

SRA Research Project Final Report



Sugar Research
Australia

Research Funding Unit

Cover page

SRA project number:	GGP063
SRA Project title:	Investigating renewable feedstock's such as (Hibiscus Cannabis – Kenaf and Crotalaria Juncea – Sunn Hemp) for generation at Mackay Sugar Limited.
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Body of the Report:

Executive Summary:

As the Australian sugar industry embarks on the opportunity to value add from its waste streams our industry will become more sustainable into the future. This project has investigated the opportunity to replace the coal feedstock at the Racecourse Mackay Sugar co-generation facility with fibre, produced from fibre crops such as Kenaf and Sunn Hemp to power the steam boiler to generate electricity. The co-generation unit produces 31mwh of electricity and is powered by bagasse the waste stream from the sugar process and coal when the bagasse runs out. 30,000 tons of coal is burnt firing the steam boiler to generate electricity in conjunction with bagasse, the coal feedstock would require 90,000 tons of fibre to allow for the total replacement of coal. The fibre feedstock would also attract a green certificate value as the product is a renewable source.

Mackay Fibre Producers (MFP) has produced the fibre crops for testing at Mackay Sugar, it has also investigate how the product would be prepared to allow it to be handled by the current bagasse handling system at the sugar mill. MFP produced Kenaf and Sunn Hemp for trials to be tested by Mackay Sugar, samples were taken and analysed by SGS lab to determine the combustion test and the residues left after the burning of the product. MFP has tested two harvesting processes and presented the two forms to Mackay Sugar. The bulk density of the two forms of product have been established, this information will be utilized in the business case. The MFP grower group has worked with members of the engineering and management team at Mackay Sugar Limited to develop the results compiled by this project.

MFP has successfully produced Kenaf(cannabis hibiscus) and Sunn Hemp (crotalaria juncea) for testing at the Racecourse Mackay Sugar factory and delivered the product in a billet form as well as a foraged state.

The kenaf hasn't successfully flowed through the bagasse handling system, the fibre stands wrapped with componentry which could not be tolerated having the potential to choke feed systems. The chlorine value's of Kenaf were also outside the boiler specified levels which would have a detrimental effect on corrosion within the boiler. At this stage Kenaf would not be suitable as a feedstock to produce co-generation.

However Sunn Hemp has met the feedstock criteria's from the perspective of flowing through the current bagasse handling system, chlorine levels are also at an acceptable level, the product calorific value will also meet an acceptable level. Sunn Hemp could be an alternative feedstock for the co-generation unit at the Racecourse Mackay Sugar Co-generation unit.

Background:

Mackay Sugar Limited (MSL) announced approval of its co-generation project recently which will be a turn-key operation to be commissioned in February 2013. MSL will utilise bagasse and coal as their feedstocks to power boilers to produce electricity.

This GGIP project will investigate the feasibility of replacing the coal feedstock with Kenaf and Sunn Hemp fibre which will be produced locally and is a renewable feedstock source. Mackay Fibre Producers (MFP) investigations have found that bagasse and fibre crops when burnt for energy have similar heat exchange qualities, this is measured by the amount of Kilojoules of energy produced from 1 kg of product when burnt. This research has been undertaken in Italy and indicates that 17,000 KJ of energy produced from 1 kg of kenaf product (www.vt.tuwien.ac.at/biobib/fuel115.html).

It is anticipated that 50 – 70 tonnes of product is required to operate the sugar mill boiler for one hour, 600 tonnes of fibre products will operate the boiler for approximately 10 - 12 hrs.

MFP has completed a GGIP project which produced an agronomic and economic assessment into producing fibre crops in the central region. This project will build on SRDC's previous investment (GGP024).

This previous GGIP project (GGP024) developed the confidence of growers to produce fibre crops in the central region. The biomass produced by both Kenaf and Sunn Hemp in this project equaled or surpassed productivity levels produced by other countries.

The sugarcane farming system allows for fibre crops to be grown in rotation and they will enhance the productivity of the following sugarcane crop. The production window for Kenaf and Sunn Hemp fits extremely well with sugarcane, planting in September and harvesting March to April allows for industry utilisation of miller, harvester and grower infrastructure. This concept will value add to all industry stakeholders. Investigating this market option has the ability to increase profitability for growers, harvesters and transport sectors.

Objectives:

- To establish if fibre crops (Kenaf and Sunn Hemp) are compatible to current co-gen feedstocks such as bagasse and coal
- To determine what efficiencies and gains can be produced by specifically replacing the coal feedstock with fibre crops
- To identify and test product (Kenaf and Sunn hemp) suitability for transport, receivables (i.e the area at the mill that receives the product) and entry into mill boiler, storage and harvest logistics
- Conduct combustion tests for both Kenaf and Sunn Hemp
- Determine the amount of product (Kenaf and Sunn Hemp) required to replace the coal feedstock at Mackay Sugar Limited
- Develop a pest management program that will allow for the propagation of Sunn Hemp and Kenaf seed for planting

- Prepare a business case that will identify the transition of producing a renewable feedstock for co-generation that will replace the coal feedstock, and that will take this concept into a commercial venture.

Methodology:

Outline of project process;

- Produce Sunn Hemp and Kenaf fibre crops
- Establish a pest management (insect spray program) system for Sunn Hemp
- Record and document input costs to produce crops.
- Prepare fibre crops to enable current bagasse handling system to function without modification.
- Determine the bulk density of Kenaf and Sunn hemp for both harvesting methods.
- Prepare transport logistics
- Document energy produced for both Kenaf and Sunn Hemp
- Prepare feasibility of replacing coal feedstock with Fibre at the Racecourse Sugar Mill (Mackay Sugar)

Bayer Crop Science (Tim Murphy)

6810 John Deere Forage harvester

7700 CaseIH cane harvester

Hand cut samples (yield)

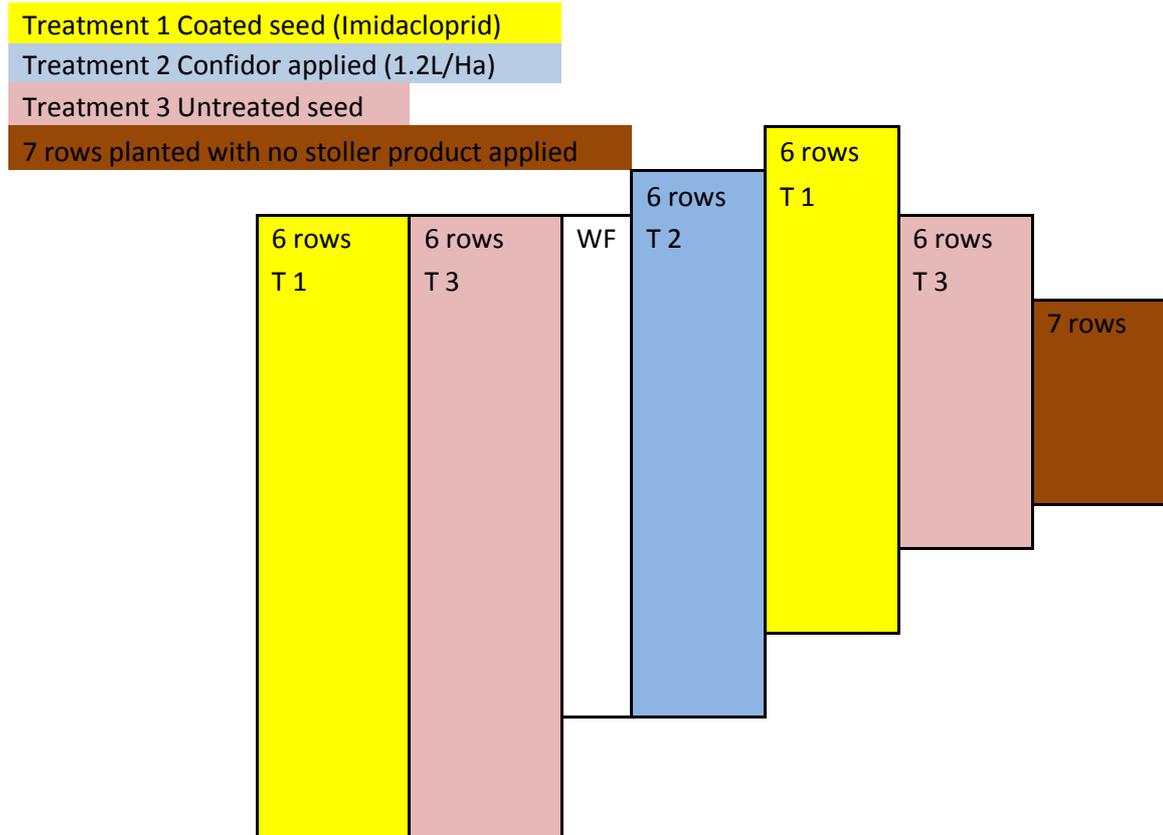
SGS Australia Pty Ltd (combustion and residue tests)

