Influence of yield and other cane characteristics on cane loss and product quality

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Abstract  Field and crop conditions affect cane loss, cane-supply quality and the amount of extraneous matter that is mixed with cane billets supplied to the mill. The size of the crop produced also impacts on machine performance and cane loss during harvest. Crop physical properties and the composition of the sugarcane stalk are driven by a wide range of agronomic practices, including nutrition. The objective of this study was to investigate the impact of different crop conditions on sugar loss during harvest, with in-field nutrient practises being the primary driver of the changing cutting pour rates when the ground speed is fixed. The physical properties of the sugarcane (stalk length and diameter, population density and yield) were measured in the experimental plots in Bundaberg in 2014 and Macknade in 2015 that had received a range of different nitrogen (N) application rates before being cut by a chopper harvester. Cane loss during cutting was then determined at harvest by collecting all material (leaves, tops, stalks, etc.) discarded from the harvester. This procedure was performed using a standard ‘tarp test’ combined with a loss-assessment method based on measuring juice loss on trash to evaluate cane loss, juice loss, etc. The residue samples gathered from the tarp were shredded and frozen for determination of sugar loss by colorimetric method, using a Glucose and Sucrose Colorimetric Assay Kit. Different N rates resulted in a range of stalk physical properties (stalks per unit area, billet size and stalk weight) and cane yields (t/ha). With the harvester operating at a constant ground speed (and set fan speed) the pour rate was driven by the N applied. As pour rate increased, the ability of the extractor fan to efficiently differentiate trash from billets decreased, resulting in greater sugar loss. Sugarcane sizing influenced by the varying N rates led to the sugar loss differences occurring during the cutting by the harvester.

Key words  Cane loss, cane harvesting, pour rate, field and crop conditions

INTRODUCTION

Sugarcane is the most important sucrose crop in the world. Sugarcane that is delivered to the mill is harvested by three methods: hand-cut, labour combined with machines, and fully automated harvesting (whole-stick or chopper system). In Australia, sugarcane is one of the main agricultural crops in Queensland and New South Wales and is all of the crop is cut by chopper harvesters. During cane harvesting, parameters such as the proportion of cane tops and leaves, stalk weight and size result in changes to the quality and quantity of cane supply during harvesting. In addition, harvester settings (ground and fan speed, etc.) and pour rate impact on the amount of cane loss and extraneous matter (EM) delivered to the mill (Anon. 2014). Cane variety and the severity of lodging affect harvester performance and cane quality (Anon. 2013).

Attempts have been made to solve and reduce the problem by improving the machinery and reviewing the process (Davis et al. 2009), harvesting best practise (Agnew et al. 2002; Anon. 2014; Jones 2004) and improving the field and crop conditions (Anon. 2014) to assist the cane feed systems. However, other factors also impact on the cane loss and quality during cutting due to the different pour rates resulting from the various crop densities within a row. The applied fertiliser rates are one of the important methods for driving the crop size to increase or decrease the different characteristic of cane. Variations in crop sizes during harvest cause the machine capacity, especially pour rate and cane cleaning efficiency, to decrease. Here we investigate the impact of changing crop conditions on sugar loss during cutting, with in-field nutrient practises being the primary driver of the changing pour rate.

MATERIALS AND METHODS

The trials to find cane loss from varying pour rates were conducted in fields in tandem with an SRA-funded project 2014/045 ‘Boosting nitrogen use efficiency in sugarcane through temporal and spatial management’. The tests for measuring cane loss during cutting by the mechanical harvester were investigated in two trials (Bundaberg and Ingham (Macknade field)).
that were conducted to evaluate the different rates of applied nitrogen (N) on agronomic variables. In Bundaberg, the trial was in variety KQ228\(^c\) that was grown on a row spacing of 1.83 m and received a range of nitrogen rates (75, 150 and 225 kg/ha). The crop was harvested with an Austoft model 7000/1996 (specifications: three knives per chopper drum (knife size 65 mm wide), a vertical primary extractor fitted with three standard blades). In the Macknade trial, the cane variety was MQ239\(^c\) grown on a row spacing of 1.83 m and receiving a range of nitrogen rates (0, 100 and 200 kg/ha). The experimental fields were cut by a Cameco model 2500/1997 (specifications: four blades (width 65 mm each) per chopper drum, three standard blades for primary extractor fan). In both trials, the harvesters were not using the toppers but the secondary extractor was operating.  

The physical properties of sugarcane (stalk diameter, length, weight, population density and yield) in each plot were measured before cutting. Cane loss due to mechanical harvesting was determined by gathering all materials (tops, stalks, leaves, etc.) discharged from the harvester. We fixed ground and extractor speed of the chopper harvester during cutting (4.5 km/h ground speed, 1150 rpm fan speed for the Austoft, and 3.3 km/h, 1210 rpm for the Cameco), so that yield variation due to the N rate would be reflected in the pour rate. To collect all cane fractions, an invisible loss technique, based on the standard ‘tarps test’ was used. This method was developed by Whiteing (2013) and attempts to measure the juice lost on trash to capture of the entire sugar (juice, etc.) loss. The residues from the harvest were shredded and frozen in-field before laboratory analysis. The samples were blended with distilled water and the juices were extracted by a hydraulic press for later evaluation of the amount of sugar loss by the colorimetric technique (Campbell et al. 1999). In addition to the sampling regime from Bundaberg in 2014, samples of billets were collected from the Macknade field during cutting from each plot in order to measure the billet size distribution and quantify the amount of extraneous matter from the chopper harvester following the method of De Beer et al. (1985).

