THE EFFECT OF WHOLE CROP HARVESTING ON CROP YIELD

By

PJ MCGUIRE[1], M INDERBITZIN[2], B RICH[3], GA KENT[4]
[1]*BSES Limited, Condong*
[2]*NSW Sugar Milling Co-operative Limited, Broadwater*
[3]*NSW Sugar Milling Co-operative Limited, Condong*
[4]*Queensland University of Technology, Brisbane*
pmcguire@bses.com.au

KEYWORDS: Whole Crop, Trash, Yield, Cane Loss, Trash Separation.

Abstract

ONE OF THE advantages gained by whole crop harvesting is a reduction in cane loss since there is no trash separation system in operation on the harvester that could discard billets of cane with the separated trash. The amount of cane lost through the harvester trash separation system has been a subject of debate for many years. This paper presents the results of experiments conducted in the Condong and Broadwater districts where single blocks of cane have been harvested using several distinct harvesting methods, including green cane harvesting of the whole crop (including trash) and burnt cane harvesting with trash extracted. The results showed that whole crop harvesting yields about 24% more biomass than conventional burnt cane harvesting, including at least 40% extra dry, ash-free fibre. The results showed a 14% increase in pol yield for whole crop harvesting compared to conventional burnt cane harvesting although the amount of this extra pol that can be converted to sugar is unknown.

Introduction

The NSW Sugar Milling Cooperative has built electricity cogeneration plants at Condong and Broadwater in a joint venture arrangement (Palmer *et al.*, 2009). These plants were built for several reasons including reduced cane burning in response to community expectations and value adding at a time of increasing renewable energy prices. The fuel supply for the plants was intended to be mainly derived from sugarcane, including both the bagasse derived from the cane stalk and the trash. Trash was intended to be harvested and transported to the factory with the cane stalk using a 'whole crop' harvesting process.

Palmer *et al.* (2009) reported that the whole crop was intended to be processed through the factory. This process was expected to be a lower capital cost option than installing a trash separation plant at the factory so that the trash could be processed separately. Investigations found that whole crop processing considerably reduced sugar recovery and sugar quality (Kent *et al.*, 2010) and caused significant operational difficulties (Moller *et al.*, 2010). It was expected that these losses would be offset by potential gains in sugar production due to reduced cane losses during whole crop harvesting. The current project was undertaken to quantify those potential gains and to provide information that would enable estimation of the costs and benefits of installing a trash separation plant.

Sugar losses during harvesting represent a major loss to the Australian sugar industry. Sichter *et al.* (2005) estimated these losses to range from 5% up to 15%. The major sources of these losses are the chopper mechanism and the extractors. The expectation of the NSW sugar industry

was that additional losses at the factory through whole crop processing would be more than offset by gains in the field. This expectation was supported by Davis and Norris (2001) who stated that, 'most of the CCS lost from cane as a result of damage during harvesting can be recovered at the mill, provided that the cleaning extractors are not operating.'

With burnt cane, sugar losses begin before the harvesting operation. Fuelling *et al.* (1978) conducted a comparison of green and burnt cane in the wet tropics region and found an additional 0.4 to 1.4 units of CCS in green extracted cane in comparison to burnt cane. More recently, Gomez *et al.* (2006) conducted trials in Argentina and found a difference in CCS of approximately 0.4 units between green and burnt harvested cane.

Hockings *et al.* (2000) found that cane and juice losses in the chopping process averaged 3.4% in the units they tested. Losses as high as 7.2% were recorded in their harvester test rig. Ridge and Dick (1987) estimated similar losses using an early test rig concluding that the 'chopper component of cane loss is approximately 3% of the cane harvested.' This figure by Ridge and Dick was based on work with 'long' and 'short' billet lengths of 300 mm and 220 mm respectively. Greater losses could be expected with the shorter billet lengths currently used in NSW.

Crook *et al.* (1999) reported on investigations into the cause of low CCS at Mulgrave during the 1998 season. They found that whole stalks of cane had an extra 0.75 units of CCS immediately before harvest compared to the sound billets from those stalks immediately after harvest. This loss, attributed to the chopper box, resulted in significant levels of juice on trash with an average CCS increase of 1.8 units between trash on standing cane and trash in harvested cane. Berding *et al.* (2002) had similar findings when they measured CCS on trash of 1.9 units which was believed to be due to juice splatter during the billeting process.

Sugar on trash may be recoverable during the milling process but it first has to avoid being separated by the cleaning mechanism on the harvester and so lost. In his report on reducing harvester losses Linedale (1997) cited average extractor losses of 6.47 t cane/ha in 172 harvester tests mostly in green cane conducted by BSES staff over the 1992 and 1993 seasons. Linedale described nine green cane harvesting tests on 'high loss' varieties with average additional losses of 4.8 t cane/ha when the primary fan speed was increased from 1000 r/min to 1200 r/min. Increasing the fan speed to 1300 r/min resulted in 13.1 t/ha cane loss compared to the 1000 r/min standard.

For two trials in the Ramu Valley in 2010 with clean cane yields of 100 to 110 t/ha cane losses increased by 5% and 7% as the primary extractor speed was increased from 650 r/min to 800 and 880 r/min respectively (C Norris pers. comm.).