Outputs:

The Sunn Hemp seed trial site was planted on Joe and Christine's Muscat farm with a specific focus on managing pests within the growing and podding period of the crop cycle. In past seed crops planted by MFP it has been noted that crotalaria moth and crotalaria pod borer are of great concern to the seed production.

Sunn Hemp seed production trial site

Plant date 25/5/2011 Farm 4533B Block 11-2



Planting rate 12 kg / ha

Group M

innoculant

All treatments have stoller product applied except the last 7 rows

Stoller product

Biofordge 1.2L/ha

Clearstart 15L/Ha

Zinc 2L/ha

Copper 0.5L/ha

Trial Aim

MFP in conjunction with Tim Murphy from Bayer Crop Science, are to develop a pest management strategy to successfully propagate Sunn Hemp seed.

Sunn Hemp issue;

In past seed crops seed has been extensively damaged by insects mainly crotalaria pod borer, which lays its eggs on a freshly formed pod, caterpillar hatches in 3 to 5 days and then bores into the pod and feeds on the developing seed inside the pods, the caterpillar then pupates inside the pod and then the moth exits the pod and the cycle starts again, cycle time is about 14 to 16 days. End result in past seed crops is 25kg of viable seed from 2 ha site

Treatments were determined to build systemic resistance to insect damage, throughout the life of the trial no evidence was demonstrated in any of the treatments. Insects were apparent over the whole trial site



Photo 1
Sunn Hemp flowering 79 DAP



Photo 2
Distinctive yellow flower produced by Sunn Hemp from which pods will Develop.

Tim Murphy from Bayer Crop Science visited the trial site to develop a spray program to protect seeds from insect damage. The trial site was scouted and insects were identified, thifts, red banded shield bugs, crotalaria moths and crotalaria pod borer.

The spray program developed by Tim in Table 1 will be varied as per insect pressure and pod set by the Sunn Hemp plants

Days	Product	Rate
0	Belt Wetter	100ml/ha
7	Belt Wetter	100ml/ha
14	Success II Wetter	300ml/ha
21	Success II Wetter	300ml/ha
28	Belt Wetter	100ml/ha



Table 1
Spray table prepared by Tim Murphy Bayer

Photo 3
Heavy podding 139 DAP

Belt 480 SC

Active Constituent, 480 g/l Flubendiamide

Monitor crops and commence insecticide applications once local economic spray thresholds are reached. Apply at egg hatch in crops with nil thresholds for damage. Otherwise, apply at egg hatch or very soon after egg hatch to target young larvae. For potato moth (tomato leafminer), commence sprays when young larvae are first detected in leaves. Use the higher application rate during periods of moderate or high pest pressure or where extended spray intervals are used. Generally, spray intervals of 7 - 14 days are suitable. A maximum of three applications may be applied to any one crop, within a time period of not less than 14 days.

Success 2 NEO

Active Constituent, 120g/l Spinetoram

Carefully monitor crops for eggs and larvae of pest species by regular field scouting. Target sprays against mature eggs and newly hatched larvae when numbers exceed spray threshold. Apply repeat applications at 7-14 days intervals as new infestations occur or as specified under critical comments.

Both insecticides are targeting egg lays and hatching eggs of both the crotalaria moth, crotalaria pod borer, as both of these insects deliver devastating damage to Sunn Hemp seeds.

Treatment / Activity	Application date
Plant trial	25/5/2011
Spray pre-emergent 2.25L/ha Clincher plus 1L/ha Triflan 1L/ha Powermax 0.5L Activator	29/05/2011
Sunn Hemp started flowering	04/08/2011
Spray insects Belt 100mls / ha 0.5L activator	10/09/2011
Spray insects Belt 100mls /ha 0.5l activator	18/09/2011
Spray insects Success 2 300mls / ha 0.5L activator	24/09/2011
Spray insects 2L/ha lannate	04/10/2011
Heavy podding evident	11/10/2011
Spray insects Success 2 300mls /ha 0.5L activator	16/10/2011
Spray insects Belt 100 mls / ha 0.5 L activator	26/10/2011
Spray insects 500mls / ha Decis Options	03/11/2011
Spray insects Belt 100mls/ha 0.5 L activator	11/11/2011
Desiccate Sunn Hemp 3.5L / ha Firebolt 1.5 L deluge	01/12/2011
Harvest Sunn Hemp	08/12/2011

Table 2
Highlights trial work program



Photo 4
Harvested Sunn Hemp seed pre-cleaning

This seed propagation has been successful from the prospective of seed production, seed yield is light due to some shade out by large tree's. Harvested seed has been sent to Regal Seeds and Grain to be cleaned , graded and bagged.

At this stage 7 ha at Joe Muscat's property has been planted with Kenaf and Sunn Hemp, 2.5 ha to Sunn Hemp and 4.5 ha planted to Kenaf. This site was planted on the 26th of October 2011 with excellent emergence of both Kenaf and Sunn Hemp. Photo's below demonstrate the emergence and establishment of trial sites. Both the Kenaf and Sunn Hemp are progressing very well with excellent crop prospects.



Photo 5
Kenaf at 7 DAP (Days After Planting)



Photo 6
Sunn Hemp 7 DAP



Photo 7
Kenaf at 14 DAP



Photo 8
Sunn Hemp at 14 DAP

Prepare a production plan for each site, including planting rate, nutrient plan, herbicide plan.

Both trial sites selected have been previously planted to sugar cane and would be considered as a normal fallow period in a sugar cane production cycle.

MFP production plan of Kenaf and Sunn Hemp consists of;

Preparation of field that will allow for water infiltration, seed to soil contact at planting, reduced weed pressure, establishment of beds to allow for effective harvesting, irrigation, water logging resistance.

This production plan would be implemented at both sites.

1. Block preparation

- a. Cane trash residue left behind from harvesting sugar cane as been incorporated into the soil
- b. Soil tests, packametra and nematode counts have been taken to determine the current state of each site, from this information a nutrient plan would be developed.
- c. Each site has been; offsetted to incorporate trash residue, deep ripped to allow for good water infiltration and cultivated to establish good seed to soil content and minimal clodding that will improve herbicide pre-emergent's to be effective.

