FINAL REPORT 2016/953

Commercial scale economic evaluation of post-harvest cane cleaning to maximise the returns to the supply chain.

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Co-funder(s):	Department of Agriculture
Date:	1/5/2019
Key Focus Area (KFA):	4. Farming systems and harvesting

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Australian Government
Department of Agriculture

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Please cite as: Ginns SP, Kent GA, Robotham B, Panitz J, Johnston W, 2019 Commercial scale economic evaluation of post-harvest cane cleaning to maximise the returns to the supply chain: Final Report Project 2016/953. Sugar Research Australia.

ABSTRACT

This project examined three cane supply treatments; Commercial harvesting, Low Loss harvesting and Low Loss Harvesting plus cleaning; to determine if post-harvest cane cleaning offered benefits over harvesting alone. As a basic concept, it was expected that reducing harvester extractor fan speed would reduce cane loss, resulting in increased CCS yield but also increased trash content, and that the post-harvest cane cleaning operation would remove the additional trash, maintaining the higher CCS yield.

To facilitate this project, a mobile cane cleaner (MCC) was purchased from Norris ECT by SRA. The MCC was leased by the project from SRA. Major modifications to the cleaning chamber of the NorrisECT 180 mobile cane cleaner (MCC 180) were necessary. The MCC was a prototype machine not suitable for commercial use.

The results did support the expectation of higher CCS yield with lower extractor fan speed, but much of the higher yield measured by low loss harvesting was lost after post-harvest cane cleaning. Economic analysis quantified harvesting costs and the resulting product income. In an experiment on Rajinder Singh’s farm, the treatment with post-harvest cane cleaning was found to be less economically attractive than the normal harvesting treatment, even with the lower transport cost in getting cane to Mossman Mill, a distance of 95 km. The project did not measure an increase in CCS yield from the low loss harvesting plus cane cleaning treatment to improve upon sugar income.

EXECUTIVE SUMMARY

This project is one component of SRA's Rural R&D for Profit project 'Enhancing the sugar industry value chain'.

The project involved field and factory measurements of different harvesting and cane supply strategies in an effort to identify strategies that maximise the total industry benefit, considering in particular the cost of the harvesting and cane supply strategy, the resulting cane loss and the impacts of the resulting extraneous matter in the cane supply.

The project was conducted in conjunction with sugar industry stakeholders in the Bundaberg region, including Bundaberg Sugar and Isis Central Sugar Mill, and in the Tableland region with MSF Tableland Mill and Mackay Sugar Mossman Mill. The initial activity involved the conduct of experiments to assess the effects of three different harvesting and cane supply strategies:

1. Commercial harvesting (higher primary extractor speed, with secondary extractor on)
2. Low loss harvesting (lower primary extractor speed, secondary extractor off)
3. Low loss harvesting and post-harvest cleaning using a Norris ECT trash separation plant.

Following commissioning of the trash separation plant in 2017, two series of the three treatment tests were conducted at Fairymead Plantation and the cane was processed at Bingera Mill. Two further series of tests were conducted at Emdex and processed at Isis Mill. The analysis of results revealed very few statistically significant differences between the different cane supply strategies, mainly due to the small number of tests completed. Further tests were required to be confident of the results.

Two preliminary experiments and three large experiments were conducted on the Atherton Tablelands. Most of the experiments were conducted on MSF Sugar farms growing KQ228$^{\Phi}$, with the cane supplies processed at Tableland Mill. The final experiment was conducted on Rajinder Singh's farm growing Q208$^{\Phi}$, with the cane supplies processed at Mossman Mill. The main objective of the experiments was to determine the change in CCS yield that could be achieved by changes to harvesting parameters (principally extractor fan speed), with and without cane cleaning. As a basic concept, it was expected that reducing extractor fan speed would reduce cane loss, resulting in increased CCS yield but also increased trash content, and that the post-harvest cane cleaning operation would remove the additional trash, maintaining the higher CCS yield. The results did support the expectation of higher CCS yield with lower extractor fan speed, but much of the higher yield measured after low-loss harvesting was not measured after post-harvest cane cleaning.

Following the first three experiments, additional focus was placed on the mass balance around the cane cleaner to understand the fate of the higher CCS yield. The most likely explanation was that the higher yield of the low loss harvesting treatment was overstated, resulting from the use of NIR analysis of CCS calibrated to first expressed juice analysis. The final experiment focussed on this issue by using, in addition to NIR analysis, conventional first expressed juice analysis and direct cane analysis to provide additional measures of CCS. While this final experiment also found a reduction in CCS yield across the cane cleaner using the NIR and conventional first expressed juice analysis, that difference was not evident in the direct cane analysis results. It was concluded that the direct cane analysis method gave CCS yield results that were most consistent with mass balance analysis results.

An economic analysis was undertaken on the three large Tableland experiments to assess the most economically attractive harvesting and cane cleaning strategy of the three strategies tested. The analysis considered costs associated with harvest and haulouts, transport, trash and cane cleaner

operation, along with gross income based on tonnes of cane and CCS at the factory. In all three experiments, the treatment with post-harvest cane cleaning was found to be less attractive than the harvest-only treatments. In the Rajinder Singh farm experiment that same result was achieved, even taking into account the lower transport cost in getting cane to Mossman Mill, a distance of 95 km. In two of the experiments where a treatment with a higher than normal extractor fan speed was included, the higher fan speed treatment was more economically attractive than the normal speed.

The mobile cane cleaner that was used by the project was a prototype machine that could not be used commercially. Modifications would be required to improve both its performance and operation.

Based on this work, it seems unlikely that cane cleaning has a place in areas growing varieties such as KQ228⌽ and Q208⌽ which are regarded as low loss varieties. A different result may be achieved in an area that is growing varieties considered to result in high cane losses during harvest.

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1. BACKGROUND

The Australian sugar industry annually produces approximately $1 billion value of sugar. Industry cost pressures are forcing harvesters to operate at higher harvesting speeds with an associated increase in pour rate. This results in higher harvesting losses and strong upward trends in leafy EM and fibre levels in the product to be milled. Anon (2014) quotes "a conservative industry estimate of 10% avoidable cane loss in regional trials annually". The increasing EM levels reduce mill capacity and sugar recovery; both are significant costs to the milling sector (Kent 2014).

"Low Loss" harvesting with post-harvest cane cleaning can potentially be used to manage this issue. Australian trials utilising a prototype cleaning system demonstrated increases in both the amount of cane delivered to the mill and the expected sugar recovery, with overall increases in tonnes CCS/ha ranging from 10% to more than 30%. Increases in milling rate consistent with the significant reduction in fibre levels have also been noted, as well as significant reductions in soil in cane (Norris et.al 2015).

The cost and logistics associated with harvesting and cane cleaning, and further quantification of the potential gains to all sectors of the Industry, are the primary issues which this project further quantified.

The industry is investing time, money and resources to maximise sugar cane production. Potential sucrose is lost due to poor harvester design and practices. Post-harvest cane cleaning may be the required 'step' change to ensure continued viability of this industry.

2. PROJECT OBJECTIVES

The project objectives were:

- To increase the industry value by increasing the proportion of sucrose in the crop prior to harvest which can be practically and economically recovered by determining the impact of:
  - Changes in harvester operating parameters to reduce cane loss on the harvester ("low loss" harvesting), and
  - Post- harvest cleaning to enhancing sucrose recovery at the mill by presenting product which has low levels of leafy extraneous matter.
- To determine the impact of the different harvesting strategies and post-harvest cleaning on the productivity and cost of the harvesting operation, the potential impact on the transport system of different post-harvest cleaning strategies (field edge or mill-based), and the impact on sugar production costs.
- To enable the impact of post-harvest cleaning on all stakeholders to be determined.
- To inform the growing, harvesting and milling sectors of the industry of the benefits of changes to harvesting practices.
- To identify and address barriers to adoption of changes to harvesting practices and the introduction of cane cleaning.
- To provide industry with a 'closed loop' economic analysis of improved harvester practice combined with post-harvest cane cleaning, a detailed evaluation on the impact on total Industry returns, and the potential benefits and costs to all sectors of the Industry.

3. OUTPUTS, OUTCOMES AND IMPLICATIONS

3.1. Outputs

The primary project output was to develop sound economic data to enable the growing, harvesting and milling sectors to determine the whole of industry effect of different harvesting and cane cleaning practices on operating costs, crop yield and product recoveries (sugar, molasses, mud, bagasse) across the value chain.

The project delivered:

- An assessment of the magnitude of losses and the interactions between harvester outputs and mill recovery, mainly in the Tableland region.
- Knowledge based on field and factory measurements of the effect of different harvesting treatments and cane cleaning on operating costs, yield and product recoveries across the value chain.
- Evaluation of sucrose recovery and the role of harvester set-up, with or without cane cleaning, in contributing to those recoveries.
- Increased industry awareness of improved sugar quality produced from a cane supply with less extraneous matter.

In particular, the project delivered cane and sugar yield measurements from different harvesting treatments, including post-harvest cane cleaning, and an economic analysis of the different treatments for growers in the Tableland region. For harvesting cane varieties such as KQ228Ⓟ and Q208Ⓟ that constitute a large proportion of Tableland cane and are recognised as low loss varieties, cane cleaning cannot be justified.

3.2. Outcomes and Implications

The project has added to the Australian sugar industry data on the quantity of sucrose lost in the harvest process, the impact of harvest set-up on those losses and a cost:benefit analysis of cane cleaning as a strategy to mitigate those losses. Harvesting cane loss has been identified as a significant cost to the industry and this project has increased industry awareness of the amount of sugar left in the field due to current harvesting practices.

In the Tableland region where the majority of the cane supply is considered to consist of low loss varieties, maximising industry profitability will be achieved through optimisation of the harvesting process alone. In terms of grower economics, existing harvesting practice appears to be close to optimal, considering harvester pour rate and extractor fan speed. Further optimisation will require consideration of other parameters such as various aspects of harvester design and billet length.

4. INDUSTRY COMMUNICATION AND ENGAGEMENT

4.1. Industry engagement during course of project

Growers visited the Mobile Cane Cleaner (MCC) at MSF's 'Mousa' farm on the Tableland and witnessed its performance.

Trial results were presented to industry/grower update meetings at Meringa, Isis and Bundaberg, 2018.

Trial results were presented at the SRA/QUT Regional Research Seminars to mills in 2018 and 2019.

Norris ECT are selling and exporting many MCCs to Central American countries.

4.2. Industry communication messages

Since the concept of the mobile cane cleaner project began to form in mid-2016, industry Harvest Best Practice has been widely accepted by the harvesting contractors and growers. The reduced primary extractor fan speeds of commercial harvesting that we have seen during our trials may have taken the economic advantage away from low loss harvesting and mobile cane cleaning.

It was expected that gains in CCS would overcome any additional harvesting and transport costs generated by the inclusion of the MCC in the process, but that proved not to be the case in the trials undertaken.

The economic analysis quantified harvesting costs and the resulting product income. The economic analysis was undertaken on three large Tableland experiments to assess the most economically attractive harvesting and cane cleaning strategy of the three strategies tested. The analysis considered costs associated with harvest and haulouts, transport, trash and cane cleaner operation, along with gross income based on tonnes of cane and CCS at the factory. The project did not measure an increase in CCS yield from the low loss harvesting plus cane cleaning treatment compared to the commercial harvesting treatment and therefore no improvement in sugar income.

5. METHODOLOGY

5.1. Introductory remarks

This project mainly consisted of experiments to measure the impact of different cane supply strategies involving different harvesting parameters, with and without post-harvest cane cleaning, and economic analysis of the alternatives to identify the most economically attractive strategy.

Three harvesting treatments were assessed:

- “Commercial practice”. Commercial harvesting practice for the area/contractor (relatively high primary extractor fan speeds coupled with secondary extraction) at commercial ground speed and typically at a reduced billet length setting. The outcome is a high harvester pour rate and “typical” load density.
- “Low loss” harvesting. The primary extractor fan at lower speed to reduce cane loss and the secondary extractor turned off. The harvester operating at similar pour rate to commercial practice.
- “Low loss harvesting and post-harvest cleaning”. Low loss harvesting followed by post-harvest siding/field edge cane cleaning using a Norris ECT 180 mobile cane cleaner. This cleaner was used to clean the cane prior to forwarding to the mill.

The Norris ECT 180 mobile cane cleaner was leased to the project (picture below). Due to a delayed construction phase and delayed delivery date, the mobile cane cleaner was not available for field trials until mid to late August 2017. Experiments were conducted in the Bundaberg region during 2017 and the Tableland region during 2018.

The cane supply for each treatment was randomly selected across the field using the mass balance or linear method. This proven method involves harvesting a haul-out load of cane using one treatment and then applying another treatment, in random order, so that each treatment is composed of cane supply from across the block, minimising the effects of field variability on the experimental results. Harvesters were equipped with GPS navigation systems to log the start and end point of each treatment, enabling yield assessments to be made.

Picture of Norris ECT180 Mobile Cane Cleaner and Haulouts on MSF's 'Mousa Farm' 2018

All treatments were harvested using established protocols, with key field measurements being:

- Total harvested yield/ha, clean cane (total – EM) yield/ha and CCS yield/ha delivered to the mill for the different treatments.
- Extraneous matter percentage (EM%) where 15 kg to 20 kg samples were randomly taken from each bin. The collected material was processed to determine EM%. The sample components were categorised into cane billets, tops and trash and weighed.

5.2. Methodology for research and data gathering for year one (2017)

5.2.1. Fairymead / Bingera mill experiment

At Bundaberg Sugar's farm, "Fairymead", trials were conducted on consecutive days on two blocks. The block for experiment one was plant cane Q238$^{\Phi}$ established in Autumn 2016 and the block for trial two was a ratoon crop of Q242$^{\Phi}$ established in Autumn 2013. The three harvesting treatments, commercial (primary extractor fan speed 850 r/min), low loss (primary extractor fan speed 750 r/min) and low loss plus cleaning, were used to harvest the blocks and create rakes of cane consisting of 20 rail bins for each treatment. These bins are nominally 6 t cane bins. The bins were then transported by rail to the Bingera Mill where they were processed continuously through the factory over a period of approximately one hour per treatment.

The cane was analysed by first expressed juice for pol and can fibre for fibre, and final bagasse was analysed for moisture and pol. To better estimate sugar and molasses production, mixed juice samples were analysed and clarified and concentrated to produce liquor in small scale equipment constructed for SRA project 2012/057 (Broadfoot et al. 2015). Sugar and molasses production were predicted from this data.

5.2.2. Emdex / Isis mill experiment

At Isis Central Sugar's farm, "Emdex", trials were conducted on consecutive days on two blocks of older ratoon cane KQ228$^{\phi}$ established in Autumn 2013. The three harvesting treatments, commercial (850 r/min), low loss (750 r/min) and low loss plus cleaning, were used to harvest the blocks and create rakes of cane consisting of 24 rail bins for each treatment. These bins are nominally 6 t cane bins. The bins were then transported by road and rail to the Isis Central Sugar Mill where they were processed continuously through the factory over a period of approximately one hour per treatment.

The factory sampling and analysis approach at Isis was similar to that at Bingera.

5.3. Methodology for research and data gathering for year two (2018)

5.3.1. MSF Tableland mill experiment

A methodology similar to the year one methodology was used in year two's trials. The main difference in year two was that Tableland cane was delivered to the mills by road transport and so the size of each test was reduced to the size of a truck load. As a result, many more tests were conducted for each experiment. All experiments were conducted in a randomised block design.

At MSF's Tableland farm, "Moussa" Block 12A, the first trial was conducted over two consecutive days on a block of plant cane KQ228$^{\phi}$ established in Autumn 2017. The two harvesting treatments used to harvest the blocks were commercial (800 r/min) and low loss (680 r/min) plus cleaning. Each treatment consisted of filling one road bin of cane. During each treatment, the distance (hence area harvested) was recorded. Bins at the pad were filled in a controlled order and bin numbers matched to field treatments. These bins were nominally 24 t bins and the treatments were repeated 19 times. The bins were transported by road to the Tableland Mill where they were processed through the factory when received. The cane was analysed by NIR cane analysis.

The second trial conducted at MSF's Tableland farm was a small series of tests conducted between two major trials on another block of plant cane KQ228$^{\phi}$ established in Autumn 2017. The trial consisted of two treatments, commercial (900 r/min) and low loss (700 r/min) plus cleaning. The same experimental procedure was followed and 11 replicates were completed.

The third trial conducted at MSF's Tableland farm was conducted over two consecutive days on another block of plant cane KQ228$^{\phi}$ established in Autumn 2017. The three harvesting treatments used to harvest the block were commercial (900 r/min), normal (800 r/min) and low loss (700 r/min) plus cleaning. Again, the same experimental procedure was followed.

Field testing of sugar loss was conducted on trials one and three at MSF's Tablelands Farm as sugar is lost in all parts of the field residue including trash, tops and smashed billets. The project used the SRA Infield Sucrose Loss Measurement System (ISLMS) developed by Cam Whiting et al. (2013). The unit is equipped to collect, process and analyse field residue and was used to measure sugar content of material in the field left behind by the harvester.

The fourth trial conducted on MSF's Tableland farm was conducted over three consecutive days on another block of plant cane KQ228$^{\text{Ⓟ}}$ established in Autumn 2017. The three harvesting treatments used to harvest the block were commercial (900 r/min), low loss (700 r/min) and low loss plus cleaning. The same experimental procedure was followed and 17 replicates were completed.

5.3.2. Rajinder Singh/Mossman mill experiment

The fifth trial on the Tablelands was conducted on Rajinder Singh's farm over four consecutive days on a block of plant cane Q208$^{\text{Ⓟ}}$ established in Autumn 2017. The four harvesting treatments used to harvest the block were high (850 r/min), commercial (750 r/min), low loss (600 r/min) and low loss plus cleaning. Each treatment consisted of filling three road bins of cane, which constituted one transport load. Apart from the difference in bins, the same experimental procedure was followed and 10 blocks were completed. During this fifth trial, additional cane analysis was conducted at the mill with conventional first expressed juice analysis undertaken and prepared cane samples collected and analysed for can fibre and also utilised for direct cane analysis.

Extraneous matter percentage (EM%) was calculated from 20 kg to 30 kg samples randomly taken from each haulout by an excavator bucket before being tipped into the road bins on all trials. The excavator bucket swept a volume of harvested material away from the sampling point before taking the sample. The bucket then took the sample and tipped the sample into two 100 litre tubs on the ground. The tubs were then lifted and the sample then placed into a plastic chaff bag. The collected material was processed to determine EM%. The sample components were categorised into sound billets, damaged billets, mutilated billets, tops, roots and trash and weighed. This process was repeated for all samples taken.

5.4. An economic analysis methodology for 2018 trials three, four and five

The determination to assume that the grower, or harvest group, was the investor in the harvest and cane cleaning machinery, shifted the economic focus to developing a partial budget analysis whereby the MCC could be introduced into the harvesting and transport process, as compared to standard practice. For this analysis, the gross income from the experimental harvest was calculated based on CCS (NIR) results, less harvesting and haul-out contract rates (including fuel and labour). Where the cane cleaner was injected in the process, additional costs were accounted for and included FORM (fuel, oil, repairs and maintenance), depreciation and operating labour.

For experiments 3, 4 and 5, a number of treatments were conducted comparing standard practices with varying harvester fan speeds, as well as a treatment that incorporated the MCC. Table 1 provides a summary of the treatments under each experiment.

Table 1 Summary of the economic analyses conducted for each experiment (see Tables 16, 24 and 31)

Experiment Detail	Treatment 1 (TR1)	Treatment 2 (TR2)	Treatment 3 or 4 (TR3 or TR4)
Experiment 3 (June 2018)	Commercial	Normal	Low loss + Cane Cleaner
Experiment 4 (August 2018)	Commercial		Low loss + Cane Cleaner
Experiment 5 (October 2018)	Commercial	Normal	Low loss + Cane Cleaner

Note: Experiment 4 only conducted trials for standard practice and harvesting with cane cleaner.

The results for each treatment, under each overarching experiment, were assessed similarly to derive a gross income per hectare and per tonne, to provide a standardised basis for comparison. The cost structures for each treatment were accounted for on this basis to provide a net income calculation for the same units of measure. Some of the base harvest parameters for each of the experiments and treatments are listed in Table 2.

Table 2 Base harvest output parameters for each conducted experiment

Parameter	EXP3/TR1	EXP3/TR2	EXP3/TR3	EXP4/TR1	EXP4/TR3	EXP5/TR1	EXP5/TR2	EXP5/TR4
Harvest area (Ha)	1.30	1.44	1.56	2.55	2.23	2.73	3.08	3.36
Tonnes harvested / Ha	154	149	141	151	160	125	116	119
CCS (NIR)	15.40%	15.44%	15.29%	16.45%	16.33%	14.19%	14.46%	14.46%

6. RESULTS AND DISCUSSION

6.1. Bundaberg and Isis 2017 experiments

6.1.1. Introductory remarks

Results and discussion of tests conducted in the 2017 season of different harvesting treatments included consideration from the factory perspective.

During this series of tests, three harvesting treatments were assessed:

1. Commercial harvesting
2. Low loss harvesting (extractor fans at low speed to reduce cane loss)
3. Low loss harvesting and post-harvest cleaning using a Norris ECT trash separation plant.

During these tests, cane was processed at Bingera and Isis factories. The full test series is summarised in Table 3.

Table 3 Harvest treatments

Factory	Harvest date	Block	Treatment
Bingera	22 August 2017	1	Commercial
		1	Low loss
		1	Cleaned
Bingera	23 August 2017	2	Commercial
		2	Low loss
		2	Cleaned
Isis	10 October 2017	3	Commercial
		3	Low Loss
		3	Cleaned
Isis	11 October 2017	4	Commercial
		4	Cleaned

6.1.2. Cane supply

Cane at both factories was supplied in nominally 6 t cane bins. The cane supply details are presented in Table 4. Considering the two factory results separately, bin weights for the commercial treatment were higher than for either the low loss or cleaned cane supply. There are some obvious reasons for that result.

