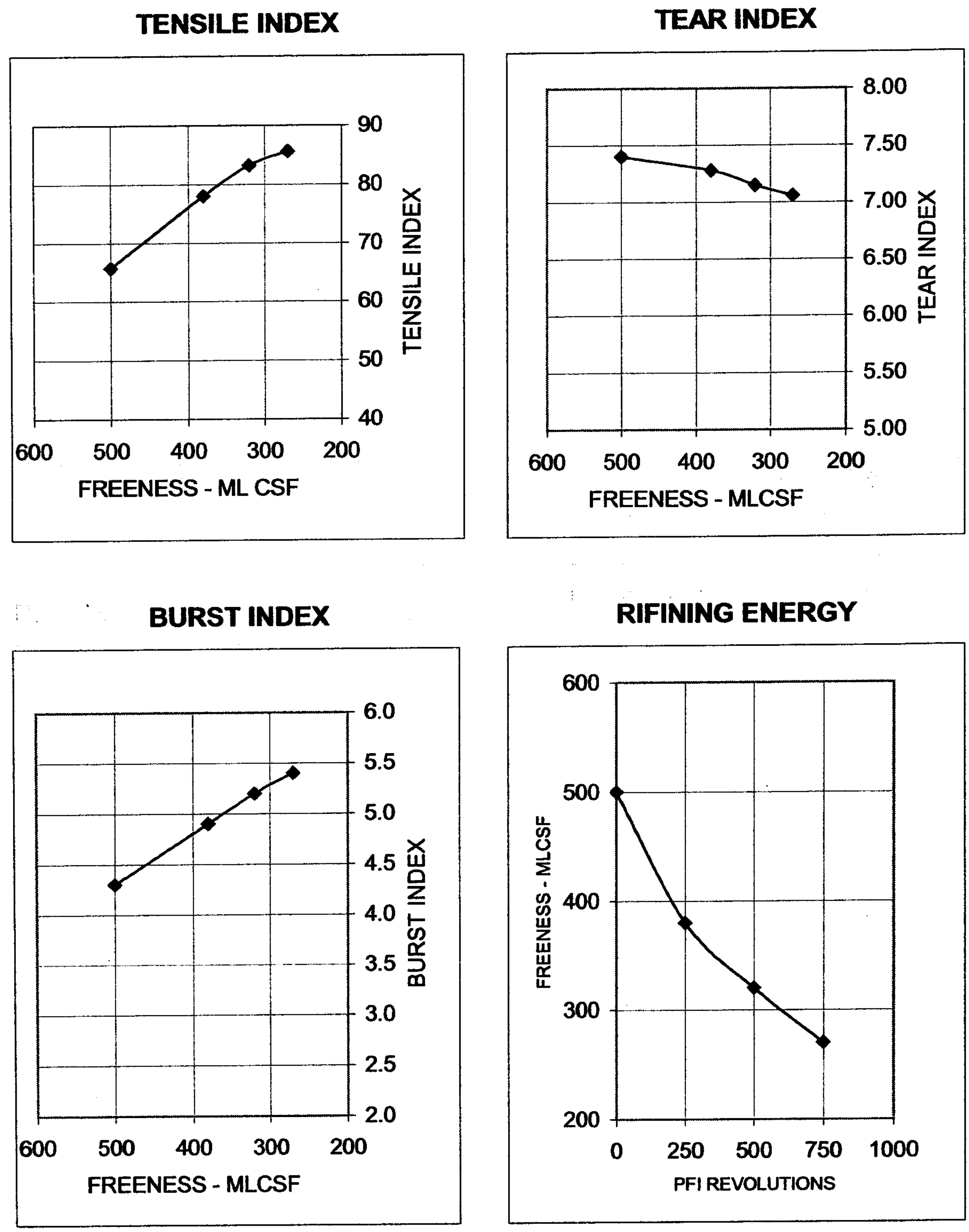


Figure: 4 Unbleached strength properties of 10 month old sugarcane bagasse at various freeness levels

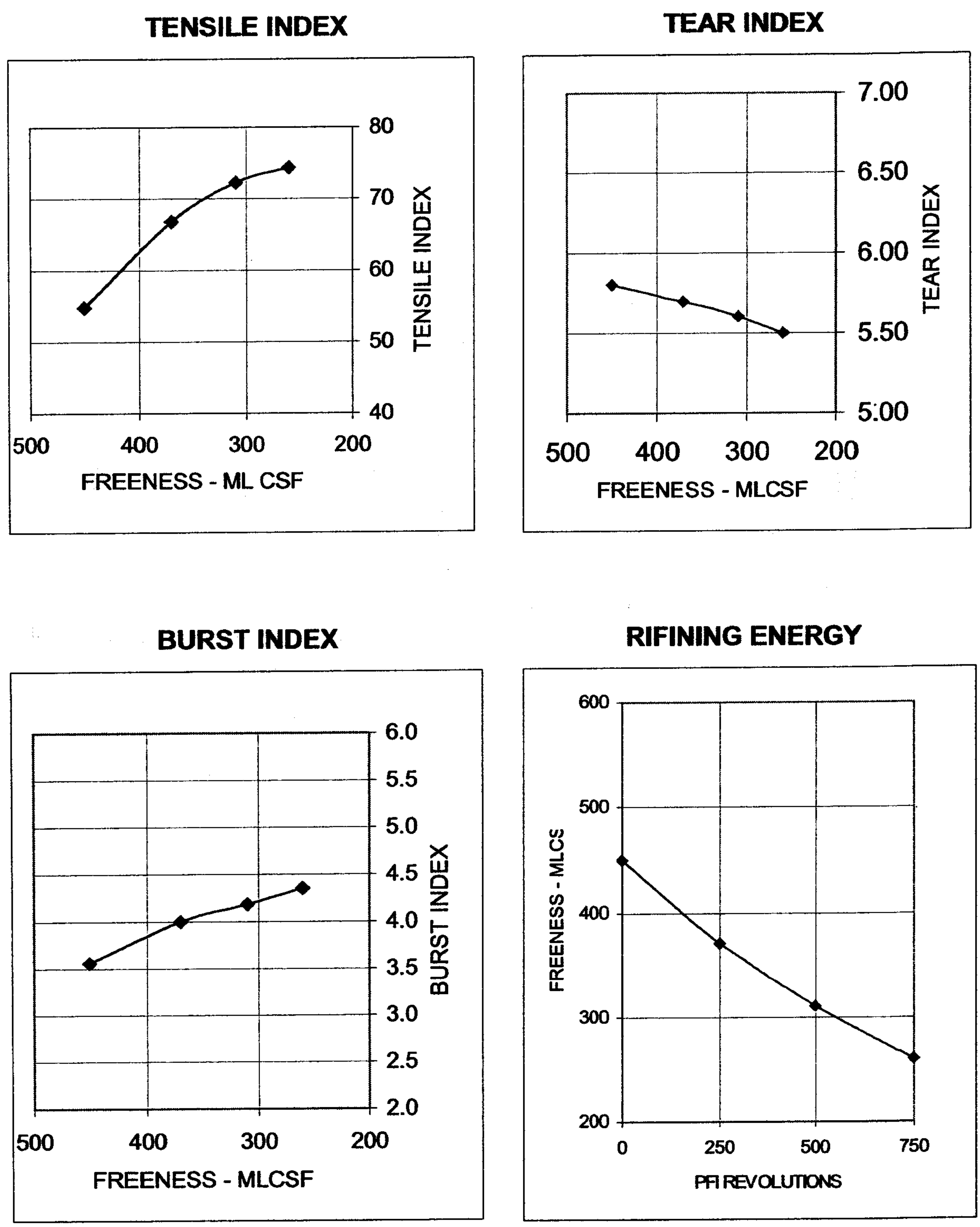


Figure: 5 Unbleached strength properties of 11 month old sugarcane bagasse at various freeness levels

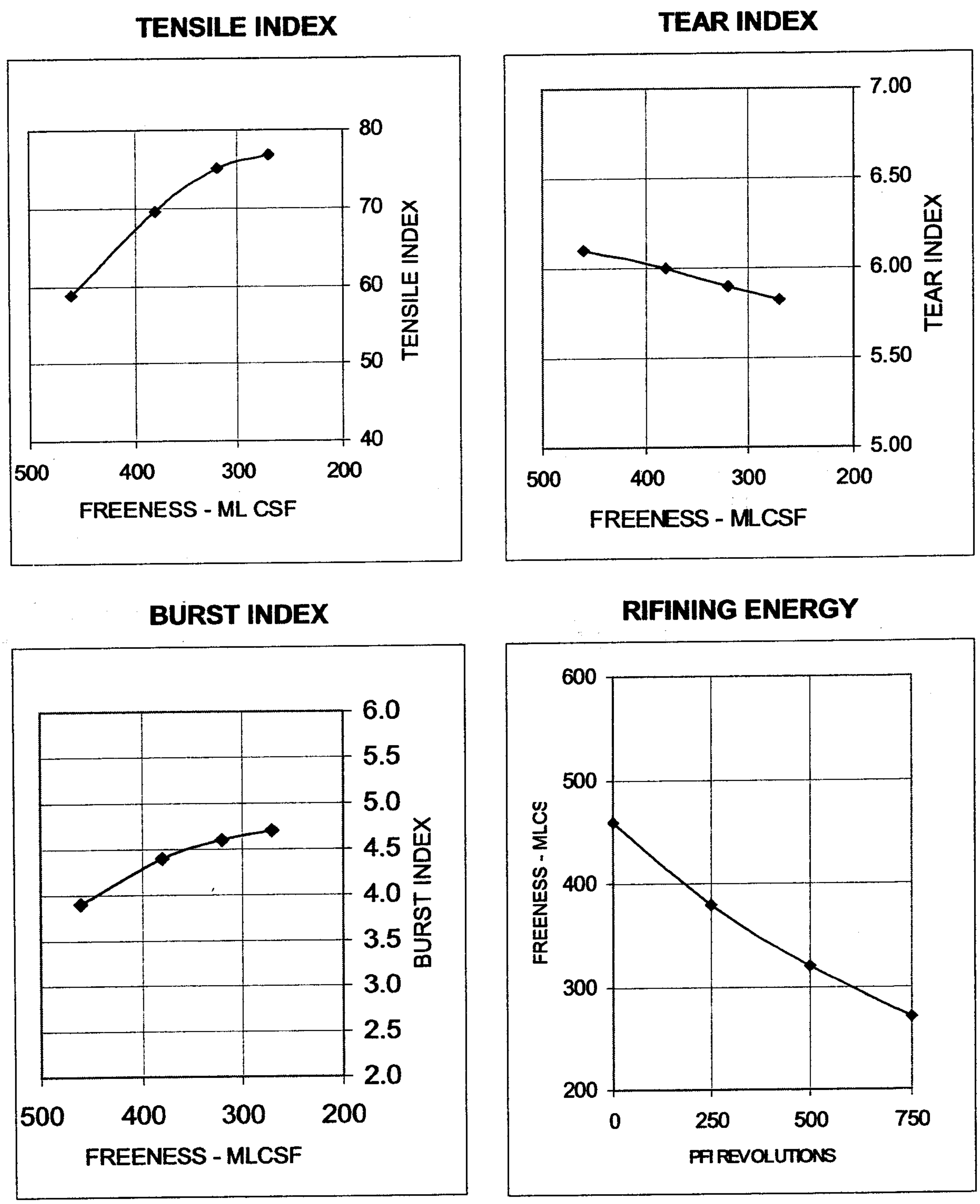


Figure: 6 Unbleached strength properties of 12 month old sugarcane bagasse at various freeness levels

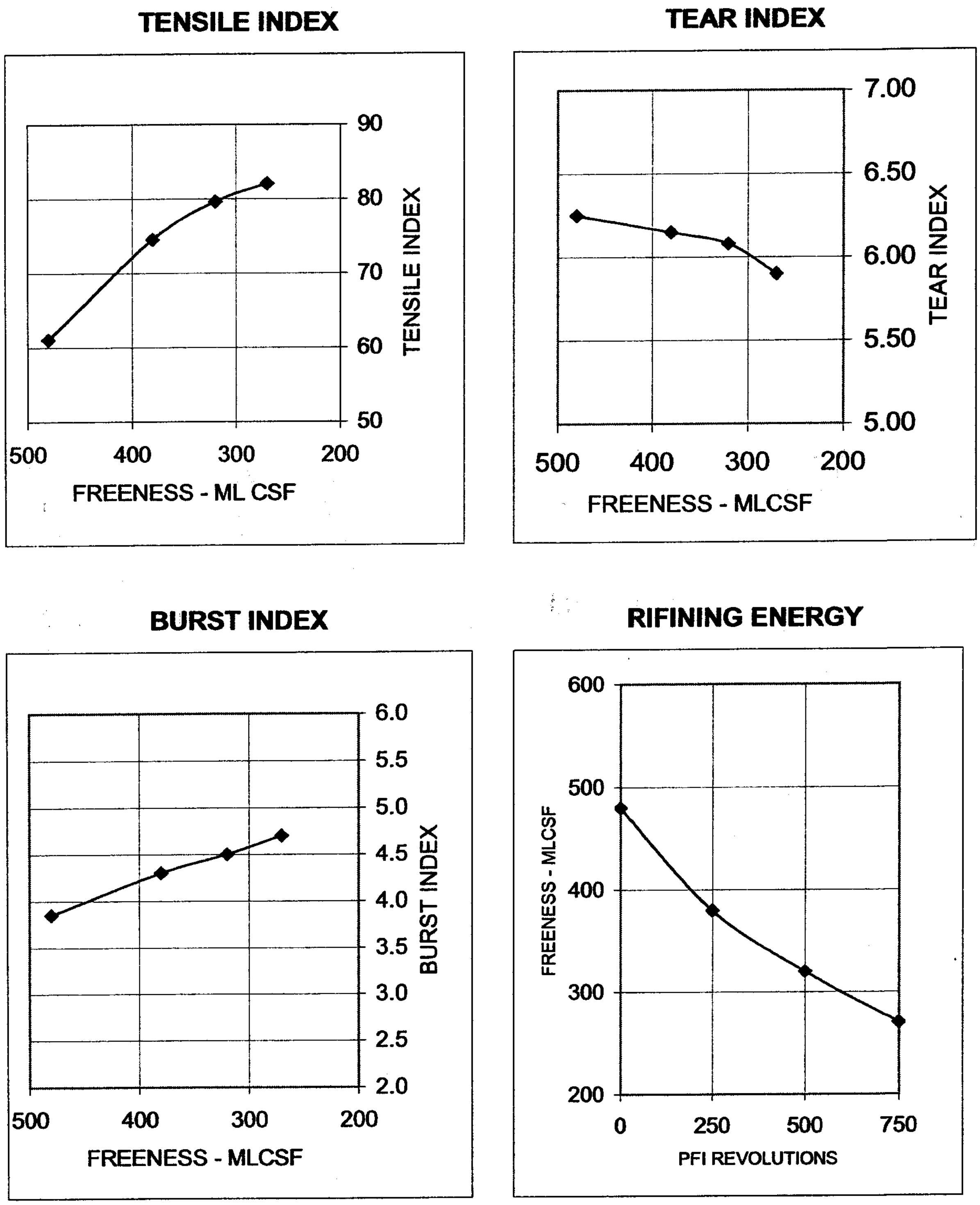


Figure: 7 Unbleached strength properties of 8 month old *Erianthus arundinaceus* clone SES 159 [whole plant bagasse] at various freeness levels

