Assessment of the yield and sugar recovery from green-cane chopper-harvesting and burned-cane hand-cutting for a South African operation

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Abstract Internationally, green-cane chopper-harvesting is increasing, with drivers being environmental constraints on pre-harvest burning, the potential benefits relating to the utilisation of leafy extraneous matter (EM) in varying proportions for agronomic benefit or as an industrial feedstock. The potential for significant cane and sucrose loss with chopper harvesting is a concern, and in the Southern African Industry harvesters have been introduced, then rejected, primarily because of reduced sugar recoveries. The re-introduction of chopper harvesters in Mpumalanga Province of South Africa in 2014 initially resulted in a significant decline in recoverable sugar content (tonnes RV/ha) for the fields harvested relative to traditional harvesting practices. This paper presents the results of a replicated field trial undertaken in 2015 to fine-tune ‘best practice’ settings for the harvesters under local conditions. It then presents the results from four replicated trials that were undertaken to compare the sugar recovery from chopper-harvested green-cane and traditional burned cane using manual cutting and machine loading. In all trials, direct delivery of the machine-harvested cane to the mill resulted in harvest-to-crush times of 6-8 h. For the manual-harvest burned-cane treatments, ‘mill average’ burn-to-crush delays of 70-85 h were targeted, but in one trial a burn-to-crush time of less than 24 h was targeted to quantify this effect. The green-cane chopper-harvesting operation, when optimised for minimal losses, achieved 10-15% higher indicated sugar recovery per hectare than burning and manual cutting for the mill average burn-to-crush delay. When the burn-to-crush delay for the hand-cut cane was reduced to less than 24 h, both systems gave similar indicated total recoverable sugar. Despite the known multiple losses associated with chopper harvesting, the losses associated with well-supervised burned cane with manual harvesting are as great or greater than optimised chopper harvesting, with the losses associated with the pre-harvest burn and burn-to-crush delays possibly being significant factors.

Key words Burned-cane harvesting, green-cane harvesting, burned versus green cane yield, chopper harvesting, sugar recovery

INTRODUCTION

Burned cane that is hand-cut and machine-loaded is the major harvesting system in the irrigated cropping area of Mpumalanga Province in South Africa, and the adjacent cane-production areas in Swaziland. Several attempts have been made over two decades to introduce chopper harvesting on a commercial scale but cane loss and secondary issues such as reduced crop-cycle length because of poor ratooning resulted in a reversion to manual cutting and mechanised loading of burned cane.

In the mid 2000s harvesters were introduced into Ubombo Ranchers’ Estate at Big Bend, Swaziland, as a strategy to facilitate green-cane harvesting and collection of field residues for fuel for power generation. Shortly after that, harvesters were introduced at Royal Swazi Sugar Corporation (RSSC), again as a strategy to facilitate the collection of crop residues as fuel for cogeneration. The RSSC operation ran for only 3 years before the chopper-harvesting operation was closed down: the primary reasons being reduced observed yields relative to hand cutting and increased field damage resulting in accelerated ratoon yield decline. The Ubombo Ranches’ operation has moved to a strategy of running the harvesters with only topping operational, and transporting ‘cane plus trash’ to a cleaning facility near the mill where leaf is extracted and processed for the cogeneration operation and cleaned cane forwarded to the mill. Leaf supplied by this operation is a significant contributor to the energy supply of the cogeneration plant.
The re-introduction of harvester in the neighbouring Mpumalanga area was driven by factors including declining labour availability, the potential to significantly reduce crop irrigation requirements by residue blankets (Olivier and Singles 2007), and potential value-adding opportunities for a portion of the leaf.

The Mpumalanga operation incorporated the use of GPS auto-steer guidance in both farming operations and on the harvesters. This strategy, along with matching crop row spacing to the machine wheel/track spacing, was designed to minimise soil compaction and cane stool damage and, thus, minimise the negative impacts on ratoon yield often encountered when chopper harvesters are introduced.

After initially experiencing high losses in machine-harvested fields, strategies were pursued to manage the losses by defining ‘best practice’ harvester operational techniques. Trials were then undertaken to compare the sucrose recovery from green-cane chopper-harvesting with traditional burned-cane manual-harvesting strategies.