Table 4 Cane supply details

Factory	Block	Treatment	Number of bins	Total tonnes	Average bin weight
Bingera	1	Commercial	20	107.6	5.4
	1	Low loss	19	76.8	4.0
	1	Cleaned	20	73.4	3.7
Bingera	2	Commercial	20	80.0	4.0
	2	Low loss	20	57.6	2.9
	2	Cleaned	20	48.0	2.4
Isis	3	Commercial	24	146.5	6.1
	3	Low Loss	24	104.4	4.0
	3	Cleaned	24	132.8	5.5
Isis	4	Commercial	24	145.5	6.1
	4	Cleaned	24	129.6	5.4

The commercial and low loss cane supply results can be directly compared. For both treatments, a full 6 t tipper was used to fill the cane bin. The lower mass for the low loss treatment reflects the higher trash content caused by the lower extractor fan speed.

At Bingera, a cleaned cane bin was filled with the cane stream from the trash separation plant, supplied with one 6 t tipper of the low loss harvest treatment. Removing the trash stream from the cane supply significantly reduced the volume of cane in the cane bins from the cleaned treatment. Although not statistically significant, both blocks showed lower bin weight from the cleaned cane supply than the low loss cane supply, as expected because of the removal of the trash stream.

At Isis, additional tippers with the low loss cane supply were used to increase the volume of cane in the cleaned cane bins. As a result, the one comparison of low loss to cleaned cane supplies (block 3 in Table 4) shows a higher bin weight for cleaned cane than for low loss harvested cane.

At both factories, cane fibre content was determined through can fibre analysis (CFM fibre) and cane brix and pol content were determined through first expressed juice analysis. The cane analysis details are presented in Table 5.

Table 5 Cane analysis details

Factory	Block	Treatment	CFM fibre content (%)	CCS	Cane purity (%)
Bingera	1	Commercial	14.85	14.84	87.50
	1	Low loss	15.46	14.64	86.92
	1	Cleaned	13.64	15.29	87.82
Bingera	2	Commercial	17.06	13.04	84.62
	2	Low loss	17.46	12.62	83.96
	2	Cleaned	14.57	13.54	84.02
Isis	3	Commercial	14.88	14.95	86.33
	3	Low loss	16.51	14.53	86.34
	3	Cleaned	13.34	15.15	86.52
Isis	4	Commercial	13.79	14.63	86.38
	4	Cleaned	13.30	14.69	86.29

For cane fibre content, considering the results from each factory separately did not identify a statistically significant effect, but analysing the combined data set from the two factories identified that the cane fibre content from the low loss treatment was higher than that from the cleaned treatment. This result was expected since the cleaned cane supply is created by removing trash with higher fibre content from the low loss treatment cane supply. No statistically significant difference in fibre content was identified between the commercial and cleaned cane supplies.

For CCS, the Bingera results showed a statistically significant difference between the low loss and cleaned treatments. As expected, the cleaned cane treatment had a higher CCS than the low loss treatment. Since the trash component of the low loss cane supply has low CCS, this result was expected. No statistically significant effect was identified in either the Isis or combined data sets.

No statistically significant difference in cane purity was identified in any of the examined data sets.

6.1.3. Factory effects

Rate effects

The cane rate and cane fibre rates achieved while processing the test rakes of cane are presented in Table 6 along with the #1 mill drive speed that controls the rate. No statistically significant effects were identified. Although it was desired to maintain a constant speed during the tests, the low bin weights at Bingera necessitated reductions in speed to maintain chute level in #1 mill, particularly during the block 1 processing.

Table 6 Cane rate results

Factory	Block	Treatment	Cane rate (t/h)	Cane fibre rate (t/h)	Mill 1 drive speed (r/min)
Bingera	1	Commercial	296	44.0	2799
	1	Low loss	280	43.3	2800
	1	Cleaned	267	36.5	2600
Bingera	2	Commercial	277	47.3	2511
	2	Low loss	222	38.8	2499
	2	Cleaned	192	28.0	2600
Isis	3	Commercial	411	60.8	822
	3	Low Loss	349	55.7	813
	3	Cleaned	418	55.9	822
Isis	4	Commercial	423	59.3	884
	4	Cleaned	398	54.4	800

Extraction effects

Because of the short nature of the cane rakes, care was taken to ensure that the correct cane supply was being processed when measurements were being made. Prepared cane, first expressed juice and #1 mill bagasse samples were taken during the period that the factory sample tracker identified the rake was being processed. A 10-minute delay was allowed before any of the instrument measurements, #5 mill bagasse and juice and mixed juice samples were taken. All measurements ceased when the sample tracker identified the end of the rake. The specific times for each test are presented in Table 7.

Table 7 Measurement periods

Factory	Block	Treatment	Date	Start #1 mill	Start remainder	Finish
Bingera	1	Commercial	23/08	08:28	08:38	08:50
	1	Low loss	23/08	08:12	08:22	08:26
	1	Cleaned	23/08	07:58	08:08	08:11
Bingera	2	Commercial	24/08	08:15	08:25	08:26
	2	Low loss	24/08	07:52	08:02	08:08
	2	Cleaned	24/08	07:44	07:51	07:52
Isis	3	Commercial	11/10	08:15	08:25	08:34
	3	Low Loss	11/10	07:57	08:07	08:14
	3	Cleaned	11/10	08:36	08:46	08:54
Isis	4	Commercial	12/10	08:01	08:11	08:21
	4	Cleaned	12/10	08:23	08:33	08:40

Consideration was given to the following parameters:

- #1 mill and overall pol extraction
- #5 mill bagasse moisture content

- #1 and #5 mill reabsorption factor multiplier
- Added water rate
- #1 to #5 mill torque
- #1 to #5 mill feed chute flap position
- #1 to #5 mill roll lift
- #1 to #5 mill delivery nip compaction.

Of these parameters, the only statistically significant effect at the 5% level was the #2 mill torque at Bingera. This mill is of the BHEM two-roll mill design and does not have a feed chute flap. Consequently, its only torque control mechanism is roll lift. The results showed that the low loss treatment resulted in higher #2 mill torque than the cleaned treatment.

At the 10% level, three other effects were significant:

- Added water rate (% fibre) at Isis and Bingera

The higher added water rate is a consequence of maintaining an added water rate in tonnes per hour while the cane fibre content varies. As a result, the added water rate % fibre was higher for the cleaned cane tests where the cane fibre content was lower.

- #1 mill and overall pol extraction for Bingera and Isis combined

The #1 mill and overall pol extraction results show higher extraction from the cleaned treatment than from the low loss treatment.

These more significant results are presented in Table 8.

Table 8 Extraction related results

Factory	Block	Treatment	#2 mill torque (%)	Added water (%fibre)	#1 mill extraction (%)	Overall extraction (%)
Bingera	1	Commercial	67	239	75.19	96.92
	1	Low loss	70	242	73.98	96.92
	1	Cleaned	64	288	75.77	97.26
Bingera	2	Commercial	85	190	76.16	96.64
	2	Low loss	86	243	70.34	96.29
	2	Cleaned	82	335	76.19	-
Isis	3	Commercial	65	293	77.10	97.31
	3	Low Loss	64	319	78.18	96.88
	3	Cleaned	65	318	77.95	97.08
Isis	4	Commercial	65	329	76.91	96.64
	4	Cleaned	64	358	77.43	96.64

Sugar production

To gain an indication of the likely impact of the cane supplies on sugar production, mixed juice samples were collected and processed into liquor using small scale clarification and evaporation equipment. True purity of the liquor was then measured to provide an indication of sugar and molasses production. Reducing sugar (RS) and ash measurements were also used to assess the likely effect on molasses exhaustion. The results are presented in Table 9. No statistically significant effects were identified.

Table 9 Liquor analysis results

Factory	Block	Treatment	Purity (%)	RS/Ash
Bingera	1	Commercial	80.0	0.7
	1	Low loss	80.6	0.7
	1	Cleaned	80.1	0.7
Bingera	2	Commercial	78.8	0.5
	2	Low loss	77.8	0.6
	2	Cleaned	79.5	0.5
Isis	3	Commercial	79.0	1.5
	3	Low Loss	79.2	1.3
	3	Cleaned	78.1	1.5
Isis	4	Commercial	81.4	0.9
	4	Cleaned	78.8	1.0

6.1.4. Conclusions

The harvesting tests conducted in 2017 did appear to produce cane supplies with different levels of cane quality. Statistically significant differences in cane fibre content and CCS were identified between low loss and cleaned cane supplies but not between the commercial and other treatments. This is believed to be mainly caused by the small number of tests and can be remedied by conducting further tests.

The factory results showed higher extraction from the cleaned treatment than from the low loss treatment but few other significant differences.

No statistically significant sugar production effects were identified from the liquor analysis.

6.2. Tableland experiments

6.2.1. Introductory remarks

The mobile cane cleaner received some major modifications during the off-season following the 2017 tests. These modifications included:

- New axles to carry the mobile cane cleaner for moving around the farm/district.
- New cleaning chamber fitted to the machine.
- Modified accelerator drum housing, a new trajectory for cane billets passing through the jet stream.
- 'Hungry boards' on the hopper to hold more cane for the high lift tipping cane haulouts in north Queensland.

The cane cleaner was then disassembled in Bundaberg and cleaned down to pass a biosecurity inspection to enable transport across four cane zones. It was packed up and transported to an MSF farm 'Mousa' near Mareeba. The cane cleaner was then assembled and made ready for the first trial.

Four trials were successfully conducted on MSF's Mousa farm as stage one of the Tableland trials before the trials were stopped as the cane cleaner was not producing the economic results that were expected.

Rajinder Singh agreed to allow us to conduct a trial on his farm. Rajinder Singh sends his cane approximately 95 km to the Mossman mill. Mossman mill agreed to process the cane and allow us to conduct further CCS analyses.

To allow transport of the cane cleaner along Tableland district roads, the cane cleaner elevator had to be removed and transported separately by truck to the new farm while the cane cleaner was towed by a large 200 hp tractor. A mobile crane was hired for the removal and re-installation of the elevator once it was in position on the new farm.

In the trial on Rajinder Singh's farm the cane cleaner hopper floor carrier stopped working when a full load of cane was tipped onto the hopper floor. This issue necessitated the field haulouts only tipping approximately half a load into the cane cleaner. This half a hopper load was then cleaned and the rest of the load was subsequently tipped and cleaned. This was a very slow process, requiring a big thankyou to Ross Bray Harvesting and their haulout drivers for cooperating with the project. We realise this was only possible because they were on reduced bin numbers for the four days. If they were on normal bin allocations then the experiment would not have happened.

Here is a list of some of the issues that were experienced using the cane cleaner:

- While the hopper is relatively full of cane and the hopper floor is moving faster than a setting of 5 to 6 on the hydraulic drive, then bunching of cane was occurring at the scratcher and spillage of cane occurred over the side of the cleaner hopper.
- Trash was being sucked onto the air in-take screens and reducing the efficiency of the cleaning chamber.
- Leakage of billets from various places occurred around the cane cleaner.
- Damage to billets was also occurring in the cane cleaning process.

An excavator and operator were hired to take extraneous matter samples. These samples were then processed to determine the amount of sound, damaged and mutilated billets and also the amount of tops, and trash in the harvested sample.

6.2.2. Experiment 1

Introductory remarks

Three experiments were conducted in the first part of the 2018 harvest season to measure the effect of different cane supply strategies on cane yield. The experiments were conducted on Tableland Farm 2 Block 12A, processing KQ228⚘ plant cane. This block was a very good block to conduct the trial in, having an erect crop, with a thick stalk diameter. The billet length after harvest was averaging 200 mm and most of the block was being topped with a moderate pour rate.

Each test consisted of filling one road bin of cane. During each test, the distance (hence area) harvested was recorded. Bins at the pad were filled in a controlled order and bin numbers matched to field treatments. When the bin was processed through the factory, the bin weight and the NIR cane analysis were recorded. Bin weights and sample numbers were available through factory cane supply reports. Cane analysis was obtained from the factory Cane Analysis System, with the appropriate bias, as utilised for cane payment, applied to the CCS results.

The Cane Analysis System did not provide analysis averages for every bin in the experiment, due to either the sampling period not being defined or the sampling period being too short for an average according to the Cane Analysis System criteria. For the purpose of obtaining complete results for this experiment, the raw Cane Analysis System data was reanalysed, altering the averaging criteria. Only scans passing the Cane Analysis System criterion, ScanOK = True, were accepted. The acceptance criteria were relaxed in the following ways for samples where an average result was not originally provided:

- If valid scans were assigned to the sample, these scans were accepted.
- If the sample period was not defined and if the previous and subsequent sample had defined periods, the sample period was defined by adding three minutes to the end of the previous sample and subtracting three minutes from the start of the subsequent sample. The mean time between the end of one sample and the start of the next sample for the total period of the tests was a little less than three minutes.

In addition to the test data, extraneous matter analysis was conducted in the field and cane loss measurements were also undertaken using SRA's cane loss trailer, to gain further information about the characteristics of each treatment.

The first experiment was conducted with a randomised block design and consisted of 19 replicates of two treatments. The treatments are described in Table 10.

Table 10 Experiment 1 treatments

Treatment	Treatment	Fan speed (r/min)	Cleaned
1	Normal	800	No
2	Low loss + cleaning	680	Yes

Extraneous matter analysis

Six measurements of extraneous matter were made for both treatments. In addition, extraneous matter from cane in treatment 2 (low loss + cleaning) was measured before the cane cleaner (called treatment 2a). For the analysis, cane was sorted into five components: sound billets, damaged billets, mutilated billets, tops and trash. The results are summarised in Figure 1. The only parameter with statistically significant differences at the 5% level was trash content (significant at 0.06% level). Statistically significant differences were found between treatments 1 and 2a and between treatments 2 and 2a. In other words, the low loss treatment has more trash than either the commercial treatment or the low loss treatment after cleaning.

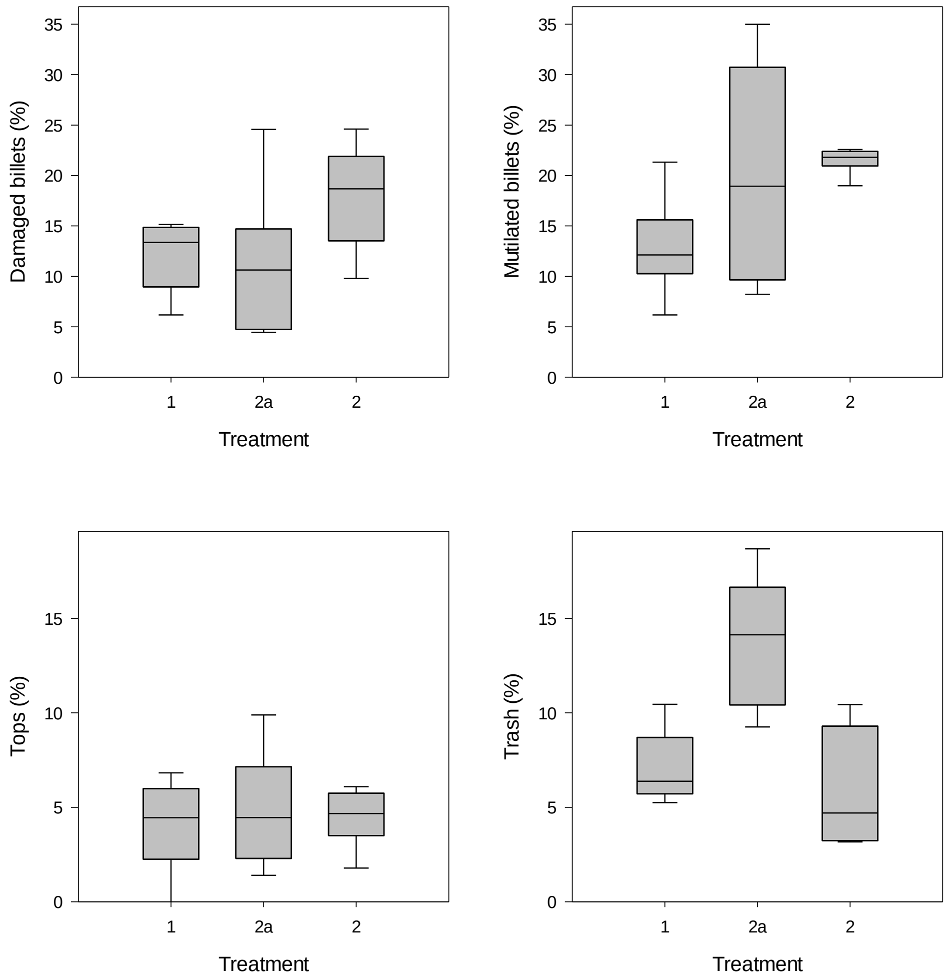


Figure 1 Extraneous matter results from experiment 1

Cane analysis

The NIR cane analysis results (CCS, purity, fibre content and ash content) for each test in the experiment are presented in Table 11. One test, treatment 2 for block 10, was not undertaken. No statistically significant differences in these cane properties were identified between the treatments at the 5% level.

Table 11 Experiment 1 results

Treatment	Tonnes	CCS (%)	Purity (%)	Fibre (%)	Ash (%)	Area (ha)	Yield (t/ha)	
							Cane	CCS
1	18.37	15.19	88.73	15.51	1.65	0.115	161	24.4
2	16.34	15.30	88.60	14.50	1.42	0.106	153	23.4

Yield analysis

The results for both cane yield and CCS yield in t/ha are presented in Table 11. The raw data, tonnes supplied and area harvested are also presented in Table 11. The area harvested was planted on a 2m row spacing and can be converted to metres of row harvested by multiplying the area by 5000.

An analysis of variance found that treatment had a statistically significant effect on cane yield at the 2% level. The results are shown graphically in Figure 2. Treatment 1 (normal) had a higher cane yield than treatment 2 (low loss + cleaning) by an average of 8 t/ha.

An analysis of variance found that the treatment had a statistically significant effect on the CCS yield at the 4% level. The results are shown graphically in Figure 3. Treatment 1 (normal) had a higher CCS yield than treatment 2 (low loss + cleaning) by an average of 1.0 t/ha.

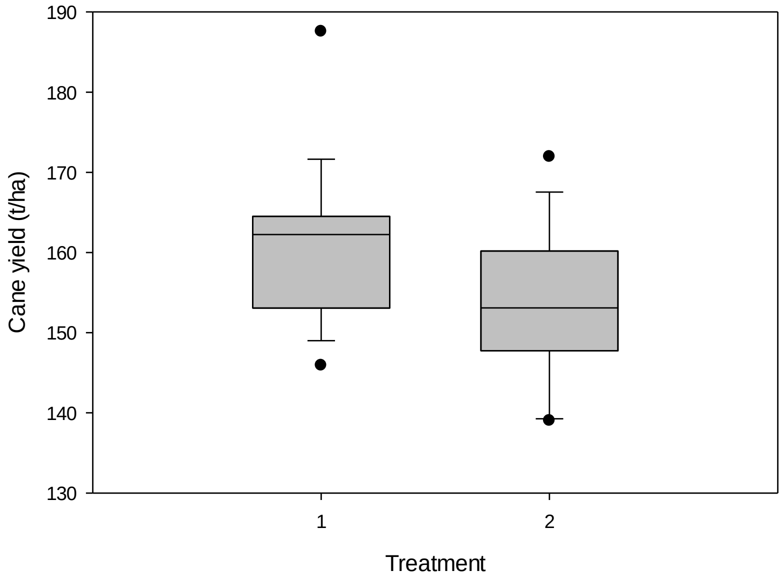


Figure 2 Summary of cane yield results from experiment 1

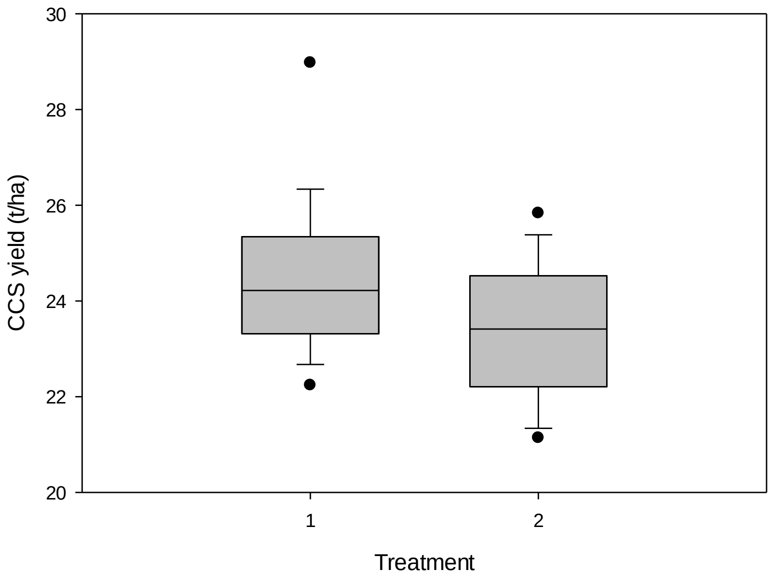


Figure 3 Summary of CCS yield results from experiment 1

Average sugar/cane loss from the Infield Sucrose Loss Measurement System (ISLMS)

The average sugar/cane loss data was gathered throughout experiment 1 using the ISLMS. The results are shown in Table 12. The results show that there was more sucrose and cane lost in commercial harvest treatment 1 than in the cleaned cane treatment 2.

Table 12 Average sugar/cane loss from the ISLMS for Experiment 1

Treatment	Average of t/ha Trash	Av. of tonnes sucrose/ha	Av. of $/ha	Av. of tonnes cane/ha
1	27.3	1.62	649	10.67
2	18.1	0.74	297	4.89

6.2.3. Experiment 2

Introductory remarks

A small series of tests were conducted between the two major experiments. Only one replicate consisting of three treatments was completed. The treatments are described in Table 13. Five bins were filled in the tests for the first treatment, and four bins were filled for a combination of the second and third treatments. As a result, treatments 2 and 3 have been analysed together.

Table 13 Experiment 2 treatments

Treatment	Treatment	Fan speed (r/min)	Secondary fan	Cleaned
1	Commercial	900	On	No
2	Low loss + cleaning	725	On	Yes
3	Low loss + cleaning	725	Off	Yes

No extraneous matter analysis was undertaken for this experiment.

Cane analysis

The NIR cane analysis results (CCS, purity, fibre content and ash content) for each test in the experiment are presented in Table 14.

