BSES Limited

CANE FIBRE YIELDS

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by

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PR04011

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1.0 INTRODUCTION

This report was prepared for the New South Wales sugar industry to provide an estimate of the additional cane-based fuel available for the proposed cogeneration project. It summarises the work done to date in NSW, as well as drawing on research conducted in the Mackay, Bundaberg and Tully canegrowing districts. Studies conducted as part of the Brazilian sugar industry's Biomass Power Generation project are also reported.

2.0 ESTIMATING TRASH YIELDS

Based on work in the Mackay district, Mitchell and Larsen (2000) developed a simple model to estimate the dry yield of cane trash plus tops relative to cane yield. Cane yields in that study ranged from 50 t/ha to over 130 t/ha with total dry matter (DM) residues showing a strong linear relationship to cane yield over the range of yields. This was given as:

$Y = 0.18x - 2.5$ $(R^2 = 0.88, p < 0.01)$
where Y = dry weight trash + tops; x = cane yield t/ha (fresh weight).

Applying this formula to 1-year-old cane yields at Condong gives an estimate of 13.8 t/ha additional fibre after allowing for extraneous matter in the existing cane supply:

5-year average cane yield 1996-2000 (t/ha)	96.3
less 5-year average EM (5.9% x 96.3) (t/ha)	5.7
'clean' cane yield (t/ha)	90.6

(Dry wt trash + tops) = (90.6 x 0.18) – 2.5
= 13.8 t/ha

less 1.03 t trash (DM) present in extraneous matter (see Appendix 1)
= 12.76 t **additional trash** per 90.6 t clean cane

Additional fibre yield is the equivalent of 13.25 t per 100 t of cane as presently delivered to the mill (12.76 / 0.963).

3.0 TULLY FIELD MEASUREMENTS

Cargnello and Fuelling (1998) conducted a series of field trials with green cane in the Tully district. Samples were obtained by harvesting alternate rows with the extractor run either at 'normal' speed (~ 10% trash) or at 'slow' speed (~ 20% trash). Sample sizes based on the 'normal' treatment ranged from 41 t to 52 t. Results are given in Tables 1 and 2.

Normal extractor speeds resulted in an average trash content of 6.8 % and 15.8% fibre, while cane harvested with the reduced extractor speed averaged 20% trash and 20.7% fibre.

Not all trash was harvested during these trials as the extractors were slowed rather than turned off. This would have the effect of underestimating trash and fibre yields but would be offset by cane losses, which would have occurred at 'normal' extractor speeds.

Table 1 Green-cane harvesting trials at Tully

Trial	Extractor treatment	Cane yield[1] t/ha	Fibre %	Fibre t/ha	Trash %	Soil %
3	Normal	91	17.2	15.7	6.2	3.1
	Slow	157	21.8	34.2	16.3	4.9
4	Normal	94	14.2	13.3	5.3	1.7
	Slow	132	20.1	26.5	23.4	2.3
5	Normal	41	17.2	7.1	8.6	2.6
	Slow	46	23.2	10.4	20.7	4.4
6	Normal	75	14.7	11.0	7.0	1.2
	Slow	91	17.5	15.9	19.7	1.8
Average	Normal	75.3	15.8	11.9	6.8	2.2
	Slow	106.5	20.7	22.0	20.0	3.4

[1]Cane yield includes trash, dirt and other extraneous matter.

Table 2 Estimated additional fibre available from Tully trials

Extractor treatment	Cane yield[1] t/ha	Fibre %	Fibre t/ha	Tonnes fibre per 100 t cane as delivered (ie with 6.8% trash)	Additional fibre available (t)
Normal (as delivered)	75.3	15.8	11.9	15.8[2]	
Slow		20.7	22.0	29.3[3]	13.5

1Cane yield includes trash, dirt and other extraneous matter.
[2] 11.9 x 100 / 75.3 = 15.8.
[3] 22.0 x 100 / 75.3 = 29.3.

Based on the average results of these trials, 13.5 t of additional fibre would be available per 100 t of cane as delivered to Tully mill, ie at 6.8% trash.