**HARVESTING LOSSES**

Meyer *et al.* (2002) conducted trials at RSSC in Swaziland to compare conventional burned-cane manual-cutting with push-pile loading against chopper-harvesting of both burned and unburned cane. The trials were conducted over 3 years. Sugar recovery was highest with burned cane and manual harvesting, lower with burned-cane machine-harvesting, and lowest with green-cane harvesting, with the effect being driven predominantly by yield differences. The differences in cane quality at the mill among the different systems was not significant. This reduction in sugar recovery was one factor which encouraged RSSC not to proceed with chopper harvesting at that time.

No harvesting system can achieve the translation of 100% of the recoverable sugars in the field prior to harvest to potentially recoverable sugar at the mill. Losses commence with the burning operation (Gomez *et al.* 2006; Foster *et al.* 1977) and from that point are a combination of physical losses and product deterioration, plus additional reductions in sucrose recovery associated with the inclusion of non-cane (EM) components in the product being milled. Key issues include:

- Whilst manual harvesting and machine loading of burned cane (B-MH) typically gives the lowest direct physical losses of cane during the harvesting processes, and relatively low EM, the losses associated with the burning process and deterioration associated with extended ‘kill-to-mill’ times (primarily due to logistics management) can be significant.
- Burned-cane chopper-harvesting (B-CH) has the disadvantage of the direct and indirect (accelerated deterioration) losses associated with billeting. However, these losses can be managed/offset by shorter kill-to-mill times normally associated with properly managed transport logistics.
- Green-cane manual-cutting (G-MH) can potentially give the highest recoverable sucrose in the delivered product. However, higher cane losses due to visibility and adverse working conditions often result in lower total yields, lower overall sucrose recovery and high harvesting costs.
- Green-cane chopper-harvesting (G-CH) maintains the advantage of no burning-related losses, but losses associated with trash extraction can be very significant, as can be billeting losses. Additional losses in the mill are associated with higher EM levels. Managed properly, green-cane machine-harvesting typically results in higher sucrose recovery than burned-cane machine-harvesting (Gomez *et al.* 2006; Smith *et al.* 1984).

**BENCHMARKING AT MPUMALANGA**

Following the introduction of a fleet of five John Deere 3520\(^1\) harvesters late in the 2014 harvest season, cane yields and sugar recovery were observed to be well below yield estimates for the fields harvested mechanically. The machines were typically being operated at high extractor-fan speed settings, with the goal being to minimise leafy EM in the product being supplied to the mill.

The machines were also running at short billet-length settings. Whilst one harvester was fitted with a six-blade chopper system giving a maximum billet length of approximately 230 mm, all other machines were fitted with eight-blade chopper systems, giving maximum billet lengths of less than 170 mm. Additionally, the machines were being operated at less than the maximum billet length setting, on the understanding this would both further increase transport payloads and enhance leaf and EM extraction.

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\(^1\) The make and model of the harvester is included for reference purposes only and similar results could be anticipated from harvesters from other manufacturers under the same field conditions.
Significant ‘bad press’ associated with the initial results was a concern for the owner/operator of the machines. Advice was sought from a third party, and the general guidelines recommended by the BSES Harvest Best Practice Manual (Sandell and Agnew 2002) were applied, although no specific measurements were undertaken.

In June 2015, NorrisECT was commissioned by the owner to optimise setup and develop operating guidelines to maximise potential sugar recovery. We undertook an initial trial to benchmark the performance of the harvesters under local conditions. The machine fitted with the six-blade chopper system was selected for the trial; as direct billeting losses are highly correlated with billet length (Hockings et al. 2000). The aim of the trial was to assess the impact of changing the harvester settings controlled by the operator on:

- total product delivered to the mill
- levels of leafy EM in the product delivered to the mill, and
- recoverable sugar (RV% and RV/ha) associated with the different harvester settings.

This information could then be used to both enhance understanding of the interactions inherent in chopper harvesting and develop harvester settings optimised for the conditions.