Table 14 Experiment 2 results

Test	Treatment	Tonnes	CCS (%)	Purity (%)	Fibre (%)	Ash (%)	Area (ha)	Yield (t/ha)	
								Cane	CCS
1	1	113.18	14.74	88.77	15.37	1.47	0.767	148	21.8
2	2/3	108.94	14.68	88.33	14.38	1.31	0.753	145	21.2

Yield analysis

The results for both cane yield and CCS yield in t/ha are presented in Table 14. The raw data, tonnes supplied and area harvested are also presented in Table 14. The area harvested can be converted to metres of row harvested by multiplying the area by 5000.

Due to the small nature of this experiment, no statistical analysis of results was possible. The trend observed in the experiment matched that of the other experiments.

Bin weights

The individual bin weights for experiment 2 are presented in Table 15.

Experiment 2 was undertaken to show increased cane yield and higher bin weights to the mill.

Table 15 Experiment 2 bin weight tonnes

Treatment 1	Treatment 2
21.72	26.60
21.96	26.98
21.82	28.22
23.88	27.14
23.80	

6.2.4. Experiment 3

Introductory remarks

Like the first experiment, experiment 3 was conducted with a randomised block design, this time consisting of 11 replicates of three treatments. The treatments are described in Table 16.

Table 16 Experiment 3 treatments

Treatment	Treatment	Fan speed (r/min)	Cleaned
1	Commercial	900	No
2	Normal	800	No
3	Low loss + cleaning	700	Yes

The actual average fan speeds and average groundspeeds achieved are shown in Table 17. The results show that the desired treatment fan and groundspeeds were achieved.

Table 17 Actual average fan speed and ground speed across all blocks in Experiment 3

Treatment	Treatment	Fan speed (r/min)	Ground speed (km/h)
1	Commercial	898	3.9
2	Normal	797	3.9
3	Low loss + cleaning	703	4.0

Extraneous matter analysis

Extraneous matter sampling was taken from one field bin within all three treatments of each block. In addition, extraneous matter from cane in treatment 3 (low loss + cleaning) was measured before the cane cleaner (called treatment 3a). As for experiment 1 (section 6.2.2), cane was sorted into five components: sound billets, damaged billets, mutilated billets, tops and trash. The results are summarised in Figure 4. The parameters with statistically significant differences at the 5% level were mutilated billets content and trash content (both significant at better than 0.01% level). For mutilated billets, the cleaned cane treatment had more mutilated billets than any of the non-cleaned treatments. This trend can also be seen in the medians in the experiment 1 extraneous matter analysis (Figure 1) although the result was not statistically significant. Like the experiment 1 extraneous matter analysis, statistically significant differences were found between treatments 1 and 3a, between treatments 2 and 3a and between treatments 3 and 3a. Unsurprisingly, the low loss treatment has more trash than any of the other treatments.

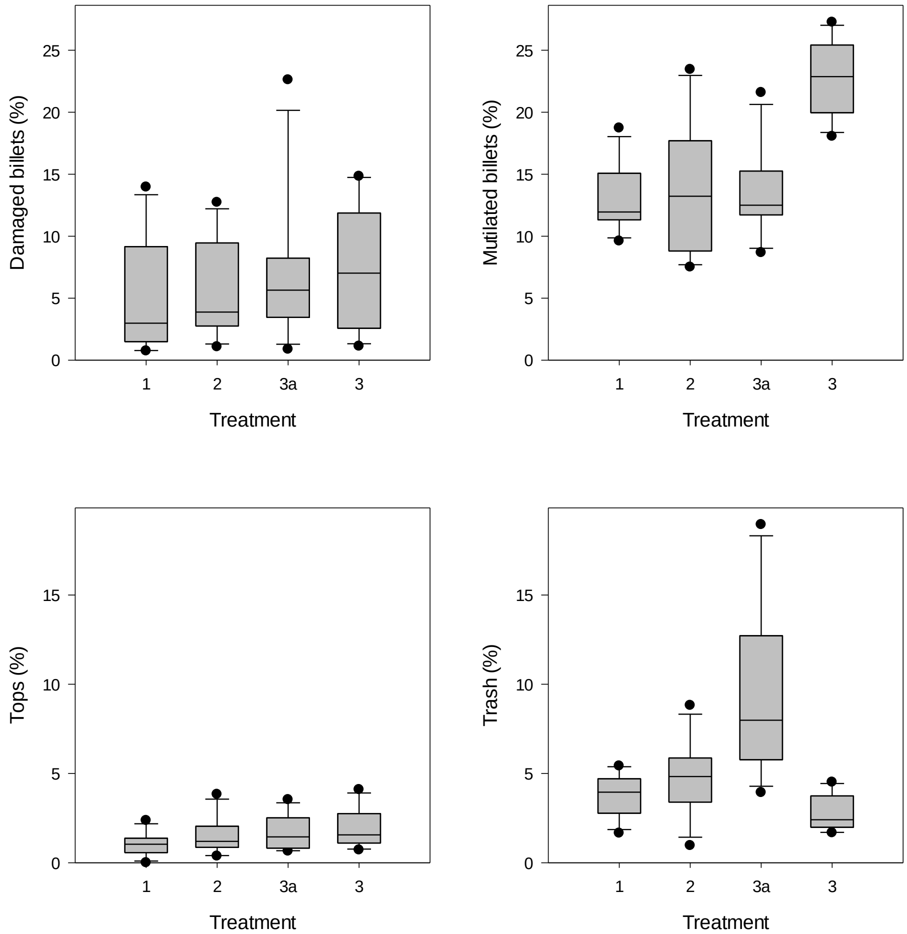


Figure 4 Extraneous matter results from experiment 3

Cane analysis

The NIR cane analysis results (CCS, purity, fibre content and ash content) for each test in the experiment are presented in Table 18. Two tests, treatments 1 and 2 for block 7, were discarded since their contents were mixed across two bins. The only statistically significant difference in these cane properties was in the fibre content where a difference between the treatments was found at the 0.5% level. The fibre content of the cleaned cane treatment was lower than the fibre content for the two uncleaned treatments.

Table 18 Experiment 3 results

Test	Block	Treatment	Tonnes	CCS (%)	Purity (%)	Fibre (%)	Ash (%)	Area (ha)	Yield (t/ha)	
									Cane	CCS
Average		1	21.49	15.44	89.29	15.56	1.43	0.144	152	23.4
		2	20.02	15.40	89.30	15.81	1.49	0.130	156	23.9
		3	22.11	15.29	88.40	14.97	1.59	0.156	144	21.9

Yield analysis

The results for both cane yield and CCS yield in t/ha are presented in Table 18. An analysis of variance did not find that treatment had a statistically significant effect on the cane yield or CCS yield at the 5% level. The cane yield results are shown graphically in Figure 5. The CCS yield results are shown in Figure 6.

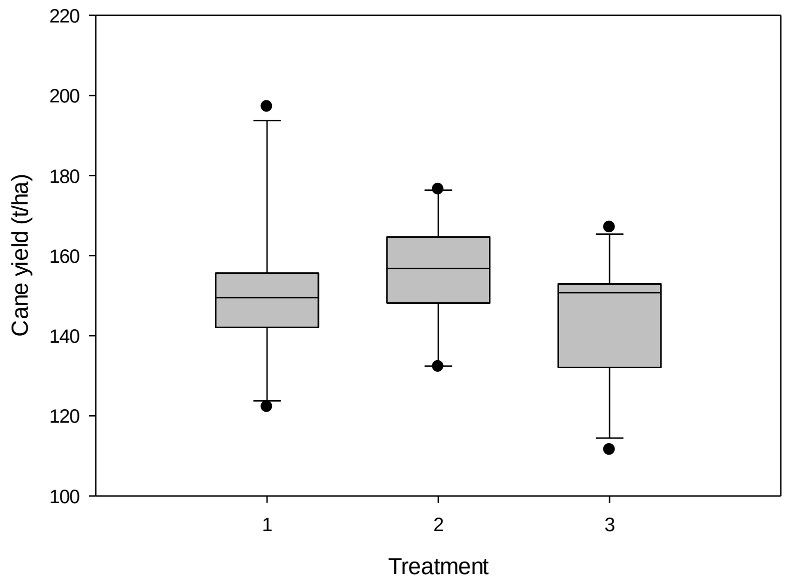


Figure 5 Summary of cane yield results from experiment 3

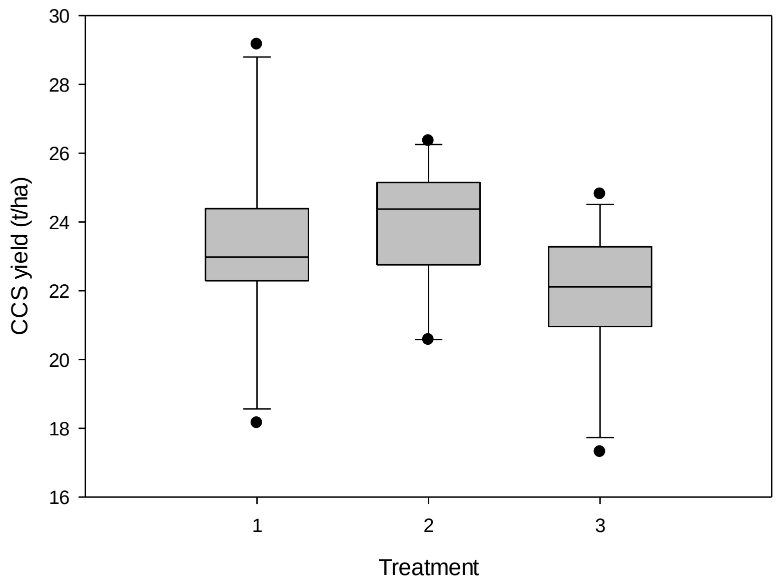


Figure 6 Summary of CCS yield results from experiment 3

Average sugar/cane loss from the ISLMS for experiment 3

The average sugar/cane loss data was gathered throughout experiment 3 using the ISLMS. The results are shown in Table 19. The results show that there was more sucrose and cane lost in commercial harvest treatment 1 than in the cane treatment 2 and cleaned cane treatment 3.

Table 19 Average sugar/cane loss from the ISLMS for Experiment 3

Treatment	Average of t/ha trash	Av. of tonnes sucrose/ha	Av. of $/ha	Av. of tonnes cane/ha
1	34.7	2.2	881	14.48
2	26.5	1.29	515	8.46
3	20.9	0.9	361	5.93

Cane cleaner throughput

The average times of operation of the mobile cane cleaner were recorded throughout experiment 3. The results are shown in Table 20. The results show that the average time for cleaning a treatment 3 cane haulout of approximately 8 tonnes was 15.5 minutes. Note that these are research times and are not a true representation of the capacity of the machine in field operation.

Table 20 Mobile cane cleaner operational times for Experiment 3

Date	Rep	1st Bin	2nd Bin	3rd Bin	Minutes to Clean
2/7/17	1	11:20 -11:25	Hopper Jam	Estimated	16
2/7/17	2	12:30 -12:35	12:45 - 12:49	12:50 - 12:55	16
2/7/17	3	14:14 -14:20	14:22 -14:27	14:30 –14:34	15
2/7/17	4	14:39 -14:39	14:44 -14:46	14:46 -14:53	15
2/7/17	5	17:26 -17:33	17:40 -17:49	2 Carter Bins	14
3/7/17	6	07:28 -07:23	07:40 -07:45	07:47 -07:53	16
3/7/17	7	08:40 -08:46	08:50 -08:56	08:59 -09:04	17
3/7/17	8	09:30 -09:35	09:37 -09:43	09:45 -09:50	16
3/7/17	9	10:26 -10:31	10:39 -10:44	11:01 -11:07	16
3/7/18	10	11:45 -11:50	11:57 -12:04	12:06 -12:10	16
3/7/18	11	13:00 -13:07	13:08 -13:15	2 Carter Bins	14

The average tonnes cleaned per hour of operation of the mobile cane cleaner were recorded throughout experiment 3. The results are shown in Table 21. The results show that the average tonnes cleaned per hour for treatment 3 was 85 tonnes per hour. Note that these are also tonnes cleaned per hour under research conditions and are not a true representation of the capacity of the machine in field operation.

Table 21 Mobile cane cleaner average tonnes per hour for experiment 3

Date	Rep	Minutes clean	Total Minutes	Total Tonnes	Tonnes per hour
2/7/17	1	16			
2/7/17	2	16			
2/7/17	3	15			
2/7/17	4	15			
2/7/17	5	14	76	105.3	83.0
3/7/17	6	16			
3/7/17	7	17			
3/7/17	8	16			
3/7/17	9	16			
3/7/18	10	16			
3/7/18	11	14	95	138	87.12

6.2.5. Discussion of first three experiments

Cane yield

The trial parameters chosen for the first experiment were determined from discussions with MSF staff. Primary extractor speeds of 800 r/min for the commercial treatment and 680 r/min for cane to be processed by the cane cleaner were selected. It was evident early in the experiments that our range of fan speeds were significantly lower than those used for some commercial harvesting. This resulted in the bin weights from our highest fan speed being significantly lower than those from commercially cut cane and were unacceptable. The first experiment found cane yield from the normal treatment to be higher than the cane yield from the low loss + cleaning treatment. The third experiment, while not providing a statistically significant result, showed the same trend, as did the small second experiment.

The third experiment contained two treatments without cleaning. Again, the results were not statistically significant, but the trend from high fan speed to lower fan speed was similar to that observed in many other experiments and showed increasing cane and CCS yield with lower fan speed.

The third experiment was done in parallel with cane loss measurements undertaken by the sucrose trailer team. Their measurements showed 6 t/ha and 0.9 t/ha increase in reducing fan speed from 900 r/min to 800 r/min for cane and CCS yield respectively. The average results from Table 18, comparable to the sucrose trailer results were 4 t/ha and 0.6 t/h respectively. The experimental results were around 65% of the sucrose trailer results. A multiple comparison test using the Tukey method required a reduction in confidence from the usual 95% to 20% in order to conclude that the results for the first two treatments were different. Considerably more tests would have been necessary to gain confidence in the size of the difference between these two treatments.

Trash separation

The primary purpose of the cane cleaner is trash separation and removal. Both the first and the third experiment identified significantly lower trash levels in the cane leaving the cane cleaner than in the cane presented to the cane cleaner. The results showed an average of 61% of trash being removed in experiment 1 and an average of 73% of trash being removed in experiment 3. The operating speed of the diesel engine of the cane cleaner was increased from 2100 r/min in the first and second experiment to 2300 r/min in the third experiment. This change proportionally increased the speed of the extraction fan on the cane cleaner resulting in greater airflow and increased trash removal.

Billet mutilation

The significant increase in the proportion of mutilated billets measured through the cane cleaner in experiment 3 is of concern. An average increase of about 9% of total billets damaged was measured. The experiment 1 results, which show a similar trend in the median results, are far less convincing. The cleaning chamber of the cane cleaner has recently been redesigned and these experiments were the first usage of this configuration. Billet damage during the cane cleaning process is an important consideration and additional measurements were included as part of future testing.

Reality check

The ISLMS measurement and analysis was conducted to check the validity of the measured mass balance results. ISLMS average results were used to provide estimates of the cane supply entering the cane cleaner. The extraneous matter analysis was used to determine the change in yield expected from trash being removed in the cane cleaner.

The experiment 1 results, with statistically significant differences in cane yield and CCS yield, were considered first, since there was more confidence in the magnitudes of the measured results. Table 22 presents the results. A factor of 1.15 was used to calibrate the ISLMS cane loss measurements. This value was chosen to minimise the difference in yield for both treatment 1 and treatment 2. It contrasts to the best estimate of 0.65 as discussed in above, by looking at the direct measurements (which were not statistically significant). In addition, an infield cane yield of 173.12 t/ha and CCS yield of 26.28 t/ha were chosen to get an exact match between the ISLMS calibrated results and the experimental results for treatment 1. Utilising these assumed values, and the measured trash contents of the treatment 3 cane supply before and after the cleaner, a good mass balance was achieved for cane. However, the results show a CCS loss of about 2 t/ha of CCS between the ISLMS calibrated yield before the cane cleaner and the measured yield after the cane cleaner.

A similar exercise was conducted for experiment 3. For this analysis, the same factor of 1.15 was used to calibrate the ISLMS cane loss measurements. The infield cane yields were adjusted to minimise the sum of squares of yield differences for the three treatments. The results are shown in Table 23. Getting a perfect match between three treatments is not as easy as two. A better cane yield match was achieved by calibrating both the calibration factor and the infield cane yield, but the resulting calibration factor of 0.51 seemed an unreasonably different value than that determined in the more statistically significant experiment 1. Yield differences about 3 t/h were predicted which may well be the result of experimental errors. Consistent with the experiment 1 results in Table 22, however, is a CCS yield loss of over 2 t/h in the cleaned cane treatment.

Table 22 Mass balance modelling for experiment 1

Parameter	Treatment 1		Treatment 2	
	Cane	CCS	Cane	CCS
ISLMS cane loss (t/ha)	10.67	1.62	4.89	0.74
Calibration factor	1.15	1.15	1.15	1.15
Calibrated cane loss (t/ha)	12.27	1.86	5.62	0.85
Infield cane yield (t/ha)	173.12	26.28	173.12	26.28
Predicted cane yield (t/h)	160.85	24.42	167.50	25.43
Trash content in cane supply to cleaner (%)			13.83	13.83
Trash yield in cane supply to cleaner (t/ha)			23.16	0.00
Trash removal through cleaner (%)			61.00	61.00
Trash loss through cleaner (t/ha)			14.17	0.00
Predicted yield in cane supply to factory (t/ha)	160.85	24.42	153.32	25.43
Measured yield in cane supply to factory (t/ha)	160.85	24.42	153.28	23.44
Difference in yield (t/ha)	0.00	0.00	-0.04	-2.00

Table 23 Mass balance modelling for experiment 3

Parameter	Treatment 1		Treatment 2		Treatment 3	
	Cane	CCS	Cane	CCS	Cane	CCS
ISLMS cane loss (t/ha)	14.48	2.20	8.46	1.29	5.93	0.90
Calibration factor	1.15	1.15	1.15	1.15	1.15	1.15
Calibrated cane loss (t/ha)	16.65	2.53	9.73	1.48	6.82	1.04
Infield cane yield (t/ha)	165.00	25.70	165.00	25.70	165.00	25.70
Predicted cane yield (t/h)	148.35	23.17	155.27	24.22	158.18	24.67
Trash content to cleaner (%)					10.56	10.56
Trash yield to cleaner (t/ha)					16.70	0.00
Trash removal through cleaner (%)					73.00	73.00
Trash loss through cleaner (t/ha)					12.22	0.00
Predicted yield to factory (t/ha)	148.35	23.17	155.27	24.22	145.96	24.67
Measured yield to factory (t/ha)	151.56	23.36	155.66	23.94	143.51	21.89
Difference in yield (t/ha)	3.21	0.19	0.39	-0.28	-2.45	-2.78

Conclusions

The first three experiments were well controlled and have produced cane yield results that are consistent within about 3 t/ha with the ISLMS cane loss measurements. The results show lower cane yield from the low loss harvesting plus cane cleaning treatment, primarily because of the extraction of trash that included billets from the cane cleaner.

The main objective of the experiments was to measure the increase in CCS yield from the low loss harvesting plus cane cleaning treatment to improve sugar income. The ISLMS cane loss measurements show an increase in CCS yield with the low loss harvesting treatment, but there appears to be a loss of CCS yield of about 2 t/ha in the cleaned cane supply that has not yet been explained. As a result of this deficiency, the fourth experiment (section 6.2.6) was designed to provide more information about the cane cleaner itself.

6.2.6. Experiment 4

Introductory remarks

The experiment was conducted on Tableland Farm 2 Block 18A, containing KQ228Φ plant cane with estimated yield of 145 t/ha.

As for experiments 1 and 3, each test consisted of filling one road bin of cane. During each test, the distance (hence area) harvested was recorded. Bins at the pad were filled in a controlled order and bin numbers matched to field treatments. A sample was taken from each bin for extraneous matter analysis. When the bin was processed through the factory, the bin weight and the cane analysis were recorded. Bin weights and sample numbers were available through factory cane supply reports. Cane analysis was obtained from the factory Cane Analysis System, with the appropriate bias, as utilised for cane payment, applied to the CCS results.

Experimental design

Experiment 4 was conducted in a randomised block design, consisting of 18 blocks of three treatments. The treatments are described in Table 24.

Table 24 Experiment 4 treatments

Treatment	Treatment	Fan speed (r/min)	Cleaned
1	Commercial	900	No
2	Low loss	700	No
3	Low loss + cleaning	700	Yes

Treatments 1 and 3 were the same as for experiment 3. Treatment 2 was changed to the same harvesting treatment as for treatment 3, so that measurements for the input and output of the cane cleaner were available to enable a better mass balance around the cane cleaner.

Harvester ground speed was maintained constant at nominally 4 km/h. The cane cleaner was operated with constant parameters: engine speed of 2300 r/min (controlling fan speed) and hydraulic floor drive speed set between 6 and 7 (controlling pour rate). These conditions were nominally the same as for experiment 3.

The actual average harvester fan speed and groundspeed for each test is shown in Table 25. The results show that the desired treatment fan and ground speeds were achieved.

Table 25 Actual average fan speed and ground speed for each test

Block	Treatment	Fan speed (r/min)	Ground speed (km/h)
1	1	910	3.8
1	2	700	3.8
1	3	700	3.8
2	1	910	3.9
2	2	700	3.8
2	3	710	4.0
3	2	700	4.0
1	910	3.8	
	2	700	3.8
	3	710	3.9

Harvesting was undertaken in one direction through the field, except for test 22 which was harvested in the opposite direction.

Extraneous matter analysis

Extraneous matter samples were taken from one field bin from each test. As for experiments 1 and 3, cane was sorted into six components: sound billets, damaged billets, mutilated billets, tops, roots and trash. The results are presented in Table 26 and summarised in Figure 7.

Statistically significant differences were found for damaged and mutilated billet content and for trash content. There were more damaged billets from treatment 3 than from treatments 1 and 2. There were more mutilated billets from treatment 3 than from treatment 2. Statistically significant differences were found between the trash contents of all three treatments.