That there are large losses which may be captured was shown by Whiteing (2002) when he used a whole crop harvesting (no extractor fans) approach to measure potential sugar yield in a field trial. Harvesting with the extractor fans turned off gave a yield of 22.65 t sugar/ha compared to harvesting with a primary extractor fan speed of 950 r/min which yielded 19.12 t sugar/ha, a loss of 15.6% through the extractors.

To determine the extra sugar that can be collected through whole crop harvesting, a series of trials commenced in 2008 as part of an extension program to demonstrate the benefits of whole crop harvesting. For the 2009 and 2010 seasons the program was expanded and supported by additional laboratory analysis. This paper reports on the results of the trial program and on other tests conducted to explore whole crop harvesting effects.

Yield experiment methods

Tests were conducted in 17 blocks, each of which included several harvesting treatments within a single paddock. The harvesting treatments examined in the experiment are shown in

Table 1. Not all treatments were tested in each block. The number of times each treatment was tested is shown in Table 1. The burnt extracted (BE), green 50% trash (GE0.5) and green unextracted (GU) harvesting treatments were the main treatments studied. The BE and GU harvesting treatments represent the conditions of least trash and most trash in the cane supply.

Table 1—Harvesting treatments used in the yield experiments.

Harvesting treatment	Symbol	Number of tests
Burnt extracted	BE	14
Burnt unextracted	BU	3
Green extracted	GE	4
Green 50% trash	GE0.5	14
Green unextracted	GU	16

Table 2 contains a list of the blocks and the treatments that were tested in each block.

Table 2—Blocks and treatments tested in each block.

Block	District	Treatment				
		BE	BU	GE	GE0.5	GU
RA	Condong	✓		✓	✓	✓
BR	Condong		✓	✓	✓	
DI0	Condong	✓		✓	✓	✓
HA	Condong		✓		✓	✓
NO	Condong	✓				✓
QU	Condong		✓	✓	✓	✓
ST	Condong	✓			✓	✓
GH 1	Condong	✓			✓	✓
RC	Condong	✓			✓	✓
GH 2	Condong	✓			✓	✓
4133	Broadwater	✓			✓	✓
GH 3	Condong	✓			✓	✓
McG	Broadwater	✓			✓	✓
JH 2	Condong	✓			✓	✓
JH 3	Condong	✓			✓	✓
DI1	Condong	✓				✓
DI2	Condong	✓				✓

For practical reasons, it was not possible to randomise the order in which tests within a block were conducted or to randomise the location of the sections of each paddock where the various treatments were taken. The green cane treatments were always harvested first. The remainder of the paddock was burnt after the green cane harvest was completed and then the burnt cane harvest was undertaken.

For each test, several rows of cane were fully harvested with the total quantity being sufficient to fill two or three cane bins of typically 22 t capacity. The area of those rows was measured.

For ten of the blocks (see Table 4), three samples of cane were taken from most of the bins for extraneous matter analysis. The NIR-based Cane Analysis System at the factory (Staunton *et al.*, 1999) was used for cane analysis.

For nine of the blocks (see Table 5), shredded trash samples were submitted to the mill laboratory to determine their pol content. To gain some indication of the possible deterioration of pol on trash, shredded trash from two blocks (GH 1 and JH 2) was kept for 16 hours, with pol analyses being done on delivery to the laboratory, after 8 hours and after 16 hours.

In another examination of the pol loss over time, nominal 22 t bins were left on the pad overnight and their cane analysis was compared to the analysis of cane from similar bins crushed

shortly after harvesting. These tests were done on block GH 2 and across blocks DI1 and DI2. Two bins each of burnt cane (BE) and green unextracted cane (GU) were crushed on the day of the trial and two bins of each were crushed on the following day.

Yield experiment results

The raw yield data are presented in Table 3. Note that ash refers to total ash.

Table 3—Raw data from yield experiments.