Field conditions for the trial

The trial was conducted in Field 24 at Inyoni Boerdery, an even crop of seventh ratoon of N36, a relatively ‘heavy stalk’ variety. Row spacing was 2.0 m, and the crop was irrigated through sub-surface drip irrigation. The crop was predominantly erect, and conditions were cool and dry. The six treatments tested in the trial program are detailed in Table 1. The ‘low loss’ treatment incorporates low harvesting speed, low primary extractor speed and secondary extractor ‘off’ to achieve moderate cleaning whilst minimising cane loss. This treatment, rather than a ‘fans off’ treatment is used as the reference to compare yields from the different treatments to minimise the sampling accuracy issues associated with the very high leaf levels in the ‘fans off’ treatments.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Ground speed (km/h)</th>
<th>Primary extractor (rpm)</th>
<th>Secondary extractor (on/off)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low loss settings</td>
<td>2.00</td>
<td>550</td>
<td>Off</td>
</tr>
<tr>
<td>Optimum fan speed, low ground</td>
<td>2.25</td>
<td>750</td>
<td>On</td>
</tr>
<tr>
<td>speed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optimum fan speed, higher ground</td>
<td>3.25</td>
<td>750</td>
<td>On</td>
</tr>
<tr>
<td>speed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High fan speed, low ground</td>
<td>2.25</td>
<td>950</td>
<td>On</td>
</tr>
<tr>
<td>speed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High fan speed, higher ground</td>
<td>3.25</td>
<td>950</td>
<td>Off</td>
</tr>
<tr>
<td>speed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very high fan speed, higher</td>
<td>3.25</td>
<td>1250</td>
<td>On</td>
</tr>
<tr>
<td>ground speed</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Measurements

We used the standard ‘mass balance’ trial strategy where:

- The row distance harvested to fill the required number of infield haul out units to fill one bin on the main field-to-mill transport unit is recorded utilising a handheld GPS unit. All six treatments were undertaken, and the process replicated six times, with full randomisation of the treatments within each replicate.
- A sample of approximately 100 kg was taken from each transport unit and sorted into components:
  - Clean cane billets and pieces,
  - Tops or ‘cabbage’,
  - Brown and green leaf,
  - Roots and stool, plus loose soil.

The sampling process is shown in Figure 1. The mass of product associated with each treatment, and the subsequent yield/ha was determined by the analysis of the samples, the area associated with each treatment and the tonnage from the treatment determined at the mill weighbridge. At the mill, full laboratory analyses of samples taken at the sampling station after the shredder were used to determine recoverable sugar by the standard RV% process used at South African Mills.
The composition of the cane after harvesting is determined by sorting 100 kg samples from each replicate of each treatment into key components.

Cane loss and EM

Figure 2 shows that, as harvester fan speed increased, the total mass of product delivered reduced, the tonnage of clean cane reduced and the level of all types of EM also reduced. At the highest extractor fan speed, the product had very low EM levels, and was visually very clean. Statistical analysis indicated that whilst there was no difference between clean cane yield across the 750 rpm and 950 rpm settings, but the 550 rpm setting and the 1250 rpm setting gave clean-cane yield results which were higher and lower (respectively) than the central group at the 95% confidence level.

![Fig. 1. The composition of the cane after harvesting is determined by sorting 100 kg samples from each replicate of each treatment into key components.](image)

![Fig. 2. Delivered product at different harvester operating parameters. Different letters on the cane yield of the different treatments indicate statistical significance.](image)
Overall, the magnitude of the cane loss measured was lower than would normally be anticipated for the particular harvester (Anon. 2014). Under the conditions of the trial possible reasons for this discrepancy were:

- The crop was generally erect, and fed evenly into and through the machine.
- The pour rates were moderate, allowing the cleaning system to operate in an efficient range.
- The crop was able to be topped, reducing leaf material loading into the extractor chamber, and subsequently reducing cane billet loss associated with the interactions between billets and leaf being extracted.
- The deflector plate in the extractor chamber was at the lowest setting, which reduces cane loss, although at the expense of cleaning efficiency.
- The variety had above-average stalk diameter and billet weight, and these characteristics are known to reduce cane loss.

Further analysis of the results showed:

- Increasing extractor fan speed from 550 rpm to 750 rpm (at averaged groundspeeds) reduced leafy EM levels from 15 t/ha to 8.8 t/ha, a reduction of 6.2 t/ha. However, to achieve this, 5.8 t/ha of cane was extracted (lost through extractor system). This ratio of cane loss: total extracted product was higher than anticipated.
- At the highest extractor speed, 16.9 t/ha of cane was extracted to extract 22.4 t/ha of total extraneous matter relative to the 550 rpm fan speed. This cane loss was lower than anticipated.
- Increasing forward speed at a constant extractor fan speed reduced cane loss and generally increased leafy EM levels, which was anticipated.

The trial results show losses of similar general magnitude to other trials (Anon. 2014), again confirming the common observation ‘the more tonnes of leafy EM which are bought to the mill, the more tonnes of cane is delivered with it’.