4.0 NSW FIELD MEASUREMENTS

4.1 One-year-old cane Condong 2001

Three trials were conducted at Condong on one-year cane during the 2001 season to compare burnt cane fibre yield and fibre yield from 'whole-cane' harvesting. Yield was calculated from the weight of material delivered to the mill and a measurement of the area harvested for each trial. Results are given in Table 3.

Table 3 Yields and fibre levels from one-year-old cane at Condong 2001

Variety	Class	Whole cane			Burnt cane			Additional fibre	
		t/ha	Fibre %	t fibre/ha	t/ha	Fibre%	t fibre/ha	t/ha	% burnt cane
Q141	1yo	112.5	24.25	27.28	84.4	15.75	13.29	13.99	16.57
Q136	1yo	137.4	18.65	25.63	94.1	15.01	14.12	11.50	12.22
Delta	1yo	155.0	25.00	38.75	125.0	15.34	19.18	19.58	15.66
Average		**135.0**	**23**	**30.55**	**101.2**	**15**	**15.53**	**15.02**	**14.82**

The additional amount of fibre approximates the estimate based on the method developed by Mitchell and Larsen (14.33%).

4.2 One-year-old cane 1999-2000

P Nielsen (unpublished data) sampled three 'one-year-old' crops at Broadwater in 1999. The crops varied from 13 to 16 months of age at the time of sampling. Leaf and tops yield (DM basis) from these samples was estimated at 15.7% of the total stalk weight.

Table 4 Proportions of weights and dry matter of different cane fractions

Cane fraction	% weight	% dry matter
Stalks	72	-
Tops	8	15.4
Green leaf	13	32.1
Dead leaf	7	83.0
Tops + green leaf + dead leaf	28	40.4

Assuming that cane delivered to the mill contains 6% extraneous matter of which 1.72% represents usable fuel, the potential additional trash yield would be 12.54% of cane as delivered to the mill.

Calculations:

72%stalk @ 6% EM = 76.3 t as delivered to the mill

Additional fibre available(wet) = 28 – (76.3 - 72.0)
= 23.7

Additional fibre available(dry) = 23.7 x .404 (% DM)
= 9.57 t per 76.3 t as delivered
= 12.54 t per 100 t as delivered

Two trials carried out at Condong and Broadwater on one-year crops in 2000 confirm these results (R Watts, unpublished data) (Table 5).

Table 5 Proportions of weights and dry matter of different cane fractions

Cane fraction	Condong		Broadwater		Average	
	% weight	% dry matter	% weight	% dry matter	% weight	% dry matter
Stalks	75.83	-	73.67	-	74.75	-
Tops	5.37	15.6	6.86	21.7	6.12	18.7
Green leaf	13.83	30.3	12.70	39.2	13.27	34.8
Dead leaf	4.97	86.7	6.77	77.6	5.87	82.1
Tops + green leaf + dead leaf	24.17	38.6	26.33	44.5	25.25	41.9

Again assuming that cane delivered to the mill contained 6% extraneous matter, the potential additional trash yield would be 11.0% of cane as delivered to the mill.

Calculations:

74.75% stalk @ 6% EM = 79.2 t as delivered to the mill

Additional fibre available (wet) = 100 – 79.2
= 20.8

Additional fibre available (dry) = 20.8 x .4187
= *8.*7 t per 76.3 t as delivered
= 11.0 t per 100 t as delivered

4.3 Two-year-old cane

Trials were conducted in two-year-old cane at Condong and Broadwater during the 2001 season. Of the two trials conducted at Broadwater in 2001, reliable cane yield estimates were obtained from only one trial. Results from the trials are presented in Table 6.

Table 6 Yields and fibre levels from two-year-old cane (2001 trials)

Variety	Mill	Whole cane			Burnt cane			Additional fibre	
		t/ha	Fibre %	t fibre/ha	t/ha	Fibre%	t fibre/ha	t/ha	% burnt cane
Q124	Cdg	196.9	20.08	39.54	165.9	14.72	24.42	15.12	9.11
BN81-1394	Bwr	200.9	20.92	42.03	156.8	17.10	26.81	15.22	9.70
Average		198.9	20.50	40.77	161.35	15.90	25.65	15.12	9.37

Beattie (unpublished data) conducted additional trials at Broadwater in 2002. Results from these trials are shown in Table 7.