2. Nutrient plan

- a. Soil assays would provide the basis of block nutrient plans, Our trial site would be incorporating both Kenaf and Sunn Hemp, both crops will require different nutrient plans because Sunn Hemp is a legume and will develop it own nitrogen through nodulation. Soil tests are attached as Appendix 1. Nematode and Packametra assays are attached as Appendix 2.
- b. Kenaf nutrient requirements will require more nitrogen than Sunn Hemp, our target yield will also determine nutrient required. Kenaf nutrient application was as follows;
Nitrogen : 170 kgs per hectare
Phosphorus; nil
Potassium; 108 kgs per hectare
Sulphur; 17.6 kgs per hectare
The product applied was Econo LOS dunder at 4 m³ per hectare, this was applied at pre-planting onto the beds. The target yield is 65 – 75 tons per hectare fresh weight.
- c. Sunn Hemp nutrient requirements have been established from prior experience when producing Sunn Hemp, nutrient application is as follows;
Nitrogen : 20 kgs per hectare
Phosphorus: 8.8 kgs per hectare
Potassium : 71.5 kgs per hectare
Sulphur : 13 kgs per hectare
The product applied was Soy starter dunder at 2.5 m³ per hectare, this was applied pre-planting onto the beds. The target yield is 55 – 65 tons per hectare fresh weight.

3. Herbicide plan

- a. As with any crop production weed management becomes a vital component of the crop cycle, with both Kenaf and Sunn Hemp registered herbicides are not evident so as done in the past an experimental approach is adopted and past experience is relied upon. Work conducted in GGP024 identified that Dual Gold (Residual pre-emergent herbicide, Active Constituent: 960g/l S-metolachlor) at 1.5L per hectare gave the best pre-emergent result in a range of broad leaf and grasses that are normally present in a cane production system. GGP024 also identified Basta (Non

– Selective Herbicide, Active Constituent: 200g/l Glufosinate-Ammonium) as a good control for knock downs of broad leaf and grasses in Kenaf but was not applied in the Sunn Hemp situation. These two herbicides would form the basis of weed management in the two trial sites.

4. Insecticide control

- a. Kenaf is more susceptible to insect damage than Sunn Hemp, in the past Kenaf has been attacked by Monolepta (Red shouldered leaf beetle), this beetle is more prominent when the crop is 70 days old and younger, Carbaryl is registered for control of red shouldered leaf beetle in Kenaf. Both crops can be vulnerable to caterpillars such as loppers, heliothis and can be managed with an appropriate insecticide.

5. Harvesting

- a. Fibre crops such as Kenaf and Sunn Hemp need to be managed so that harvesting isn't left too late, if the plants are mature and the fibre's are matured it becomes difficult to harvest because of its rope like characteristics. MFP will prepare for harvest at the flowering stage so that harvesting will tackle immature fibre's. Both Kenaf and Sunn Hemp will be harvested with a sugar cane harvester, the modified chopper system will enable the cane harvester to chop the stalks into 45 – 55 mm billets. Each site has been planted onto raised beds to allow for effective harvesting with a cane harvester and will be hauled to Mackay Sugar by truck.

6. Planting rate

Planting rates were established after conducting seed germination and seed count per kg, armed with this information, MFP were able to calculate a planting rate.

Kenaf : germination 48%, seed count 34,000 seed / kg

Live seed count 16,320 seeds / kg, Target plant population 346,000 plants / ha

Kenaf planting rate 21.2 kg / ha, actual calibrated planting rate 21.44 kg / ha

Sunn Hemp: germination 85% seed count 30,000 seed / kg

Live seed count 25,500 seeds / kg, Target plant population 346,000 plants / ha

Sunn Hemp planting rate 13.56 kg / ha, actual calibrated planting rate 13.88 kg /

ha

Undertake crop management as per production plan

Plant 2 ha of Sunn Hemp, document production cost, determine yield achieved, determine crop moisture content, Transport to Mackay Sugar, transload crop into transport option, soil test, packmetra test.

Photo 9

Planting Sunn Hemp 6th Dec 2013 (21.7kg/ha)



Photo 10 Sunn Hemp (30 DAP)



Photo 11 Sunn Hemp 221 DAP



Photo 12
Harvesting Sunn Hemp (175mm Billets)



Photo 13
Sunn Hemp billets ready for transport to Mackay Sugar



Photo 14
Sunn Hemp Billets



Photo 15
Forage harvesting Sunn hemp



Photo 16
Foraged Sunn Hemp ready for transport to Mackay Sugar



Photo 17
Stock pile of Foraged Sunn Hemp



Photo 18
Trans loading Foraged Sunn Hemp



Photo 19
Trans loading Kenaf for transport to Mackay Sugar



Photo 20
Trans Loading Sunn hemp



Production Observations of Sunn Hemp (*Crotalaria Juncea*)

To accumulate high amounts of bio-mass Sunn Hemp requires planting into increasing day length which will maximise bio-mass accumulation. This site had excellent establishment as can be seen in Photo 2 and growth was very vigorous. Large amount of rain that fell in early March (541mm in four days) had an impact on bio-mass accumulation. This wet period killed areas within the trial site, next door to the Sunn Hemp site was a soybean variety plot trial which handled the wet quite well, demonstrating that Sunn Hemp will not tolerate extreme wet conditions.

The Sunn Hemp lodged at various stages through its growth, generally growing erect when the weather was good, fine and hot. Plants that were taller than 3.5m were more vulnerable to lodging, when Sunn Hemp lodges it doesn't present well for harvesting with a forage harvester, however lodge sunn hemp doesn't pose any issues for a cane harvester.

Once the crop had a canopy the weed pressure was reduced, although it was evident that some board leaf, (vines) were present in the crop. Established plant population was 216,000 plants per ha, which provided a stem size of 16mm in diameter. Sunn hemp didn't demonstrate any disease or insect related issues throughout its growth cycle.

Harvest ability:

The production time of sunn hemp is approximately 120/140 days, this crop was harvested in mid June, (221 DAP) which demonstrates that the crop will stand ready for harvesting without any deterioration, this harvesting trait reduces the risk of loss at harvesting.

Foraging sunn hemp proved to difficult where the crop was lodged, the 6 metre kemper front was unable to present the sunn hemp stalks to the chopper mechanism.

Photo 21

Kemper front on 6810 John Deer forage harvester choked with sunn hemp



These lodged areas were harvested with a cane harvester, as the fronts on a cane harvester are designed to manage lodge sugar cane crops.

Mackay Fibre Producers objective was to produce Kenaf and Sunn Hemp billets (45mm to 55mm) long for presentation to Mackay Sugar to burn in its steam boiler. It was a requirement by Mackay Sugar to present this product in short billets so that the product would be conducive to its baggase handling system. In the past MFP had experimented with a Toft 6000 cane harvester by placing two extra chopper blades on a flywheel to chop the fibre billets at 75mm length, this was successful and worked well.

In this project with a requirement to present the product at 45 – 55mm length billets it was decided that MFP would construct a new flywheel that would incorporate four blades which would chop the product at the desired length. Sammut Engineering was chosen for the job and the flywheel was constructed and fitted into a Toft 4000 cane harvester.

MFP also investigated building chopper drums that would house 12 blades per drum which would also present the product at the desired length. It was decided by MFP not to pursue this option as the construction cost would be \$50,000. EHS manufacturing was the engineering works which was approached to build these chopper drums, at the time of this research it was noted that a cane harvester in NSW had these drums fitted to it and was working in whole of crop harvesting.

Photo 22

New Flywheel with 4 blade holders constructed by Sammut Engineering



Photo 23
Flywheel fitted to Toft 4000 cane harvester



On the 1st of May 2012 the Toft 4000 was shifted to Oakenden where the Kenaf crop was ready for harvesting. The harvester would be trialled before Reg Simpkin transport would be engaged to transport the product to Mackay Sugar. When the cane harvester started harvesting the Kenaf it stalled out the chopper system. A number of attempts was made without success, what was happening the product was wrapping around the flywheel and stalling it out. MFP trialled the Kenaf crop in a number of places, the variance being the moisture content still without success, it was decide to abort this option.