Block	Treatment	Area (ha)	Mass (t)	Pol (%)	Fibre (%)	Ash (%)	Purity (%)
RA	BE	0.360	41.10	13.69	18.0	2.8	82
RA	GE	0.360	35.25	13.81	15.2	2.0	85
RA	GE0.5	0.360	39.90	12.54	17.8	2.6	82
RA	GU	0.240	28.15	12.66	18.1	2.6	82
BR	BU	0.347	38.54	11.01	23.2	2.7	76
BR	GE	0.345	37.08	12.31	18.7	2.8	80
BR	GE0.5	0.349	42.86	11.40	16.8	2.3	78
DI0	BE	0.285	30.10	12.91	18.1	2.8	85
DI0	GE	0.285	30.46	12.26	19.2	3.7	83
DI0	GE0.5	0.285	37.46	11.97	22.0	4.0	81
DI0	GU	0.285	38.08	11.85	23.9	3.6	80
HA	BU	1.117	87.64	13.01	17.0	1.4	84
HA	GE0.5	0.328	26.98	12.43	17.4	2.5	82
HA	GU	0.867	79.06	11.51	20.8	3.0	80
NO	BE	0.919	68.82	14.15	20.4	4.2	82
NO	GU	0.759	67.22	12.84	22.9	5.1	79
QU	BU	0.342	46.05	11.66	14.7	1.0	80
QU	GE	0.352	51.30	11.36	14.4	0.8	80
QU	GE0.5	0.350	53.85	11.48	16.5	1.6	80
QU	GU	0.344	53.75	11.13	17.2	1.6	79
ST	BE	0.501	87.48	12.57	14.5	1.5	85
ST	GE0.5	0.510	105.00	12.19	17.0	2.8	82
ST	GU	0.510	108.00	11.51	17.6	2.6	81
GH 1	GE0.5	0.737	62.90	11.41	17.0	3.4	82
GH 1	GU	0.409	39.08	10.89	18.0	2.9	79
GH 1	BE	0.737	61.70	11.48	14.7	2.7	83
RC	GE0.5	0.808	57.94	10.69	16.4	3.6	79
RC	GU	0.458	39.38	10.30	18.4	4.6	78
RC	BE	0.948	63.26	11.51	15.5	3.3	82
GH 2	GE0.5	0.485	44.50	10.59	17.1	2.4	78
GH 2	GU	0.397	43.08	10.08	19.4	2.3	77
GH 2	BE	0.823	65.50	11.57	15.9	2.0	81
4133	GE0.5	0.502	67.66	12.56	18.9	3.7	83
4133	GU	0.338	57.68	10.56	21.1	4.8	–
4133	BE	0.388	63.98	11.84	16.5	3.2	83
GH 3	GE0.5	0.491	59.62	11.42	20.1	5.9	78
GH 3	GU	0.284	37.18	11.54	20.9	5.5	77
GH 3	BE	0.655	64.14	12.72	16.7	2.6	81
McG	GE0.5	0.372	68.42	11.42	17.8	2.7	82
McG	GU	0.312	52.32	11.74	18.9	4.0	82
McG	BE	0.443	67.90	12.29	14.9	1.7	82
JH 2	GE0.5	0.407	47.10	10.59	16.4	2.3	76
JH 2	GU	0.432	60.62	10.21	18.3	2.0	74
JH 2	BE	0.547	65.34	11.29	15.2	1.6	77
JH 3	GE0.5	0.544	70.28	10.29	18.7	2.7	76
JH 3	GU	0.505	66.36	10.35	20.8	3.5	76
JH 3	BE	0.692	71.04	11.78	16.5	3.1	80
DI1	GU	0.408	44.04	8.96	18.7	4.0	60
DI1	GU	0.414	40.60	10.17	18.8	3.2	56
DI2	BE	0.601	46.20	11.56	15.8	2.8	79
DI2	BE	0.606	45.50	11.22	16.0	2.9	77

A summary of the cane analysis results for each harvesting treatment is presented in Figure 1 in the form of box plots. In each box plot, the white bar through the centre identifies the median value.

The top and bottom coloured box surrounding the median represents the range of the 50% of values closest to the median. The extensions above and below the solid box show the minimum and maximum values.

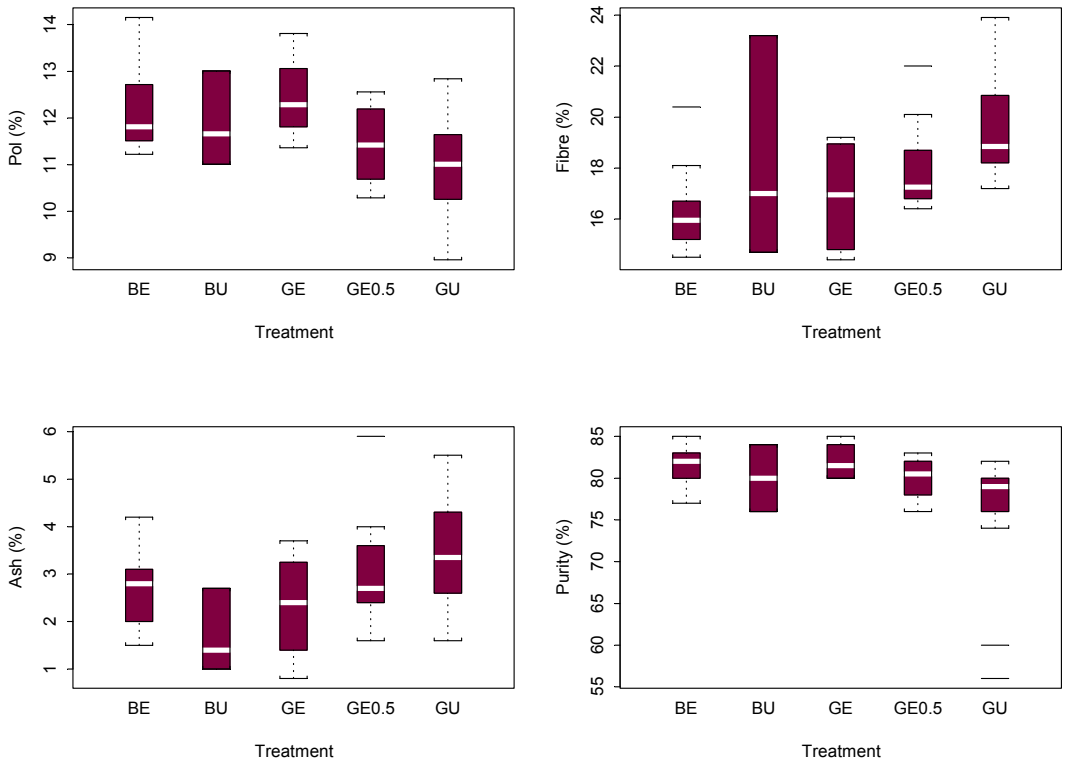

Fig. 1—Cane analysis results from yield experiment.