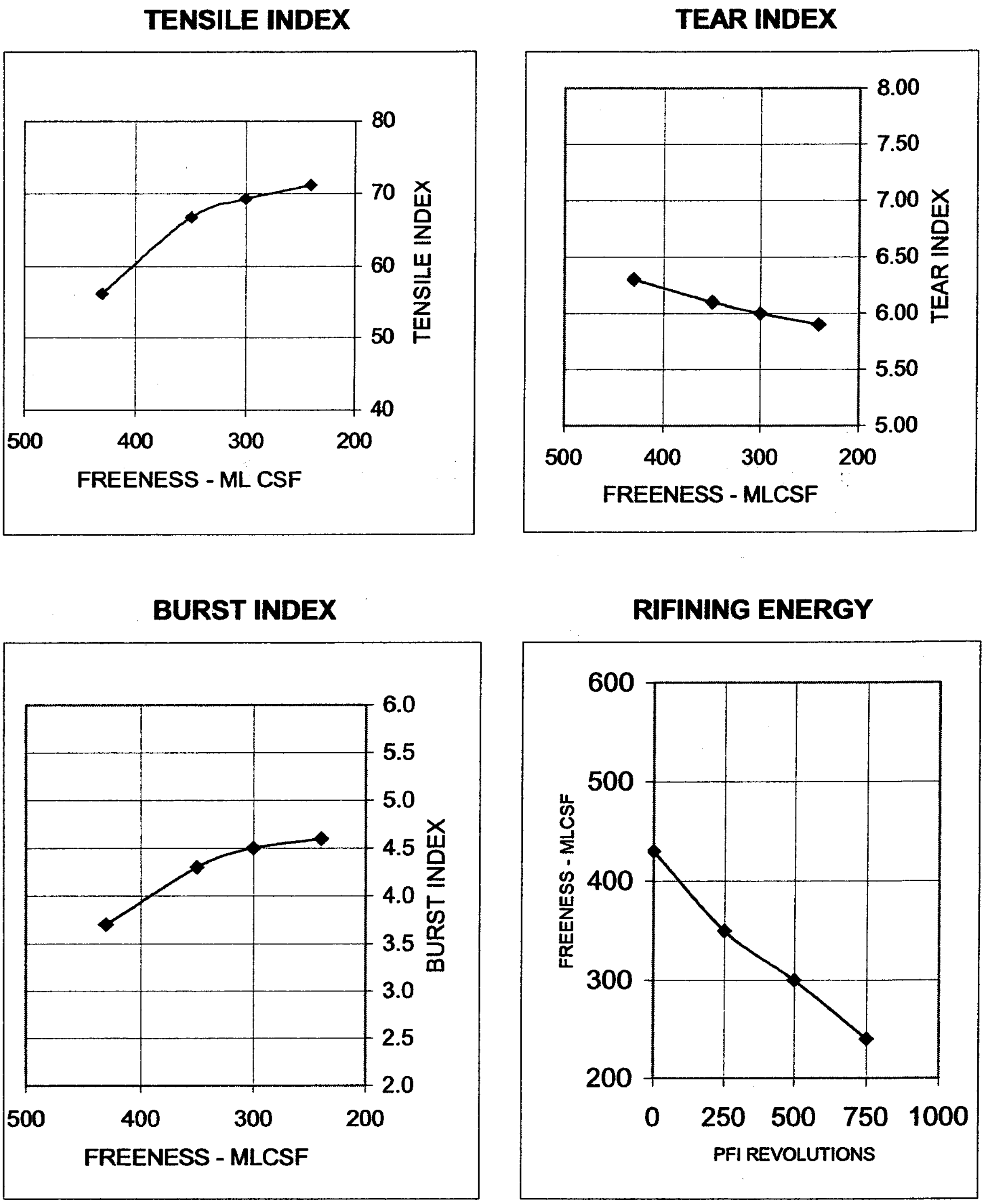


Figure: 8 Unbleached strength properties of 9 month old *Erianthus arundinaceus* clone SES 159 [whole plant bagasse] at various freeness levels

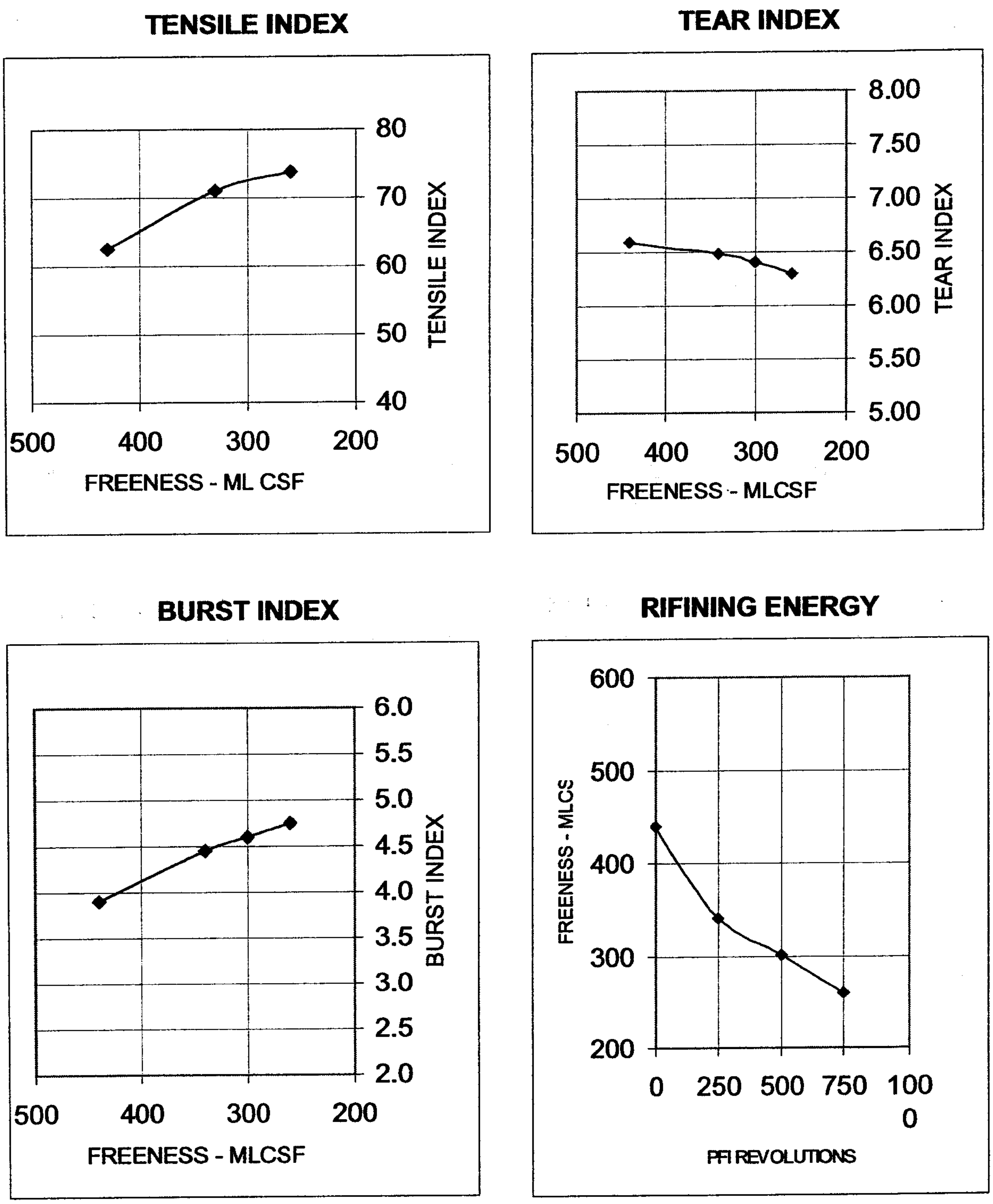
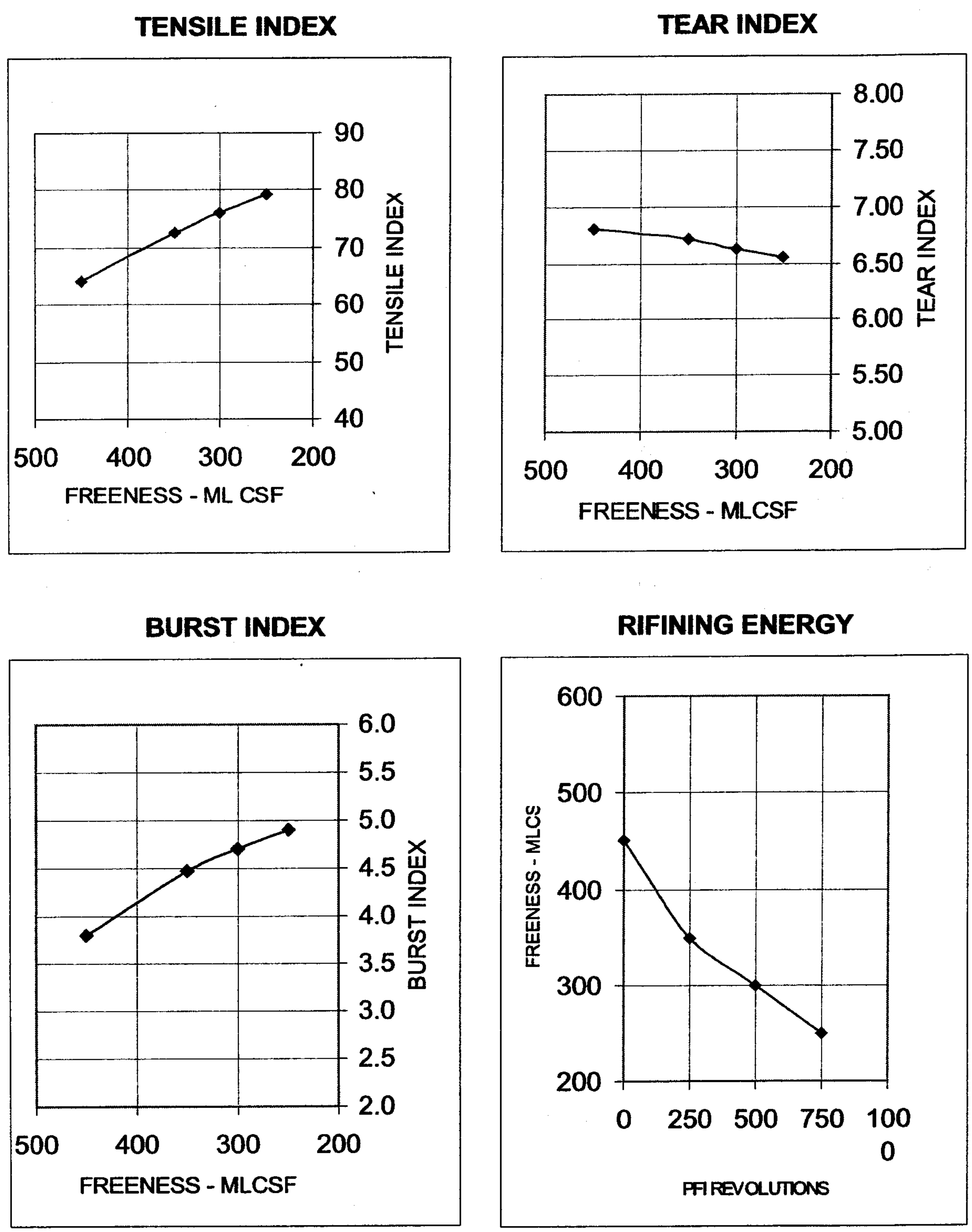


Figure: 9 Unbleached strength properties of 10 month old *Erianthus arundinaceus* clone SES 159 [whole plant bagasse] at various freeness levels



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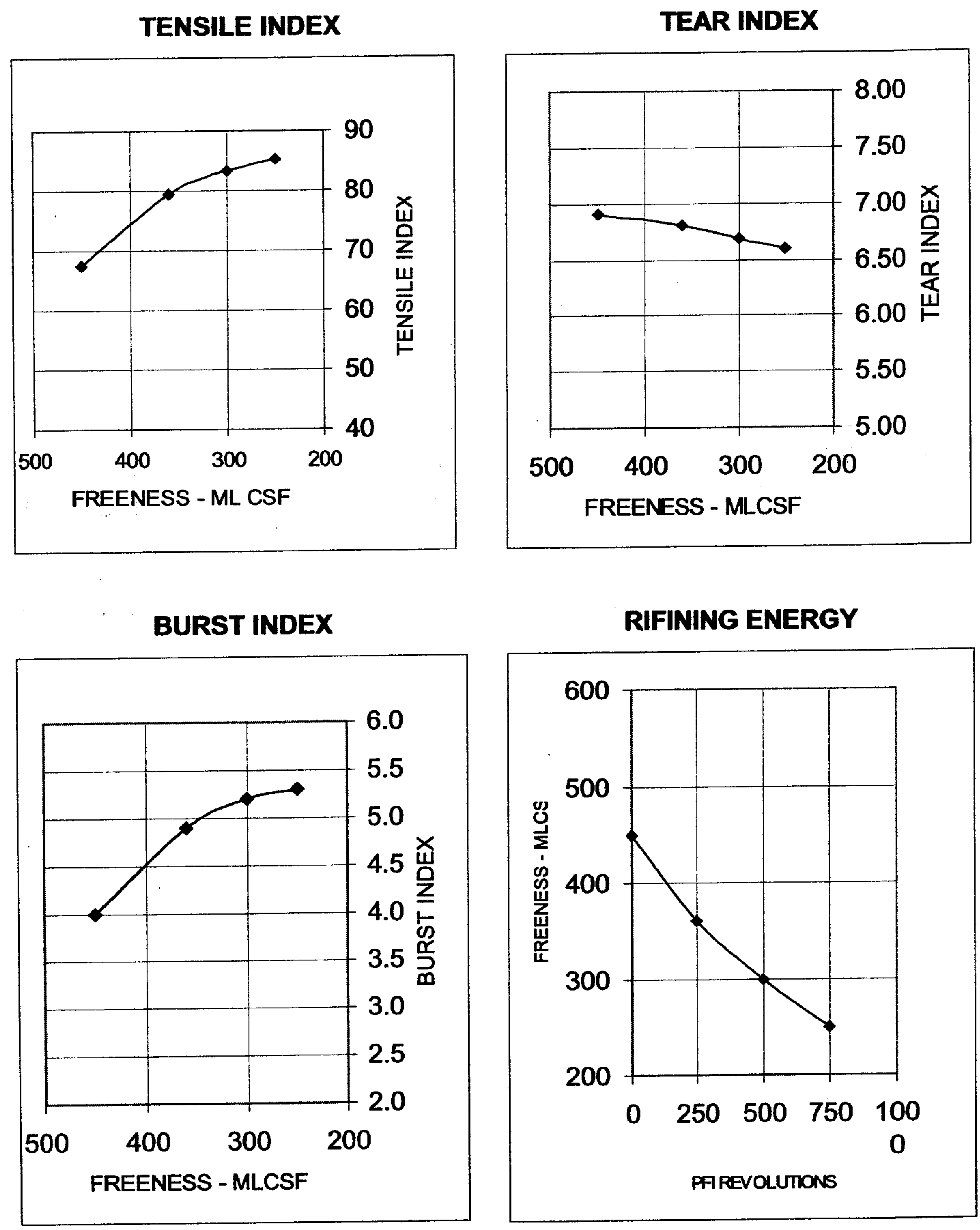

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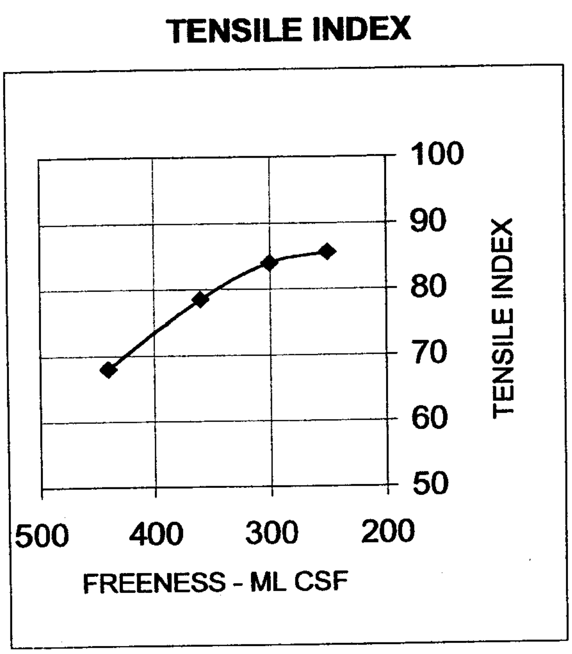