### Recoverable sugar

The results for RV (Fig. 3) illustrate that:

- There was no statistically significant difference in RV% at different harvester settings although the anticipated inverse trend relationship with leafy EM was generally evident.
- The RV/ha displayed a decreasing trend as extractor fan and ground speeds increased.
- The RV/ha was primarily driven by the increase in clean cane delivered at the lower harvester fan speed settings.

![Fig. 3. RV% and RV/ha for the different harvester settings. Whilst there was no statistical difference among RV% for the different treatments, RV/ha differences for the lowest and highest fan speeds were statistically different to the centre group at the 95% confidence level.](image-url)
On this basis, the highest returns are achieved at the least aggressive extraction settings. This trend is consistent with the findings of Whiteing et al. (2001), but it does not fully consider the impact of increasing EM levels across the full value chain, including transport and milling performance and costs.

Whilst in these trials cane loss at the 950 rpm extractor speed was only marginally higher than cane loss at 750 rpm, typically cane loss at 950 rpm will be very significantly higher than at 750 rpm (Anon. 2014) for this machine. For this reason, extractor speeds above 750 rpm should be used with extreme caution. Different machines and extractor fan options for any machine have different relationships between fan speed and cane loss, but the general relationships are very similar.

COMPARING HARVESTING SYSTEMS

On the basis of the guidelines for optimised settings, four trials (Table 2) were then conducted to compare machine harvesting with conventional burned-cane harvesting.

Table 2. Details of the four trials conducted to compare harvesting methods.

<table>
<thead>
<tr>
<th>Location</th>
<th>Field and variety</th>
<th>Area harvested (ha)</th>
<th>Treatments*</th>
<th>Replicates/ treatment</th>
<th>Duration and conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inyoni Boerdery</td>
<td>Field 24; N36</td>
<td>24.4</td>
<td>B-MH, G-CH, G-MH</td>
<td>9</td>
<td>24/6 to 30/6 Cool &amp; dry</td>
</tr>
<tr>
<td>Noordgrens</td>
<td>Field 7A; N23</td>
<td>16.4</td>
<td>B-MH, B-CH, G-CH</td>
<td>4</td>
<td>8/7 to 17/7 Cool &amp; dry</td>
</tr>
<tr>
<td>Shubombo-Casthilopolis</td>
<td>Field 507; N25</td>
<td>10.97</td>
<td>B-MH, G-CH</td>
<td>6</td>
<td>21/7 to 8/8 Cool &amp; dry</td>
</tr>
<tr>
<td></td>
<td>Field 508; N36</td>
<td>7.55</td>
<td>B-MH, G-CH</td>
<td>6</td>
<td>29/7 to 8/8 Cool &amp; dry</td>
</tr>
</tbody>
</table>

*B-MH = Burned, Manual Harvest; G-CH= Green, Chopper Harvested; B-CH= Burned, Chopper Harvested; G-MH=Green, Manual Harvest

In the Inyoni Boerdery trial, an area adjacent to Replicate 1 was harvested by cutting and hand-stripping green cane. This was forwarded to the mill as a ‘reference’ relating to the quality of the product in the field prior to harvesting.

Whilst all trials were different in actual layout, the overall concept followed in all trials is shown in Figure 4. Typically, the machine harvested green cane plots were harvested after the burned cane plots were harvested, to avoid knocking down cane in adjacent plots with haul-out equipment.

Fig. 4. Layout of harvest system comparison trial, Inyoni Boerdery block 24.
In the Inyoni Boerdery and the Shubombo-Casthilopolis trials, the two treatments were B-MH and G-CH, but at the Noordgrens site, a third treatment, burned-cane chopper-harvesting (B-CH) was introduced. All trials were conducted over a period of several days to allow sequential burning of fields as the trial progressed. In all trials, burning was undertaken at night to give a 'cool' burn, thus maximising potential recoveries by minimising the losses potentially associated with 'hot' burns, as discussed by Gomez et al. (2006). Other considerations included:

- For the burned cane manual cut treatments, the 'burn-to-cut' and the 'cut-to-crush' delays were managed to, as closely as possible, match the mill ‘average’ for the period. The exception was the Noordgrens trial, where the total burn-to-crush time was managed to be less than 24 h, well below the mill average.
- The machine-harvested treatments were generally given preferential treatment at the mill and cut-to-crush delays were typically less than 8 h.