The results are consistent with those presented by Kent *et al.* (2010) and show that, with increasing trash content from the BE harvesting treatment to the GU harvesting treatment, pol and purity reduce while fibre and ash increase. Multiple comparison tests showed that these differences between BE and GU treatments were statistically significant at the 5% level.

Crop yield

Crop yield was calculated by dividing the harvested mass by the harvested area. Across all blocks, crops harvested green without extraction (GU) produced an extra 24% biomass yield compared to crops that were burnt and harvested with the extractors on (BE).

Green harvest treatments which aimed to collect 50% of the trash (GE0.5), produced an extra 22% biomass. These results, shown in Figure 2, are in general agreement with the in-house investigations done prior to the decision to construct the cogeneration plants.

The average results of the extraneous matter analysis for each harvesting treatment in each block sampled are presented in Table 4. The medians and range of results for the individual bins is shown in Figure 3.

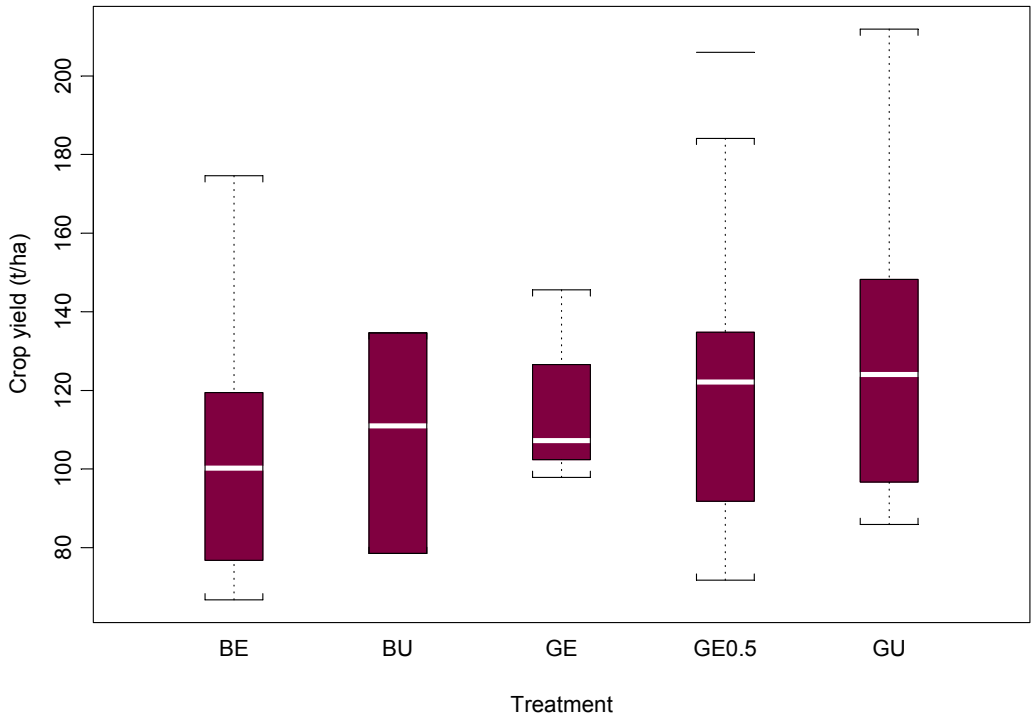

Fig. 2—Crop yields for treatments of the yield experiment.

Table 4—Measurements of trash and tops content.

Block	Trash and tops content (%)		
	BE	GE0.5	GU
GH 1	–-	22	34
RC	–-	21	35
GH 2	10	19	29
GH 3	7	16	25
4133 (2yo)	6	11	24
McG (2yo)	3	18	22
JH 2	12	18	25
JH 3	9	21	26
DI1, DI2	9	–-	37
Median	7	19	27

If only the yield experiment results for which BE and GU extraneous matter analyses were undertaken are included, the increase in crop yield from the BE harvesting treatment to the GU harvesting treatment is 31%.

For these same tests, the median trash content of the BE samples was 7% and of the GU samples was 27% (Table 4). From these extraneous matter results, 27% greater crop yield could be expected.

While there is undoubtedly some sampling error in the extraneous matter analysis, the fact that the measured crop yield for these tests was greater than the expected crop yield from the extraneous matter analysis is an indication that there could be less cane lost with the GU harvesting treatment, providing approximately 3% more crop that otherwise might be lost through the harvester extraction system.