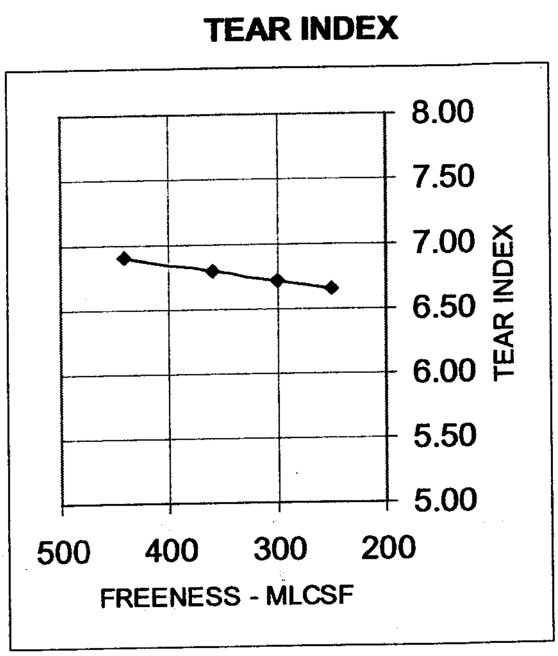

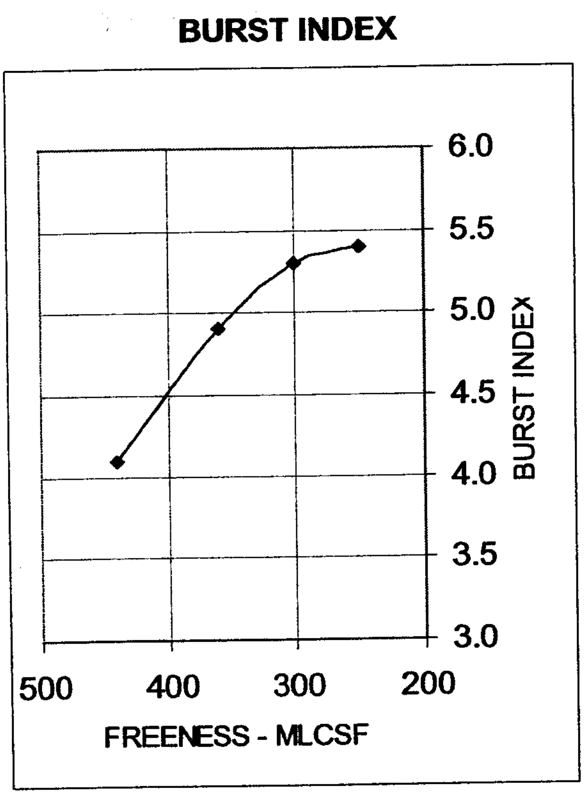

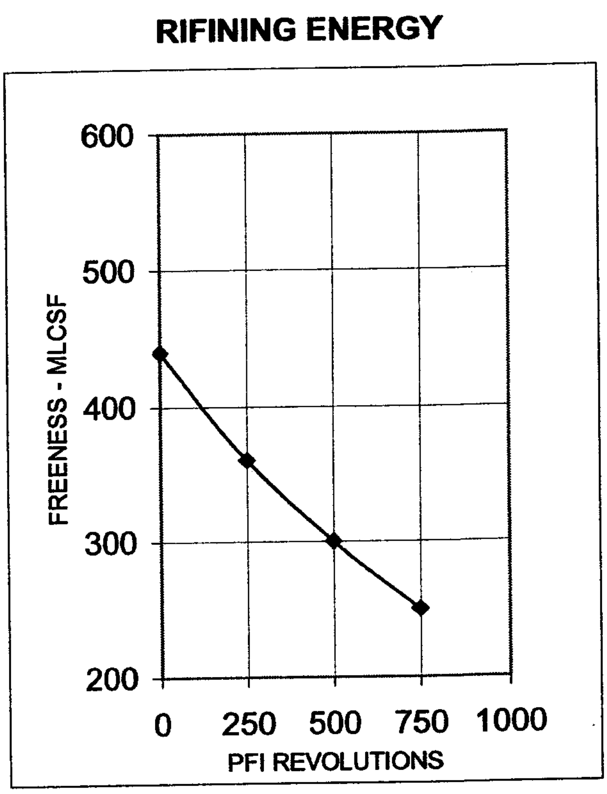

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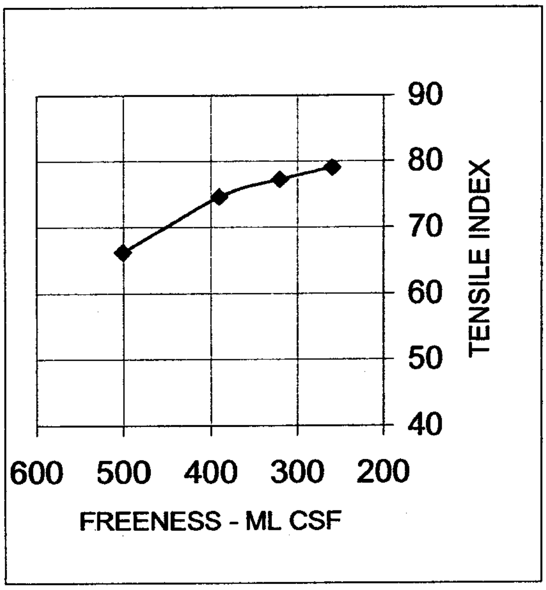

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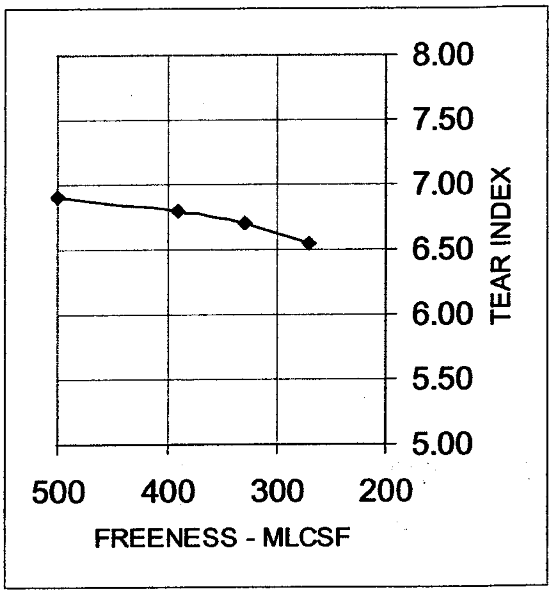

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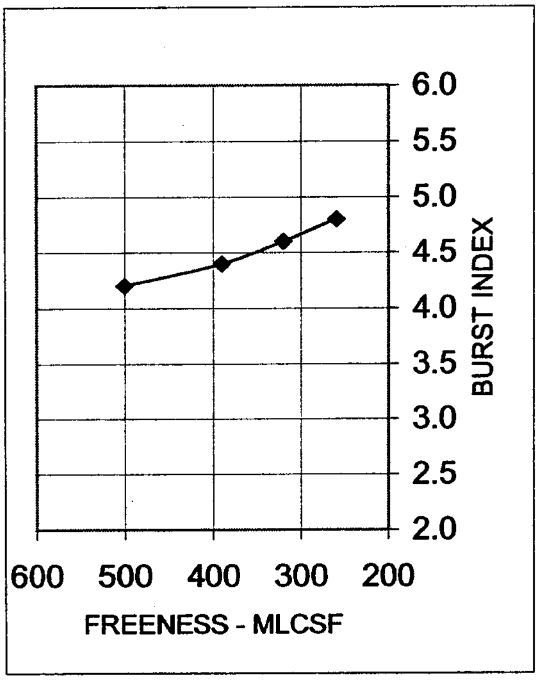

RIFINING ENERGY

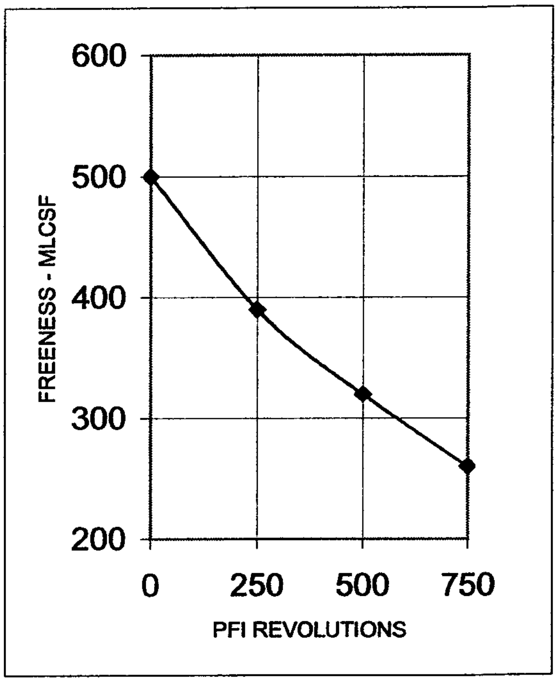

Figure:13 Bleached strength properties of 11 month old *Erianthus arundinaceus* clone SES 159 [cane bagasse] at various freeness levels

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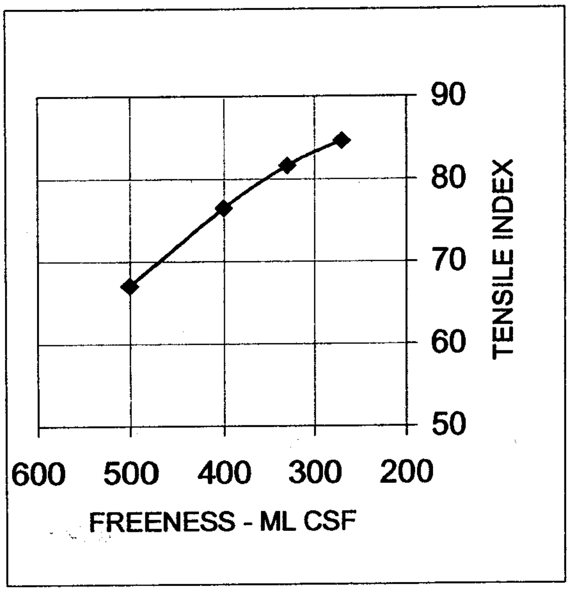

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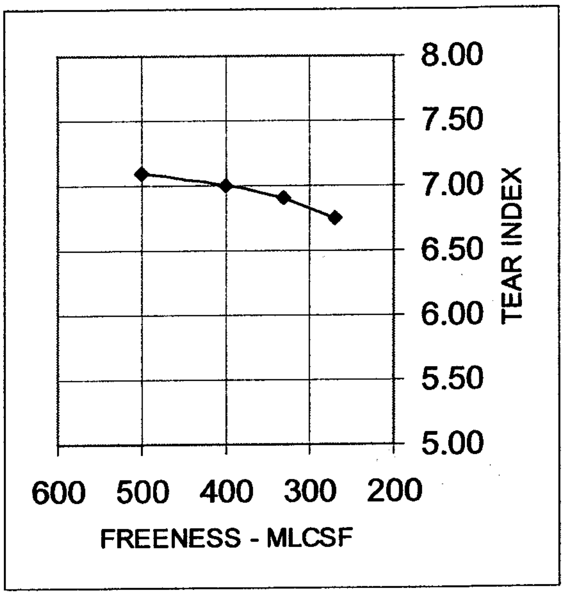

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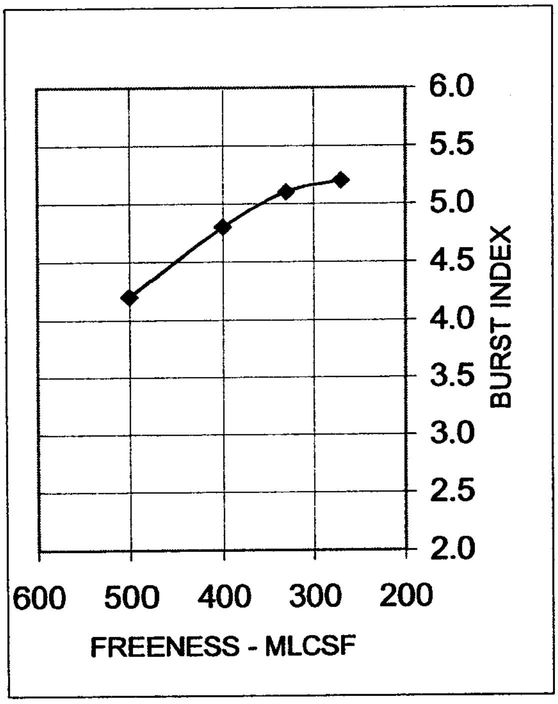

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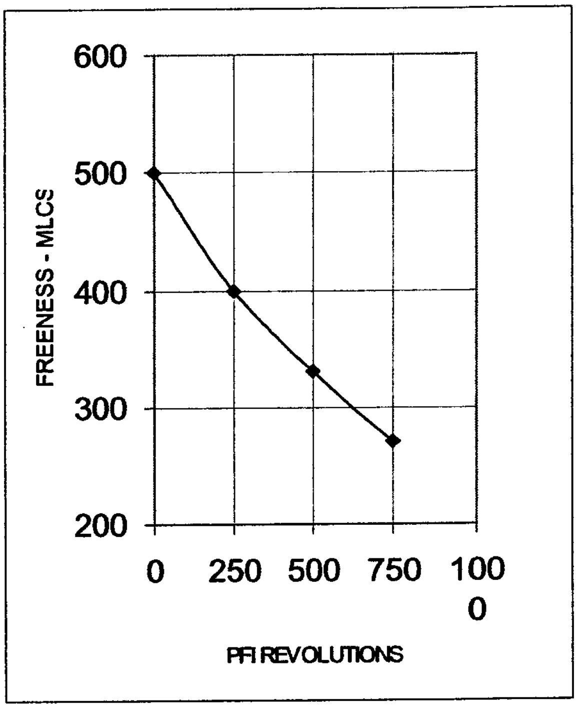

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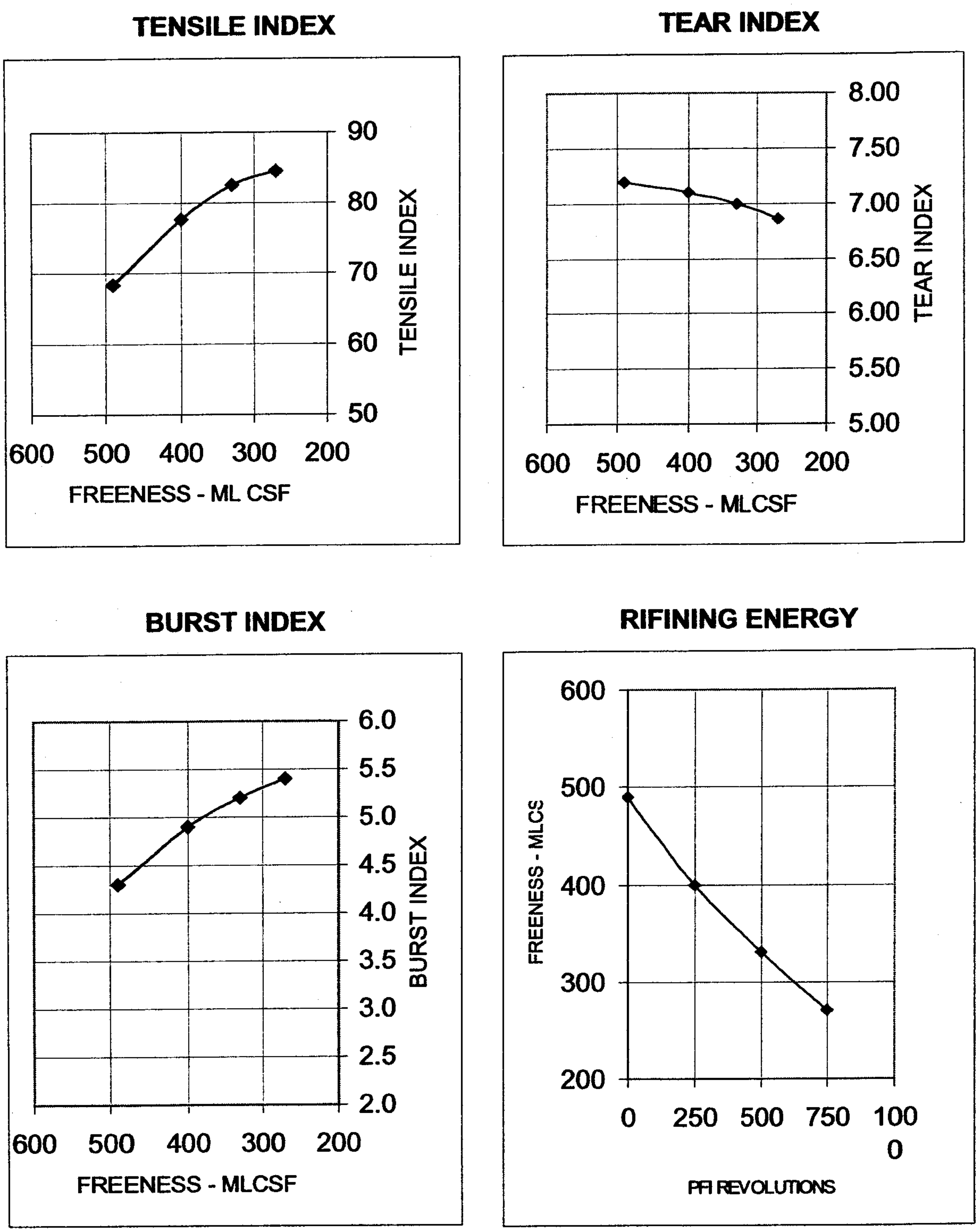