Table 26 Extraneous matter results from experiment 4

Test	Replicate	Treatment	Damaged billets (% billets)	Mutilated billets (% billets)	Tops (% cane)	Roots (% cane)	Trash (% cane)
1	1	1	19.67	12.65	0.65	0.35	6.71
2	1	2	10.59	15.52	1.46	3.00	11.72
3	1	3	27.24	15.33	1.40	0.85	3.04
4	2	1	13.23	18.58	1.70	1.49	1.94
5	2	2	6.53	10.55	1.78	2.12	8.02
6	2	3	17.48	18.70	1.92	0.00	3.65
7	3	2	12.50	12.15	2.01	0.00	15.23
8	3	1	7.68	16.63	1.58	0.00	5.54
9	3	3	14.81	12.74	1.38	0.22	1.85
10	4	3	12.54	15.52	0.58	0.00	1.46
11	4	1	8.80	16.31	0.82	0.57	2.88
12	4	2	11.38	16.67	1.95	0.00	2.33
13	5	1	11.69	10.46	0.29	0.00	4.40
14	5	3	11.04	11.04	4.74	0.00	2.21
15	5	2	4.88	17.89	1.37	0.53	13.75
16	6	1	5.31	6.89	0.74	0.00	5.71
17	6	3	10.62	19.61	0.80	0.70	1.12
18	6	2	9.85	9.19	0.79	0.54	8.32
19	7	2	5.21	10.96	0.47	0.00	14.05
20	7	3	9.18	10.68	0.66	0.00	0.99
21	7	1	9.44	17.13	1.27	0.95	7.01
22	8	1	11.30	31.20	1.34	1.28	7.35
23	8	2	9.38	12.81	0.00	0.00	11.85
24	8	3	10.41	14.93	1.17	0.00	1.76
25	9	3	8.68	11.64	0.96	0.50	1.15
26	9	1	10.02	15.14	1.09	0.00	1.30
27	9	2	8.62	11.69	1.57	0.00	13.58
28	10	2	11.74	7.09	2.42	0.00	7.49
29	10	1	3.57	13.31	2.41	0.00	4.82
30	10	3	11.76	10.55	0.85	0.00	0.68
31	11	1	4.36	9.54	1.17	0.00	5.24
32	11	3	17.43	15.03	1.55	0.30	1.36
33	11	2	11.84	9.21	1.37	0.00	11.87
34	12	1	15.49	12.81	1.46	0.00	3.10
35	12	3	14.81	15.11	1.34	0.00	1.19
36	12	2	11.43	6.49	1.40	0.00	5.43
37	13	1	7.53	11.78	0.95	0.00	2.68
38	13	3	11.47	28.50	0.81	0.84	2.44
39	13	2	4.48	13.45	1.48	0.00	10.37
40	14	1	6.67	13.83	0.80	0.00	2.73
41	14	3	14.36	16.09	2.32	0.00	1.82
42	14	2	5.21	8.44	0.45	0.57	8.33
43	15	3	12.72	15.64	0.99	2.45	0.71
44	15	2	7.11	7.91	1.71	0.00	11.64
45	15	1	4.37	11.66	1.04	1.08	3.11
46	16	1	9.45	12.83	0.82	5.50	3.28
47	16	3	8.90	13.87	0.99	0.00	2.32
48	16	2	4.61	7.37	2.41	0.52	10.04
49	17	3	6.56	15.54	1.05	0.56	2.93
50	17	1	7.54	12.86	1.86	0.00	4.96
51	17	2	10.45	16.04	0.65	0.00	12.34
Mean		1	9.18	14.33	1.18	0.66	4.28
		2	8.58	11.38	1.37	0.43	10.37
		3	12.94	15.33	1.38	0.38	1.80

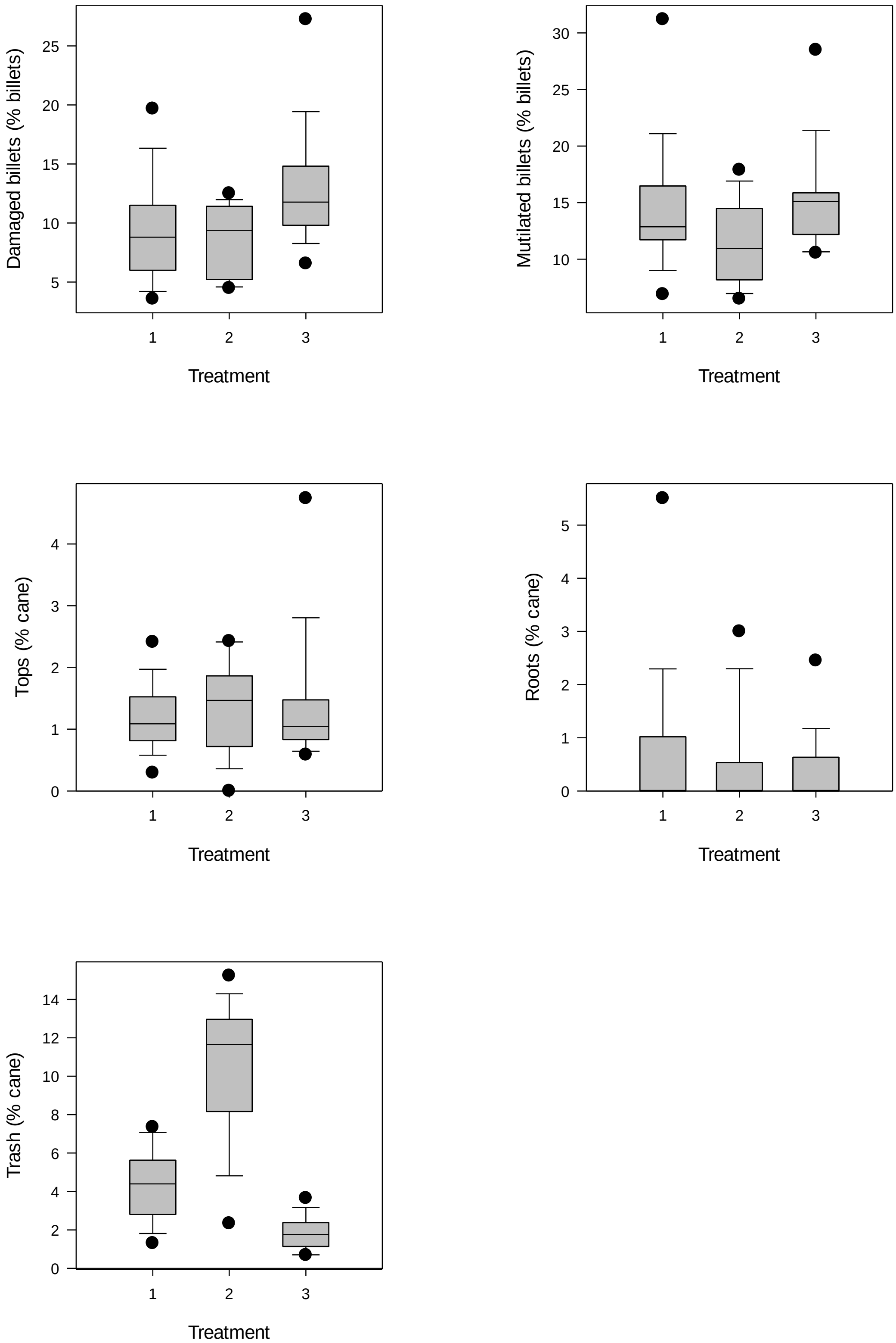


Figure 7 Extraneous matter results from experiment 4

Cane analysis

The NIR cane analysis results (CCS, purity, fibre content and ash content) for each test in the experiment are presented in Table 27. Statistically significant differences at the 5% level were found for bin weight, purity, fibre content and first expressed juice pol. For bin weight and fibre content, statistically differences were found between all three treatments. For purity, statistically significant differences were found between treatment 1 and treatment 2 and between treatment 2 and treatment 3. For first expressed juice pol, a statistically significant difference was found between treatment 2 and treatment 3. The results are presented graphically in Figure 8.

The bin weights for treatment 2 (low loss) were much less than desired but the bins were filled to their volumetric capacity. The high trash content of these bins and the consequential low bulk density prevented the desired bin weight from being achieved.

The higher purity for treatment 2 was a surprising result that cannot be correct. Trash has much lower purity than cane and so the additional trash in treatment 2 must decrease purity. The result suggests that the cane analysis is in error. Most likely, the NIR calibration for CCS or first expressed juice pol or both are not equally valid across the range of trash contents in these cane supplies. Most likely, treatment 2 with higher trash content than normal cane deliveries is the treatment that is less accurately measured.

The fibre content results are as expected and match the extraneous matter analysis, with higher trash content corresponding to higher fibre content.

Table 27 Experiment 4 cane analysis results

Test	Replicate	Treatment	Bin weight (t)	CCS (%)	Purity (%)	Fibre (%)	Ash (%)	FEJ pol (%)
1	1	1	20.52	15.56	90.01	15.93	1.68	20.84
2	1	2	14.68	15.51	91.36	17.96	1.88	21.13
3	1	3	20.20	16.12	90.34	14.81	1.35	21.23
4	2	1	23.68	16.28	91.02	15.25	1.21	21.47
5	2	2	17.10	16.07	91.72	18.10	1.49	21.89
6	2	3	19.84	16.24	90.50	14.43	1.46	21.27
7	3	2	14.94	16.26	92.28	18.44	1.71	22.16
8	3	1	19.90	16.12	90.16	15.10	1.18	21.34
9	3	3	20.38	16.36	89.54	13.85	1.40	21.42
10	4	3	17.86	16.58	90.71	14.12	1.24	21.60
11	4	1	23.12	16.17	89.97	15.58	1.17	21.57
12	4	2	15.20	16.02	91.13	17.50	0.82	21.73
13	5	1	22.40	16.41	90.35	15.54	0.97	21.82
14	5	3	19.60	17.15	92.31	14.70	1.84	22.28
15	5	2	13.56	16.12	92.46	19.26	1.34	22.19
16	6	1	21.78	16.53	90.78	15.09	1.31	21.79
17	6	3	20.36	16.63	91.68	15.14	1.42	21.81
18	6	2	14.76	16.79	93.64	18.81	1.63	22.81
19	7	2	15.20	16.43	92.02	18.55	1.14	22.46
20	7	3	18.82	16.68	90.14	14.65	0.88	21.96
21	7	1	21.98	16.64	90.34	15.54	1.09	22.12
22	8	1	21.52	16.71	91.31	15.79	1.20	22.14
23	8	2	13.56	16.68	91.80	17.74	1.08	22.60
24	8	3	19.96	16.46	89.38	13.97	1.42	21.59
25	9	3	21.00	13.33	85.77	15.79	3.90	18.35
26	9	1	22.70	16.27	90.10	15.78	1.66	21.73
27	9	2	15.26	15.68	88.63	17.28	1.34	21.56
28	10	2	15.12	16.63	91.32	18.14	1.28	22.72
29	10	1	22.06	16.70	89.38	14.99	1.36	22.18
30	10	3	18.02	16.08	88.31	14.58	2.00	21.41
31	11	1	21.20	16.72	89.77	15.78	1.41	22.38
32	11	3	22.18	16.05	88.34	14.92	1.66	21.46
33	11	2	14.72	15.94	90.62	17.39	1.01	21.66
34	12	1	23.54	16.15	90.09	15.09	1.50	21.39
35	12	3	21.96	16.81	89.86	13.70	1.28	21.91
36	12	2	19.08	15.57	89.73	16.91	1.28	21.14
37	13	1	24.44	16.40	89.65	14.79	1.61	21.71
38	13	3	21.86	16.55	90.61	14.19	1.40	21.61
39	13	2	14.58	16.22	91.88	17.69	1.49	21.95
40	14	1	23.34	16.62	89.81	15.19	1.29	22.08
41	14	3	23.56	16.36	88.64	15.28	2.37	21.92
42	14	2	19.14	16.37	90.74	16.97	1.27	22.10
43	15	3	22.88	16.72	90.08	14.82	1.49	22.07
44	15	2	15.42	16.68	91.16	17.50	1.10	22.62
45	15	1	24.86	17.02	91.18	15.30	1.38	22.43
46	16	1	24.42	16.62	90.11	15.72	1.68	22.19
47	16	3	24.60	16.64	89.73	14.03	1.47	21.80
48	16	2	16.06	16.79	91.53	17.91	1.39	22.85
49	17	3	22.62	16.92	90.30	14.55	1.61	22.23
50	17	1	23.58	16.65	90.43	16.36	1.88	22.35
51	17	2	15.80	16.40	90.58	18.01	1.86	22.47
Mean		1	22.65	16.45	90.26	15.46	1.39	21.86
		2	15.54	16.24	91.33	17.89	1.36	22.12
		3	20.92	16.33	89.78	14.56	1.66	21.53

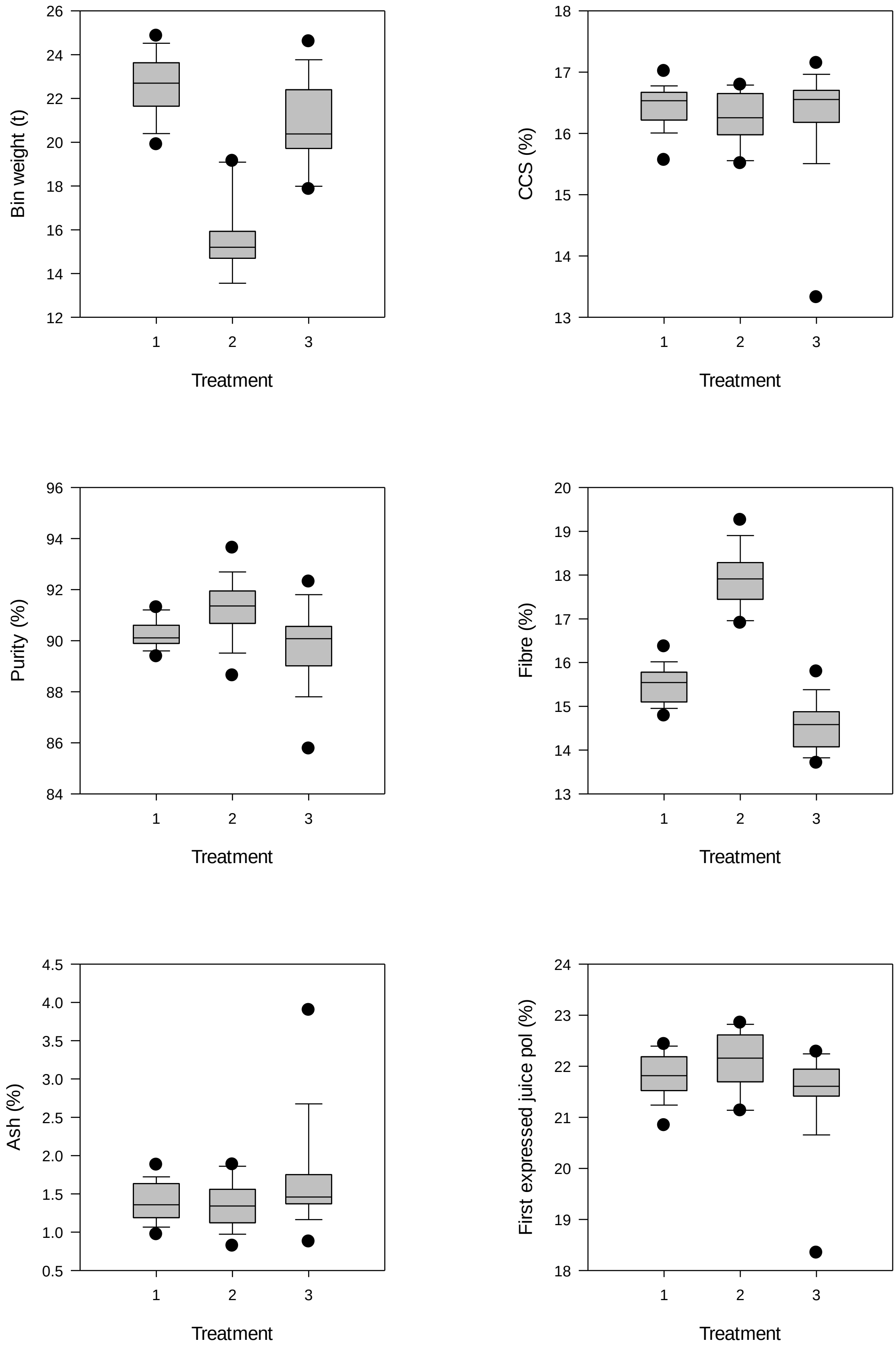
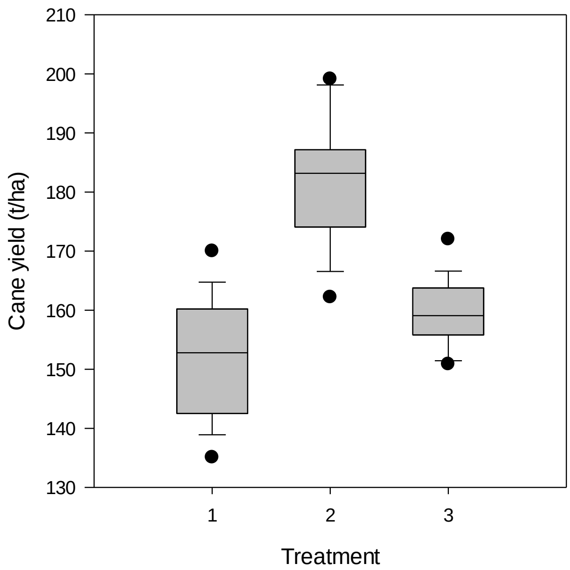


Figure 8 Cane analysis results for experiment 4

Yield analysis

The results for both cane yield and CCS yield in t/ha are presented in Table 28. The yield results are shown graphically in Figure 9. Statistically significant differences were found at the 5% level for both cane yield and CCS yield. In both cases, statistically significant differences were found between treatment 1 and treatment 2 and between treatment 2 and treatment 3 but not between treatment 1 and treatment 3.



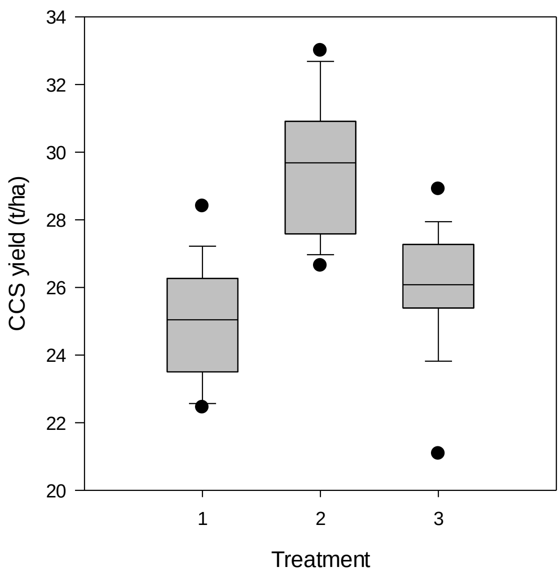


Figure 9 Summary of yield and CCS results from experiment 4

Table 28 Experiment 4 yield analysis results

Test	Replicate	Treatment	Harvested distance (m)	Harvested area (ha)	Cane yield (t/ha)	CCS yield (t/ha)
1	1	1	681	0.136	151	23.4
2	1	2	427	0.085	172	26.6
3	1	3	664	0.133	152	24.5
4	2	1	827	0.165	143	23.3
5	2	2	505	0.101	169	27.2
6	2	3	658	0.132	151	24.5
7	3	2	408	0.082	183	29.8
8	3	1	609	0.122	163	26.3
9	3	3	625	0.125	163	26.7
10	4	3	589	0.118	152	25.1
11	4	1	719	0.144	161	26.0
12	4	2	410	0.082	185	29.7
13	5	1	724	0.145	155	25.4
14	5	3	616	0.123	159	27.3
15	5	2	362	0.072	187	30.2
16	6	1	740	0.148	147	24.3
17	6	3	657	0.131	155	25.8
18	6	2	398	0.080	185	31.1
19	7	2	428	0.086	178	29.2
20	7	3	595	0.119	158	26.4
21	7	1	692	0.138	159	26.4
22	8	1	633	0.127	170	28.4
23	8	2	418	0.084	162	27.0
24	8	3	630	0.126	158	26.1
25	9	3	664	0.133	158	21.1
26	9	1	737	0.147	154	25.0
27	9	2	432	0.086	176	27.7
28	10	2	413	0.083	183	30.5
29	10	1	735	0.147	150	25.0
30	10	3	563	0.113	160	25.7
31	11	1	694	0.139	153	25.5
32	11	3	694	0.139	160	25.7
33	11	2	415	0.083	177	28.3
34	12	1	841	0.168	140	22.6
35	12	3	638	0.128	172	28.9
36	12	2	483	0.097	197	30.7
37	13	1	765	0.153	160	26.2
38	13	3	698	0.140	157	25.9
39	13	2	402	0.080	182	29.4
40	14	1	864	0.173	135	22.5
41	14	3	713	0.143	165	27.0
42	14	2	481	0.096	199	32.6
43	15	3	694	0.139	165	27.6
44	15	2	390	0.078	198	33.0
45	15	1	885	0.177	140	23.9
46	16	1	861	0.172	142	23.6
47	16	3	751	0.150	164	27.3
48	16	2	429	0.086	187	31.4
49	17	3	691	0.138	164	27.7
50	17	1	729	0.146	162	26.9
51	17	2	471	0.094	168	27.5
Mean		1	749	0.150	152	25.0
		2	428	0.086	182	29.5
		3	655	0.131	160	26.1

Cane cleaner billet loss

Following the completion of the first day's testing (after test 7), a sufficient quantity of the cane billets surrounding the cane cleaner was collected so that an estimate of billet loss could be made. At this stage, two tests had been undertaken using the cane cleaner (tests 3 and 6) and so all billet material surrounding the cane cleaner could be attributed to these tests. An estimated 38.6 t of billets was processed through the cane cleaner, based on the total cane delivered to the factory, the calculated billet loss and the extraneous matter analysis (Table 26).

Billets were collected from separate sources of loss:

- Loading (cane spilt when transferring cane from the haulout to the cane cleaner)
- Hopper conveyor (cane found under the hopper conveyor near the discharge end)
- Feed elevator (cane found under the feed elevator in the enclosed space around the fan)
- Discharge elevator (cane found under the discharge elevator)
- Unloading (cane spilt when transferring cane from the cane cleaner to the haulout)
- The trash chute (cane in the trash flow that did not discharge from the chute)
- The discharged trash (cane found in the trash discharged from the cane cleaner).