Photo 24

Stalled chopper system in Toft 4000 cane harvester.



A small amount of product was harvested which Mackay Sugar had inspected, it was decided that it would not be suitable to trial in the boiler.

Photo 25

Product not suitable for the Mackay Sugar boiler



Photo 26
1996 Cameco This harvester is fitted with variable speed choppers, basecutters and roller train.



Photo 27
200mm billet from the 1996 Cameco



Photo 28

2012 Cameco variable speed rollers and 4 blade chopper drums



Photo 29

125mm billet length from the 2012 Cameco



Photo 29

Sample supplied from modified 24 bladed chopper drums Cameco harvester (Allan Partridge) NSW



Photo 30

82mm billet length 24 bladed chopper drum (NSW)

The sample supplied from NSW was trialled at Mackay Sugar, while the sample flowed through the current bagasse handling system and burnt on the grate without residue, it was decided not to pursue more product as the sample supplied was 82mm in length and the preferred length Mackay Sugar required was 45 – 55mm billet length.

Discussions held with Steve Lawn from EHS Manufacturing identified that it was physically impossible for 15” centre chopper drums to house more than 12 blades per chopper drum. It was then determined that it would not be possible to chop Kenaf at 45 – 55mm billets in length through a cane harvester. The objective was to present Kenaf and Sunn Hemp billets at 45 – 55 mm length billets to accommodate the current bagasse handling system, it would also determine that modifications to the bagasse handling system would need to happen to allow the 82mm billets to be utilised, this project would not have the scope to undertake such modifications.

MFP fallback position was to modify a 8610 John Deere forage harvester to cut kenaf at the desired billet length, this was completed and the forage harvester was used to forage the kenaf crop. The forage harvester had its chopping system modified with the removal of one third of its cutting blades, adjusting the paddles on the blower that would allow removal of the larger particles. The machine was tested with billets cut a 30mm average. The problem was that the cutting action of a forage harvester is a cutter blade driving past a stationary anvil which doesn’t deliver a clean cut and in fact with fibrous material it leaves stringy material which could pose some problems when handling the product.

Photo 31
John Deere 8610 forage harvester foraging Kenaf on the 6th of July 2012.



Photo 32
Kenaf foraged for delivery to Mackay Sugar.



Photo 33
Stockpile of foraged kenaf (approx 200tons)



A truck load was taken to Mackay Sugar to be trialled, the product was fed through the current bagasse handling system and was burnt in the boiler, it was observed that the fibre strands were wrapping on the distribution roller and it was feared that this could choke the supply into the boiler. Mackay Sugar's decision was not to feed any more of this product into the boiler.

Hand cut samples were randomly taken across the Kenaf block, 1.8m² samples were cut and weighed, results provided in table 1.

Table 3

Sample no	Weight in Kg	No of stalks	Average length (meters)	Tons per ha
1	6.65	44	3	36.94
2	12.68	38	3.5	70.44
3	10.92	33	3.5	60.66
4	4.9	35	2.6	27.22
Average result	8.79	37.5	3.15	48.81

Hand cut samples were taken prior to harvesting on the 30/04/2012, table 3 demonstrates sample results, moisture percentages of sub samples were taken and average moisture content was 70.84%. The achieved plant population was 208,333 plants per ha.

- Report on the results of factory trials undertaken in March/April 2012

Mackay Sugar Kenaf trial report.

Summary:

Mr. Joe Muscat harvested a trial plot of Kenaf with a Forage Harvester and delivered the harvested material to Racecourse to trial as boiler fuel.

Approximately 12 m³ of chopped Kenaf was burnt in No.2 Boiler at Mackay Sugar Racecourse Mill on June 7, 2012. The Kenaf was loaded into the bagasse system via No.6 Bagasse Belt with an end loader. The Kenaf was fed into the boiler by the bagasse feeder system. The Kenaf was wet and burnt slowly on the grate.

The Kenaf in the chopped form was very stringy and prone to tangling on rotating equipment. The Kenaf as delivered from the Forage harvester was not suitable as boiler fuel in large quantities.

Kenaf Trial Report:

A trial of burning Kenaf in suspension fired boilers was conducted at Racecourse Mill on June 7, 2012.

A small amount of Kenaf was harvested with a “Forage” harvester and delivered to Racecourse Mill. The approximate volume of chopped Kenaf delivered to the Mackay Sugar Bagasse pad was 12 m³. The Kenaf was harvested on June 1, 2012 and was added to the bagasse system 6 days later. The chopped Kenaf was exposed to 50 mm of rain during the period it was on the bagasse pad.



Photo 34 Kenaf prior to harvesting

The Kenaf was chopped into small sections 25 mm long and strands 200-400 mm long. These strands had a tensile strength similar to hemp string. The strands clumped together into a mat. The chopped Kenaf was loaded into the bagasse system by a Case loader with a 1.5 m³ bucket at 1:00 pm June 7. The Kenaf was loaded into No.6 Bagasse Belt and blended into the existing bagasse in circulation. The bagasse system was feeding No.2 Boiler, which was operating on bagasse only. The Kenaf was added to the bagasse system over the course of one hour. The Kenaf was metered into the bagasse system to avoid chokes.

Photo 35 Loading Kenaf into bagasse belt



Chopped Kenaf being added to the Bagasse System

The Kenaf was circulated through the bagasse system and then ploughed off into No.2 Boiler bagasse feed chutes. The Kenaf was ploughed off No.4 Bagasse belt without problems. The Kenaf did not mix into the bagasse and remained in a tight dense mass. The Kenaf was feed into the boiler via the bagasse feeders and was deposited on the grate where it was burnt. The Kenaf did not burn in suspension and was slow in combusting on the grate compared to the bagasse. The slower ignition and combustion rates were probably due to its high moisture content. No changes were observed in the boiler's performance due to the small amount of Kenaf burnt.

Due to the stringy nature of the chopped Kenaf some strands did remain on No.4 Bagasse belt ploughs. The long strands of the Kenaf looped over the plough shaft. Some of the Kenaf strands wrapped around a feed conditioning drum and overloaded the drive (No.2 boiler No.2 fluffier).



Photo 36 Kenaf removed from Bagasse Plough Shaft

Observations:

Chopped Kenaf was very stringy with strands 200-400 mm long. The Kenaf was very strong in tension and formed matted bundles. The Kenaf was wet due to its exposure to the rain. The chopped Kenaf did not blend in the existing circulating bagasse. The Kenaf burnt on the boiler grate at a slower rate than the bagasse.



Photo 37 Kenaf strands collected on Bagasse Plough

Kanaf Characteristics:

An analysis was conducted on the Kanaf to determine its suitability as boiler fuel. The results of the analysis were compared to previous bagasse analysis.

Table 4

	Kanaf	Bagasse
Moisture	41%	51%
Ash	3.4%	3.0%
Calorific Value (MJ/kg) as burnt	8.22 (approximately)	9.85
Gross Calorific Value (MJ/kg)	16.23	19.5

Chloride levels for the Kanaf are significantly higher than the bagasse levels. This may cause corrosion inside the boiler on the super heater surfaces.

Racecourse Mill Boiler Plant description:**No.2 Boiler:**

No.2 Boiler is a Riley Dodd designed boiler with a MCR of 150 tph on bagasse and 100 tph on coal. The bagasse is burnt in suspension and coal is burnt on the grate. The grate is a flat traveling grate. Both coal and bagasse can be burnt simultaneously to produce steam.