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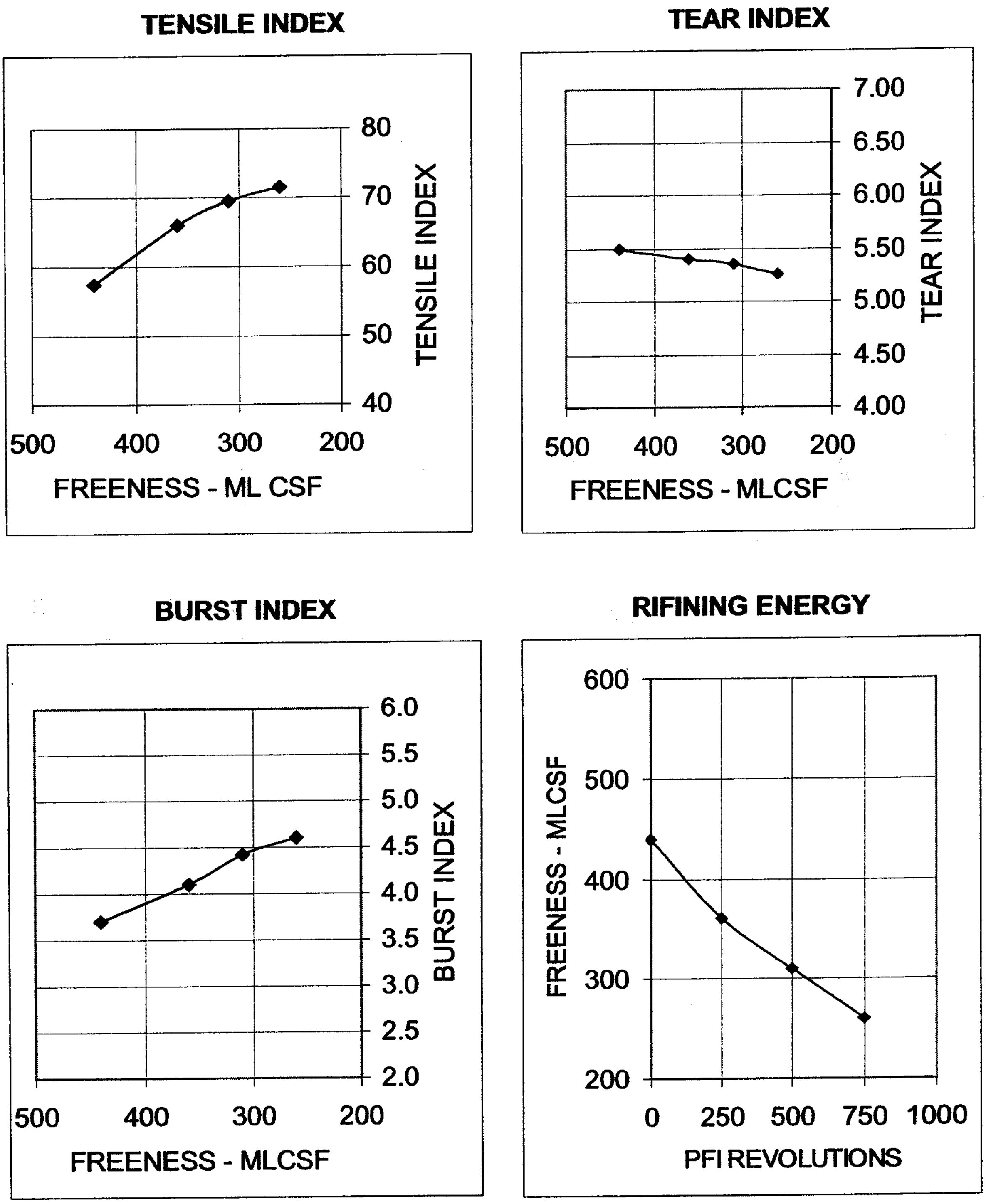


Figure: 16 Bleached strength properties of 11 month old sugarcane bagasse at various freeness levels

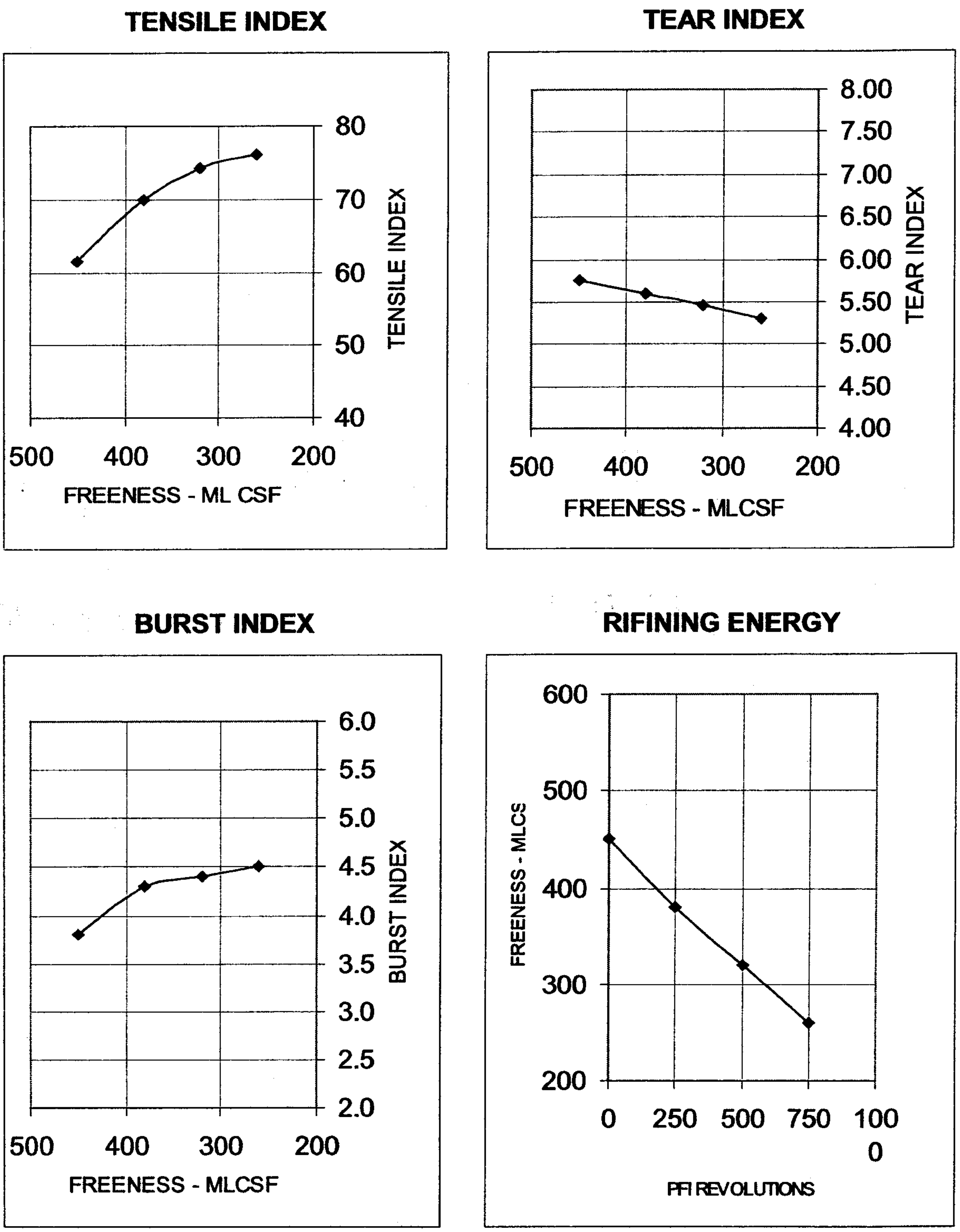


Figure: 17 Bleached strength properties of 12 month old sugarcane bagasse at various freeness levels

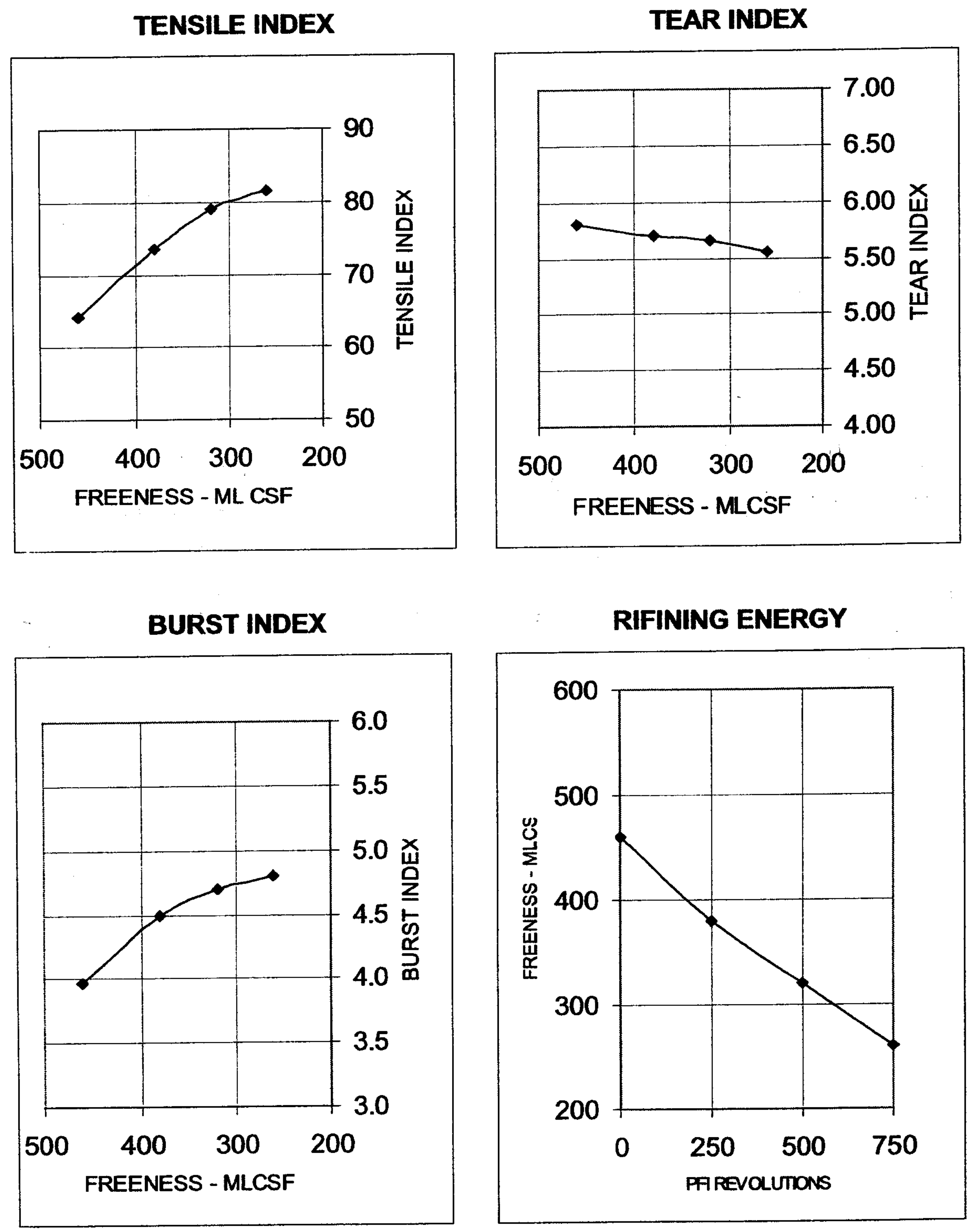


Figure: 18 Bleached strength properties of 8 month old *Erianthus arundinaceus* clone SES 159 [whole plant bagasse] at various freeness levels