The measured quantities of billets lost are presented in Table 29. Note that access under the feed elevator was restricted. After collecting a substantial quantity of the billets from that location, it was estimated that the collected quantity was about a third of the billets in that location. Because of the large volume of the trash pile behind the cleaner, it was considered too laborious to sort through the entire pile. The trash closest to the trash chute and for about 3 m from the chute, where the majority of the cane billets and fragments land, was sorted. It was estimated that this area contained 50% to 80% of the ejected billets (50% was assumed in the billet loss calculations). The measurements indicate a total of about 2% of the cane delivered to the cleaner was lost through the cleaner.

Table 29 Measurements of billet loss

Location	Measured mass (kg)	Scaling factor	Estimated mass (kg)	Percentage (%)
Loading	6.2	1	6.2	0.02
Hopper conveyor	3.5	3	10.5	0.03
Feed elevator	21.5	1	21.5	0.06
Discharge elevator	71.1	1	71.1	0.18
Unloading	71.9	1	71.9	0.19
Trash chute	197.0	1	197.0	0.51
Discharged trash	150.8	2	301.5	0.78
Total			679.7	1.76

6.2.7. Discussion of experiment 4

Cane cleaner cane loss

The cane cleaner cane loss measurement described above was a first attempt at measuring the cane loss. It was conducted after two bins containing 40 t of cane had been filled Because of the large amount of cane processed, it was not feasible to collect all of the lost cane and assumptions were made via the scaling factor in Table 29 to address this deficiency.

It is recommended that further cane loss measurements be undertaken to more accurately measure the cane loss. The proposed method is to commence with the cane cleaner on ground containing no cane material and to run the cane cleaner to process cane from one haulout. All of the cane from this haulout would be collected and weighed. A sample of cane from the cane supply to the cane cleaner and the cane supply from the cane cleaner would be taken and analysed for extraneous matter content. The mass of uncleaned cane and the mass of cleaned cane would be weighed by taking the haulouts across the mill weighbridge before and after dumping the load. This method would enable a full mass balance around the cane cleaner to be calculated.

Cane cleaner mass balance

As reported in the previous experiment, one of the biggest uncertainties from the previous experiments surrounded the losses from the cane cleaner, since there were no mass measurements of the cane entering the cane cleaner. In this experiment, treatment 2 provided those mass measurements and enabled a much more certain mass balance.

The mass balance is presented in Table 30. Cane here refers to the total cane supply. Billets refers to the component of the cane supply that is not extraneous matter (tops, roots or trash) and consists of the sound billets, along with the damaged and mutilated billets reported in Table 26. The extraneous matter analysis was used to calculate the billet yield from the cane yield for both treatment 2 (entering cleaner) and treatment 3 (exiting cleaner). The billet loss calculated from the mass balance of 6 t/ha corresponds to a cane cleaner billet loss of 4%, about twice that estimated in Table 29.

Table 30 Cane cleaner mass balance

Yield (t/ha)	Cane	Billets	CCS
Entering cleaner	182	160	29.5
Exiting cleaner	160	154	26.1
Loss (including trash stream)	22	6	3.5

It is feasible that there is some loss of billet mass, since there were more damaged and mutilated billets in the cane exiting the cleaner than in the cane entering the cleaner. It seems unlikely, however, that the loss of billet mass could be as large as the mass of billets found and reported in Table 29.

The billet yield entering the cleaner is based on a measured average extraneous matter content of 12%. If the true extraneous matter content was 14%, it would account for the discrepancy in cane cleaner billet loss.

It seems that a combination of these two mechanisms could adequately explain the 2% billet loss discrepancy in the mass balance.

Table 30 also presents a CCS mass balance. Comparing the CCS yield to the cane yield provides an average CCS in the cane stream to the cleaner of 16.25%, an average CCS in the cane stream out of the cleaner of 16.34% and an average CCS in the loss stream of 15.57%. The CCS in the loss stream seems impossibly large, given the expected negligible CCS of the trash component of that stream. Following the discussion in the cane analysis section above, it seems likely that the CCS of the cane supply entering the cleaner was overstated.

Ivin and Doyle (1989) reported measurements of the CCS of tops to be close to zero. Based on the brix and pol measurements of trash reported by McGuire et al. (2011), the CCS of trash is negative. For the purposes of this discussion, it has been assumed that the CCS of extraneous matter is 0. If it is assumed that the CCS measurement for treatment 3 is correct then, based on the information in Table 30, the CCS of billets is 16.9%. Applying that billet CCS to treatment 2, a CCS of 14.9% is expected, compared to the measured CCS of 16.3%. With a CCS of 14.9%, treatment 2 would have a CCS yield of 27.1 t/ha, instead of 29.5 t/h as shown in Table 30.

6.2.8. Experiment 5

Introductory remarks

The experiment was conducted on the farm of Rajinder Singh, designated grower 6208, supplying Mossman Mill. The specific block contained Q208$^{\Phi}$ plant cane with estimated yield of 125 t/ha.

Each test consisted of filling three bins of cane (one road transport load). During each test, the distance (hence area) harvested was recorded. Bins at the pad were filled in a controlled order and bin numbers matched to field treatments. A sample was taken from each treatment for extraneous matter analysis. When the bins were processed through the factory, the sample number was noted, and the bin weight and the cane analysis were recorded. For each sample (apart from missed samples), a prepared cane sample was collected and first expressed juice was sampled through the automatic sampling system. Bin weights, cane analysis from the factory Cane Analysis System and laboratory first expressed juice analysis were available through the factory's Mirrabooka database. The factory's bias was applied to the Cane Analysis system results.

The prepared cane samples were analysed for fibre by the Australian laboratory manual Method 4A (can fibre machine), moisture by Australian laboratory manual Method 6 and Brix and pol by Australian laboratory manual Method 5.

The Cane Analysis System (NIR) did not provide analysis for two of the tests in the experiment. For the purpose of obtaining complete results for this experiment, the raw Cane Analysis System data were reanalysed for these tests, relaxing the averaging criteria, the same as for experiments 1 to 4. Only scans passing the Cane Analysis System criterion, ScanOK = True, were accepted. The acceptance criteria were relaxed in the following ways for samples where an average result was not originally provided:

- If valid scans were assigned to the sample, these scans were accepted.
- If the sample period was not defined and if the previous and subsequent sample had defined periods, the sample period was defined by adding three minutes to the end of the previous sample and subtracting three minutes from the start of the subsequent sample. The mean time between the end of one sample and the start of the next sample for the total period of the tests was a little less than three minutes.

Experimental design

Experiment 5 was conducted in a randomised block design, consisting of 10 replicates of four treatments. The treatments are described in Table 31.

Table 31 Experiment 5 treatments

Treatment	Treatment	Fan speed (r/min)	Ground speed (km/h)	Secondary Extractor	Cleaned
1	850	850	6.0	On	No
2	750	750	5.0	On	No
3	600	600	4.5	On	No
4	600 + cleaning	600	4.5	On	Yes

Treatment 2 corresponded to the typical harvester parameters used on this farm but resulting in lower bin weight than desired. Treatment 1 was chosen to provide a higher bin weight. Treatment 3 was considered to be a suitable low loss treatment. Treatment 4 involved the same harvesting treatment as treatment 3, but with the addition of post-harvest cleaning. Treatments 3 and 4 were similar to treatments 2 and 3 in experiment 4.

Harvester ground speed was varied to maintain a constant pour rate. The cane cleaner was operated with constant parameters: engine speed of 2250 r/min (controlling fan speed) and hydraulic floor drive speed set between 6 and 7 (controlling pour rate). These conditions were nominally the same as for experiments 3 and 4.

Harvesting was undertaken in one direction through the field.

Extraneous matter analysis

An extraneous matter sample was taken from the cane supply for each test. For convenience, the samples for treatment 3 (600 r/min fan speed) were actually taken from the cane supplied for treatment 4 (also 600 r/min fan speed). To provide a 'treatment 3' sample, the cane was analysed before the cane cleaner, while the treatment 4 sample was taken after the cane cleaner. As for experiments 1, 3 and 4, cane was sorted into six components: sound billets, damaged billets, mutilated billets, tops, roots and trash. The results are presented in Table 32 and summarised in Figure 10.

Statistically significant differences at the 5% level were found for mutilated billet content and for roots and trash content. There were more mutilated billets from treatment 4 than from treatments 1, 2 and 3. There were more roots from treatment 2 than from treatment 1. There was more trash from treatment 3 than from the other three treatments. There was also more trash from treatment 2 than from treatment 4.

Table 32 Extraneous matter results from experiment 5

Test	Replicate	Treatment	Damaged billets (% billets)	Mutilated billets (% billets)	Tops (% cane)	Roots (% cane)	Trash (% cane)
1	1	1	16.87	15.03	1.02	0.29	3.92
2	1	2	11.22	15.59	2.27	0.70	5.07
3	1	3	12.13	21.35	2.42	0.56	14.15
4	1	4	12.55	35.52	4.41	1.52	5.68
5	2	2	11.86	12.29	1.50	1.88	7.89
6	2	4	10.63	21.90	0.93	1.39	1.55
7	2	3	9.86	6.09	2.12	0.49	6.21
8	2	1	8.63	9.38	2.51	0.18	1.79
9	3	4	14.22	20.03	0.91	1.97	3.33
10	3	1	11.24	6.86	0.70	1.40	5.95
11	3	2	12.23	12.77	0.74	0.99	7.18
12	3	3	7.96	6.87	0.78	2.03	10.64
13	4	3	8.56	14.90	0.90	1.05	10.49
14	4	4	9.49	18.18	1.12	0.56	3.74
15	4	2	8.52	15.42	0.58	0.39	3.86
16	4	1	13.32	15.11	0.74	0.74	5.37
17	5	2	7.11	11.32	1.21	1.93	5.07
18	5	3	6.83	13.65	0.82	0.33	9.85
19	5	1	10.71	16.37	0.84	0.00	5.04
20	5	4	9.07	19.11	0.75	0.94	0.57
21	6	1	7.25	16.31	0.00	0.57	5.67
22	6	3	10.54	8.86	0.73	2.76	9.72
23	6	4	10.37	22.79	1.15	1.48	0.98
24	6	2	8.67	8.43	1.33	1.77	2.43
25	7	1	9.66	24.68	0.82	1.03	2.06
26	7	3	10.36	11.57	1.15	1.15	14.27
27	7	2	14.68	13.76	1.29	6.44	7.99
28	7	4	9.79	15.99	0.91	1.14	2.73
29	8	2	9.82	15.07	1.46	3.95	3.53
30	8	4	7.56	12.10	0.33	0.82	1.79
31	8	1	10.65	11.05	0.39	0.39	1.54
32	8	3	5.64	8.58	1.36	0.91	5.22
33	9	1	13.22	13.56	0.93	2.48	4.97
34	9	4	9.13	15.87	0.83	1.04	2.49
35	9	2	11.07	9.00	0.63	1.26	7.23
36	9	3	11.53	11.53	0.89	0.36	13.88
37	10	2	14.42	14.74	1.14	1.42	8.81
38	10	4	11.61	15.09	1.66	0.74	2.21
39	10	1	7.68	8.10	0.41	0.41	2.27
40	10	3	5.44	11.05	0.48	0.48	7.69
Mean		1	10.92	13.64	0.84	0.75	3.86
		2	10.96	12.84	1.21	2.07	5.91
		3	8.88	11.45	1.17	1.01	10.21
		4	10.44	19.66	1.30	1.16	2.51

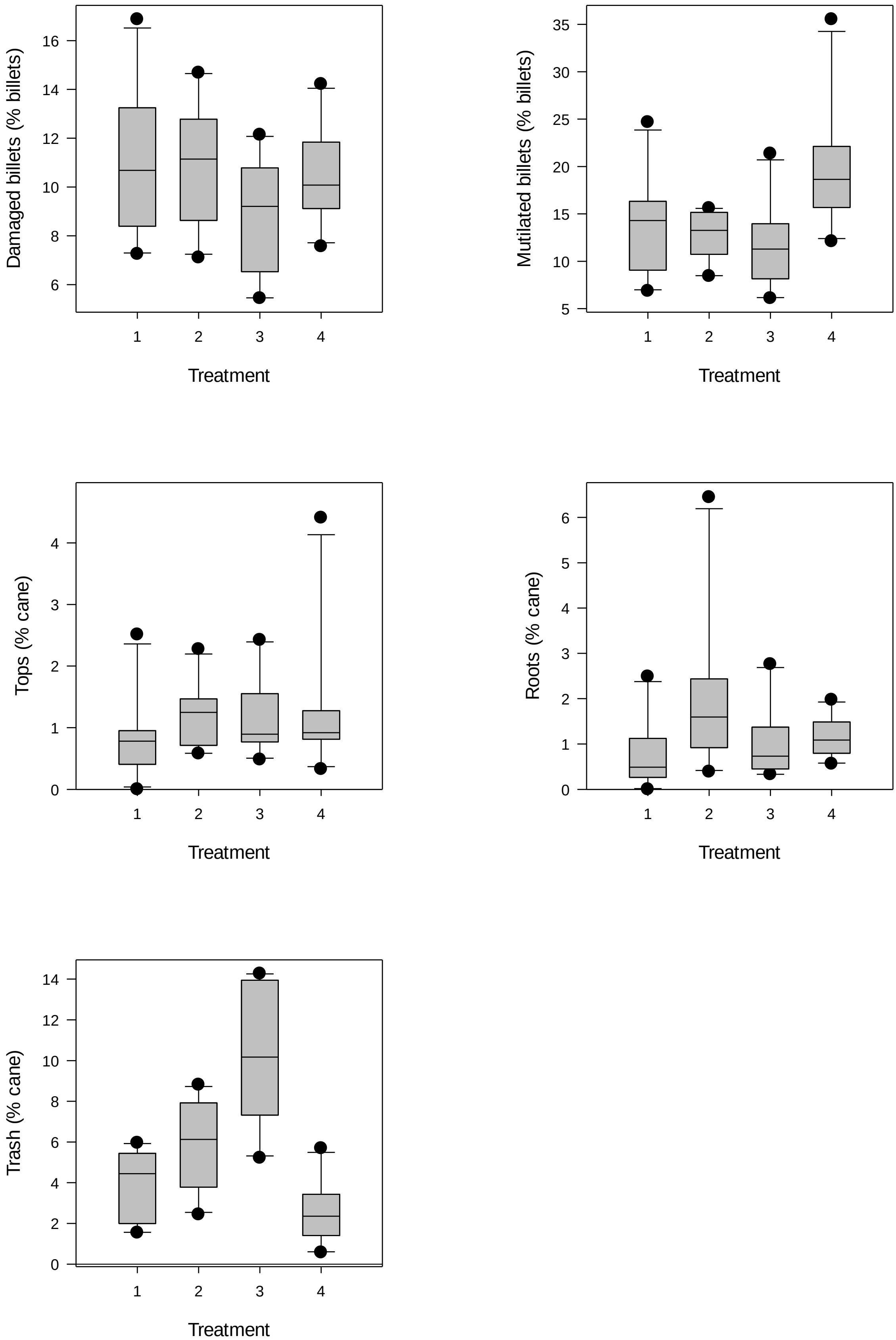


Figure 10 Extraneous matter results from experiment 5

Bin weights

The bin weight results for each test in the experiment are presented in Table 33. A statistically significant difference at the 5% level was found for bin weight. The difference between treatments 1 and 2 were not statistically different but bin weight for treatment 3 was less than for treatments 1 and 2 and bin weight for treatment 4 was more than for treatments 1 and 2. The results are presented graphically in Figure 11. These results are a mirror image of the trash content results shown in Figure 10 as expected.

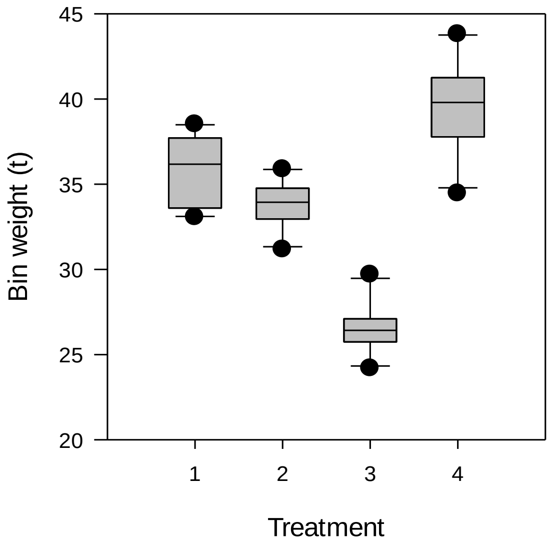


Figure 11 Bin weight results for experiment 5

Table 33 Experiment 5 bin weight results

Test	Replicate	Treatment	Bin weight (t)
1	1	1	33.87
2	1	2	34.11
3	1	3	26.26
4	1	4	34.46
5	2	2	31.17
6	2	4	40.14
7	2	3	29.69
8	2	1	37.52
9	3	4	43.81
10	3	1	38.52
11	3	2	32.83
12	3	3	25.77
13	4	3	26.08
14	4	4	39.84
15	4	2	35.88
16	4	1	36.92
17	5	2	34.44
18	5	3	26.59
19	5	1	35.45
20	5	4	39.62
21	6	1	33.61
22	6	3	25.67
23	6	4	37.77
24	6	2	33.13
25	7	1	33.06
26	7	3	24.19
27	7	2	33.00
28	7	4	39.76
29	8	2	35.79
30	8	4	43.29
31	8	1	38.29
32	8	3	27.65
33	9	1	33.58
34	9	4	37.79
35	9	2	33.80
36	9	3	26.93
37	10	2	34.44
38	10	4	40.58
39	10	1	37.17
40	10	3	26.89
Mean		1	35.80
		2	33.86
		3	26.57
		4	39.71

Cane analysis

Due to concerns about the validity of the NIR cane analysis for high trash samples in experiment 4, additional cane analysis was undertaken for this experiment.

As for the previous experiments, NIR cane analysis was undertaken. At Tableland factory in the previous experiments, the NIR fibre, CCS and pol in juice measurements were calibrated. At

Mossman factory for this experiment, the calibrated NIR parameters were fibre, CCS, Brix in cane and pol in cane. Following the practice in previous reports, the main cane analysis parameters of focus were fibre, CCS and purity. Purity can be calculated using any two of CCS, Brix in cane and pol in cane, indicating that one measurement is redundant. For this analysis, purity was calculated three ways, using each combination of the three parameters. The results are presented in Table 34.

From the prepared cane and first expressed juice samples, fibre, CCS and purity could also be calculated from can fibre and the Brix and pol of first expressed juice, using the conventional laboratory analysis procedure (Table 35).

From the prepared cane sample, moisture, Brix and pol in cane were also calculated directly using the direct cane analysis (DAC) methodology (Table 36). As an alternative method, Brix and pol in cane were calculated using can fibre methodology (CFM), rather than moisture (Table 37).

The cane fibre analysis results using NIR, CFM and direct cane analysis (DAC) methods are summarised in Figure 12. Note that the direct cane analysis method calculates fibre by difference from the moisture and Brix measurements. For the NIR fibre results, statistically significant differences were found between all treatment combinations. For the CFM results, statistically significant differences were found between all treatment combinations except for between treatments 1 and 2. For the direct cane analysis fibre results, the only statistically significant difference found was between treatments 3 and 4. Although the three fibre measurements show the same trends in Figure 12, it is clear that the direct cane analysis fibre analysis, based on the moisture and brix analysis, has more variability. The trends for all three analysis methods are similar to those for trash content (Figure 10) as expected.

A comparison between the three cane fibre measurement methods is presented in Figure 13. The results show quite a good correlation between the NIR fibre and CFM fibre results. This result is encouraging since CFM measurements are used to validate the NIR fibre results. The direct cane analysis fibre results are somewhat more variable. The analysis of variance shows a much lower mean square of residuals for the NIR fibre (0.07) than for the CFM fibre (0.3) and the direct cane analysis fibre (2), indicating greatest consistency for the NIR fibre results.