For all trials, the machine setup was optimised on the basis of the Harvest Best Practice Guidelines (Anon. 2014) and the results from the benchmarking trial at Inyoni Boerdery. Machine settings, selected to minimise losses whilst maximising the quality of the delivered product were:

- The crop was topped to minimise the leafy EM passing through the machine and minimise subsequent extractor cane loss.
- The machine with the six-blade chopper was used, with the feedtrain roller speed set at the maximum billet length setting to maximise billet quality and minimise billeting losses.
- Primary extractor fan speed of 750 rpm was selected, standard blades were fitted.
- Secondary extractor on and elevator speed 100% to maximise the efficiency of the secondary extractor.
- Harvesting speed 2.5-3.5 km/h, with actual speed determined by the operator to achieve only light leaf removal by the secondary extractor of the harvester (a technique used to maximise product quality whilst minimising losses from the secondary extractor).

## Results

### Cane yield

At Inyoni Boerdery, the average delivered yield for the B-MH treatment was 108 t/ha, whilst the average yield for the G-CH treatment was 132.8 t/ha (Fig. 5; Table 3), an increase of approximately 23%. The single G-MH treatment yielded 109.4 t/ha, which was lower than anticipated, but cane loss can be expected to have been high because of the problems with the high leafy EM levels on the ground and consequent poor visibility for the cutters.

![Fig. 5. Delivered cane yield (t/ha) for the harvesting treatments in the Inyoni Boerdery trial.](image)

Whilst we would have expected the EM levels in the G-CH treatments would have been several units higher than the EM of the B-MH treatments, the magnitude of the differences are greater than can be explained by EM levels alone. Inspection of the B-MH plots indicated good cutting and losses well within normal expectations. The implication is that losses associated with the pre-harvest burn directly and indirectly impact on yield.
Table 3. Delivered cane yields (t/ha) and recoverable sugar (RV% and RV/ha) for the four trials comparing green-cane machine-harvesting and burned-cane manual-harvesting.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Treatment</th>
<th>Inyoni Boerdery</th>
<th>Noordgrens</th>
<th>Shubombo-Casthilopolis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>N36</td>
<td>N23</td>
<td>N25</td>
</tr>
<tr>
<td>Delivered</td>
<td>Burned: Manual</td>
<td>107.9</td>
<td>134.4</td>
<td>111.7</td>
</tr>
<tr>
<td>yields (t/ha)</td>
<td>(B-MH)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Burned: Chopper</td>
<td>133.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(B-CH)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Green: Chopper</td>
<td>132.8</td>
<td>138.3</td>
<td>136.8</td>
</tr>
<tr>
<td></td>
<td>(G-CH)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Significant at</td>
<td>95% CI</td>
<td>Y</td>
<td>NS</td>
<td>Y</td>
</tr>
<tr>
<td>RV%</td>
<td>Burned: Manual</td>
<td>13.0</td>
<td>12.2</td>
<td>12.6</td>
</tr>
<tr>
<td></td>
<td>(B-MH)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Burned: Chopper</td>
<td>12.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(B-CH)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Green: Chopper</td>
<td>12.2</td>
<td>11.7</td>
<td>11.3</td>
</tr>
<tr>
<td></td>
<td>(G-CH)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Significant at</td>
<td>95% CI</td>
<td>Y</td>
<td>NS</td>
<td>Y</td>
</tr>
<tr>
<td>RV/ha</td>
<td>Burned: Manual</td>
<td>14.1</td>
<td>16.4</td>
<td>14.1</td>
</tr>
<tr>
<td></td>
<td>(B-MH)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Burned: Chopper</td>
<td>16.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(B-CH)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Green: Chopper</td>
<td>16.2</td>
<td>16.2</td>
<td>15.5</td>
</tr>
<tr>
<td></td>
<td>(G-CH)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Significant at</td>
<td>95% CI</td>
<td>Y</td>
<td>NS</td>
<td>Y</td>
</tr>
<tr>
<td>Green/burned %</td>
<td>115</td>
<td></td>
<td>99</td>
<td>110</td>
</tr>
<tr>
<td>Recoverable</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>sugar RV%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The Noordgrens data indicated little difference between the delivered yields for the B-CH and G-CH treatments, with only a small increase in delivered product for the G-CH treatments (Table 3). The less-than-anticipated relative yield in this trial may be related to higher cane loss through the harvester extractor system in green cane because of the thin stalk characteristic of N23. Small fragments of cane were clearly visible on the ground, indicating relatively high cane loss through the extractor fans in the green-cane treatments, despite the conservative settings.