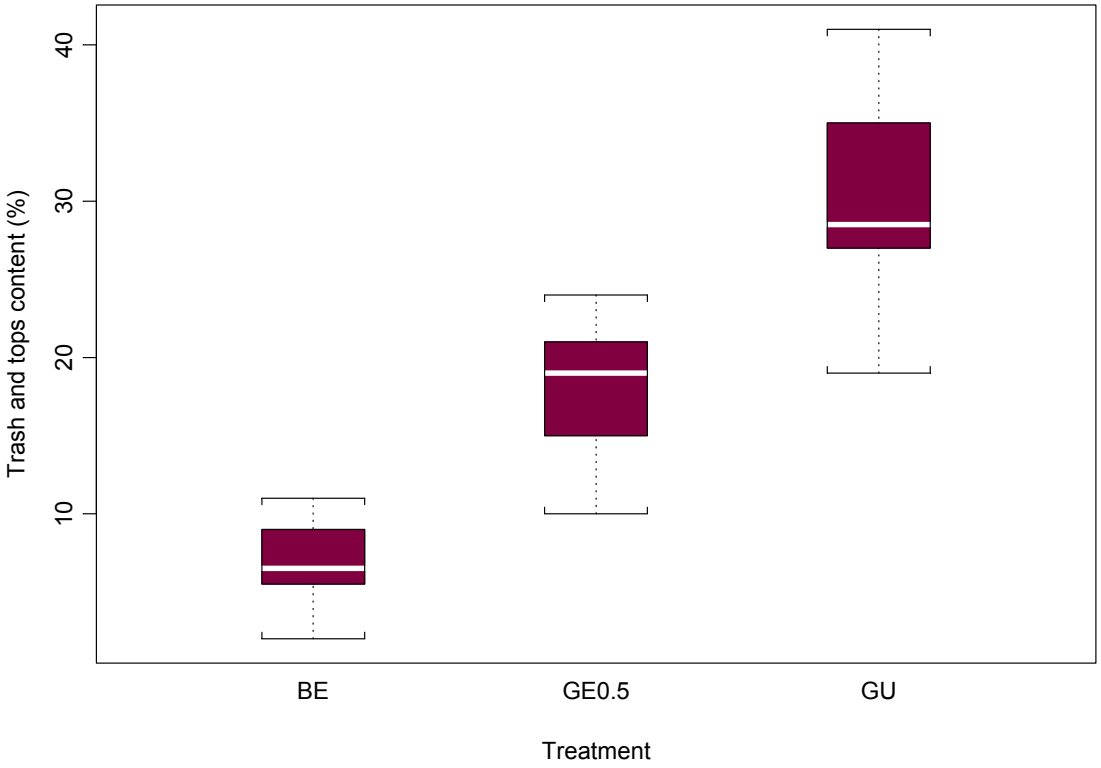

Fig. 3—Trash and tops content results for the treatments of the yield experiment.

The trash plus tops data include tops without leaves and are higher than historical extraneous matter figures for Condong mill, which are just over 4% (excluding rotten cane, tops without leaves and dirt).

These higher values are believed to be due to suckering in some late harvested trials and poor burns in some 2010 trials due to showery conditions.

Pol yield

Pol yield was calculated by multiplying the crop yield by the pol content (Figure 4). The effect of harvesting treatment on pol yield was statistically significant at the 5% level between the BE and GU treatments.

Compared to BE cane, the GU cane averaged an additional 1.7 t pol per ha measured across all trials, an increase of 14%.

The increase in pol yield was observed in all trials except RA and 4133 where variations in cane yield across the block became apparent as the trials progressed.

Although not statistically significant, the green harvest treatments, which aimed to collect 50% of the trash, gave an average increased pol yield of 13%.

For the nine blocks sampled, shredded trash samples analysed for pol content showed that the median pol content in trash was 1.1% and the range was 0.41 to 2.55 (Table 5).

As a check on the pol yield results, the pol content of the trash was used in conjunction with the trash content results to calculate pol yield. Using the results for extraneous matter analyses, the measured pol content from the BE harvesting treatment was 11.7% and from the GU harvesting treatment was 10.3%.

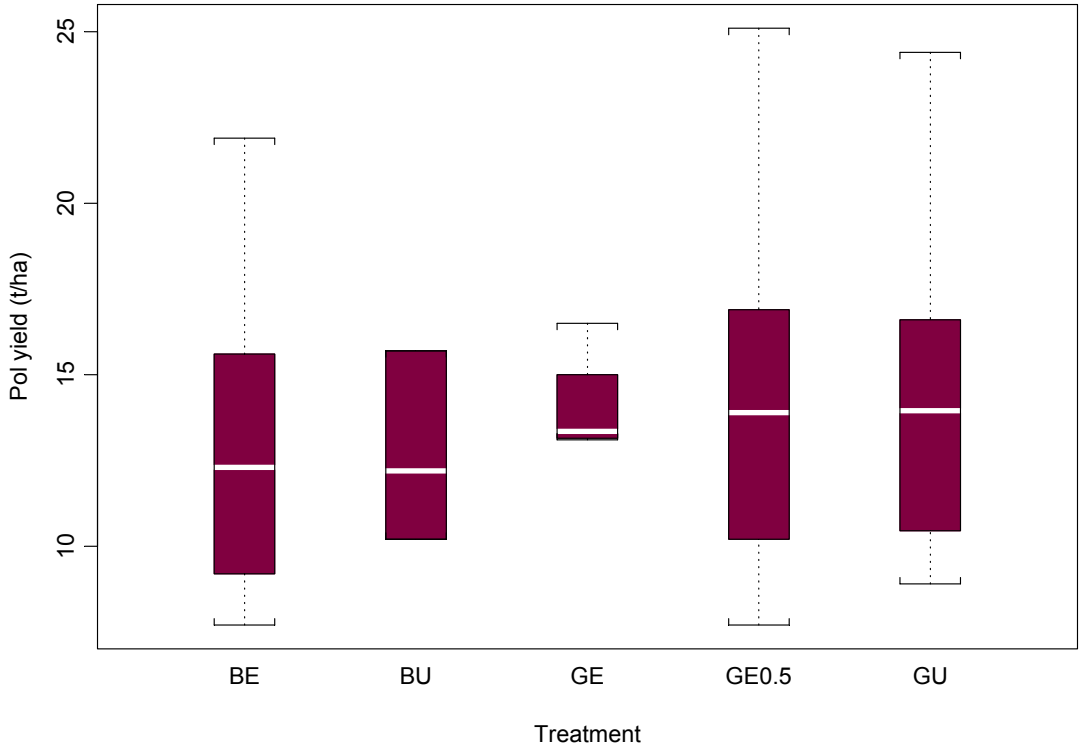

Fig. 4—Pol yields for treatments of the yield experiment.