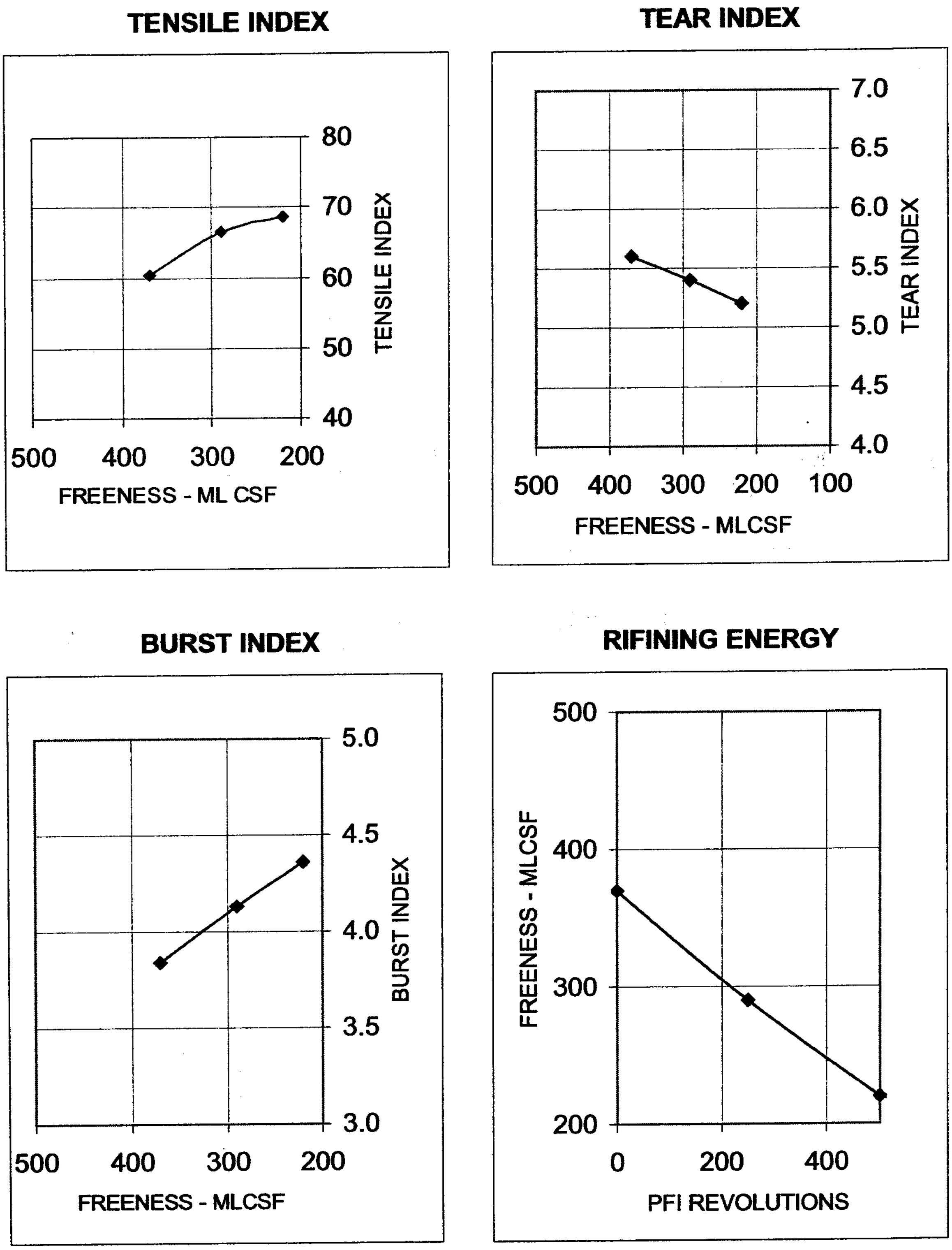
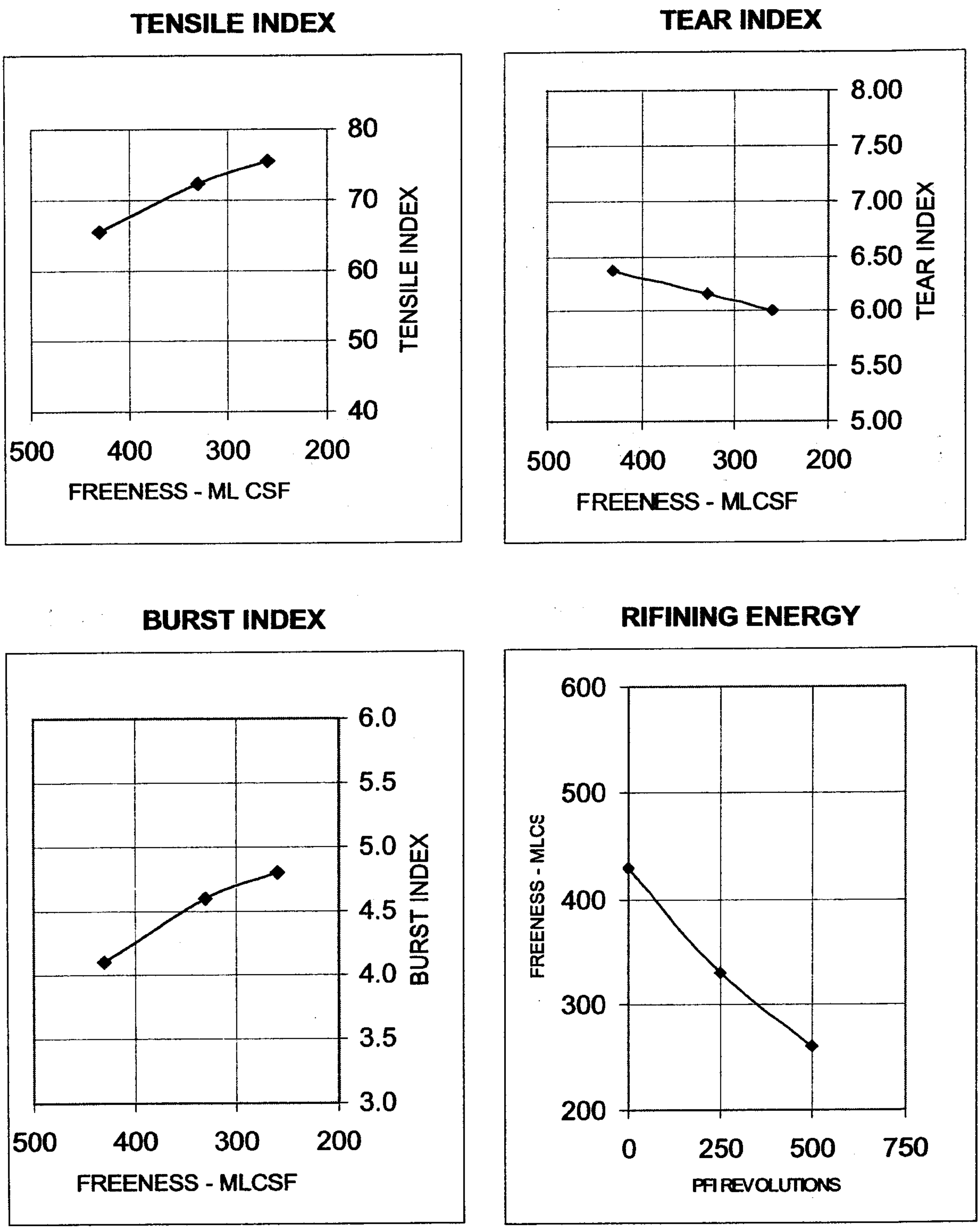


Figure: 19 Bleached strength properties of 9 month old *Erianthus arundinaceus* clone SES 159 [whole plant bagasse] at various freeness levels



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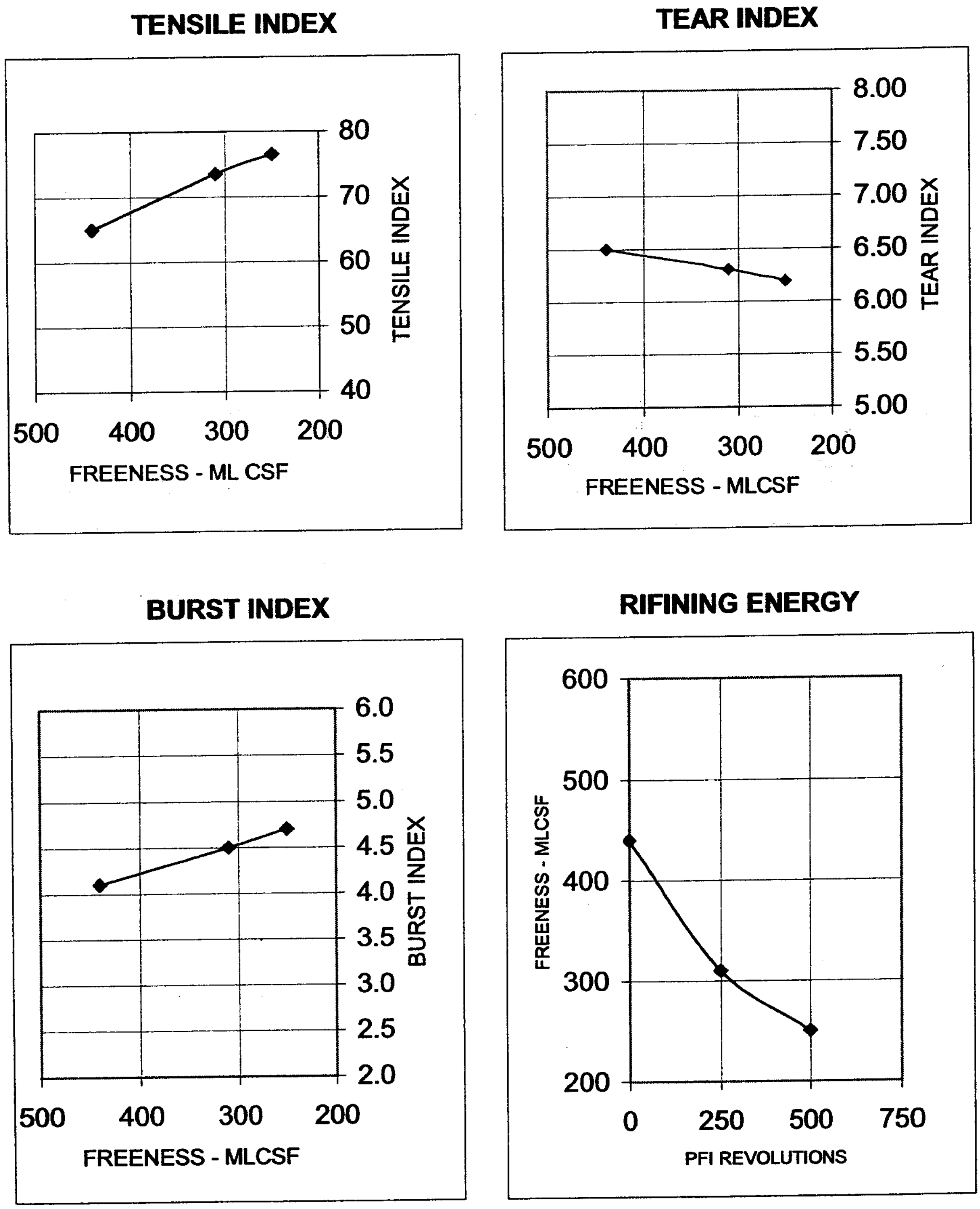

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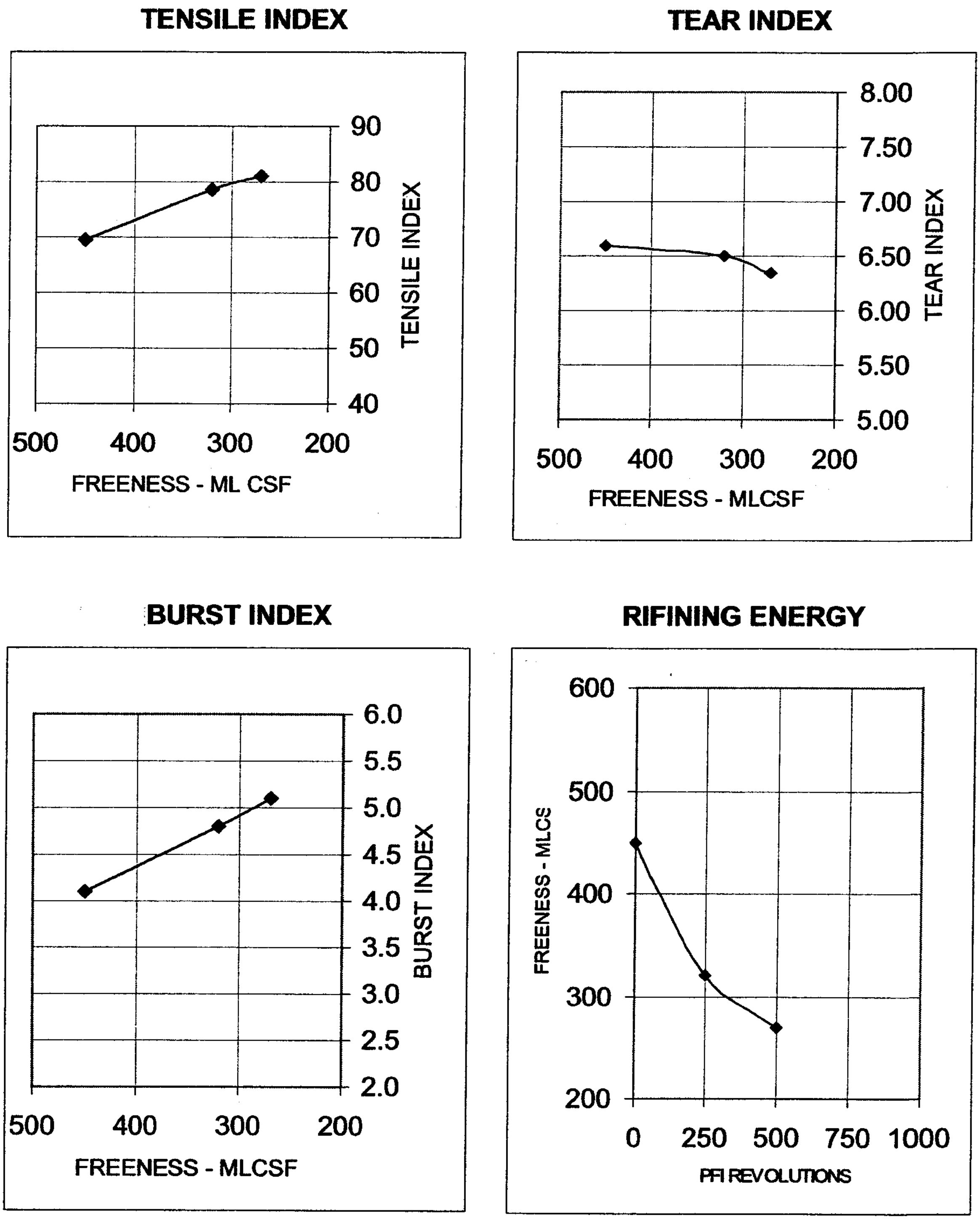