Table 34 Experiment 5 cane analysis results by NIR

Test	Replicate	Treatment	Brix (%)	Pol (%)	Fibre (%)	CCS (%)	Purity (%)		
							CCS/Brix	CCS/pol	Brix/pol
1	1	1	18.50	15.76	14.57	14.50	85.19	85.59	86.21
2	1	2	18.11	15.27	14.47	13.91	84.32	84.51	84.81
3	1	3	17.87	15.20	16.54	13.90	85.06	85.19	85.39
4	1	4	17.71	14.81	13.48	13.41	83.63	83.81	84.08
5	2	2	17.97	15.11	14.78	13.70	84.08	84.16	84.27
6	2	4	18.65	15.91	14.06	14.60	85.31	85.52	85.86
7	2	3	18.33	15.55	16.16	14.20	84.83	84.98	85.21
8	2	1	18.69	16.06	14.66	14.80	85.93	86.12	86.44
9	3	4	18.90	16.29	14.24	15.10	86.19	86.60	87.25
10	3	1	18.80	16.04	14.71	14.70	85.32	85.46	85.68
11	3	2	18.52	15.85	15.14	14.60	85.58	85.89	86.38
12	3	3	17.87	15.17	17.05	13.90	84.89	85.19	85.66
13	4	3	17.98	15.37	16.45	14.10	85.48	85.61	85.82
14	4	4	18.08	15.39	14.67	14.10	85.12	85.32	85.64
15	4	2	18.10	15.44	15.44	14.20	85.30	85.64	86.16
16	4	1	18.32	15.62	14.74	14.30	85.26	85.37	85.54
17	5	2	18.12	15.49	15.36	14.20	85.49	85.58	85.72
18	5	3	17.74	15.07	16.75	13.80	84.95	85.19	85.58
19	5	1	17.87	15.18	15.18	13.90	84.95	85.19	85.57
20	5	4	18.13	15.44	14.64	14.20	85.16	85.55	86.16
21	6	1	18.20	15.48	15.23	14.20	85.05	85.35	85.81
22	6	3	18.02	15.27	17.54	14.00	84.74	85.13	85.74
23	6	4	18.51	15.74	14.58	14.40	85.04	85.20	85.45
24	6	2	18.20	15.39	15.62	14.00	84.56	84.62	84.70
25	7	1	17.60	14.70	15.48	13.30	83.52	83.71	84.00
26	7	3	17.15	14.23	17.66	12.80	82.97	83.09	83.27
27	7	2	17.72	14.91	15.95	13.50	84.14	84.12	84.09
28	7	4	18.29	15.56	15.06	14.30	85.07	85.46	86.06
29	8	2	18.64	15.91	15.78	14.60	85.35	85.55	85.86
30	8	4	19.02	16.31	14.90	15.00	85.75	85.91	86.16
31	8	1	19.17	16.53	14.94	15.30	86.23	86.54	87.05
32	8	3	18.88	16.23	16.54	15.00	85.96	86.30	86.84
33	9	1	18.34	15.67	15.55	14.40	85.44	85.68	86.05
34	9	4	18.37	15.79	14.86	14.60	85.96	86.32	86.90
35	9	2	18.46	15.75	16.20	14.46	85.29	85.52	85.89
36	9	3	17.89	15.21	17.62	13.90	85.02	85.13	85.31
37	10	2	18.54	15.91	15.50	14.70	85.81	86.19	86.80
38	10	4	18.91	16.19	15.47	14.90	85.62	85.86	86.25
39	10	1	19.04	16.43	15.75	15.22	86.27	86.63	87.21
40	10	3	18.96	16.28	17.42	15.00	85.86	86.08	86.41
Mean		1	18.45	15.75	15.08	14.46	85.32	85.56	85.96
		2	18.24	15.50	15.42	14.19	84.99	85.18	85.47
		3	18.07	15.36	16.97	14.06	84.98	85.19	85.52
		4	18.46	15.74	14.60	14.46	85.28	85.55	85.98

Table 35 Experiment 5 cane analysis results by conventional laboratory analysis

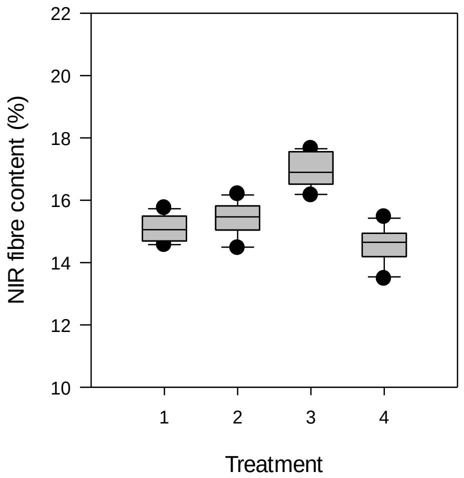
Test	Replicate	Treatment	FEJ (%)		Cane (%)		
			Brix	Pol	CFM fibre	CCS	Purity
1	1	1	22.10	19.74			
2	1	2	21.40	18.98	14.93	14.01	86.53
3	1	3	21.60	19.02	15.71	13.84	85.89
4	1	4	20.80	18.19	14.35	13.41	85.34
5	2	2	21.30	19.02	15.39	14.02	87.11
6	2	4	22.40	20.26	14.89	15.15	88.24
7	2	3					
8	2	1	22.40	20.56	15.00	15.49	89.55
9	3	4	22.60	20.86	15.04	15.76	90.05
10	3	1	22.70	20.77	15.44	15.53	89.25
11	3	2	21.70	19.93	15.74	14.88	89.58
12	3	3	21.70	19.36	16.50	14.06	87.00
13	4	3	21.30	19.52	17.79	14.17	89.33
14	4	4	21.80	19.85	14.63	14.95	88.84
15	4	2	21.90	19.80	15.84	14.62	88.18
16	4	1	21.90	19.86	14.90	14.87	88.48
17	5	2	21.90	19.79	16.08	14.57	88.13
18	5	3	21.50	19.16	17.54	13.72	86.87
19	5	1	21.40	19.04	15.55	13.98	86.79
20	5	4	22.10	19.74	14.63	14.70	87.15
21	6	1	21.80	19.96	15.83	14.86	89.30
22	6	3	22.20	19.97	18.31	14.24	87.67
23	6	4	22.10	20.38	14.81	15.43	89.97
24	6	2	21.90	19.77	15.65	14.62	88.05
25	7	1	21.10	18.74	15.78	13.70	86.63
26	7	3	20.90	18.17	16.13	13.05	84.79
27	7	2	21.20	18.87	15.70	13.83	86.82
28	7	4	22.20	20.32	14.67	15.35	89.31
29	8	2	22.40	20.56	15.60	15.37	89.53
30	8	4	23.00	21.20	14.50	16.11	89.94
31	8	1	22.90	21.10	16.12	15.70	89.86
32	8	3	22.80	20.59	16.72	15.03	88.06
33	9	1	22.00	19.87	16.83	14.48	88.07
34	9	4	22.10	20.31	15.38	15.24	89.65
35	9	2	22.80	20.59	15.80	15.20	88.08
36	9	3	21.80	19.68	16.82	14.34	88.02
37	10	2	22.40	20.35	15.87	15.07	88.61
38	10	4	23.10	21.18	15.39	15.87	89.44
39	10	1	23.20	21.05	15.18	15.71	88.52
40	10	3	23.30	21.01	17.73	15.12	87.90
Mean		1	22.15	20.07	15.62	14.92	88.49
		2	21.89	19.77	15.66	14.62	88.06
		3	21.90	19.61	17.03	14.17	87.28
		4	22.22	20.23	14.83	15.20	88.79

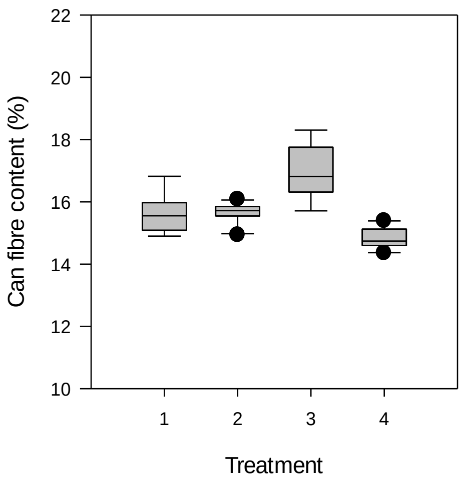
Table 36 Experiment 5 cane analysis results by direct cane analysis

Test	Replicate	Treatment	Moisture (%)	Brix (%)	Pol (%)	DAC fibre (%)	CCS (%)	Purity (%)
1	1	1						
2	1	2	68.62	17.00	14.98	14.38	13.98	88.15
3	1	3	67.48	17.12	14.36	15.40	12.98	83.89
4	1	4	70.25	17.53	14.88	12.22	13.55	84.88
5	2	2	67.64	17.15	14.90	15.21	13.78	86.88
6	2	4	68.12	17.59	15.97	14.29	15.16	90.80
7	2	3						
8	2	1	70.72	17.96	16.25	11.32	15.39	90.48
9	3	4	68.33	18.21	16.64	13.47	15.85	91.39
10	3	1	62.12	17.61	16.23	20.27	15.53	92.14
11	3	2	67.11	17.11	15.26	15.79	14.34	89.22
12	3	3	67.84	17.56	15.02	14.60	13.74	85.50
13	4	3	67.22	16.72	14.34	16.06	13.15	85.76
14	4	4	69.43	18.26	16.20	12.31	15.17	88.71
15	4	2	69.09	17.22	15.36	13.68	14.42	89.16
16	4	1	68.19	17.38	15.60	14.43	14.71	89.76
17	5	2	68.56	17.60	15.60	13.84	14.60	88.62
18	5	3	67.14	16.71	14.29	16.15	13.09	85.53
19	5	1	68.56	17.00	15.19	14.45	14.28	89.36
20	5	4	68.72	17.82	15.95	13.46	15.02	89.52
21	6	1	67.40	16.53	15.75	16.07	15.36	95.31
22	6	3	66.36	15.27	14.62	18.37	14.30	95.77
23	6	4	68.60	17.20	16.42	14.20	16.03	95.44
24	6	2	67.44	15.52	15.12	17.04	14.92	97.39
25	7	1	69.43	16.24	15.54	14.33	15.19	95.71
26	7	3	67.24	16.92	14.90	15.84	13.88	88.03
27	7	2	67.75	16.55	14.61	15.70	13.65	88.31
28	7	4	69.06	17.23	15.02	13.71	13.92	87.20
29	8	2	67.38	16.93	15.95	15.69	15.46	94.23
30	8	4	67.20	18.54	17.05	14.26	16.31	91.99
31	8	1	67.04	17.92	16.80	15.04	16.24	93.78
32	8	3	66.52	17.48	15.75	16.00	14.89	90.13
33	9	1	70.01	17.08	15.39	12.91	14.55	90.11
34	9	4	68.17	17.57	15.71	14.25	14.79	89.43
35	9	2	67.16	16.71	15.69	16.13	15.18	93.90
36	9	3	66.38	16.27	14.36	17.35	13.41	88.30
37	10	2	67.61	17.34	15.91	15.04	15.19	91.71
38	10	4	67.36	17.95	16.78	14.69	16.20	93.51
39	10	1	67.41	18.35	16.62	14.25	15.76	90.60
40	10	3	65.99	17.25	15.86	16.77	15.16	91.94
Mean		1	67.87	17.34	15.93	14.79	15.22	91.92
		2	67.84	16.91	15.34	15.25	14.55	90.76
		3	66.91	16.81	14.83	16.28	13.84	88.32
		4	68.52	17.79	16.06	13.69	15.20	90.29

Table 37 Experiment 5 cane analysis results by direct cane analysis utilising CFM fibre

Test	Block	Treatment	Brix (%)	Pol (%)	CCS (%)	Purity (%)
1	1	1				
2	1	2	16.97	14.96	13.95	88.15
3	1	3	17.11	14.35	12.97	83.89
4	1	4	17.40	14.77	13.46	84.88
5	2	2	17.14	14.89	13.77	86.88
6	2	4	17.55	15.94	15.13	90.80
7	2	3				
8	2	1	17.74	16.05	15.21	90.48
9	3	4	18.11	16.55	15.77	91.39
10	3	1	17.89	16.49	15.78	92.14
11	3	2	17.11	15.27	14.34	89.22
12	3	3	17.45	14.92	13.66	85.50
13	4	3	16.62	14.25	13.07	85.76
14	4	4	18.12	16.08	15.05	88.71
15	4	2	17.10	15.25	14.32	89.16
16	4	1	17.35	15.58	14.69	89.76
17	5	2	17.48	15.49	14.49	88.62
18	5	3	16.64	14.23	13.03	85.53
19	5	1	16.93	15.13	14.23	89.36
20	5	4	17.76	15.89	14.96	89.52
21	6	1	16.54	15.76	15.38	95.31
22	6	3	15.27	14.63	14.30	95.77
23	6	4	17.17	16.39	15.99	95.44
24	6	2	15.60	15.19	14.99	97.39
25	7	1	16.16	15.46	15.12	95.71
26	7	3	16.91	14.88	13.87	88.03
27	7	2	16.55	14.61	13.65	88.31
28	7	4	17.18	14.98	13.88	87.20
29	8	2	16.93	15.96	15.47	94.23
30	8	4	18.52	17.04	16.30	91.99
31	8	1	17.85	16.74	16.19	93.78
32	8	3	17.44	15.72	14.86	90.13
33	9	1	16.86	15.20	14.36	90.11
34	9	4	17.51	15.66	14.73	89.43
35	9	2	16.73	15.71	15.20	93.90
36	9	3	16.29	14.39	13.43	88.30
37	10	2	17.30	15.86	15.15	91.71
38	10	4	17.91	16.74	16.16	93.51
39	10	1	18.29	16.57	15.71	90.60
40	10	3	17.19	15.81	15.11	91.94
Mean		1	17.29	15.89	15.19	91.92
		2	16.89	15.32	14.53	90.76
		3	16.77	14.80	13.81	88.32
		4	17.72	16.00	15.14	90.29





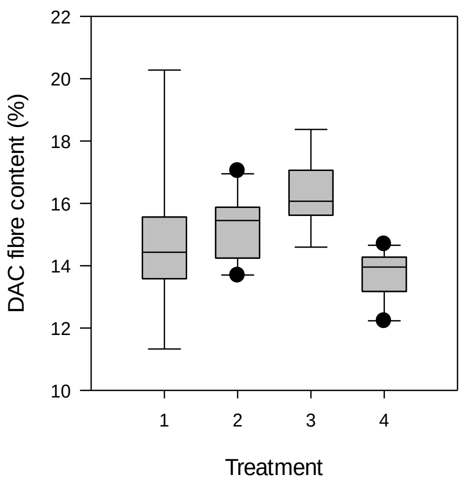


Figure 12 Cane fibre analysis results for experiment 5

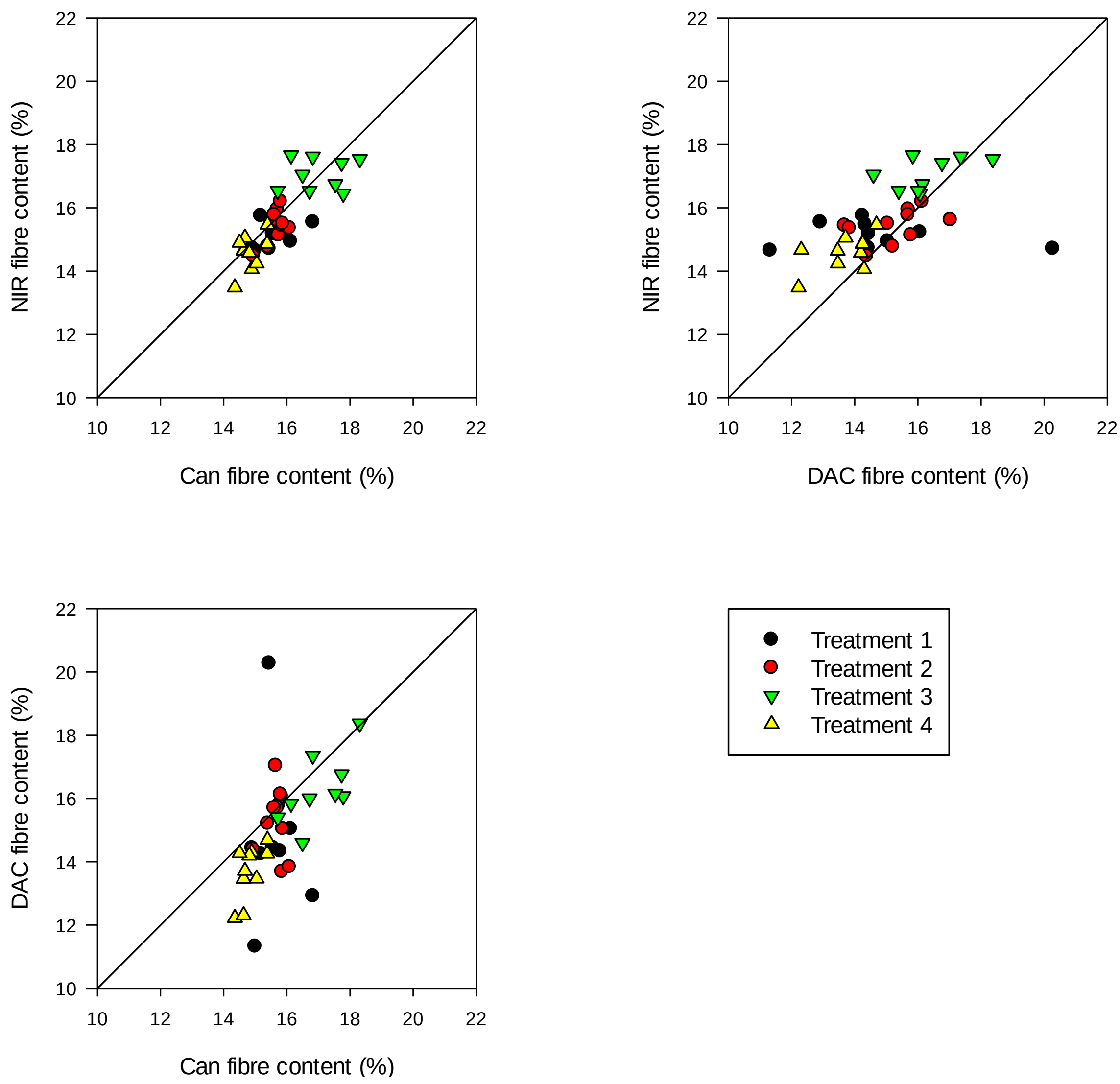


Figure 13 Cane fibre analysis comparison for experiment 5

The CCS results using NIR, first expressed juice analysis and direct cane analysis are summarised in Figure 14. No statistically significant differences between treatments were identified in the NIR CCS data. For the CCS calculated from first expressed juice analysis, statistically significant differences were identified between treatment 3 and both treatments 1 and 4. In addition a statistically significant difference was identified between treatments 2 and 4. The direct cane analysis using both methods identified the same differences as the first expressed juice analysis results, and also a statistically significant difference between treatments 2 and 3. The trends for all three analysis methods are a mirror image of those for trash content (Figure 10) as expected.

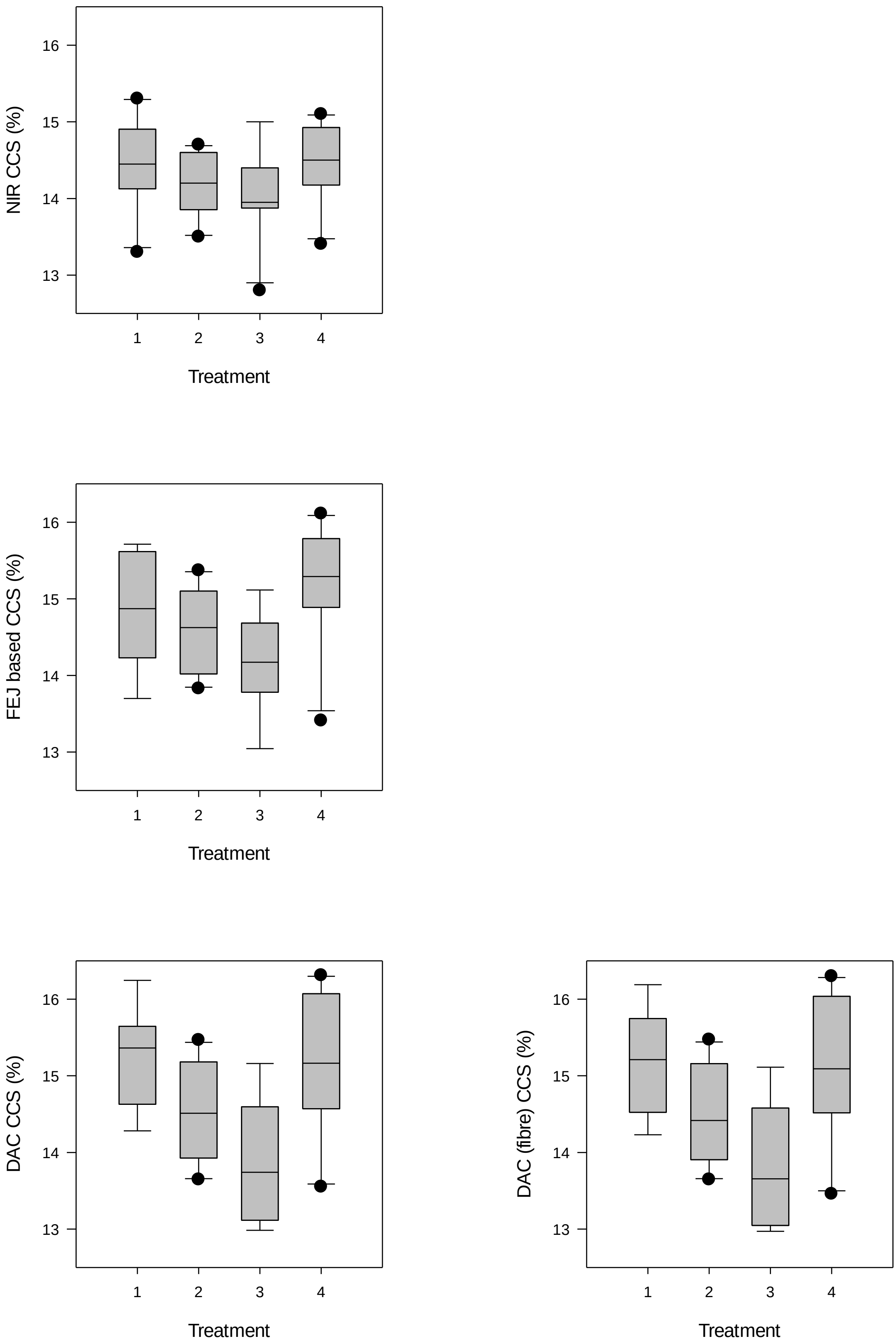


Figure 14 Cane CCS analysis results for experiment 5

A comparison between the four CCS measurement methods is presented in Figure 15. The results show that, compared to the standard first expressed juice-based CCS analysis, the NIR analysis is not capturing the magnitude of the high CCS samples adequately. The high CCS samples, as expected, are the treatment 1 and treatment 4 samples, with the lowest trash content. The comparison shows quite good correlation between the first expressed juice analysis results and the direct cane analysis results, except for some of the treatment 3 samples where the direct cane analysis shows lower CCS. The two alternative direct cane analysis methods give quite similar CCS values. The analysis of variance shows similar mean square of residuals for the three measurements: the NIR CCS (0.1), the first expressed juice-based CCS (0.2) and the direct cane analysis CCS (0.2). The mean square of residuals was slightly lower for the direct cane analysis using fibre (0.21) than using moisture (0.22).