Bagasse System:

The bagasse system consists of a 900 tonne capacity rotary stacker, reclaimer bin. The bin is fed via No.1 Bagasse belt, and delivers bagasse to the boilers via No.3 Bagasse belt. The boilers are fed bagasse via feed ploughs on No.4 Bagasse Belt. Bagasse from the Mackay Sugar Stockpile is loaded into No.6 Bagasse Belt which discharges onto No.3 Bagasse Belt. The bagasse system operates in a closed loop and excess bagasse is returned to the storage bin via No.1 Bagasse Belt. The bagasse system has a capacity of 250 -300 tonnes per hour and the Bagasse Bin can reclaim approximately 100 tonnes per hour.

Results: Results on air dried basis except where otherwise stated

Sample Identification**SUNN HEMP**

Total Moisture 17.4%

Inherent Moisture 10.3%

Ash 2.5%

Total Sulphur 0.04%

Calorific Value 4024 kcal/kg

Chlorine 0.087%

ULTIMATE dry ash free basis

Carbon 48.4%

Hydrogen 6.08%

Nitrogen 0.61%

Ash Analysis (dry ash basis)

Silicon (as SiO₂) 45.5%

Aluminium (as Al₂O₃) 7.7%

Iron (as Fe₂O₃) 9.3%

Calcium (as CaO) 9.30%

Magnesium (as MgO) 4.96%

Sodium (as Na₂O) 2.47%

Potassium (as K₂O) 11.14%

Titanium (as TiO₂) 0.62%

Manganese (as Mn₃O₄) 0.29%
Sulphur (as SO₃) 3.13%
Phosphorus (as P₂O₅) 4.45%
Strontium (as SrO) 0.08%
Barium (as BaO) 0.37%
Zinc (as ZnO) 0.07%

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Sample Identification KENAF

Total Moisture 41.5%
Inherent Moisture 11.9%
Ash 3.4%
Total Sulphur 0.074%
Calorific Value 3890 kcal/kg
Chlorine 0.375%

ULTIMATE dry ash free basis
Carbon 49.0%
Hydrogen 5.85%
Nitrogen 0.54%
Ash Analysis (dry ash basis)
Silicon (as SiO₂) 22.9%
Aluminium (as Al₂O₃) 5.0%
Iron (as Fe₂O₃) 5.6%
Calcium (as CaO) 15.8%
Magnesium (as MgO) 10.7%
Sodium (as Na₂O) 3.07%
Potassium (as K₂O) 20.59%
Titanium (as TiO₂) 0.34%
Manganese (as Mn₃O₄) 0.50%
Sulphur (as SO₃) 7.7%
Phosphorus (as P₂O₅) 6.8%
Strontium (as SrO) 0.11%
Barium (as BaO) 0.26%
Zinc (as ZnO) 0.10%

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TABLE 5: Energy value of Kenaf, Sunhemp and Bagasse (SGS analysis)

	Kenaf May 12 sample	Sunhemp May 12 sample	Bagasse June 13 sample	Bagasse COGEN design
Moisture	41.5%	17.4 %	51.1%	51.0%
Ash	3.4%	2.5%	10.8%	3.0%
Gross Calorific Value (MJ/kg)	16.2	16.8	16.1	19.5
Chlorine %	0.375%	0.087%	NR	0.03%
Calculated values based on analysis				
Calculated Calorific Value (MJ/kg) as burnt	8.5	13.45	6.62	9.0

The calculated fuel value as burnt includes the loss of fuel value to higher moistures. It is noted that the 2013 bagasse sample with the high ash (due to high dirt levels in early season cane) has lost much of its fuel value due to that ash loading.

If the kenaff and sunnhemp were burnt only at 5% or 10 % by mass, then the overall chloride levels would be reduced to an acceptable range for continuous operation. Chloride levels of 0.1% are considered the maximum levels for fuels, with the average to be closer to 0.05%.



Photo 38

Sunn Hemp being shredded from billet form into small particles that will be conducive to Mill bagasse handling equipment



Photo 39

Terry Doolan Racecourse Factory Manager Mackay Sugar, Kenaf ready for testing through bagasse handling system at Racecourse Mill



Photo 40

Shredded Sunn Hemp ready for testing through bagasse handling system Racecourse mill



Photo 41 Product entering bagasse handling system



Photo 42 Bagasse belt feeding Kenaf into the Factory boiler

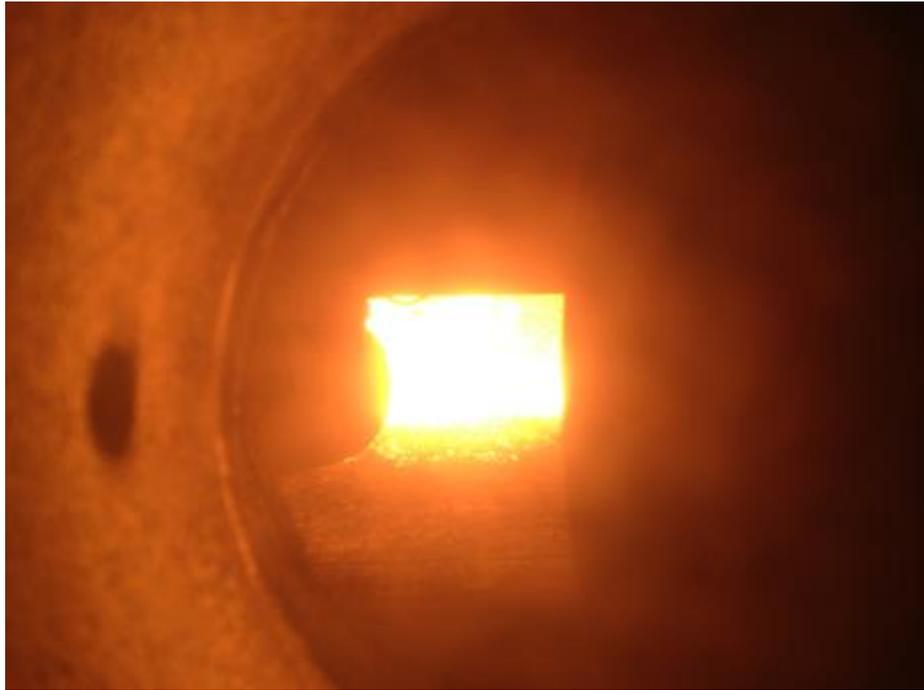


Photo 43 Kenaf being incinerated Racecourse Mill boiler

Collection of process control system data for input into factory model
 Review analytical reports(results of the factory trial, combustion test, residue results)

TABLE 6 Ash analysis of product on dry ash basis (SGS analysis)

	Kenaf May 12	Sunnhemp May 12	Wood chip1 May 13	Wood chip2 May 13	Bagasse design
Silicon as SiO ₂	22.9%	45.5%	31.8%	43.4%	49.7%
Aluminium as Al ₂ O ₃	5.0%	7.7%	7.3%	36.4%	8.6%
Iron as Fe ₂ O ₃	5.6%	9.3%	5.3%	7.9%	19.6%
Calcium as CaO	15.8%	9.3%	27.3%	5%	5.9%
Magnesium as MgO	10.7%	4.96%	10.2%	1.27%	7.4%
Sodium as Na ₂ O	3.07%	2.47%	3.25%	0.27%	0.6%
Potassium as K ₂ O	20.59%	11.14%	7.18%	0.41%	2.7%
Titanium as TiO ₂	0.34%	0.62%	0.24%	1.68%	0.1%
Manganese as Mn ₃ O ₄	0.50%	0.29%	1.6%	0.05%	0.7%
Sulphur as SO ₃	7.7%	3.13%	2.73%	0.61%	2.6%

Phosphorus as P ₂ O ₅	6.8%	4.45%	1.98%	2.23%	2.1%
Strontium as SnO	0.11%	0.08%	0.18%	0.08%	na-
Barium as BaO	0.26%	0.37%	0.18%	0.04%	na-
Zinc as ZnO	0.10%	0.07%	0.08%	0.02%	na-
Calculated Na+K as mg/kg dry fuel	13,751	24,289	652	34	2,020

Na: not assessed as significant

Due to the small quantities combusted in a larger quantity of bagasse, there were no differences observable in the boiler ash streams because of the addition of kenaff or sunnhemp.