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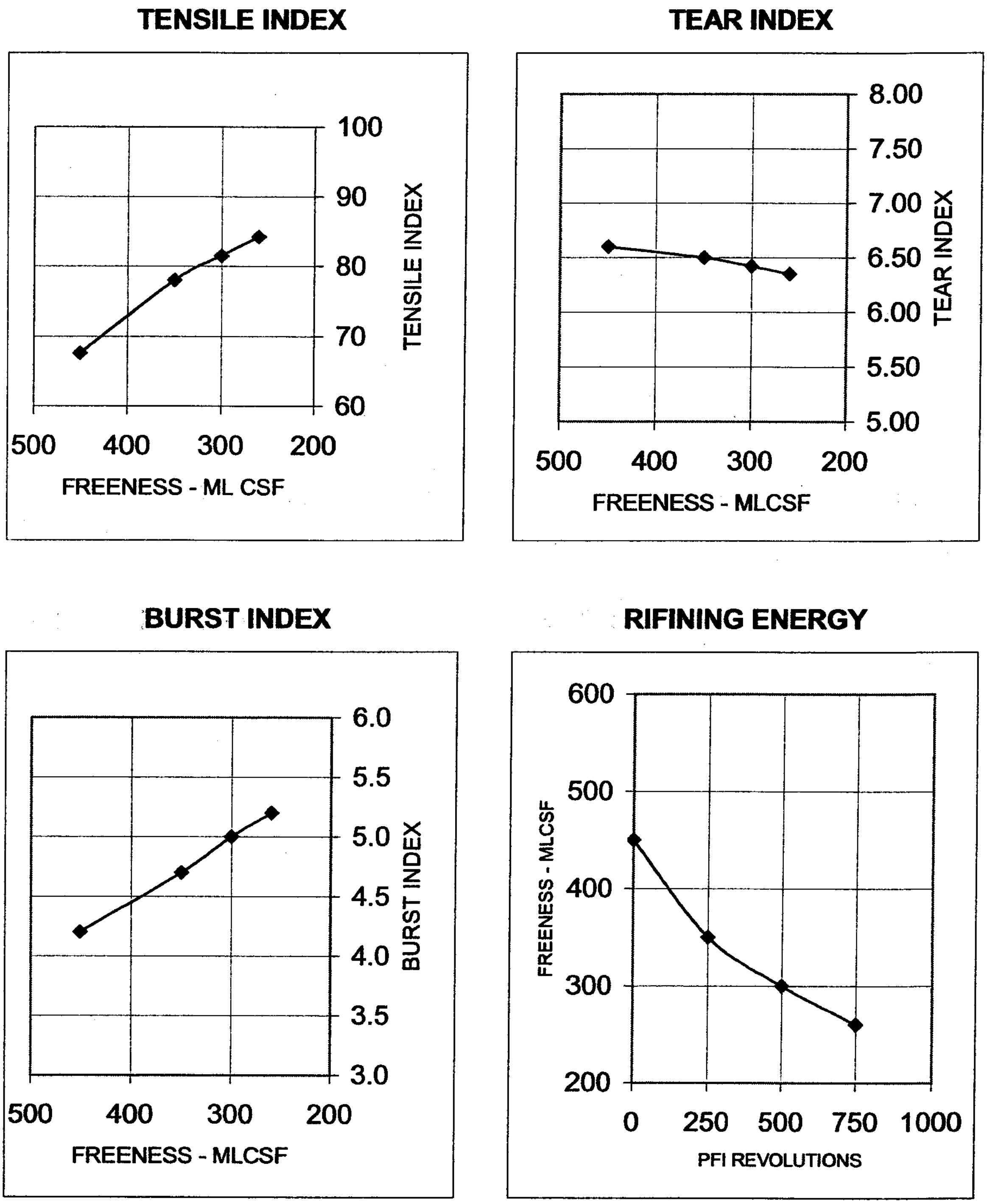
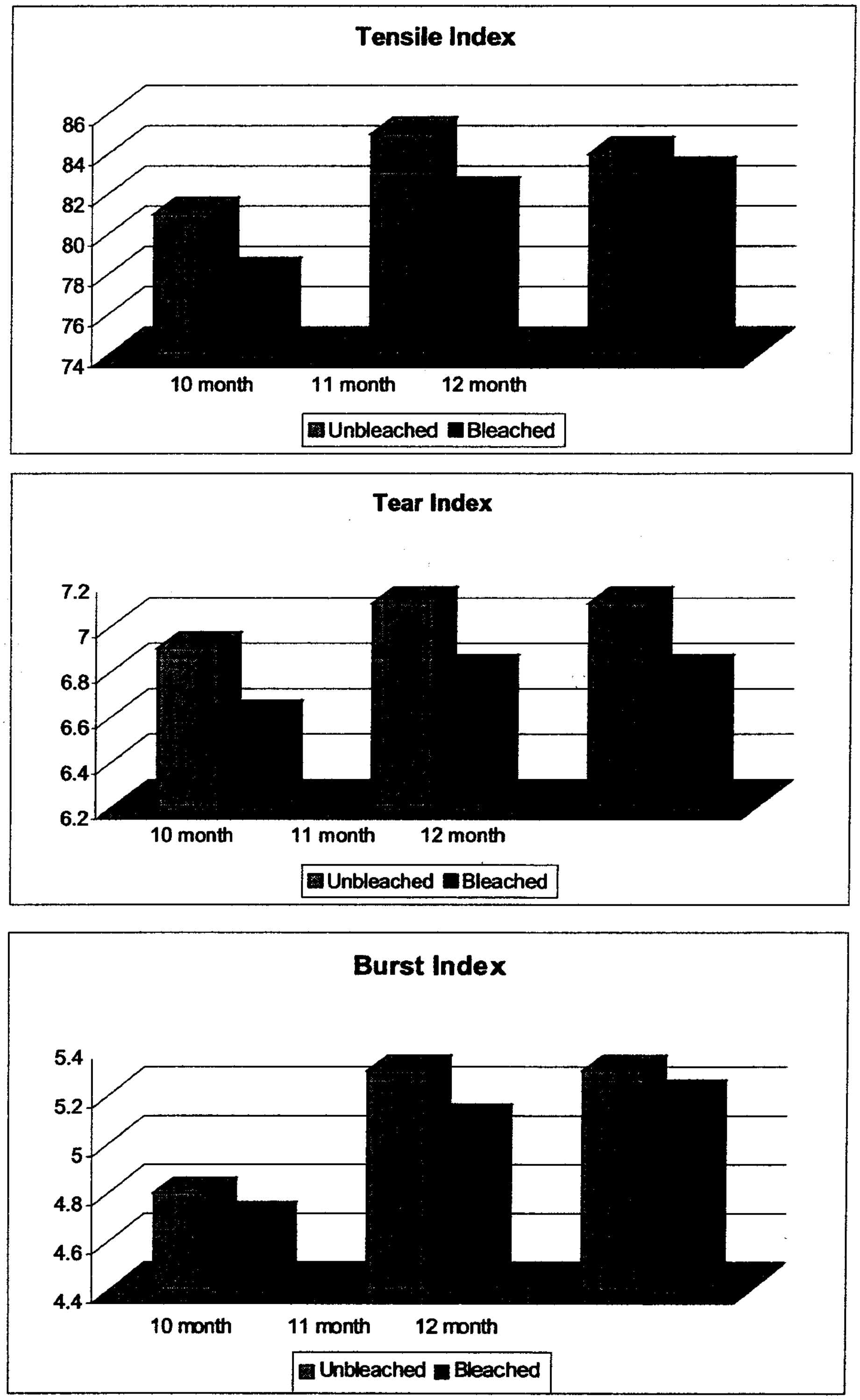


Figure: 23 Strength properties of *Erianthus arundinaceus* clone SES 159 cane bagasse at 300 mL CSF.



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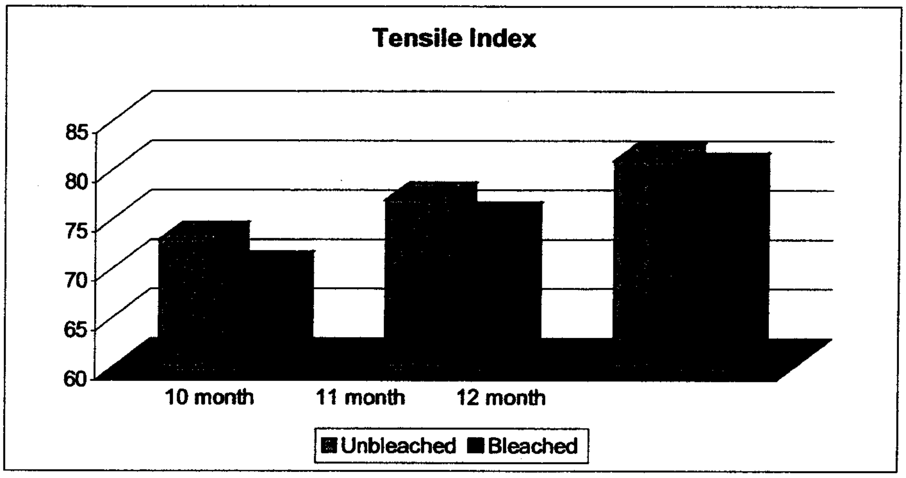
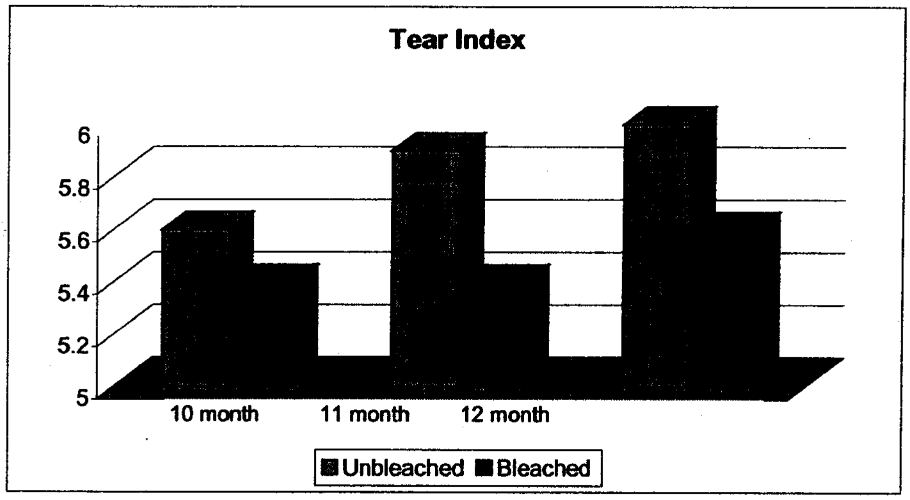




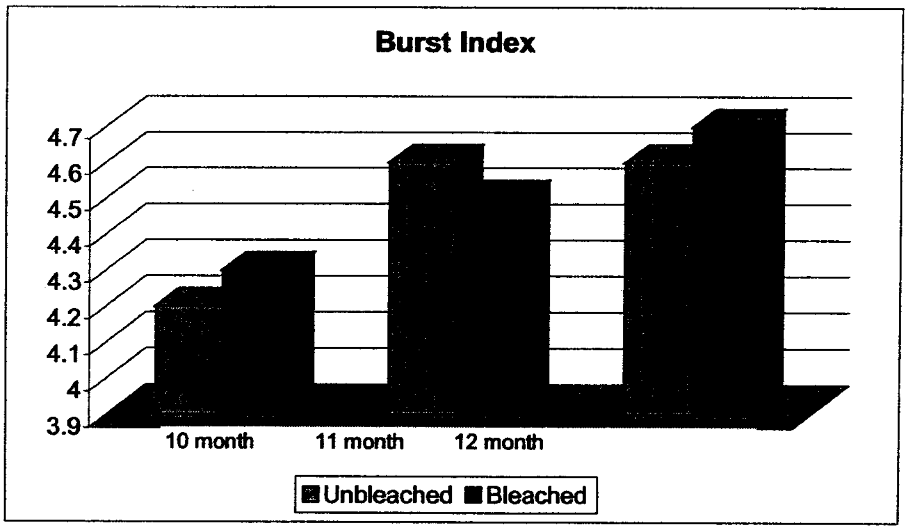


Figure: 25 Strength properties of *Erianthus arundinaceus* clone SES 159 whole plant bagasse at 300 mL CSF.