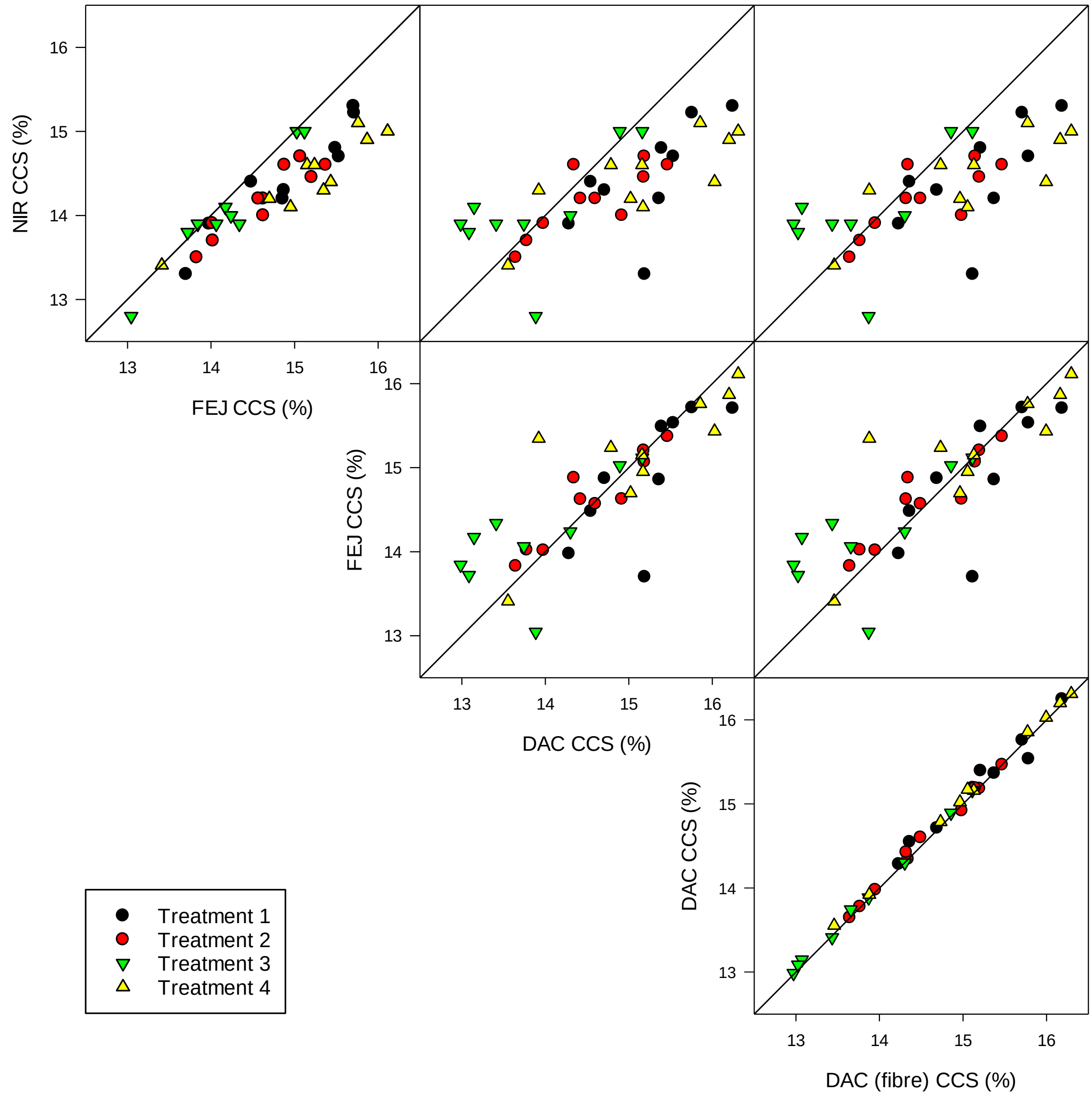


Figure 15 Cane CCS analysis comparison for experiment 5

The purity results using NIR, first expressed juice analysis and direct cane analysis are summarised in Figure 16. No statistically significant differences between treatments were identified in the NIR purity data. For the purity calculated from first expressed juice analysis, a statistically significant difference was identified between treatment 3 and treatment 4. The direct cane analysis using both methods identified a statistically significant difference between treatment 3 and both treatments 1 and 2. The trends for all four analysis methods are a mirror image of those for trash content (Figure 10) as expected.

A comparison between the three purity measurement methods is presented in Figure 17. As for the CCS results, the results show that the NIR analysis is not capturing the magnitude of the high purity samples adequately, particularly the treatment 4 samples. The analysis shows quite poor correlation between the direct cane analysis and the other two methods. The analysis of variance shows increasing mean square of residuals from the NIR purity (0.3), to the first expressed juice-based purity (0.8), to the direct cane analysis purity (4). The calculated purity using both direct cane analysis methods is the same.

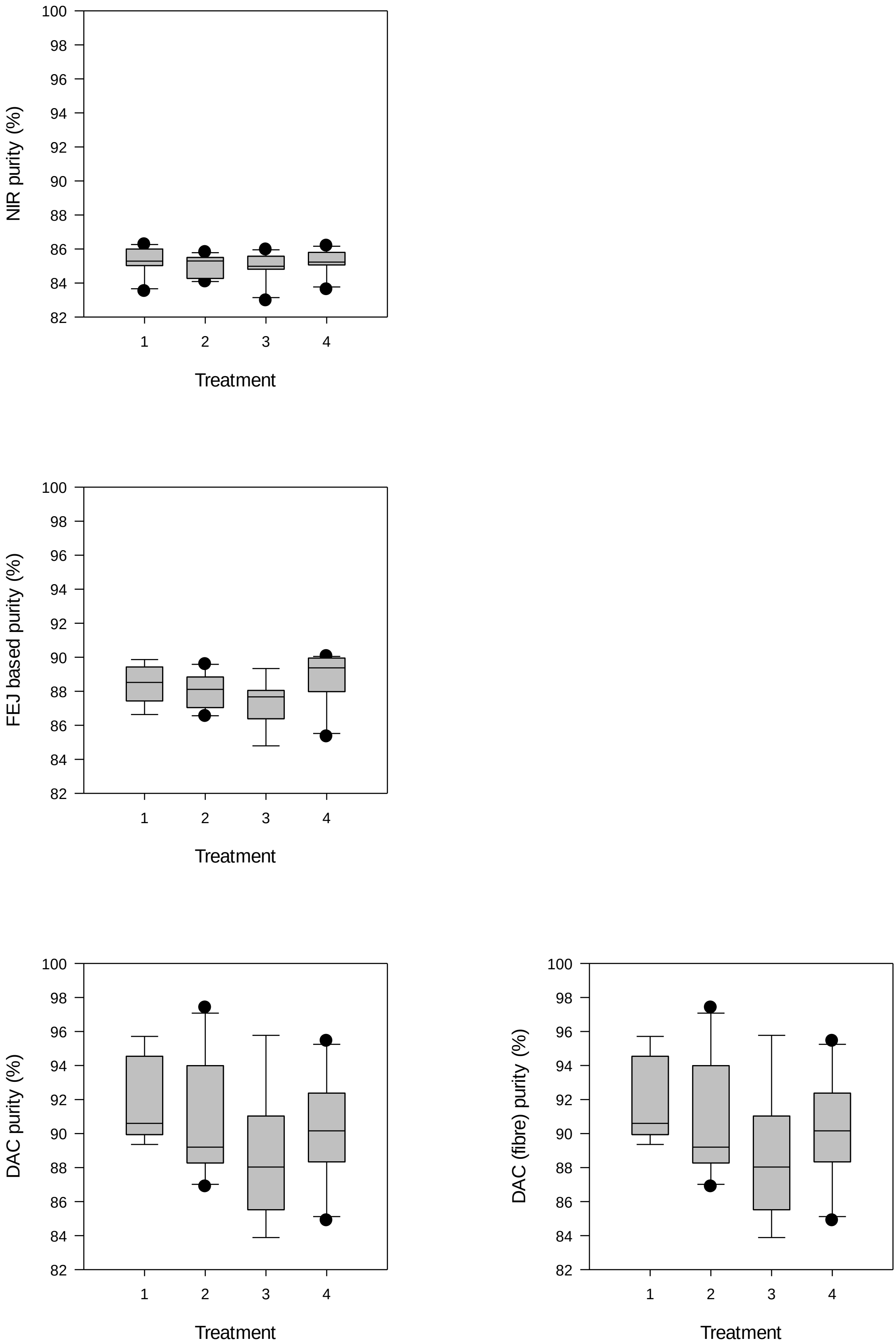


Figure 16 Cane purity analysis results for experiment 5

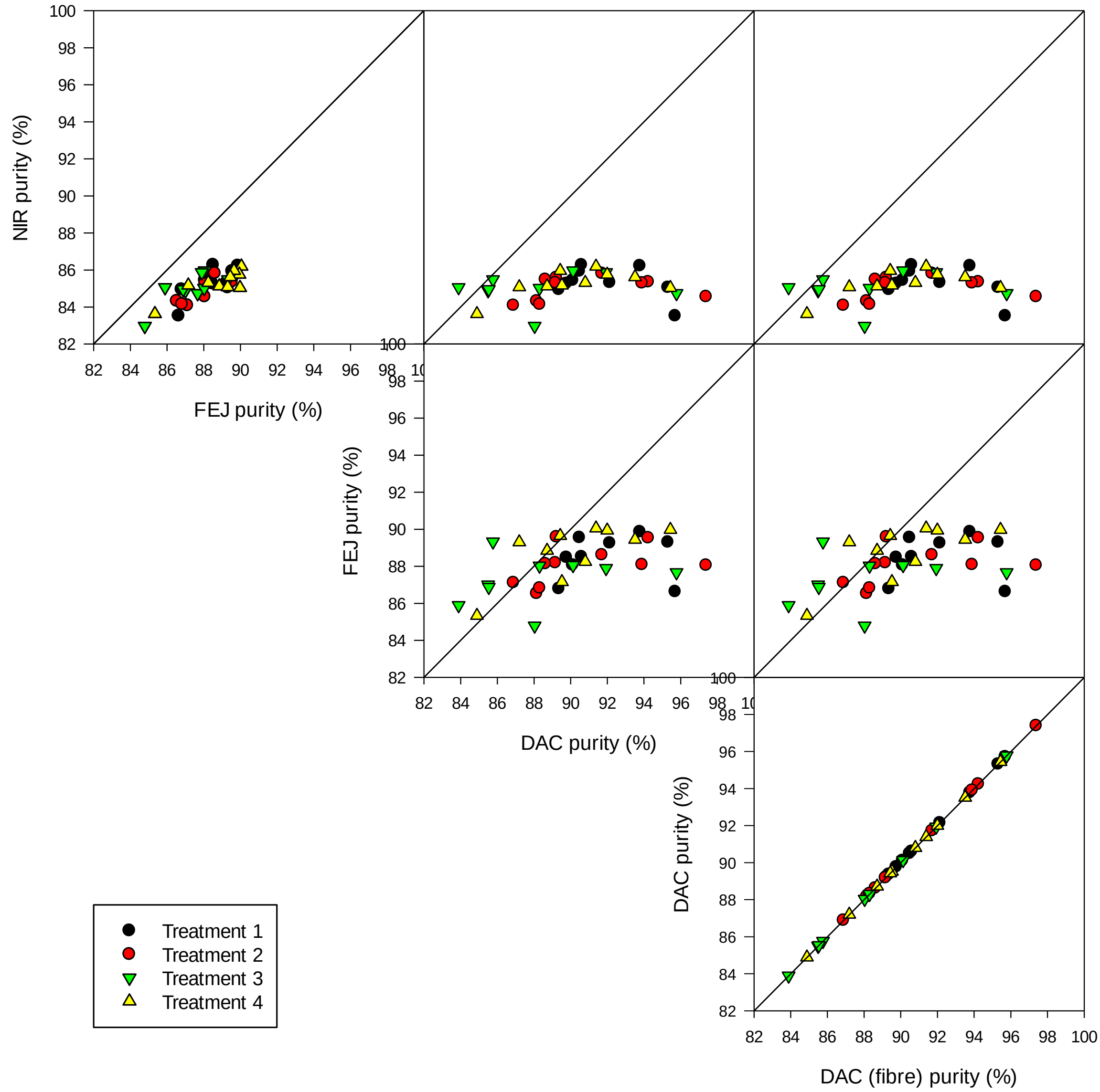


Figure 17 Cane purity analysis comparison for experiment 5

Yield analysis

The harvested areas are presented in Table 38. The yield results are presented in Table 39. Billet yield has been calculated from cane yield, using the extraneous matter results presented in Table 32. CCS yield has been calculated using the NIR, first expressed juice and direct cane analysis CCS results calculated using both moisture and fibre analysis. The yield results are shown graphically in Figure 18.

Table 38 Experiment 5 harvested area results

Test	Replicate	Treatment	Harvested distance (m)	Harvested area (ha)
1	1	1	1347	0.256
2	1	2	1401	0.266
3	1	3	960	0.182
4	1	4	1520	0.289
5	2	2	1223	0.232
6	2	4	1876	0.356
7	2	3	1223	0.232
8	2	1	1832	0.348
9	3	4	1958	0.372
10	3	1	1745	0.332
11	3	2	1377	0.262
12	3	3	995	0.189
13	4	3	1001	0.190
14	4	4	1769	0.336
15	4	2	1573	0.299
16	4	1	1652	0.314
17	5	2	1439	0.273
18	5	3	1014	0.193
19	5	1	1576	0.300
20	5	4	1768	0.336
21	6	1	1537	0.292
22	6	3	992	0.189
23	6	4	1628	0.309
24	6	2	1374	0.261
25	7	1	1408	0.268
26	7	3	987	0.187
27	7	2	1353	0.257
28	7	4	1726	0.328
29	8	2	1679	0.319
30	8	4	1864	0.354
31	8	1	1785	0.339
32	8	3	1081	0.205
33	9	1	1424	0.271
34	9	4	1644	0.312
35	9	2	1452	0.276
36	9	3	1066	0.203
37	10	2	1476	0.280
38	10	4	1905	0.362
39	10	1	1922	0.365
40	10	3	1192	0.226
Mean		1	1623	0.308
		2	1435	0.273
		3	1051	0.200
		4	1766	0.336

Table 39 Experiment 5 yield analysis results

Test	Block	Replicate	Cane yield (t/ha)	Billet yield (t/ha)	CCS yield (t/ha)			
					NIR	FEJ	DAC	DAC (fibre)
1	1	1	132	125	19.2			
2	1	2	128	118	17.8	18.0	17.9	17.9
3	1	3	144	119	20.0	19.9	18.7	18.7
4	1	4	119	105	16.0	16.0	16.2	16.1
5	2	2	134	119	18.4	18.8	18.5	18.5
6	2	4	113	108	16.4	17.1	17.1	17.0
7	2	3	128	116	18.1			
8	2	1	108	103	16.0	16.7	16.6	16.4
9	3	4	118	110	17.8	18.6	18.7	18.6
10	3	1	116	107	17.1	18.0	18.0	18.3
11	3	2	126	114	18.3	18.7	18.0	18.0
12	3	3	136	118	19.0	19.2	18.7	18.6
13	4	3	137	120	19.3	19.4	18.0	17.9
14	4	4	119	112	16.7	17.7	18.0	17.8
15	4	2	120	114	17.0	17.5	17.3	17.2
16	4	1	118	110	16.8	17.5	17.3	17.3
17	5	2	126	116	17.9	18.4	18.4	18.3
18	5	3	138	123	19.0	18.9	18.1	18.0
19	5	1	118	111	16.5	16.5	16.9	16.8
20	5	4	118	115	16.7	17.3	17.7	17.6
21	6	1	115	108	16.3	17.1	17.7	17.7
22	6	3	136	118	19.1	19.4	19.5	19.5
23	6	4	122	118	17.6	18.8	19.6	19.5
24	6	2	127	120	17.8	18.6	18.9	19.0
25	7	1	124	119	16.4	16.9	18.8	18.7
26	7	3	129	108	16.5	16.8	17.9	17.9
27	7	2	128	108	17.3	17.7	17.5	17.5
28	7	4	121	115	17.3	18.6	16.9	16.8
29	8	2	112	102	16.4	17.2	17.4	17.4
30	8	4	122	119	18.3	19.7	19.9	19.9
31	8	1	113	110	17.3	17.7	18.3	18.3
32	8	3	135	125	20.2	20.2	20.1	20.0
33	9	1	124	114	17.9	18.0	18.0	17.8
34	9	4	121	116	17.7	18.4	17.9	17.8
35	9	2	122	111	17.7	18.6	18.6	18.6
36	9	3	133	113	18.5	19.1	17.8	17.9
37	10	2	123	109	18.0	18.5	18.6	18.6
38	10	4	112	107	16.7	17.8	18.2	18.1
39	10	1	102	99	15.5	16.0	16.0	16.0
40	10	3	119	108	17.8	17.9	18.0	17.9
Mean		1	117	111	16.9	17.2	17.5	17.8
		2	125	113	17.7	18.2	18.1	18.1
		3	133	117	18.8	19.0	18.5	18.4
		4	118	113	17.1	18.0	18.0	17.9

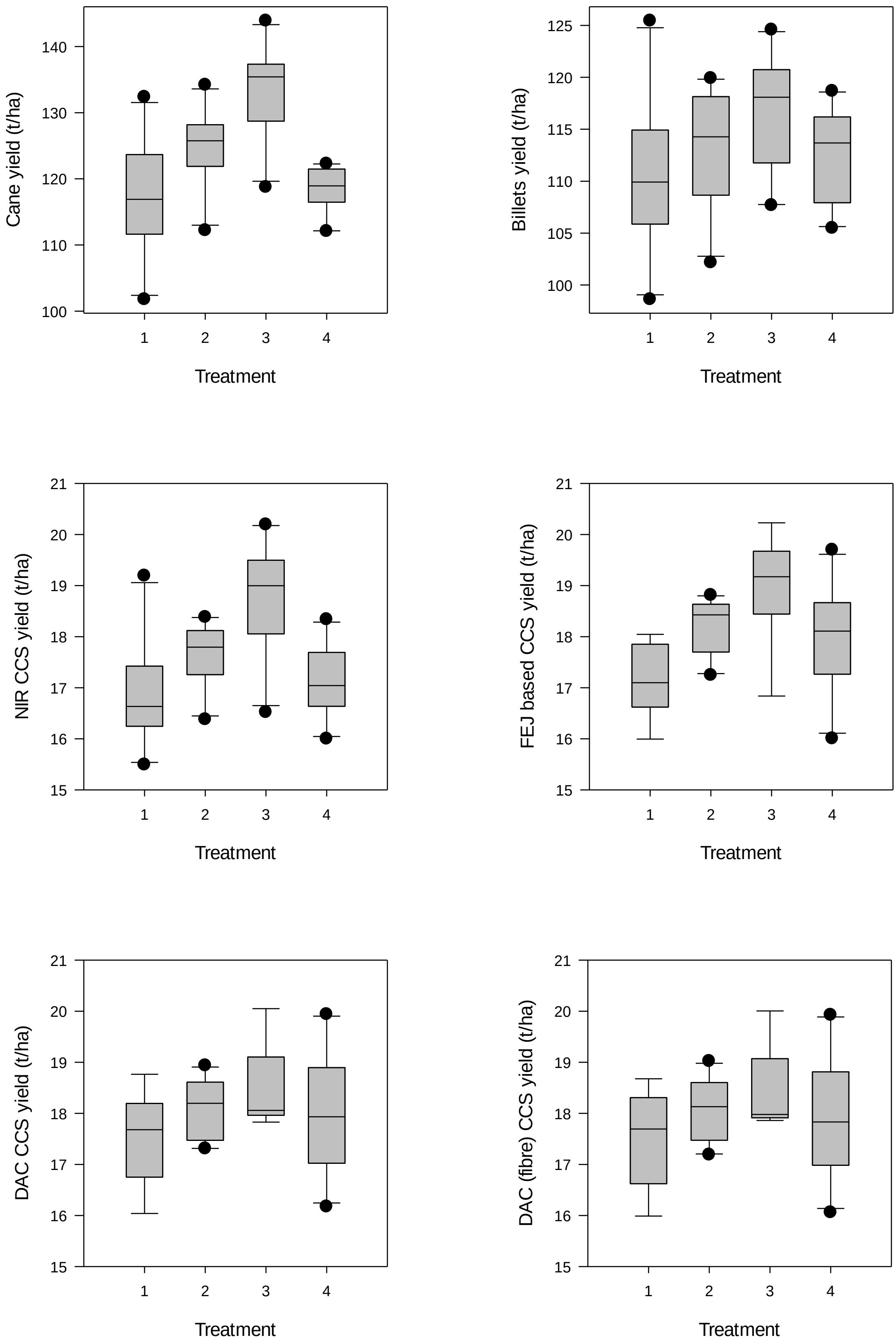


Figure 18 Summary of yield results from experiment 5

The analysis of variance found statistically significant differences in cane yield between treatment 3 and treatments 1, 2 and 4 and also between treatments 1 and 2. Statistically significant differences were also found in the NIR based CCS yield between treatment 3 and treatments 1, 2 and 4. A statistically significant difference was found in the first expressed juice based CCS yield between treatments 1 and 3.

The NIR and first expressed juice-based CCS yield results appear similar, whereas the high CCS yield for treatment 3 is absent from the direct cane analysis results.

Mass balance

As reported in experiment 1, one of the biggest uncertainties from the previous experiments surrounded the losses from the cane cleaner, since there were no mass measurements of the cane entering the cane cleaner. Experiment 4 addressed this issue by measuring the mass of cane into and out of the cane cleaner. The analysis of results indicated 4% of billets were lost, about twice that measured in a single measurement of direct cane loss by experiment 4.

Using the same methodology as experiment 4, a mass balance around the cane cleaner was conducted, using the treatment 3 and treatment 4 results. The mass balance is presented in Table 40. Cane refers to the total cane supply. Billets refers to the component of the cane supply that is not extraneous matter (tops, roots or trash) and consists of the sound billets, along with the damaged and mutilated billets reported in Table 32. The extraneous matter analysis was used to calculate the billet yield from the cane yield for both treatment 3 (entering cleaner) and treatment 4 (exiting cleaner). The billet loss calculated from the mass balance of 4 t/ha corresponds to a cane cleaner billet loss of 4%. This loss is the same size as that calculated in experiment 4 and is about twice that estimated through direct measurement of billet loss in experiment 4. Experiment 4 argued that the discrepancy between the two estimates of billet loss could be because of difficulty in getting a representative sample of the low loss treatment cane (with high trash content) for the extraneous matter analysis. It is suspicious that a virtually identical measurement of billet loss has been made in this experiment, adding weight to the 4% billet loss measurement.