The only observations that could be made are that the sodium and potassium levels in the kenaff and sunnhemp are much higher than desired for high furnace temperature operations (as a 100% fuel source), as it is likely that the furnace will be subjected to ash deposition on the superheater tubes. See reference: The Handbook of Biomass Combustion and Co-firing, VanLoo and Koppejan, 2008. In that reference the guideline is 3,000 mg/kg of combined alkali (Sodium and Potassium) per kg dry fuel. At a level of 5% by mass combined with bagasse, then the levels of alkali metals per kg dry wood reduce to 2636 and 2760 mg/kg, which is within the guidelines, and 10% mixes are just over the alkali metal guidelines.

The kenaf and sun hemp were combusted in a proportion that was small to manage the boiler stability. In this manner the process control system should not have noticed, and did not notice any variability, in the fuel mix versus normal bagasse fuel.

Kenaf was observed in 2012 combustion trials to have longer strands that wrap around the bagasse belts and bagasse feeders. In 2013, the bagasse feeders experienced fibre wrapping again. This fibrous nature means that the materials handling process in factories will not sustain extended operation with the material. Hence kenaff is not a suitable material in the physical form it is in, because of the rope like aspects it exhibits.

To be combusted, kenaff would require either

- a. its own feeding system into the boiler, such as a blower; or
- b. modification to the harvesting and chopping and size handling to reduce the rope like nature.

The strong rope like nature suggests that combustion is not the right end use for this product, and its future as a commercial crop should be considered more in those applications that value those characteristics eg insulation, mulching, ropes, and paper making.

Modify the factory model – to be undertaken by MSL engineers

Initially, the goal was to offset coal combustion in the off season, by using the biomass crops as a sole fuel replacement. Given the higher alkali and chloride levels in the biomass crops, this is not considered a viable option.

It is recommended that the above quality parameters are reassessed after removal of leaf material from the stacks to determine how much of the chlorides, sodium, and potassium are related to the stalk and how much with the leaf matter.

The operating technical model for fuel combustion was not modified. This was because the kenaf and sun hemp as standalone fuels have higher levels of chlorine than the combustion process can handle without inducing acid dewpoint corrosion on the air heaters and economiser. Otherwise the dynamic combustion characteristics appeared very similar to bagasse, provided that

- a. The moisture levels are similar to bagasse – 40 to 55% by weight
- b. The size fractions are similar to bagasse

The sugar mill receives cane and the cane is processed by

- a. the harvester to remove the dirt and leaf matter. The kenaf could have more leaf matter removed which is expected to reduce the chloride levels further.
- b. The shredder to make the size fraction smaller for sugar extraction, but not so small it will not flow as a mat. A similar processing step would be logical for kenaf or sunhemp to make the product the right size with purpose built equipment.
- c. Milling to extract juices and reduce moisture to the right level for combustion. For other crops that are wet at harvest time, milling is still an option, but will require flexibility to vary the work opening to be suitable for the much lower moisture biomass crop and a materials flow bypass direct to the bagasse belt. The juice disposal will be an extra load on the waste water system.

The sulphur levels measured in kenaf and sun hemp were at a level comparable with the cane values. This is important to manage the corrosion aspects of the existing flue gas processing installed at sugar mill boilers.

Review analytical reports(results of the factory trial, combustion test, residue results)

Table 7

	kenaff	Sunhemp	Wchip1	Wchip2	bagasse design	mixed W/W 5% kenaff & 95% bagasse	mixed W/W 5% sunhemp & 95% bagasse	mixed W/W 10% kenaff & 90% bagasse	mixed W/W 10% sunhemp & 90% bagasse	mixed W/W 5% kenaff, 10% woodchip & 85% bagasse	mixed W/W 15% sunhemp, 10% woodchip & 85% bagasse
Na	3.07%	2.47%	3.25%	0.27%	0.60%	0.72%	0.69%	0.85%	0.79%	0.84%	0.81%
K	20.59%	11.14%	7.18%	0.41%	2.70%	3.59%	3.12%	4.49%	3.54%	3.70%	3.23%
K+Na	23.66%	13.61%	10.43%	0.68%	3.30%	4.32%	3.82%	5.34%	4.33%	4.54%	4.04%
% ash	3.4%	17.4%	0.5%	0.4%	3.0%	3.02%	3.72%	3.04%	4.44%	2.77%	3.47%
% water	41.5%	2.5%	20.0%	19.4%	51.0%	50.53%	48.58%	50.05%	46.15%	47.40%	45.45%
"1-% water	58.5%	97.5%	80.0%	80.6%	49.0%	49.48%	51.43%	50.0%	53.9%	52.6%	54.6%
Na+K basis mg/kg on dry wood	13,751	24,289	652	34	2,020	2,636	2,760	3,248	3,571	2,388	2,567

Business Case

Business Case Content

1. Overview of concept
2. Sunn Hemp seed production
3. Production system
 - Training and support
 - Agronomy
4. Product Handling
 - Harvesting
 - Billets
 - Foraged
 - Transport
 - Storage
5. Quality control / payment system
6. Economics
 - Factory product requirement (fibre replacement of coal)

1. Overview of concept

Mackay Sugar commissioned a 31MhW co-generation unit at the Racecourse Factory in 2013, the steam driven alternator generating the electricity is fuelled by the waste stream from the milling operation of sugar cane called bagasse. The co-generation unit would operate all year and would require more bagasse to fuel the boiler than was available, for the period that bagasse isn't available the co-generation unit would utilise coal as a fuel source for the factory boiler. The approximate requirement is 30,000 tons of coal, which would be classed as a black fuel (non-renewable) not attracting any green certificate values for the project.

Mackay Fibre Producers was a local group of growers who were investigating fibre crop production in rotation with sugar cane and had been testing the production system in Mackay. MFP had undertaken agronomic assessments of producing Industrial Hemp (*cannabis sativa*), Kenaf (*cannabis hibiscus*), and Sunn Hemp (*crotalaria juncea*) in rotation with sugar cane. (SRDC project GGP024)

This project GGP063 (SRDC/ SRA) is investigating the replacement of the coal feedstock with either Kenaf or Sunn Hemp to fuel the Racecourse factory boiler to generate electricity. It is anticipated that 90,000 tons of fibre would be required if all the coal was replaced with fibre. It is also recognised that each cane production year would have a bearing on the amount of fuel required based on the amount of sugar cane produced in the Mackay Sugar region.

Kenaf and Sunn Hemp has been produced over a two year period to test how fibre flowed through the current bagasse handling system at the Racecourse Factory, the amount of energy derived from both fibre lines (Kenaf and Sunn Hemp) and if this fuel source was feasible to produce and transport to the Racecourse Factory. It has been determined from the trials

conducted that Kenaf is not acceptable because of its nature, being stringy and having a wrapping characteristic which would prevent an even flow of product to the boiler. The chlorine residue which was present after burning in the boiler was also higher than the specified levels for the boiler, this in turn could increase corrosive nature of the product within the boiler.

Sunn Hemp which was produced in 2013 and tested at the Racecourse factory has delivered better results to being handled by the current bagasse handling system. The characteristic nature of Sunn Hemp is that the fibres produced are softer and have less tensile strength than Kenaf, a cleaner cut was evident in the harvesting process, especially when forage harvesting. The chlorine residue in Sunn Hemp was at an acceptable level meeting the specified level for the mill boiler. Another beneficial characteristic of Sunn Hemp is that it is a legume, which would fix nitrogen for the following cane crop, it is root knot nematode resistant providing a better platform in a production system when rotating with sugar cane.