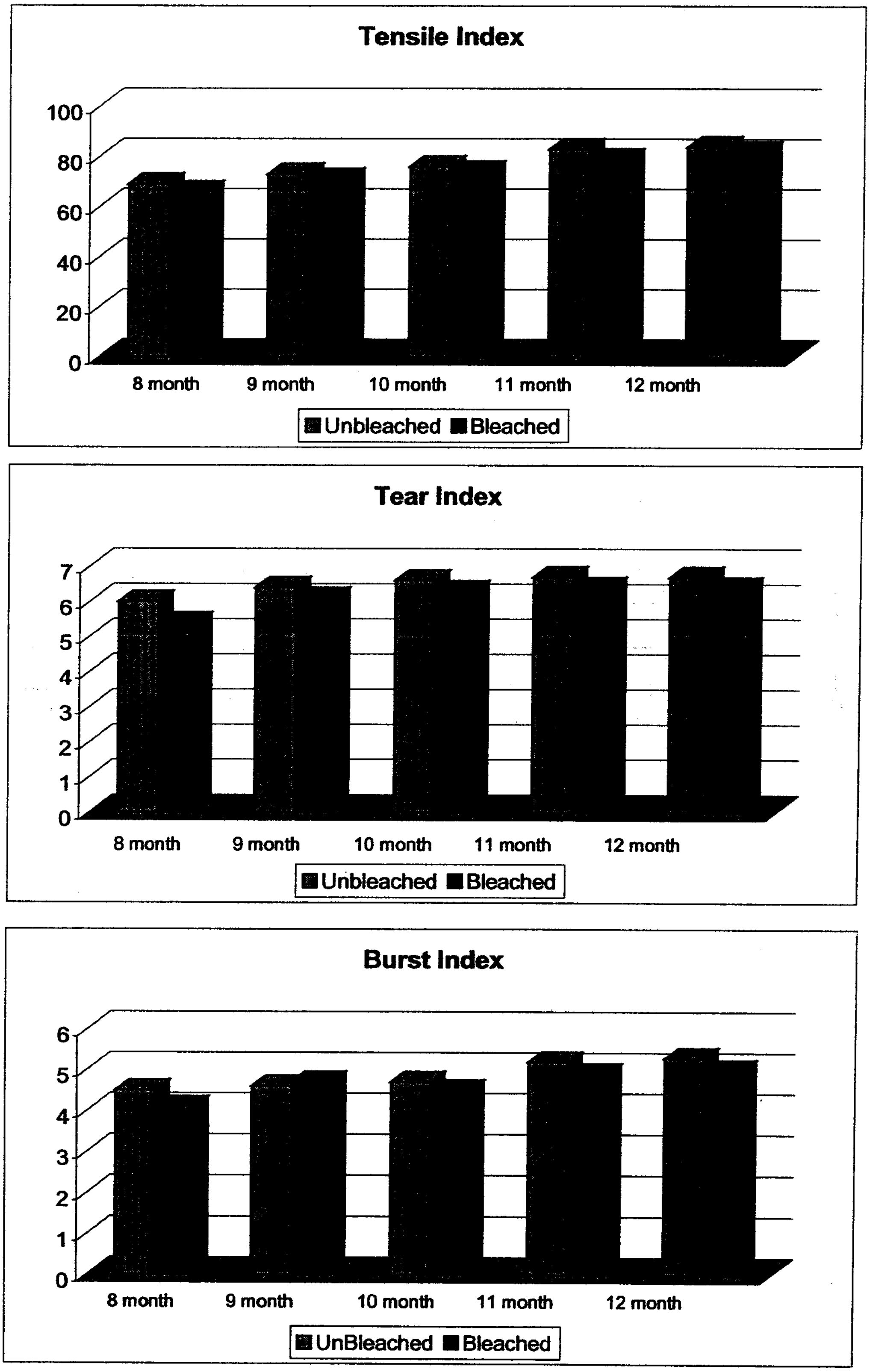


Plate 1

Plate 2

Plate 3

Plate 4

Plate 5

Plate 6

Plate 7

Plate 8

Plate 9

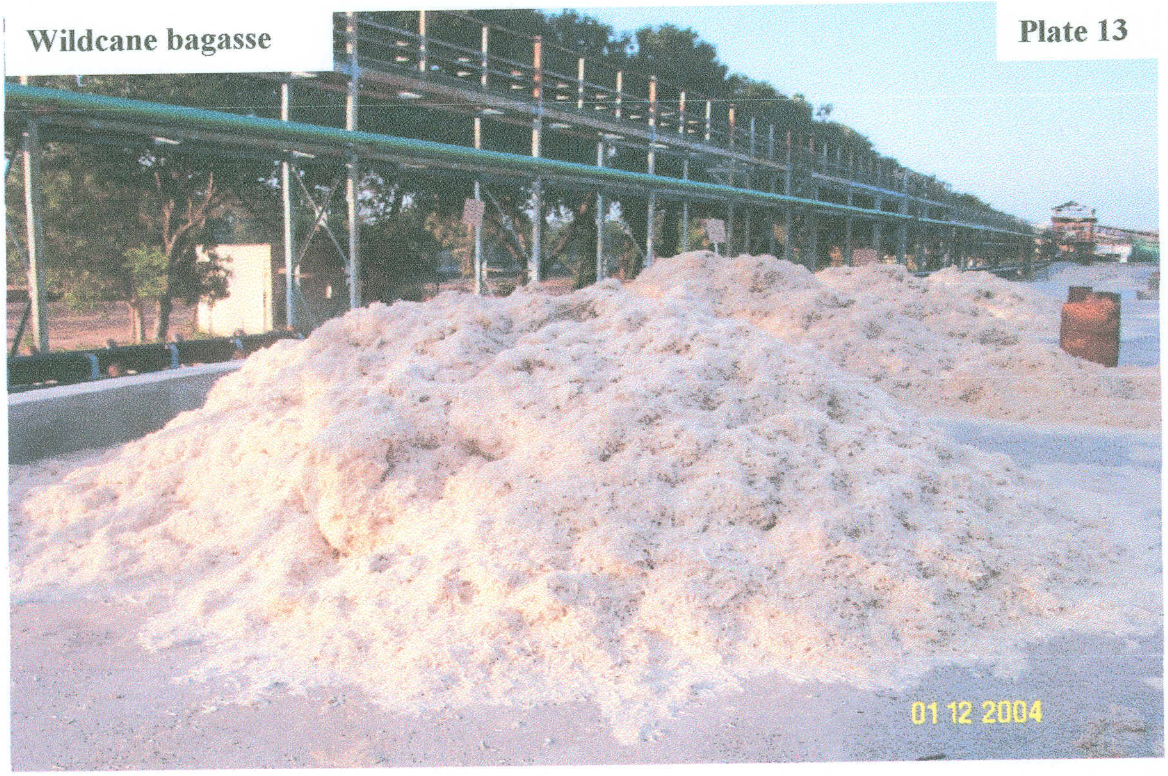
Plate 10

Wildcane harvesting **Plate 11**

Wildcane harvesting **Plate 12**

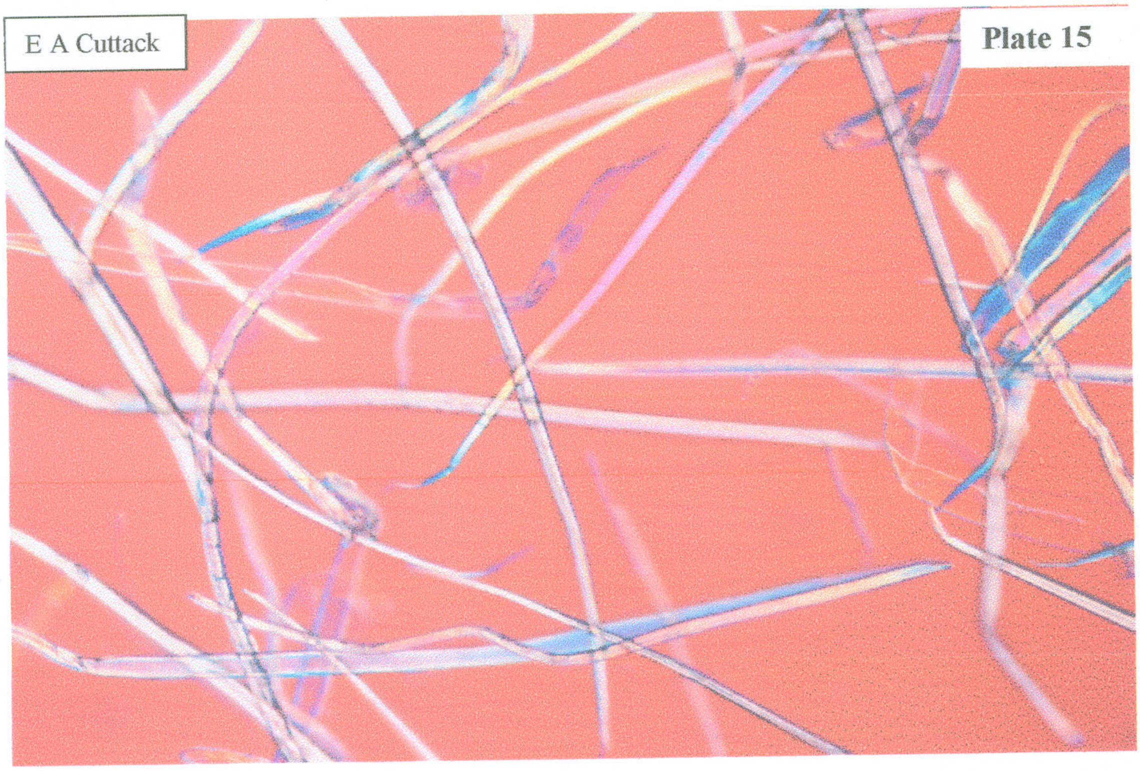
Wildcane bagasse

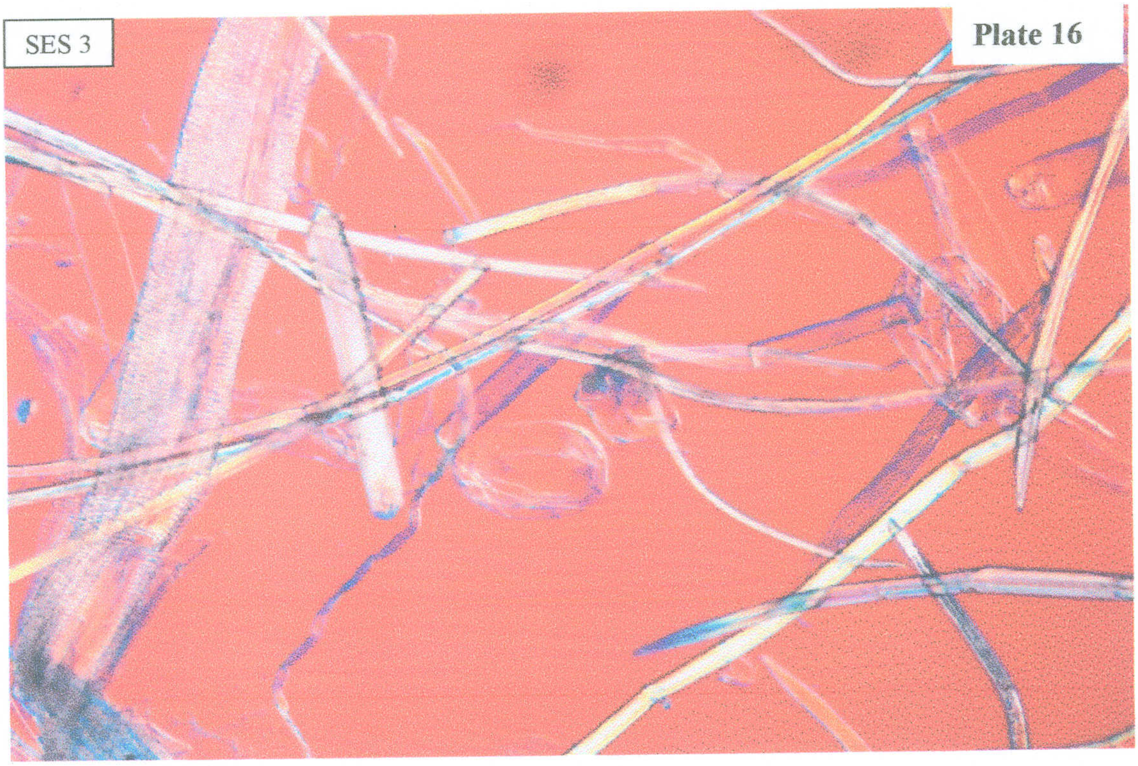
Plate 13



Wildcane bagasse

Plate 14





Photomicrograph of the pulp made from SBI clones

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Plate 17

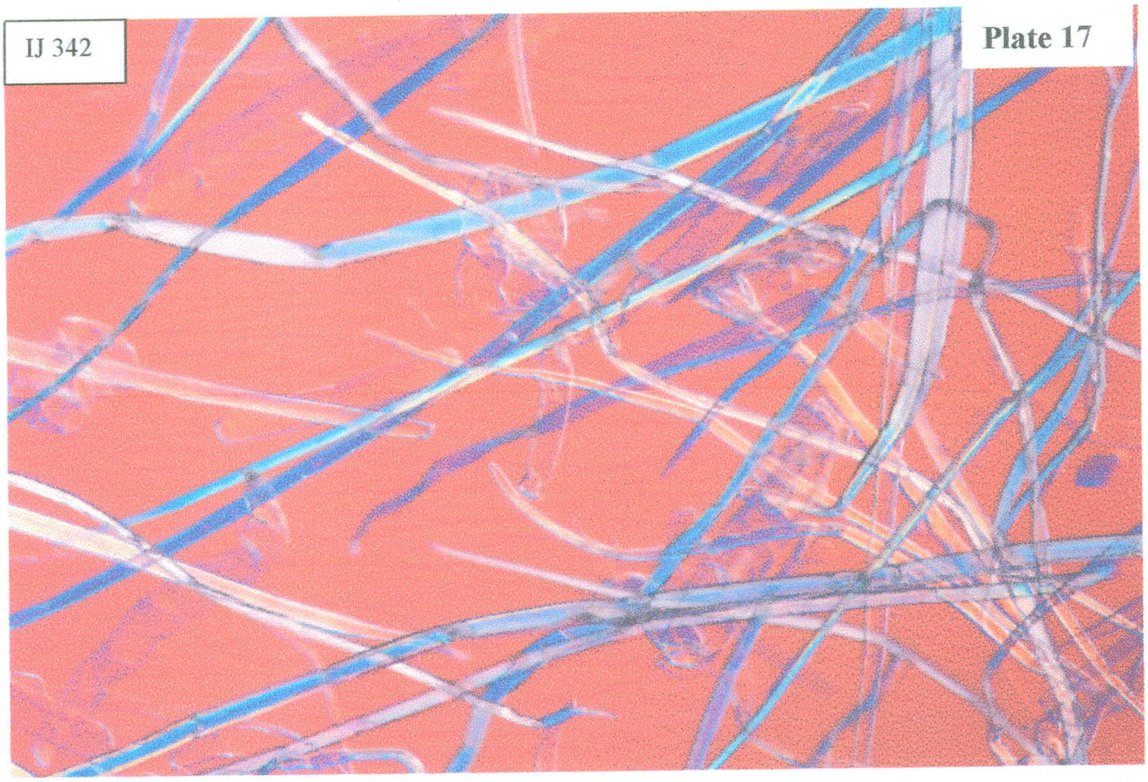

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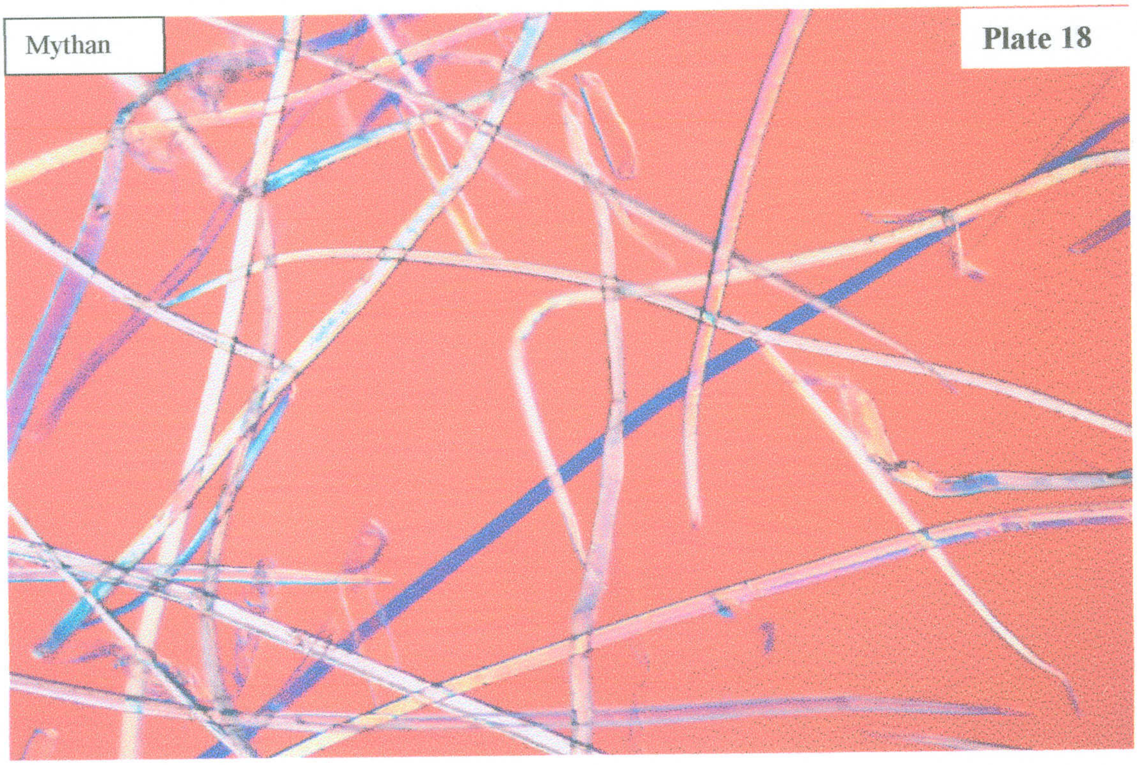
Plate 18