The data for N25 and N36 at Shubombo-Casthilopolis indicated differences in yield between the B-MH treatments and the G-CH treatments similar to the Inyoni Boerdery trial, with an average yield increase of over 20% (Table 3), with the difference being significant (at 95% CI) in all trials. No measurement was made of the total EM for these treatments, but as with the Inyoni Boerdery results, the increase in yield is well outside the increase that could be attributed to increased EM levels. High standards for both the hand cutting and machine loading were enforced to minimise field losses associated with these treatments.

Recoverable sugar RV%

In the Inyoni Boerdery trial, 100% of the loads from burned cane were tested, but only about 70% of the loads from the harvester were tested. RV% across loads within each treatment replicate were generally consistent (Fig. 6), but variability across the field is evident. As expected, the RV% of the G-MH plot is higher than the adjacent B-MH and G-CH treatments, with the B-MH treatment being significantly higher (at the 95% CI) than the G-CH treatment.

![Fig. 6. Recoverable sugar (RV%) for the harvesting treatments in the Inyoni Boerdery trial.](image-url)
The burn-to-crush delay for the B-MH treatments at Inyoni Boerdery averaged approximately 70 h, similar to the reported mill average at the time.

The RV% for burned hand-cut and burned chopper-harvested cane were similar for Noordgrens, and both approximately 0.4 units above the chopper-harvested green cane (Table 3), with the difference not being significant. This relatively small effect stands out from the other trials. The burn-to-crush delays for all treatments, including B-MH, was less than 24 h at this site. The RV% for burned cane for the two Shubombo-Castilhopolis trials was significantly higher (at 95% CI) than the green cane treatment and was generally similar to the Inyoni Boerdery trial. The burn-to-crush time averaged 82 h and 85 h, which were specifically matched to mill average over the period of the trial.

**Recoverable sugar per hectare**

The tonnes RV/ha is the most significant parameter for comparing the performance of harvesting systems, as it determines the payment received by the grower.

In the Inyoni Boerdery trial (Fig. 7; Table 3) the RV/ha for the B-MH plots averaged 14.1 t/ha, and for the G-CH plots averaged 16.2 t/ha, a significant (at the 95% confidence interval) increase of 2.2 t RV/ha (or 16%). RV/ha was similar for all treatments in the Noordgrens trial (Table 3), whilst in the two Shubombo-Castilhopolis trials this parameter was about 10-15% higher for the green-cane chopper-harvested treatments, with the difference being statistically significant (at 95% CI) in both trials. In the Noordgrens trial, the burn-to-crush time was well below industry average, and the cane characteristics pre-disposed it to higher losses with chopper harvesting.

![Inyoni Field 24 N36: RV/ha](image)

**Fig. 7.** Recoverable sugar (t/ha) for the harvesting treatments in the Inyoni Boerdery trial.

**SUMMARY AND CONCLUSIONS**

The trial benchmarking harvester performance gave results similar to those for the same harvester in similar conditions in other sugarcane production industries, with the following noted:

- Cane loss is strongly linked to extractor fan speed, but the magnitude of cane loss was less than expected at higher extractor fanspeeds. This was probably because harvesting conditions were good and efficient topping ensured even feed through the machine and minimised leafy EM extraction.
- As in numerous other trials, the level of cane extracted and lost is closely related to total leafy EM extraction. Maximising the yield of cane, therefore, implies limiting extraction of this material on the harvester.
- Overall, a compromise must be made between maximising cane delivery and the leafy EM levels acceptable from the viewpoints of transport load density and impact on the performance of the mill, including extraction, recovery and sugar quality.
Due consideration to these operating characteristics indicate that operating the harvester in a ‘low loss’ harvesting mode, and implementation of a post-harvest operation to extract leafy EM before milling, will both maximise clean cane yield and minimise cane quality supplied to the mill.