The logistics of utilising Sunn Hemp is being identified within this business case, increasing the production system of Sunn Hemp being produced in rotation with sugar cane, handling the product from the production system to the factory, storage of the product would also need to be addressed.

2. Sunn Hemp seed production

Sunn Hemp is not commercially produced in Australia which creates some challenges for the production of planting seed. The current planting seed being utilised has been imported from Brasil, this particular variety has high bio-mass production ability (20 ton of dry matter per hectare) as well as the ability to fix large amounts of nitrogen (300kg / ha).

MFP has been propagating planting seed for a number of years with varying degrees of success, recently we have been working with Bayer crop Science (Tim Murphy) to develop an insect management program that would allow for successful production of planting seed. This process has been tested in a 0.6ha site that has produced variable seed and is currently being tested in a 2 ha seed production site at Oakenden, it is at the late podding stage in the plant cycle. It is anticipated that with current knowledge that a successful seed production system could be developed.

Planting seed requirement assumptions;

Possible factory requirement for total replacement of coal feed stock: 90,000 tons of fibre

Moisture content of product: 51%

Production area required: 2720 ha (yield achieved in Trial 33tons/ha at 51% moisture)

Planting rate: 15 – 20 kgs/ha (germination and seed count variability)

Planting seed requirement: 58 tons

The planting seed requirement can be produced locally, it would be anticipated that other tropical regions could produce planting seed to eliminate risk of production losses. Our experience with Sunn Hemp seed is that it stores very well and is viable for many years. It is also recognised that Sunn Hemp planting seed could be imported to meet project demand in the early stages of establishing a production system.

1. Production system
 - o Agronomy
 - o Training and support

Production system.

In the Mackay sugar production area of some 85,000 ha's of sugar cane, at any one time sugar cane crops have a fallow period where sugar cane is taken out of production and the land is fallowed. The current management of the fallow land (10200 + ha's) varies, however best practice determines that a legume rotation provides the best situation for the following cane crop, locally soybean and peanuts, peanuts to a lesser extent are being produced in rotation with approximately 3000 ha per year being planted. The opportunity exists to further improve the management of the fallow period producing Sunn Hemp for a feedstock in the co-generation plant at the Racecourse factory. The current fallow land availability in any one year is approximately 12-15% of the total cultivated area, this provides the potential of 10,000 to 12,750 hectares available.

It would be anticipated that the production system would have a stepped approach into a production cycle starting at 50 hectares and progressively increasing over a five years period to 3000 hectares.

Agronomy.

MFP has been producing Sunn Hemp since importing seed in 2006, it has been documented by MFP in an Agronomic assessment (SRDC, Sugar Research and Development Corporation, project GGP024) developed, noting the agronomic requirements to produce Sunn Hemp. The agronomic assessment was developed from actual experience in producing Sunn Hemp, Kenaf and Industrial hemp in the Mackay region. The Agronomic assessment provided information on the following fibre production system.

- Planting window
- Seed Crops
- Seed bed preparation
- Soil type
- Nutrient requirements
- Weed Management
- Insect Management
- Irrigation
- Soil borne pests
- Harvesting and handling

The extensive agronomic notes compiled would provide relevant information to allow farmers to produce Sunn Hemp in the central region and would provide an excellent starting point from which a production system could be developed.

Training and support.

MFP also recognises that farmers in the first instance would require training and support to provide a successful transition into producing Sunn Hemp in rotation with sugar cane. In the Mackay region Mackay Productivity Services (MAPS) could provide support and training to

farmers, as is the case currently with the advisory roll provided to produce soybeans and to a limited extent for peanuts.

The sugar industry has a private consultancy in Farmacist which also provides an excellent agronomy service for farmers for the central and northern farming regions, discussions with this group indicate that they could also provide the training and support for the production of Sunn Hemp. Farmacist have indicated that the support and training in the production of Sunn Hemp would require one half of a full time equivalent with this support available from the first year until year 3 then a detraction to year 5 with an ongoing service provided while the production system was required at 25% of a full time equivalent. Approximate cost for a half full time equivalent would be in the range of \$70,000.

- 4. Product Handling
 - o Harvesting
 - Billets
 - Foraged
 - o Transport
 - o Storage

Harvesting.

In this particular trial two methods of harvesting were adopted, Forage harvesting and harvesting with a cane harvester. The two processes were utilise to manage an issue, crop presentation, lodged sunn hemp could not be handled with a 6810 John Deere forage harvester as documented in Photo 13, 6 metre Kemper front on forage harvester choked. The lodged sunn hemp was harvested with a Case Hi 7700 cane harvester which handled the lodged sunn hemp easily and efficiently, however the trade-off was that the product was presented in billet form which decreased the bulk density to 108kg per cubic metre from 171kgs per cubic metre in the foraged state. The bulk density has an impact on the transport costs.

Transport.

Managing the transport costs is a major challenge for this project, the low bulk density of the fibre product translates into high transport costs. To put this into perspective:

Billet Sunn Hemp: 108kgs/m³
Foraged Sunn Hemp: 171kgs/m³
Billet Sugar Cane: 236kgs/m³

The product was hauled to Mackay Sugar utilising a truck and super dog with a carrying capacity of 47m³

Charge rate per load, hauling 28km was \$386.66 plus gst

Cost per ton Foraged Sunn Hemp \$48/ton

Cost per ton Billeted Sunn Hemp \$76/ton

Assumption: Utilising 100m³ walking floor transport system at the same cost of \$386.66 per load:

Charge rate per load hauling 28km at \$386.66 plus gst per load
Cost per ton foraged Sunn Hemp \$23/ton
Cost per ton billeted Sunn Hemp \$36/ton

As will be noted in the economics the transport cost utilising this mode of transport will render the project unviable, the low bulk density can't capitalise on the trucks designed payload.

It is also noted that currently Mackay Sugar utilises a rail transport system in conjunction with a limited road transport operation. The rail system could have the ability to reduce the transport cost to haul the fibre product to the factory. Discussions with Mackay Sugar would require factory modifications to allow the product to be unloaded from the rail system onto a storage pad, this option would require engineering and fabrication costs which are outside the scope of this project.

Storage.

Storage of the product is very similar in nature to storing Bagasse, with the product stored on a hard stand pad under tarpaulins it could be stored for many years. In billet form Sunn Hemp would not need to be sun dried, it could be placed under tarps straight away. In a foraged state Sunn Hemp would need to be sunn dried for a period with some turning required.

5. Quality control / payment system

Quality control;

As with any supply chain, quality control would need to be applicable, with further investigations it is determined that the leaf and plant immaturities attribute to the high chorine levels which are corrosive towards the boiler components, harvesting with a cane harvester would be able to manage the leaf and immature plant ends by extracting from the supply. It is also noted that dirt in supply will have a detrimental effect on the boiler, presentation for harvesting and harvester set up would need to be monitored and maintained.

Payment system

While the harvest weight achieved would form the basics of grower payment system the plant moisture would also need to be determined. As with bagasse the acceptable moisture of 51% would set the bench mark, adjustment would need to be made of a plus or minus from the actual with payment set at 51%. Growers currently with cane supply contracts to Mackay Sugar would already be in the payments system and could easily add a fibre payment.