Table 5—Pol content of shredded trash samples.

Block	Date	Pol (%) on trash
GH 1	07/07/10	0.97
RC	15/07/10	1.47
GH 2	26/07/10	1.44
4133	17/08/10	2.55
GH 3	08/09/10	1.72
JH 2	23/11/10	1.10
JH 3	25/11/10	0.83
DI1	30/11/10	0.44
DI2	30/11/10	0.41
Median		1.10

Using a trash content of 7% and a pol content of trash of 1.1%, the pol content of the billets in the BE harvesting treatment was calculated to be 12.5%. Using this BE billet pol value, along with the 27% trash content of the GU harvesting treatment, the expected pol content of the GU samples is 9.4%. This result is somewhat less than the measured 10.3%.

The reason for the discrepancy between the calculated 9.4% and the measured 10.3% pol content has not yet been determined. Part of this difference may be due to pol lost through burning. The examination of crop yield found that the trash content measurements seemed reasonable. It is

possible that the pol content of trash is higher when it is contained within the bin than when it is separated out, as was done for the analysis. It is also likely that the measured pol content in whole crop cane is overstated.

Undetermined pol loss values recorded at Condong and Broadwater factories when processing high trash cane supplies are somewhat larger than for burnt cane supplies. Direct cane analysis measurements on whole crop cane supplies also support this theory.

The additional pol in green, unextracted cane is likely to be overestimated in the pol yield results because of the short cut-to-crush delays for these tests. To accommodate the additional analysis by laboratory staff, the test bins were dispatched soon after they were filled, greatly reducing the time available for any deterioration in harvested cane.

Deterioration of pol on trash from two blocks (GH 1 and JH 2) was investigated by analysing shredded trash on delivery to the laboratory, after 8 hours and after 16 hours. The results are presented in Table 6 and summarised in Figure 5. While the brix did not change markedly, the pol reduced to low levels after eight hours. These results provide some evidence that the measured increase in pol content may not eventuate with normal cut-to-crush delays.

Table 6—Brix and pol on shredded trash (green, extracted) over time.

Block	Time delay (h)	Brix (%)	Pol (%)
GH 1	0	9.5	1.0
GH 1	8	8.5	0.4
GH 1	16	7.4	0.1
JH 2	0	9.6	0.8
JH 2	8	8.5	–0.1
JH 2	16	10.6	–0.2

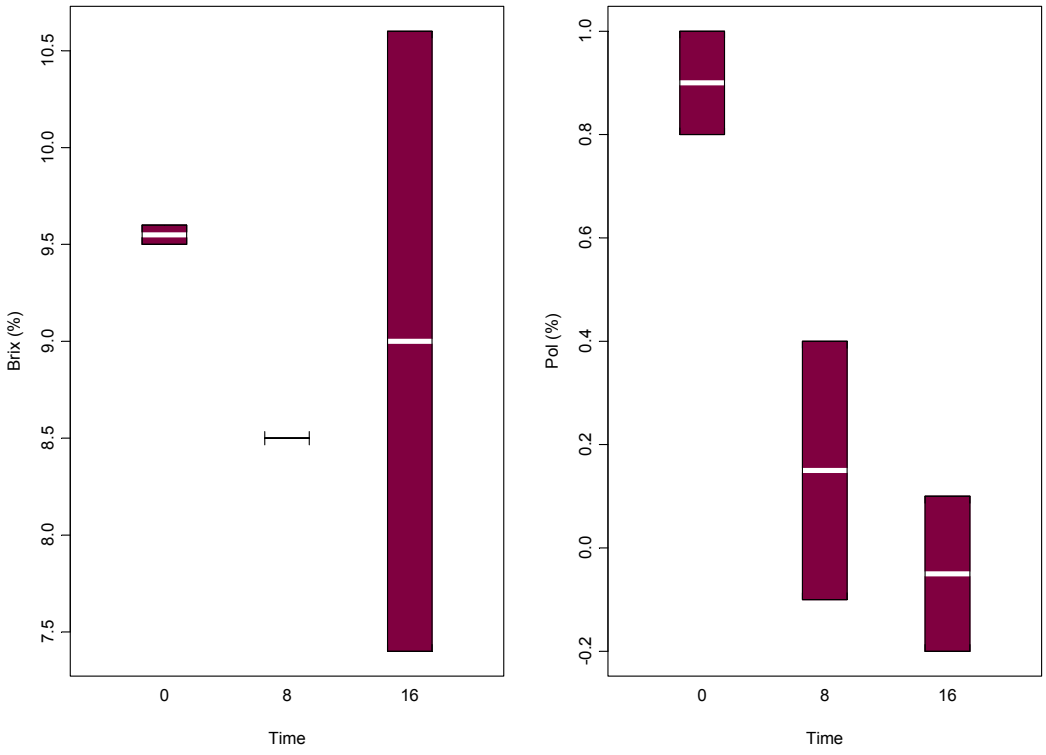

Fig. 5—The effect of time on the brix and pol of trash.