Table 7 Yields and fibre levels from two-year-old cane (2002 trials)

Variety	Mill	Whole cane			Burnt cane			Additional fibre	
		t/ha	Fibre %	t fibre/ha	t/ha	Fibre%	t fibre/ha	t/ha	% burnt cane
Q136	Bwr	275.2	19.22	52.88	200.8	15.17	30.46	22.42	11.17
Q136	Bwr	249.5	18.57	46.33	216.1	14.18	30.64	15.69	7.26
Average		262.4	18.90	49.61	208.45	14.68	30.55	19.01	9.22

The Mitchell and Larsen model was based on 'one-year' cane. Two-year cane appears to give a lower yield of additional fibre per 100 t of clean cane.

P Nielsen (unpublished data) measured the distribution in a crop at Broadwater over a 20-month period from late 1989 to 1991. Dry matter yields from this study are given in Table 8.

Table 8 Dry matter yields – 1- and 2-year-old cane

Cane fraction	Dry matter (t/ha)	
	at 12 months	at 20 months
Stem (cane + top – leaf)	17.3	35.4
Green leaf	5.7	6.5
Dry leaf	4.3	14.4
Leaf total	10.0	20.9

As the weight of fresh cane is not known, no estimate of trash yields per tonne of cane can be made. However, if 1-2 t of leaf DM is present as EM in 100 t of the normal cane supply, the yield of additional fibre could be expected to be 19-20 t/ha. This DM yield per hectare for the crop at 20 months of age exceeds those measured in the 2001 and 2002 trials by 4-5 t/ha.

5.0 BUNDABERG BIOMASS TRIAL

A sugarcane biomass-accumulation trial conducted at Bundaberg was reported on by Kingston *et al.* (1984). Crops in the experiment were planted and ratooned in March, June, September and December with harvests at 6, 9, 12 and 15 months of age. Results selected for cane harvested at 12 months of age initiated in June, September or December are shown in Table 9.

Table 9 Yields from 12-month old cane – Bundaberg experiment

Parameter	Yield (t/ha)
Clean cane (stalk) yield	91
Total fibre yield	27
Stalk fibre yield	15
(Total - stalk) fibre yield	12

Clean cane yields from the Bundaberg experiment and Condong's 5 yr average yield (less EM) (Table 10) are very similar. Using the Bundaberg stalk fibre figure, Condong should have 10.30 t/ha additional fibre available from whole cane. This translates to 10.7% additional fibre on a cane yield (inc EM) basis.

Table 10 Yields from 1-year-old cane – Condong

5 yr av cane yield(t/ha)	96.3
5 yr av EM (%)	5.9
Clean cane (stalk) yield (t/ha)	90.6
(Tot - stalk) fibre yield (t/ha)	11.95[1]
less fibre present in EM 0.963 x 1.72% (see Appendix 1)	1.65
Additional fibre available (t/ha) at a cane yield of 96.3 t/ha	10.30
Additional fibre per 100 t cane as delivered. 10.3 x 100 / 96.3	10.7

[1] (12/91) x (96.3 x (100-5.9))

6.0 NSW BULK DENSITY STUDIES

In 1999 a series of trials was conducted on methods of improving bulk density in road transport bins (Watts R, unpublished data). In those trials, the percent of extraneous matter without tops was measured and moisture determined. Trash content reported in this series of trials is higher than would normally be expected (Table 11). This is most likely due to reduced cane losses and sampling errors.

Table 11 EM after whole-crop harvesting 1- year-old cane

Trial	Total tonnes	% Trash	Cane (t)	Trash DM %	Trash DM (t)	Trash DM as % cane
Pimlico (long billets)	16.24	28.4	11.63	46.5	2.14	18.4
Pimlico (short billets)	18.74	32.6	12.63	50.1	3.06	24.2
Harwood (long billets)	13.84	26.3	10.20	45.2	1.65	16.1
Harwood (short billets)	15.38	27.7	11.12	39.6	1.69	15.2
Harwood (long billets)	13.46	22.5	10.43	43.9	1.33	12.7
Harwood (short billets)	13.18	33.1	8.82	44.3	1.93	21.9
Harwood (long billets)	12.22	27.5	8.86	66.5	2.23	25.2
Harwood (short billets)	12.10	19.1	9.79	60.7	1.40	14.3
Harwood (long billets)	12.04	27.6	8.72	63.1	2.10	24.1
Harwood (short billets)	12.48	27.3	9.07	57.0	1.94	21.4
Average	13.97	27.2	10.13	51.7	1.96	19.4

Assuming that cane delivered to the mill normally contains 6% extraneous matter of which 2.3% (ie 1.19% DM) of this is trash (leaf material), the potential additional trash yield would be 17.2% of cane as delivered to the mill.