Photomicrograph of the pulp made from SBI clones

SES 159

Plate 19

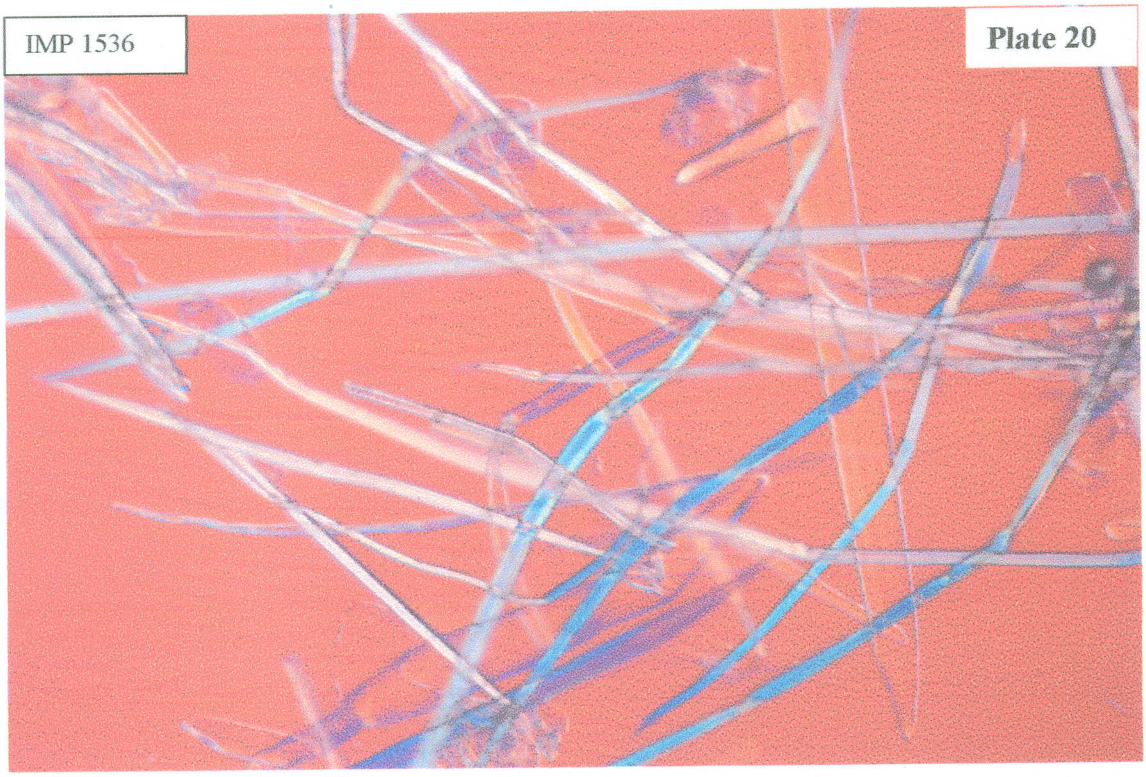


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Plate 20

Plate 21

Plate 22

Plate 23

Plate 24

Plate 25

Plate 26

Plate 27

Plate 28

Plate 29

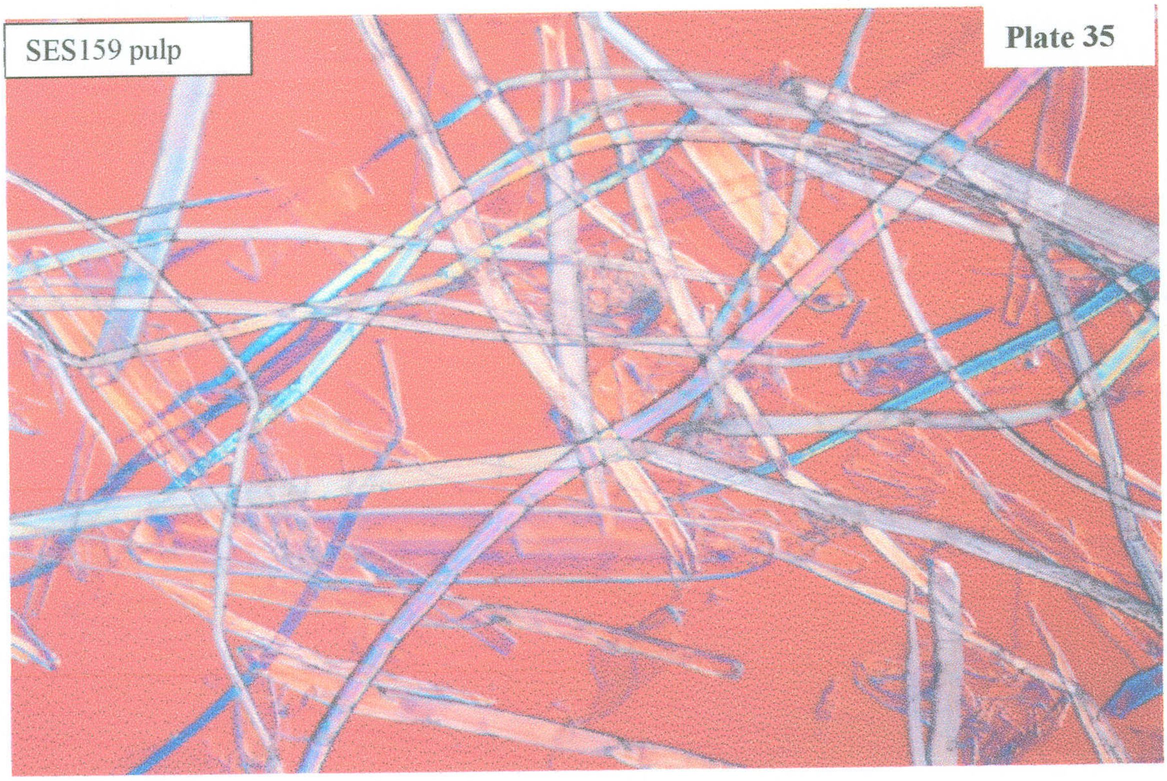
Plate 30

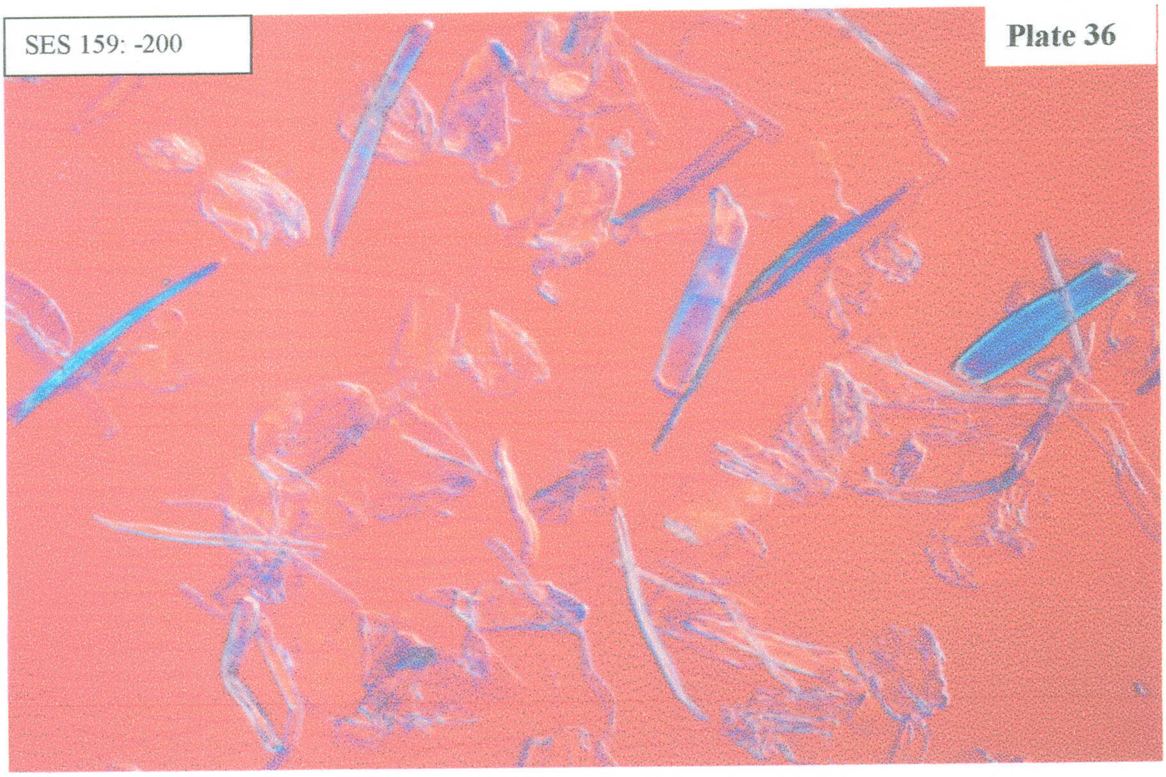
Plate 31

Plate 32

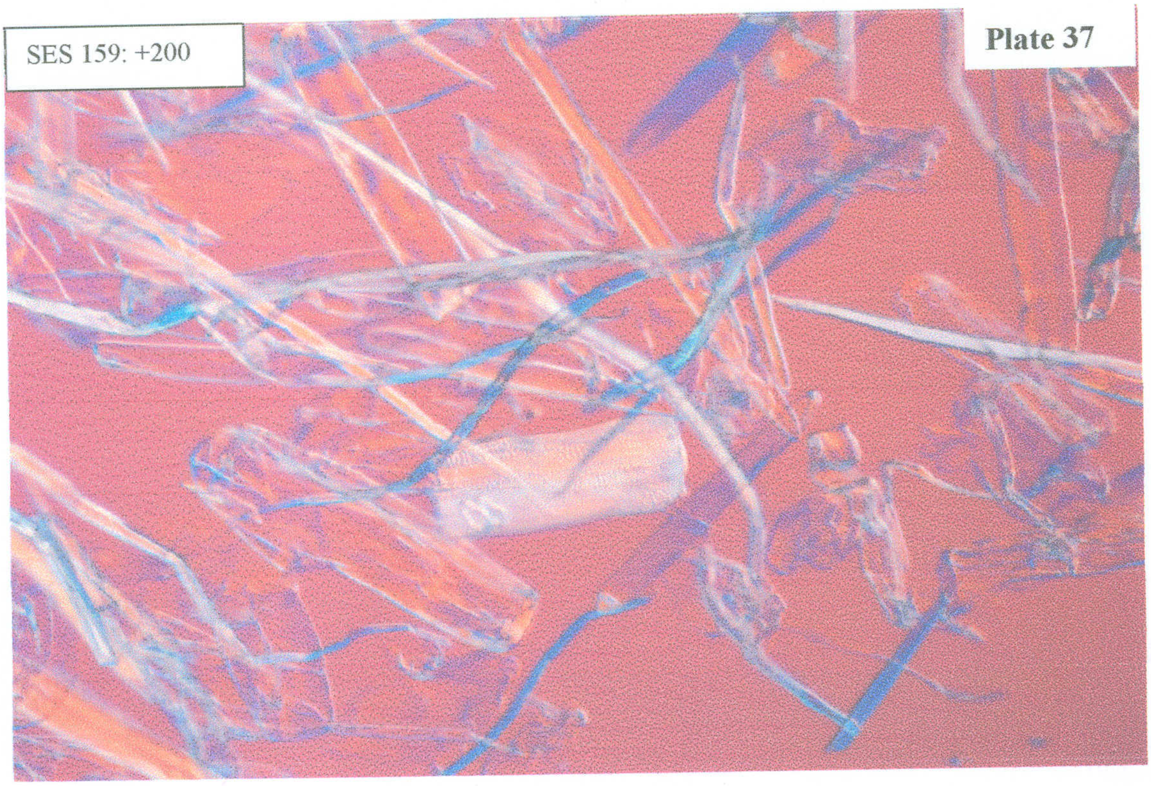
Plate 33

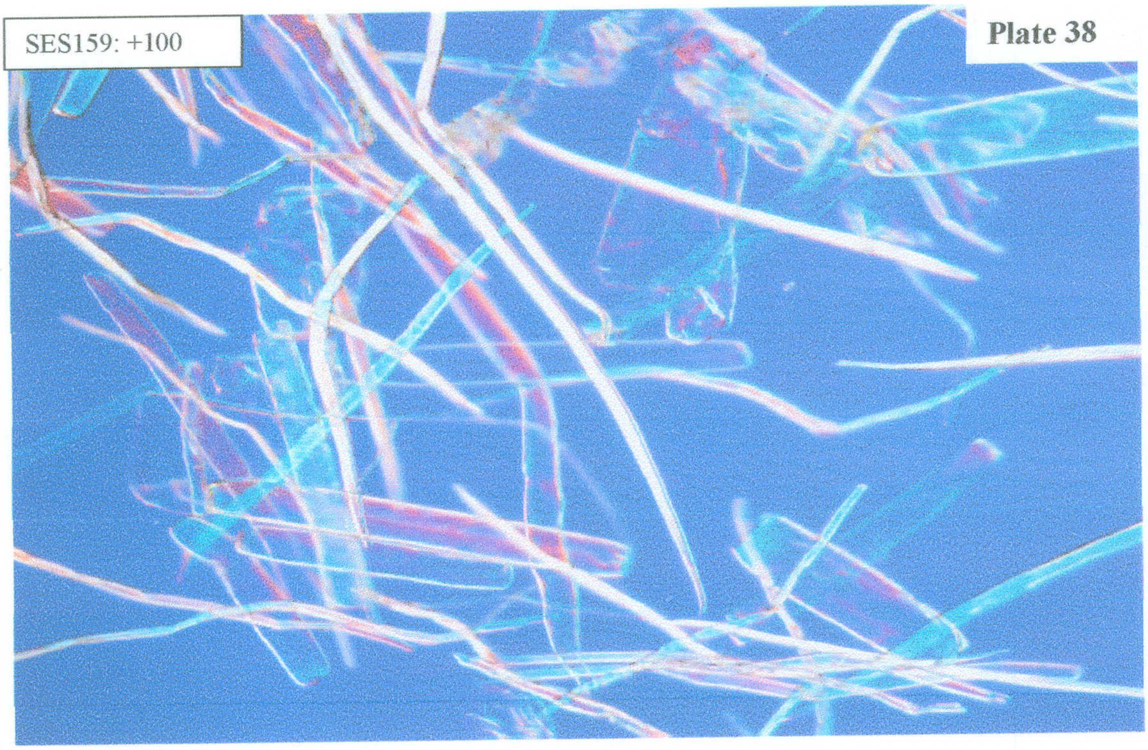
Plate 34





Photomicrograph of SES 159 pulp fibre classification





Photomicrograph of SES 159 pulp fibre classification

Plate 39

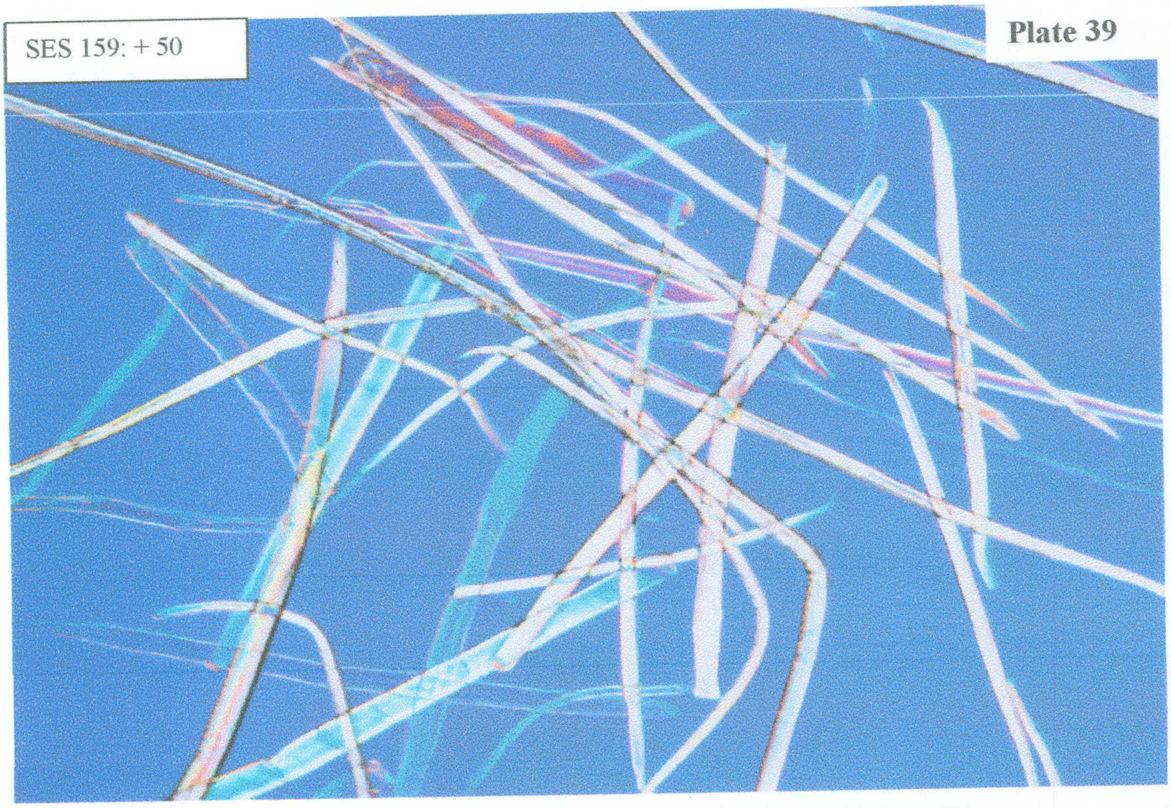
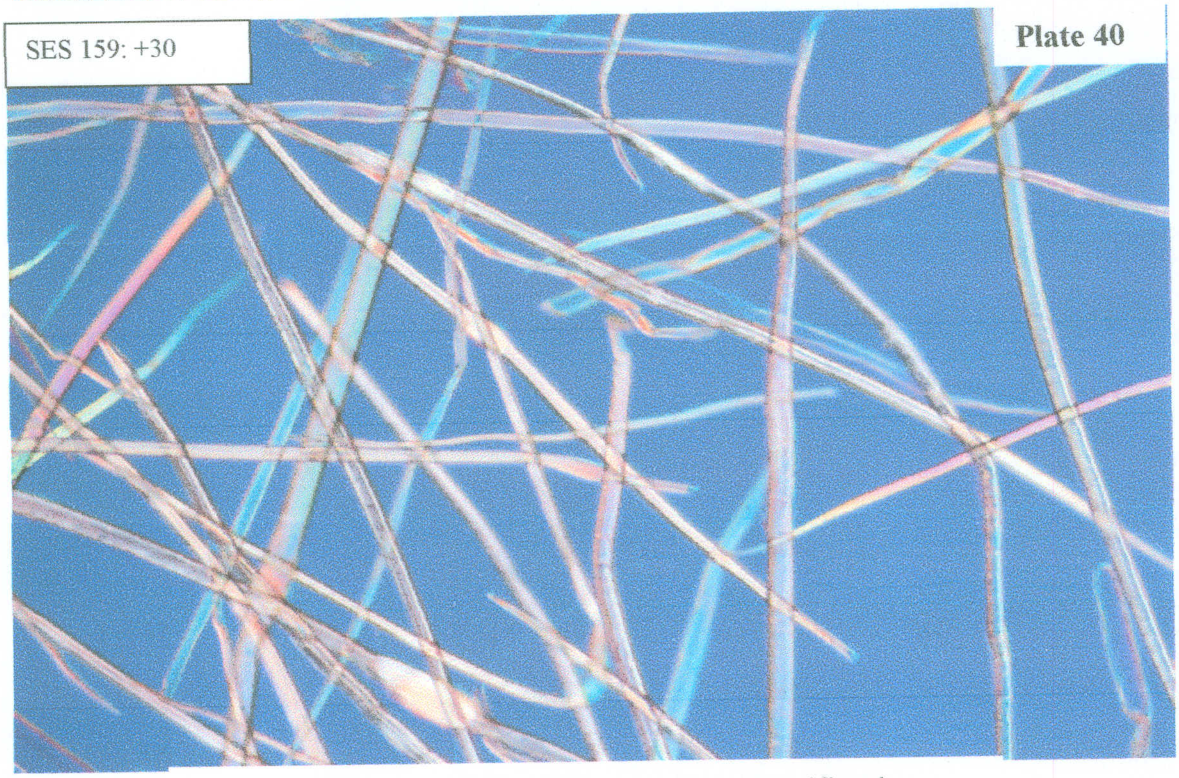


Plate 40



Photomicrograph of SES 159 pulp fibre classification