Results are given in Table 7 for the comparison of pol loss in BE and GU cane from 22 tonne bins left on the pad overnight and compared to similar bins crushed shortly after harvesting.

Table 7—Pol changes for whole bins over time during the yield experiment.

Block	Crushed same day		Crushed next day		Pol drop overnight	
	BE	GU	BE	GU	BE	GU
Av pol (%) GH 2 15 July	11.68	10.24	11.49	9.92	–0.19	–0.32
Av pol (%) DI 25 Nov	11.56	10.17	11.22	8.96	–0.34	–1.21

In the trial conducted on 25 November, 8 mm of rain fell before the bins were collected the following day which could be expected to have a slight diluting effect on the measured pol for both the burnt and green cane.

An analysis of variance showed that the reduction in pol with the delayed crush was statistically significant at the 8% level (that is, not statistically significant at the standard 5% level). Although the drop in pol was greater in the green, unextracted cane, particularly in the November trial, the difference in pol reduction rate between the BE and GU harvesting treatments was not statistically significant. It is nonetheless suspected that, had more tests been undertaken, particularly during the warmer months, a more significant result would have been found.

Fibre yield

Across all trials, dry ash-free fibre (DAFF, defined simply here as the fibre content less the ash content) yields were 5.5 t/ha higher in the green, unextracted treatments than in the burnt cane. The higher median fibre content (18.9%) compared to burnt, extracted cane (15.9%) combined with 24% higher yields resulted in a 40% increase in DAFF per ha. The fibre figure for green, unextracted is lower than the 21% reported by Kent *et al.* (2010) for the large scale trial at Broadwater during the 2009 season. The very wet conditions experienced during 2010 may account for part of this difference.

Table 8 gives the relative crop and fibre yields for all trials where yields are known to be consistent across treatments. At site MN the fibre value for burnt cane was reported as 20.4%, which appears anomalous. The low additional DAFF yield at site RC is due to the low cane yield (burnt cane 66.7 t/ha) at that site.

Table 8—Relative crop and fibre yields (%) by block.

Farm	Relative crop yield (GU – BE) / BE	Relative fibre yield (GU – BE) / BE	Relative DAFF yield (GU – BE) / BE	Additional DAFF yield t /ha	Additional DAFF yield / BE cane yield
ED	27	68	69	11.1	10.5
MN	18	32	30	3.6	4.8
AS	21	47	39	8.9	5.1
GH 1	14	40	44	4.4	5.2
RC	29	53	45	3.7	5.5
GH 2	37	67	67	7.4	9.3
GH 3	34	67	46	6.3	6.4
JH 2	17	41	41	6.7	5.6
JH 3	28	61	64	8.9	8.7
DI	35	59	57	5.6	7.4
Av	24	54	50	6.7	6.9

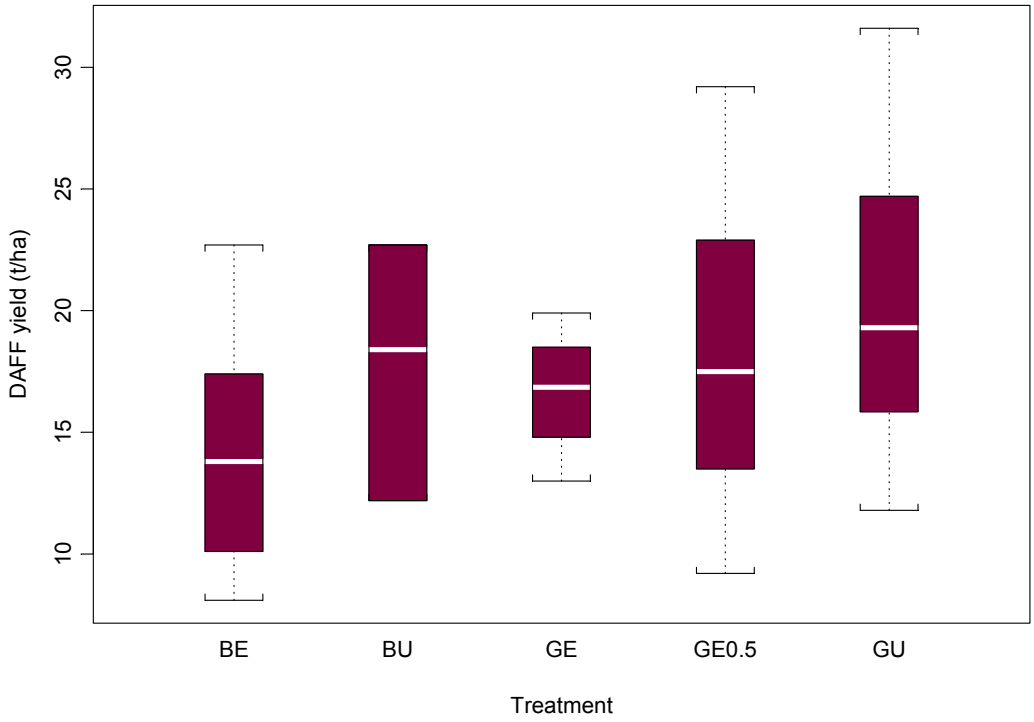

Fig. 6—DAFF yields for treatments of the yield experiment.