Table 40 Cane cleaner mass balance

Yield (t/ha)	Cane	Billets	CCS			
			NIR	FEJ	DAC	DAC (fibre)
Entering cleaner	133	117	18.8	19.0	18.5	18.4
Exiting cleaner	118	113	17.1	18.0	18.0	17.9
Loss (including trash stream)	15	4	1.6	1.0	0.5	0.5

Table 40 also presents a CCS mass balance, using the four measurements of CCS (NIR as per experiment 4, conventional laboratory analysis from first expressed juice, and direct cane analysis calculated from both moisture and fibre). The results show that the NIR analysis predicts the largest loss of CCS through the cleaner while the direct cane analysis predicts the smallest loss. One way of assessing the validity of each calculation of CCS yield is to use the mass balance to determine the CCS of the loss component in Table 40. The calculated CCS for the three measurement methods is shown in Table 41. The calculated CCS of the loss stream is highest for the NIR measurement and lowest for the direct cane analysis measurement.

Table 41 Calculated CCS of the loss stream from the cane cleaner from the mass balance

Analysis method	CCS (%) of loss stream
NIR	10.8
FEJ	6.6
DAC	3.5
DAC (fibre)	3.3

Following the approach in experiment 4, where it was assumed that the CCS of extraneous matter is zero, the CCS of the billet component was calculated and used in conjunction with the calculated billet content of the loss stream of 28%. The results are shown in Table 42. The direct cane analysis results have the closest match between Table 41 and Table 42.

Table 42 Calculated CCS of the loss stream from the extraneous matter analysis

Analysis method	CCS (%) of billets	CCS (%) of loss stream
NIR	15.2	4.3
FEJ	16.0	4.5
DAC	16.0	4.5
DAC (fibre)	15.9	4.5

As a further test of the validity of the three CCS yield measurements, the calculated billet CCS results shown in Table 42 were applied to treatments 1, 2 and 3 and used in conjunction with the extraneous matter results to calculate CCS yield. This CCS yield was then compared to the measured CCS yield shown in Table 39. The results are shown in Table 43. The results show that, on the basis of assuming the CCS of extraneous matter is zero, the direct cane analysis method has provided the CCS measurement method most consistent with the mass balance results, with the moisture-based result slightly better than the fibre-based result.

Table 43 Difference between measured and calculated CCS yield for each treatment

Treatment	CCS yield difference (t/ha)			
	NIR	FEJ	DAC	DAC (fibre)
1	0.1	-0.5	-0.1	0.1
2	0.5	0.1	0.0	0.1
3	1.0	0.3	-0.1	-0.2

6.3. Economic results and discussion

6.3.1. Introductory remarks

For each of the trials considered (Tableland experiments 3, 4 and 5), a number of components were considered for the economic analysis. These included transport parameters and costs, harvest parameters and gross income, harvest and haulout costs and the ‘cleaning’ costs. For the purpose of the study, fuel (less rebate) was set at $1.20 per litre and the wage rate was set at $35.00 per hour based on current industry payments (*pers. comm.* Mark Poggio and Stephen Ginns, 2019).

6.3.2. Transport to mill

For each trial, trucks were used to deliver the cane to the designated mill. Each of the trials had differing parameters relating to transport capacity and cost. Table 44 outlines the transport parameters and costs across each of the trials.

Table 44 Transport parameters and associated costs under experiments 3, 4 and 5.

Parameter	EXP3/TR1	EXP3/TR2	EXP3/TR3	EXP4/TR1	EXP4/TR3	EXP5/TR1	EXP5/TR2	EXP5/TR4
	900rpm	800rpm	700rpm + cleaning	900rpm	700rpm + cleaning	850rpm	750rpm	600rpm + cleaning
Tonnes transported	214.9	200.2	220.0	385.05	355.64	358.0	340.0	400.0
Truck trips to mill	10	10	10	17	17	10	10	10
Trash %	4.0 %	5.0 %	2.5 %	4.28 %	1.8 %	3.86 %	6.0 %	2.0 %
Distance to mill (km)	10	10	10	10	10	81	81	81
$ per km to mill	$4.50	$4.50	$4.50	$4.50	$4.50	$4.50	$4.50	$4.50
Total cost per trial	$450	$450	$450	$765	$765	$3645	$3645	$3645
Total cost per tonne	$2.09	$2.24	$2.05	$1.98	$2.15	$10.18	$10.72	$9.11

Note: Tableland and Mossman Mills pay for transport cost to the mill, but it is a cost to the industry.

6.3.3. Harvest and haul-out

The harvester contract rate was estimated through established harvesting cost spreadsheets developed by DAF economists working in north Queensland. Data for each of the trials was supplied to the economics team working under the SRA Project 2016/955 *Adoption of practices to mitigate harvest losses* to estimate the harvest cost per tonne (before fuel and after cleaner). Where there were data gaps, the average cost of inputs provided by harvesting groups across industry was used.

Another difference between the standard practice and the introduction of the MCC is the addition of an extra haul-out. Standard practice commonly utilises two trucks, one at the harvester and one in transit (or waiting at the harvester) to the siding to unload. The addition of the cleaner changes the practice. Two haul-outs will continue rotating between the harvester and the cleaner (previously to the siding for train bins or trucks for transport to the mill), while a third will manage the clean cane from the MCC to the siding, or alternative transport mode to the mill for processing. The additional haul-out increases fuel and labour costs to the contractor, and the rate per tonne increases (Table 45) as the cost is spread over a decreased amount of cane, trash and EM exiting the cleaner.

Table 45 Harvest and haul-out parameters and associated costs under experiments 3, 4 and 5.

Parameter	EXP3/TR1	EXP3/TR2	EXP3/TR3	EXP4/TR1	EXP4/TR3	EXP5/TR1	EXP5/TR2	EXP5/TR4
Contract rate $/t	$5.72	$5.58	$6.39	$5.66	$6.44	$5.87	$5.80	$7.70
Number of haul-outs	2	2	3	2	3	2	2	3
Harvest cost (ex. fuel)	$1,229	$1,117	$1,406	$2,179	$2,290	$2,101	$1,972	$3,080
Total harvest cost$/t (incl. fuel)	$6.29	$6.16	$7.09	$6.25	$7.10	$6.37	$6.36	$8.47

Note: Contract harvester rate does not include fuel to capture shift in travel distances for harvesters and haul-outs.

The contract rate in Table 45 clearly shows the increased rate per tonne of cane processed through the cleaner. It was expected that the subsequent processing of 'cleaner' cane at the mill would deliver an improved CCS rate to compensate for the increase in overall harvest and haul-out costs.

6.3.4. Mobile cane cleaner

Due to the nature of the experimental design, spatial challenges and data variability the option to undertake long term investment analysis was limited. As such, the partial analysis observes a 1-year harvest for a farmer, with and without the cane cleaner, as part of the harvest and transport process. The operational cost for the MCC was estimated at $1.49 per tonne of cane entering the MCC and $1.54 per tonne for the cleaned cane exiting the machine. The cost of the mobile cane cleaner incorporated FORM (fuel, oil, repairs and maintenance), depreciation and operating labour (Table 46).

Table 46 Operational costing parameters of the MCC

Parameter	Unit / Cost
Fuel usage (litres/hour)	28.00
Total fuel and oil cost (per hour)	$36.96
New price	$325,000
Productive life (hours)	10,000
Repairs and maintenance cost (per hour)	$24.38
F.O.R.M (per hour)	$61.34
Salvage value	40%
Interest rate used to calculate depreciation	8%
Depreciation and interest cost (per hour)	$18.20
Labour cost (per hour)	$35.00
Total operation cost per hour	$134.04
Cleaner pour rate - average during experiment (t/hour)	90

6.3.5. Trash options

One important facet of the MCC is that it removes trash from the harvested cane before being transported to the mill, by either truck or cane train. While no nutrient deficit to the farmer is realised as the harvester still operates under normal conditions to provide a trash blanket, there is a significant trash issue at the cleaner site.

Numerous options to deal with the trash have been discussed throughout the project including some of the following that are considered logistically feasible, but remain un-costed or investigated:

- Sale of trash to Bunnings and other nursery outlets for processing and packaging as garden mulch;
- Private contractor to spread the concentrated trash back over the harvested area to return organic matter and nutrients back to the farm, as well as add to soil moisture preservation and weed control;
- Potential for use in co-generation of electricity at mill sites (requires transport).

There is a significant amount of trash that would be generated through the applied use of the MCC across a sugarcane district. For example, under experiment 3 using the standard harvesting process (treatment 1), around 8 tonnes of trash per hectare would be generated by the harvest and transported to the mill (excluding that returned as trash blanket by the harvester. Looking at treatment 3 of the same experiment that employs the use of the MCC, 3.5 tonnes of trash per hectare would be sent to the mill as part of the harvest. Therefore, approximately 4.5 tonnes of trash are created at the MCC unit per hectare of cane that is processed. Given that southern Queensland harvests around 45,000 hectares of cane (Canegrowers Annual Report 2016-17) then theoretically (under full adoption) 180,000 tonnes of trash could be generated each year. This throws up another potential hurdle, 'adoption', if there was only small or partial adoption by industry innovators. There is potential for benefits such as reduced repairs and maintenance costs, a shift in processing capacity (less trash equals more billets), and cleaner product. Indications are that mills might not be able to respond, incrementally to this innovation due to 'choke' points along the sugar processing chain, rather it would require a significant practice change.

However, despite all the 'what ifs' the study has placed an economic cost on the trash in lieu of a defined trash strategy that would be able to deal with the volume of trash that could be potentially generated. For the purpose of this study, the economic cost of trash was approximated using a western Queensland baling cost for large round bales (*pers. comm.* Fred Chudleigh, Principal Agricultural Economist DAF, 2018). Removal or transport of the bales off-site would need to be covered by the estimated sale price of the bales so not to burden the farming operation further. The cost for baling one tonne of cane trash was $27, equating to 3 bales. Table 47 outlines the trash cost for each of the trials employing the MCC.

Table 47 Approximated trash baling costs for MCC based cleaning trials, experiments 3, 4 and 5

Experiment / Trial	Cost per Trial	Cost per Ha
EXP3 / TR3	$121.77	$78.05
EXP4 / TR3	$272.12	$122.20
EXP5 / TR4	$334.80	$99.64

6.3.6. Economic summary

The summary of data collected represents three different experiments under which numerous tests were conducted to examine standard harvesting and transport practice versus a process that incorporated the MCC. Due to the variability between experiments, each should be considered separately, and so examining the result within each experiment and not between experiments. The economic summary distils the data to per hectare and per tonne for comparability within experiments, as harvest areas, travel speeds and other variables were not constant between trials. Table 48 outlines the key economic parameters from the project.

Table 48 Economic summary of trial data with and without the MCC

Parameter	EXP3/TR1	EXP3/TR2	EXP3/TR3	EXP4/TR1	EXP4/TR3	EXP5/TR1	EXP5/TR2	EXP5/TR4
Gross income per ha	$6,412	$6,236	$5,816	$6,858	$7,184	$4,644	$4,447	$4,554
Cost per ha	$1,296	$1,252	$1,583	$1,245	$1,846	$793	$741	$1,291
Net income per ha	$5,116	$4,984	$4,233	$5,614	$5,338	$3,851	$3,706	$3,263
Net income per tonne	$33.22	$33.40	$30.02	$37.18	$33.43	$30.92	$31.88	$27.41

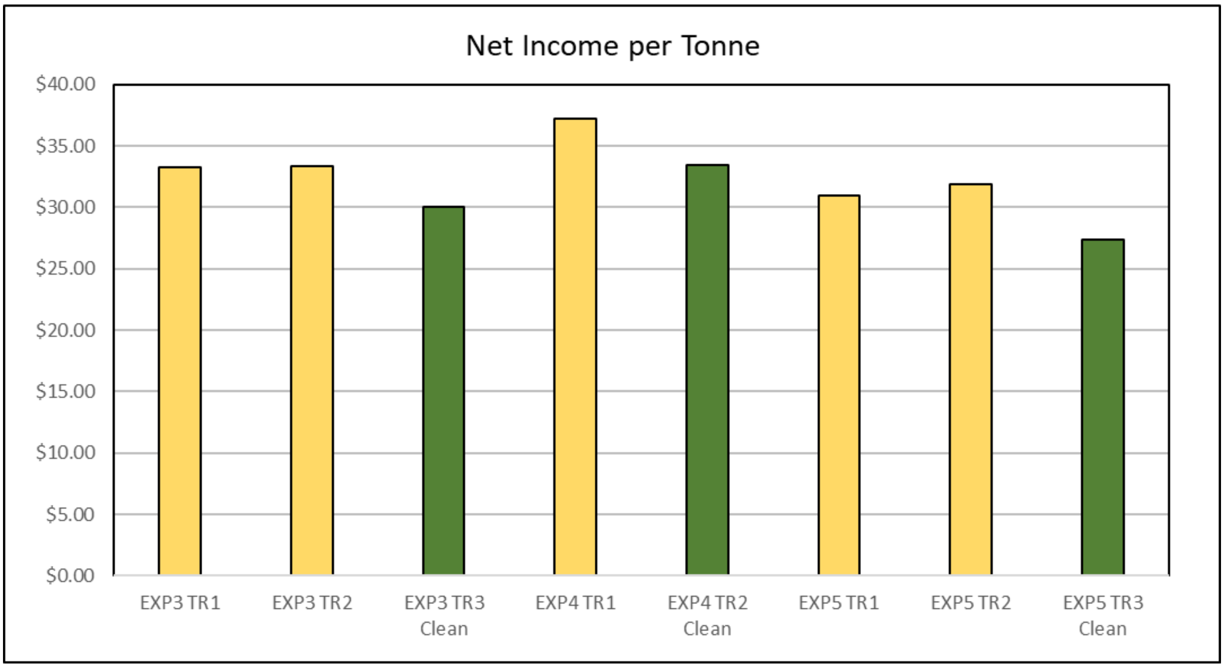


Figure 19 Net income per tonne of cane harvested

Figure 19 graphically represents the net income per tonne of cane harvested from each treatment under the three experiments examined. In each case, the cleaned cane treatment is represented in green (EXP3TR3 / EXP4TR2 / EXP5TR3). In each instance, the income generated in trials utilising the MCC are less than each of the standard practice treatments. The income generated by the MCC trials is $3.21 per tonne less than the income generated by EXP3TR1, $3.75 per tonne less than the income generated by EXP4TR1, and $3.51 per tonne less than the income generated by EXP5TR1.

It was expected that gains in CCS may overcome any additional harvesting and transport costs generated by the inclusion of the MCC in the process. Table 49 outlines the existing CCS results for the MCC trials and what they would need to achieve to breakeven with the standard practice in each case.

Table 49 Comparative CCS results from trials with MCC and CCS required to achieve a breakeven result in terms of net income per hectare

Experiment / Trial	CCS Trial Result with MCC	Breakeven CCS
EXP3 / TR3	15.29%	16.18%
EXP4 / TR3	16.33%	17.37%
EXP5 / TR4	14.46%	15.44%

6. CONCLUSIONS

In 2017, the project completed a series of field trials in the Bundaberg and Isis areas to compare “low loss” harvesting strategies, with and without post-harvest cleaning, to the current harvesting practice, thus determining the net benefit to the value chain. No economic analysis was completed on these trials to quantify harvesting costs, processing costs and the resulting product income.

The harvesting tests conducted in 2017 did appear to produce cane supplies with different levels of cane quality. Statistically significant differences in cane fibre content and CCS were identified between the low loss and cleaned cane supplies but not between the commercial and the other treatments. Lack of statistically significant differences is believed to be mainly caused by the small number of tests and could be remedied by the conduct of further tests.

The factory results showed higher extraction from the cleaned treatment than from the low loss treatment but few other significant differences. Once again, the small number of identified differences is believed to be a consequence of the small number of tests.

No statistically significant sugar production effects were identified from the liquor analysis.

In 2018 the project completed a series of field trials on the Atherton Tablelands where it compared "low loss" harvesting strategies, with and without post-harvest cleaning, to the current harvesting practice to determine the net benefit to the value chain.

Two preliminary experiments and three large experiments were conducted on the Atherton Tablelands. Most of the experiments were conducted on MSF Sugar farms, with the cane supplies processed at Tableland Mill. The final experiment was conducted on Rajinder Singh's farm, with the cane supplies processed at Mossman Mill. The main objective of the experiments was to determine the change in CCS yield that could be achieved by changes to harvesting parameters (principally extractor fan speed), with and without cane cleaning. As a basic concept, it was expected that reducing extractor fan speed would reduce cane loss, resulting in increased CCS yield but also increased trash content and that the post-harvest cane cleaning operation would remove the additional trash, maintaining the higher CCS yield. The results did support the expectation of higher CCS yield with lower extractor fan speed, but much of higher yield measured by low loss harvesting was lost after post-harvest cane cleaning.

The experiments conducted were well controlled and have produced cane yield results that are consistent within about 3 t/ha with ISLMS cane loss measurements.

The ISLMS cane loss measurements show an increase in CCS yield with the low loss harvesting treatment. There appears to be a loss of CCS yield of about 2 t/ha in the MCC-cleaned cane supply that warrants further explanation. The results show lower cane yield from the low loss harvesting and cane cleaning treatment, primarily because of the extraction of trash from the cane cleaner.

Following the first three experiments, additional focus was placed on the mass balance around the cane cleaner to understand the fate of the higher CCS yield. The most likely explanation was that the higher yield of the low loss harvesting treatment was overstated, resulting from the use of NIR analysis of CCS. The final experiment focussed on this issue, by using, in addition to NIR analysis, conventional first expressed juice analysis and direct cane analysis to provide additional measures of CCS. While this final experiment also found a reduction in CCS yield across the cane cleaner using the NIR and conventional first expressed juice analysis, that difference was not evident in the direct cane analysis results. It was concluded that the direct cane analysis method gave CCS yield results that were most consistent with mass balance analysis results.

An economic analysis was undertaken on the three large Tableland experiments to assess the most economically attractive harvesting and cane cleaning strategy of the three strategies tested. The analysis considered costs associated with harvest and haulouts, transport, trash and cane cleaner operation, along with gross income based on tonnes of cane and CCS at the factory. In all three experiments, the treatment with post-harvest cane cleaning was found to be less attractive than the harvest-only treatments. In the Rajinder Singh farm experiment, that result was achieved even with the lower transport cost for moving the cleaned cane to Mossman Mill, a distance of 95 km. In two of the experiments where a treatment involving a higher than normal extractor fan speed was involved, the higher fan speed treatment was more attractive than the normal speed treatment.

The mobile cane cleaner that was used by the project was a prototype that could not be used commercially. By the end of the project, there remained six operational issues that would render it not suitable for use other than for research purposes:

- The hopper floor carrier cannot carry a hopper full of cane.
- When the hopper floor is moving faster than a setting of 6 to 7, bunching of cane occurred in front of the scratcher and billets spilled over the side of the hopper.
- Trash was being sucked onto the air intake screens and reduced the efficiency of the cleaning chamber.
- Leakage of billets from various places occurred around the cane cleaner.
- Damage was occurring to billets in the cleaning process.
- The clean cane elevator needs to be removed from the mobile cane cleaner (MCC) before moving the MCC on local roads.

7. RECOMMENDATIONS FOR FURTHER RD&A

Further trials are recommended to gain further information about the CCS yield in supplies of cleaned cane from the latest Norris ECT mobile cane cleaner model. Three treatments would be proposed: a commercial harvesting treatment, a low loss harvesting treatment, and the same low loss harvesting treatment with cane cleaning. Sucrose loss measurements of the cane/trash product from the cleaner using the Infield Sucrose Loss Measurement System are recommended as part of this experiment to get a better assessment of sugar losses from the cleaner. Direct cane analysis is recommended for measurement of CCS.

Further trials are also recommended in crops of varieties recognised as being of high cane loss, unlike the KQ228 and Q208 varieties common on the Tablelands.

8. PUBLICATIONS

No publications have yet been prepared. It is planned that the results will be published at the 2020 conference of the Australian Society of Sugar Cane Technologists.

9. ACKNOWLEDGEMENTS

This project was supported by Sugar Research Australia through funding from the Australian Government Department of Agriculture as part of the Rural R&D for Profit program.

We acknowledge the assistance of the transport and production teams at both Bingera and Isis factories, notably Robert Powell, Robert Zahn and Salesh Kumar from Bundaberg Sugar and Ken Oliver, David Pike and Jenny Magdalinski from Isis.

We also acknowledge the QUT team of Hakan Bakir, Floren Plaza and David Moller, who helped in the coordination of tests and production of liquor for sugar and molasses production estimates in the Bundaberg and Isis tests.

The project would like to acknowledge the support provided by Bundaberg Sugar staff at Fairymead, namely Dave Helmore, and the harvest contractor Wayne Golchert. At Isis, we would like to thank farm staff on Emdex, namely Troy Manderson, the harvesting contractor Isis Central Harvesting, and Jeff Geaney from the Isis rail transport team for providing the rail bins.

The authors thank Gary Murphy and Peter Chohan of MSF Sugar for assistance with data retrieval and Steve Staunton from SRA for the provision of the data for analysis.

The authors also thank Mick Ward, Rik Maatman and the field staff of MSF Sugar, Wayne Rees and all his harvester crews for their assistance and Qube transport.

The authors thank Rajinder Singh for hosting the cane cleaner on his property. Ross Bray and his harvester crew are also acknowledged for their cooperation. The transport staff of Qube, along with Marty Mous and the traffic staff at Mossman Mill, are also acknowledged for their cooperation.

The authors thank Louie Sciacca, Craig Butland, Terry Melchert and analysts Rita Milani, Jocelyn Marr, Murray Holmes, Jack Nguyen and Sarah Rossetto at Mossman Mill for their assistance and support. Floren Plaza and Darcy Patrick are also acknowledged for their help with the sampling and analysis. Paul McNair of Mirrabooka and Steve Staunton of SRA are also acknowledged for providing analysis data from Mossman.

We also acknowledge the support of Phil Patane and the SRA sugar sucrose loss trailer team for the data gathered by the Infield Sucrose Loss Measurement System (ISLMS) in experiments 1 and 3 on the Tablelands.

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11. APPENDIX

11.2. Appendix 1 METADATA DISCLOSURE

Table 50 Metadata disclosure 1

Data	Data and data analysis for harvesting and cane cleaning experiments
Stored Location	QUT – RDSS (Research Data Storage Service) in the projects\sef\ctcb\sri\projects folder for project 4273
Access	Restricted; QUT's CTCB Bioprocessing staff with access to the projects folder
Contact	Geoff Kent – Principal Research Fellow.