The four large (7.5-24.4 ha) replicated trials comparing burned manual harvesting with green-cane chopper-harvesting were conducted to represent commercial practices, with every effort made to maximise recovery from all treatments within these constraints. Care was taken to maximise sucrose recovery by limiting burn temperatures and harvesting was managed to minimise field losses. These trials demonstrated that, with the ‘best practice’ harvester settings used:

- At three of the four trial sites the sucrose recovery (RV/ha) from green-cane chopper-harvesting significantly exceeded sugar recovery from industry standard burned, manual-harvesting practices by 10-15%. This was despite the RV% at all trials being significantly higher for the burned cane relative to the green chopper harvested cane.
- The trial at Noordgrens went against this trend, with machine harvesting achieving only similar tonnes RV/ha to the hand cut plots and a reduced difference in RV%. Two factors which were considered to contribute were:
  (i) The thin stalk characteristic of N23, which made it highly susceptible to cane loss in the green-cane chopper-harvested treatment, and
  (ii) The very short burn-to-crush period for the hand-cut burned cane that minimised mass, deterioration and losses.

Given the cool conditions throughout the trial period and the deliberate ‘cool’ burns, losses in the burned hand-cut treatments would be relatively low compared with more adverse conditions with similar burn-to-crush delays. Our data suggest that losses in well-managed burned-cane manual-harvesting with burn-to-crush delays of 70-85 h (typical of mill average at the time) are higher than generally appreciated (despite the higher observed RV%), and higher than green cane chopper harvesting operations which have been optimised to minimise cane loss. Conversely, poorly managed chopper harvesting can be demonstrated to have much higher losses than traditional burned cane manual harvest.

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Comparaison du rendement canne et du sucre récupérable entre une coupe tronçonnée en vert et une récolte manuelle en canne brûlée en Afrique du Sud

Résumé. Mondialement, la récolte en canne tronçonnée augmente, en raison de directives relatives à des contraintes environnementales liées au brûlage avant récolte, et à l’intérêt d’une valorisation des pailles à des fins agronomiques ou comme ressource industrielle. Le risque d’une perte significative en canne et en sucre d’une récolte mécanique tronçonnée est une préoccupation, si bien qu’en Afrique du
Evaluación de la productividad y recuperación de azúcar de caña verde en cosecha mecanizada y caña quemada en corte manual para una operación de Sudáfrica

Resumen. A nivel internacional, la cosecha mecanizada en verde es cada vez mayor, la causa son restricciones medioambientales a la quema previa a cosecha y potenciales beneficios relacionados con la utilización de hojarasca de materia extraña (ME) en proporciones variables para beneficio agronómico o como materia prima industrial. El potencial de tener pérdidas significativas de caña y sacarosa con la cosecha mecanizada es una preocupación y en la industria de Sudáfrica las cosechadoras se introdujeron y luego fueron rechazadas, sobre todo debido a reducciones en recuperación de azúcar. La reintroducción de cosechadoras en Mpumalanga Provincia de Sudáfrica en 2014 inicialmente resultó en una disminución significativa del contenido de azúcar recuperable (RV toneladas/ha) en relación con las prácticas tradicionales de cosecha. Este artículo presenta los resultados de un ensayo de campo replicado llevado a cabo en 2015 para poner a punto las “mejores prácticas” de configuración de las cosechadoras bajo condiciones locales. A continuación se presenta los resultados de cuatro ensayos replicados para comparar la recuperación de azúcar en caña verde de cosecha mecanizada y en caña quemada usando corte manual tradicional y carga con alzadora. En todos los ensayos, la entrega directa de la caña verde cosechada a máquina a la fábrica resultó en tiempos de cosecha a molienda de 6-8 horas. En el tratamiento de cosecha manual con quema, se apuntó a tiempos “promedio del ingenio” de 70 a 85 horas, pero en un ensayo se apuntó a un tiempo entre quema y molienda de menos de 24 horas para cuantificar este efecto. La operación de la cosecha mecanizada de caña en verde, cuando se optimizó para minimizar pérdidas, logró una recuperación de azúcar 10-15% mayor por hectárea que con quema y corte manual para el tiempo quema-molienda promedio del ingenio. Cuando el tiempo entre quema y molienda en la caña cortada a mano se redujo a menos de 24 h, ambos sistemas dieron similar azúcar recuperable total. A pesar de las múltiples pérdidas conocidas asociadas con la cosecha mecanizada, las pérdidas asociadas a la cosecha manual de caña quemada bien supervisada son tan grandes o mayores que en la cosecha mecanizada optimizada, siendo las pérdidas asociadas con la quema previa a cosecha y el tiempo quema-molienda posiblemente factores significativos.

Palabras clave: Cosecha de caña quemada, cosecha de caña verde, productividad de caña verde versus quemada, cosecha mecanizada, recuperación de azúcar