Conclusions

In the yield experiment, whole crop harvesting increases crop yield by about 24% relative to conventional burnt cane harvesting. Whole crop harvesting also has the intended effect of increasing biomass supply to the factory for generation of electricity with at least 40% extra dry, ash-free fibre measured relative to burnt cane harvesting.

There was a 14% increase in pol yield from whole crop harvesting compared to burnt cane harvesting. There is some evidence that part of this increase in pol yield is because cane and juice losses by the harvester are reduced in the field by whole crop harvesting (green, unextracted) which is able to capture chopper losses in the cane supplied to the mill. However, the question then becomes, 'How much of this additional pol can be realized at the factory?' The authors can identify three reasons why not all, and possibly none, of the additional pol measured will result in a higher sugar make:

- Firstly, the short cut-to-crush times achieved during these tests will have reduced pol loss in the green, unextracted cane that would normally have occurred as a result of typical cut to crush delays. Pol on trash appears to deteriorate faster than the pol in sound billets. This result could be expected due to the relatively larger surface area of the trash.
- Secondly, it is probable that pol in whole crop material is overstated. Current methods and assumptions used to determine pol in cane were developed in burnt cane. Although they may be robust enough to be used in commercial green cane harvesting they are yet to be proved suitable for 'whole of crop' harvesting. There is some evidence from factory recovery analyses and direct cane analysis tests that support the overstated pol theory.
- Thirdly, factory losses with whole crop milling are known to be higher than for burnt or green (extracted) cane (Kent *et al.*, 2010).

Acknowledgements

We gratefully acknowledge the efforts of the farmers and harvest crews whose cooperation made this work possible. We particularly thank Angus Stainlay who conducted one of the trials on his farm and assisted with several others. Garth Hibbard and John Harbison provided four and three sites respectively. The Sugar Research and Development Corporation is acknowledged for supporting QUT's involvement in this project. Rick Beattie, David Moller and Michelle Lowrey from NSW Sugar Milling Co-operative and Hakan Bakir from QUT are acknowledged for their assistance in the running of and analysis of results from the Broadwater tests. The authors acknowledge the support and advice received from Greg Petersen, Phil Scroope, Cam Palmer and Rick Beattie from NSW Sugar Milling Co-operative in arranging these tests and in interpreting the results.

REFERENCES

Berding N, Johnson, SE Hurney AP (2002) What happens from field to mill? Crop-fraction and CCS considerations. *Proceedings of the Australian Society of Sugar Cane Technologists* **24**, (CD-ROM) 12 pp.

Crook TD, Pope GM, Staunton SP, Norris CP (1999) A survey of field CCS versus mill CCS. *Proceedings of the Australian Society of Sugar Cane Technologists* **21**, 33–37.

Davis RJ, Norris CP (2001) Impact of chopper harvesting on the translation of field CCS to factory realised CCS. SRDC Final Report BSS244, Sugar Research and Development Corporation, Brisbane.

Fuelling TG, Henkel CR, Leverington KC, Wegener MK (1978) Sugar cane harvester performance. *Proceedings of the Queensland Society of Sugar Cane Technologists* **45**, 209–216.

Gomez J, Chapple D, McDonald L (2006) Sugar losses in burnt and green cane harvesting in Argentina. *Proceedings of the Australian Society of Sugar Cane Technologists* **28**, 291–297.

Hockings PR, Norris CP, Davis RJ (2000) Chopper systems in cane harvesters: B: Results of a test program. *Proceedings of the Australian Society of Sugar Cane Technologists* **22**, 250–255.

Kent GA, Moller DJ, Scroope PD, Broadfoot R (2010) The effect of whole crop processing on sugar recovery and sugar quality. *Proceedings of the Australian Society of Sugar Cane Technologists* **32**, 573–587.

Linedale AI (1997) An industry campaign to reduce cane harvesting losses. SRDC Final Report BS82S, Sugar Research and Development Corporation, Brisbane.

Moller D, Broadfoot R, Bell S, Bakir H (2010) Whole crop processing at Broadwater mill: Impacts on process operations. *Proceedings of the Australian Society of Sugar Cane Technologists* **32**, 559–572.

Palmer C, Farrell RM, Hurt J (2009) The development of cogeneration projects at Condong and Broadwater mills. *Proceedings of the Australian Society of Sugar Cane Technologists* **31**, 400–409.

Ridge DR, Dick RG (1987) A new method for testing cane harvester performance. *Proceedings of the Australian Society of Sugar Cane Technologists* **9**, 87–92.

Sichter NJ, Whiteing C, Bonaventura P (2005) Estimation of harvester losses by determination of sugar in harvest residue. *Proceedings of the Australian Society of Sugar Cane Technologists* **27**, 75–82.

Staunton SP, Lethbridge PJ, Grimley SC, Streamer RW, Rogers J, Mackintosh DL (1999) On-line cane analysis by near infra-red spectroscopy. *Proceedings of the Australian Society of Sugar Cane Technologists* **21**, 20–27.

Whiteing C (2002) Facilitation of harvesting best practice to reduce extraneous matter and cane loss. SRDC Final Report BSS189, Sugar Research and Development Corporation, Brisbane.