7. Economics

- Factory product requirement (fibre replacement of coal)

GGP063 Co-gen feedstock										
	Cut Date	Sample weight	Wet weight	Sub sample Wet weight	Dry weight sub sample	Dry weight % of wet weight	miosture %	Dry Matter / ha	Shoot count	Plants / ha
		(kg)	Tons / ha	(kg)	(kg)					
Kenaf sample 1	30 04 2012	6.65	36.94	0.9355	0.28021	29.95	70.05	11.07	44	244444
Kenaf sample 2	30 04 2012	12.68	70.44	0.81857	0.23221	28.37	71.63	19.98	38	211111
Kenaf sample 3	30 04 2012	10.92	60.67						33	183333
									35	194444
	average	10.08	56.02				70.84		37.5	208333
			40.33				51.00			
Sunn Hemp sample 1	05 02 2013	5.3	29.44	1.877	0.425	22.64	77.36		36	200000
		6.2	34.44						39	216666
		3.2	17.78						42	233333
	average	4.9	27.22						39	216666
Sunn Hemp sample 1	17 06 2013	6.4	35.56	1.127	0.49	43.48	56.52	15.46		
Sunn Hemp sample 2	17 06 2013	7.6	42.22	0.872	0.347	39.79	60.21	16.80		
Sunn Hemp sample 3	17 06 2013	6.5	36.11	1.187	0.496	41.79	58.21	15.09		
	average	6.83	37.96				58.31			
			33.20				51			
Forage sample 1	15 07 2013			0.3738	0.1939	51.87	48.13			
Billet sample 1	15 07 2013			0.4458	0.2116	47.47	52.53			
Billet sample 2	15 07 2013			0.5888	0.2778	47.18	52.82			

Sampling results conducted for both Sunn Hemp and Kenaf that has determined yield at 51% moisture. The spread sheet also has the plants established per ha.

Kenaf and Sunn Hemp production costs

Activity / description	Kenaf cost /ha	Sunn Hemp cost /ha
Offset 28 plate x 2	91.32	91.32
Irrigation (30mm winch 6.77ha) H 120 x 0.3582 = 42.98 L 2070 x 0.1267 = 262.27 water 4.307 x 77.30 = 332.93	94.26	94.26
Bed renovate	143.21	143.21
Fertilise Kenaf Econo Los @ 4 m3 / ha (115.70 / m3)	462.8	
Fertilise Sunn Hemp Soy starter @ 2.5 m3 / ha (87.10 / m3)		217.75
Kenaf planting seed 12.44 kg/ha (\$5 /kg)	62.2	
Sunn Hemp planting seed 21.77 kg/ha (\$25 / kg)		544.25
plant Kenaf and Sunn Hemp (63.40/ha)	63.4	63.4
Pre - emerge powermax 2l/ha 12.4/ha clincher 2.3L/ha 23.92/ha activator 2.14/ha	38.46	38.46
4 row spray rig	9.83	9.83
Irrigation (30mm winch 6.77ha) H 120 x 0.3582 = 42.98 L 2070 x 0.1267 = 262.27 water 4.307 x 77.30 = 332.93	94.26	94.26
Spray Knock down Basta 3.5L/ha (68.43/Ha) Activator .5L/tank (2.14/Ha)	70.57	
4 row spray rig	9.83	
Harvesting	201.5	166
Hauling	140	140
Total	1481.64	1602.74

Production cost for Kenaf and Sunn Hemp recorded by activity.

Transport results

	tons/ha	cost/ha	production cost /ton \$/ton
Kenaf	40.33	1481.64	36.74
Sunn Hemp	33.2	1602.74	48.28
Transport	Billets/Sunn Hemp	Forage/ Sunn Hemp	Forage/ Kenaf
Damian	2	1	
Craig	1	1	1
	weight/billet	weight/ foraged	100m3 walking floor
	5.44	8	10.82
	4.78	8.08	17.11
	5.04		
average weight (tons)	5.09	8.04	
bulk density m3 (kgs)	108.23	171.06	
	Actual	Asumpton/ 100m3 walking floor	
Cost per load (\$)	386.66	386.66	
Cost of Forgaed Sunn Hemp/ ton	48	23	
Cost of Billet Sunn Hemp / ton	76	36	

Production cost per ton collated, bulk density of both Kenaf and Sunn Hemp and transport cost determined relative to harvest method(Foraged or Billeted). We have also made an

assumption for transport costs utilising 100m³ walking floor compared to actual transport method utilising 47m³ truck and super dog configuration.

Summary of economics							
	cost per ton includes freight (\$)	Product moisture %	Fuel feedstock	Calorific Value (net) MJ/Kg	Total feedstock requirement (tons)	total energy produced MJ	cost of feedstock
Carbon tax value	\$ 150.00	11	Black coal	25.5	30,000	765,000,000	\$ 4,500,000
	\$ 57.72		at \$24.15 /t CO ₂ e		30,000		\$ 1,731,555
	\$ 207.72	11	Black coal	25.5	30,000	765,000,000	\$ 6,231,555
	\$ 287.78	17.4	Sunn Hemp	13.4	57,090	765,000,000	\$ 16,429,231
	\$ 97.39	41.5	Kenaf	8.5	90,000	765,000,000	\$ 8,765,100
	\$ 25.00	51	bagasse	9	85,000	765,000,000	\$ 2,125,000

The summary of economics is the end result of the business case, determining the feedstock value which include transport costs, the level of energy produced relative to each feedstock. For the purpose of the transport costs for Kenaf and Sunn Hemp, we have utilised transport in a foraged state hauling with 100m³ walking floors.

Economic value:

- The amount of energy produced is constant for this exercise, which is the amount of energy produced from 30,000 tons of black coal.
- Bagasse delivers the best value at 2.125 million dollars
- Black coal which includes a carbon tax cost is the next best value 7.963 million dollars.
- Kenaf at a cost of 8.765 million dollars (unacceptable due to chlorine levels in the burn residues)
- Sunn Hemp at a cost of 16.429 million dollars

Conclusion

At this stage while utilising the whole plant both Kenaf and Sunn Hemp will not stack up as a feedstock for co-generation to replace coal.

Intellectual Property and Confidentiality:

(Detail any commercial considerations or discoveries made, and means of protection (eg patents) undertaken or planned Specify any information that is to be treated as confidential, to whom and for how long.)

N/A

Environmental and Social Impacts:

Increasing the ability to plant more rotational crops delivers a beneficial environment outcome, reducing erosion, improving soil health: microbial numbers and more organic matter all are also beneficial for the following cane crops. The scope to add value at the farm gate also creates a profitable business which directly has beneficial social impact.

Expected Outcomes:

No outcomes in the short term, while freight costs have reduced the logistical reality of utilizing fibre as a feed stock for co-generation, the concept is sound. While this project didn't have the scope to investigate alternative transport options, it is anticipated that utilization of the rail transport system currently operated in the Mackay Sugar region could dramatically reduce transport costs. The benefits are reduced with the capital investment required to remove the product from the tippler and present it to the storage area or directly into the boiler.

Future Research Needs:

The synergies between sugar cane plants and fibre plants are high, the benefit in the harvesting, product handling and production system improvements are reasons why the sugar industry should keep investigating the ability to utilize fibre crops. Recently I attended the Kenaf and Allied fibres International conference in Malaysia, this conference demonstrated that high end value of fibre is in strong demand in the world. The ability to source mechanically separated fibres in large volumes is limited around the world, the market strength is high, with markets in aviation, defence and automotive all increasing products derived from fibre.

We have investigated some fibre separation process utilizing some sugar mill components, the next stage is to develop a pilot separation unit which would lead to a commercial separation unit. The world best separation is currently being done in Germany and it separates at 5ton/hr, this still remains a high cost area in the mechanized world, we believe our concept will separate at rates that will exceed 50 tons /hr which can then sustain a commercial outcome.

The waste stream from this process could then be utilized as a feedstock for co-generation.

Recommendations:

Currently discussions with Ian OHara, QUT are taken place to proceed to investigate a fibre separation process utilizing sugar mill componentry, our recommendation is for SRA to strongly support this initiative as it has the potential to add value throughout the sugar industry value chain. (happy to discuss further)

List of Publications:

Milestone reports 2 to 6 SRDC / SRA

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