Calculations:

	Experiment	as delivered to mill
Cane (t)	9.95	10.55 [2]
Tops [1] (t)	0.20	included above
Trash (t)	3.82	3.42
Total	13.97	13.97

[1] See Appendix 1

[2] 9.95 + 0.2(tops) + 0.4 (trash)= 10.55

Additional trash (DM) = 3.42 x 0.517
= 1.77 t per 10.55 t cane as delivered
= 16.76 t per 100 t cane as delivered

7.0 BRAZILIAN RESEARCH

Field studies for biomass power generation in Brazil are reported by Anon. (1998). Trash and tops left in the field from four varieties after harvest ranged from 10.4 t/ha to 15.6 t/ha. Trash residues from the three varieties for which cane yields were reported are given in Table 12.

Table 12 Amount of trash left in the field after harvest (t/ha DM)

Cane fraction	Variety			
	SP80-0185	SP79-1011	SP79-2223	Average
Cane yield[1]	108	129	149	128.7
Dry leaves	14.0	11.4	13.6	13.0
Green leaves	1.3	1.9	1.2	1.5
Tops	0.3	0.3	0.2	0.3
Total trash + top	15.6	13.6	15.0	14.7

[1] Wet basis

Trash and tops left in the field after harvest averaged 14.7 t/ha. Expressed as a proportion of cane yield this represents 11.4%.

Similar results are reported by Anon. (1999a). Fresh stalk weight and dry trash weights from three varieties over three harvests are given in Table 13.

Table 13 Dry leaf + green leaf + top availability

Variety	Crop class	Stalks (t/ha)	Trash DM (t/ha)	Trash DM as % of stalk yield
SP79-1011	Plant cane	119.96	17.79	14.83
	3 R	91.46	14.97	16.37
	5 R	84.21	13.72	16.29
	Average	**98.54**	**15.49**	**15.72**
SP80-1842	Plant cane	135.76	14.57	10.73
	3 R	100.49	12.64	12.57
	4 R	91.61	10.53	11.49
	Average	**109.28**	**12.58**	**11.51**
RB72-454	Plant cane	134.26	17.13	12.76
	3 R	99.76	14.89	14.92
	5 R	78.16	13.58	17.37
	Average	**104.06**	**15.20**	**14.6**
Average		**103.96**	**14.42**	**13.87**

Data from this series of trials were used to give an estimate of 42.2 Mt of potential dry biomass from harvest residue (green leaf + dry leaf + tops) for the 1997/98 Brazilian crop of 302 Mt (Anon. 1999b).

8.0 SUMMARY

Source	**Estimated additional fibre available** (as a per cent of cane yield)
Mitchell & Larsen	13.25
Cargnello & Fuelling	13.5
Field measurements, Condong 2001, 1 yo	14.82
NSW field studies 1999 – 2000 (Nielsen)	12.54
NSW field studies 1999-2000 (Watts)	11.0
Bundaberg biomass trial	10.7
Bulk density studies	16.76
Brazilian research (1)	11.4
Brazilian research (2)	13.87
Rough average (1 year old cane)	**13.1**
Field measurements, Broadwater & Condong (2001) 2 yo cane	9.37
Field measurements, Broadwater (2002) 2 yo cane	9.22
Rough average (1 year old cane)	**9.30**

9.0 REFERENCES

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APPENDIX 1 Extraneous matter: Condong 1996-2000

Component	Percent by weight	Dry matter %	Percent fuel as fibre
Fixed tops	1.8	20	0.36
Loose tops	1.4	20	0.28
Trash	2.3	45	1.03
Rotten cane	0.1	50	0.05
Dirt & roots	0.4	na	--
Total	**6.0**		**1.72**