**RESULTS AND DISCUSSION**

The different nitrogen rates applied to each trial (Table 1) resulted in different crop yields. The different fertiliser rates also influenced the stalks per unit area, billet size and stalk weight, including the proportion of dry leaves and tops. High nitrogen rates caused an increase in cane yield, stalk length, diameter size, weight and stalk population density. Conversely, the amount of EM (tops and brown leaves) in the plots with low nitrogen fertilisation tended to increase when compared with the highly fertilised plots. However, this increase was not significant (P=0.05), particularly at the Macknade site. Cane yield, influenced by the N applied, would then lead to the different pour rates when the ground speed of the harvester was constant.

<table>
<thead>
<tr>
<th>Site</th>
<th>N rate (kg/ha)</th>
<th>Cane yield (t/ha)</th>
<th>Stalk length (m)</th>
<th>Stalk diameter (mm)</th>
<th>Stalk weight (kg)</th>
<th>Stalks/m²</th>
<th>Weight (%)</th>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Brown</td>
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<tr>
<td>Bundaberg</td>
<td>75</td>
<td>43.90</td>
<td>1.39</td>
<td>22.36</td>
<td>0.55</td>
<td>13.13</td>
<td>78.48</td>
</tr>
<tr>
<td></td>
<td>150</td>
<td>86.49</td>
<td>1.96</td>
<td>21.92</td>
<td>0.75</td>
<td>17.40</td>
<td>77.90</td>
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<tr>
<td></td>
<td>225</td>
<td>91.00</td>
<td>2.12</td>
<td>24.51</td>
<td>0.94</td>
<td>18.44</td>
<td>80.70</td>
</tr>
<tr>
<td>Macknade*</td>
<td>0</td>
<td>62.54</td>
<td>3.02</td>
<td>21.57</td>
<td>0.92</td>
<td>11.66</td>
<td>81.84</td>
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<tr>
<td></td>
<td>100</td>
<td>82.97</td>
<td>3.41</td>
<td>23.66</td>
<td>1.07</td>
<td>13.43</td>
<td>83.94</td>
</tr>
<tr>
<td></td>
<td>200</td>
<td>91.98</td>
<td>3.66</td>
<td>24.70</td>
<td>1.17</td>
<td>13.67</td>
<td>83.35</td>
</tr>
</tbody>
</table>

*Legumes improved soil-nutrient content in the first crop before nitrogen applied  
Values within a column followed by the same tetter are not significantly different (P=0.05)

In the Macknade trials, the billets cut by the harvester were collected from each treatment. Six samples (20-25 kg per sample) of billets were collected during cutting for each treatment (De Beer et al. 1985). The samples were segmented into three categories (billet, trash and dirt). The EM increased as the N inputs increased (Fig. 1). Different N rates resulted in a range of the stalk physical properties (stalks per unit area and weight including billet size) and crop production (t/ha). With the harvester operating at a set ground speed (and set fan speed) the pour rate was driven by the N application rate. As pour rate increased, the ability of the extractor fan to efficiently differentiate trash from billets decreased.
Fig. 1. Classification of cane samples from the different pour rates impacted by varying nitrogen rates at the Macknade trial. Values of each parameter followed by the same letter are not significantly different (P=0.05). Low = 0 kg N/ha; Medium = 100 kg N/ha; High = 200 kg N/ha).

The Macknade billet samples were assessed for both billet length and quality (Figs 2 and 3). Billet-length distribution (Fig. 2) in the three fertiliser rates showed different means, but the differences were not statistically significant (P=0.05). The most abundant billet-length category was 100-150 mm (43.9% of all samples).

Fig. 2. Billet lengths from the harvester influenced by the different nitrogen rates in the Macknade trial. Low = 0 kg N/ha; Medium = 100 kg N/ha; High = 200 kg N/ha).

Billets were classified into three quality-based categories (Fig. 3) using the method of De Beer et al. (1985):

- Sound billet - stalk section longer than 100 mm with no splits, small rind crack less than 40 mm long and no section of rind more than 400 mm² removed;
- Damaged billet - spilt of rind larger than 40 mm or rind section around 400-2000 mm² removed, all billets less than 100 mm long;
- Mutilated billet - numerous rind cracks with more than 2000 mm² of rind removed.
The proportions of damaged and mutilated billets increased under the higher nitrogen rates (Fig. 3), and the proportion of sound billets increased in the lower N plots. The fertiliser rate also affected the stalk length and diameter and, hence, increased billet weight and size. The lighter billets (damaged and mutilated types in the low N plots) were ejected more easily by the cleaning system compared to the heavy ones. The proportion of sound billets driven by the lower N levels led to an increase in cane supply. Conversely, in the high nutrient plots, larger and heavier billets mixing with trash were more difficult to separate by the cleaning system. Some billets hit the extractor fan during separation of EM and fell down to mix with the other billets in the bin.

![Billet Quality](image)

**Fig. 3.** Billet quality from the harvester influenced by the different nitrogen rates in the Macknade trial. Values of each quality parameter followed by the same letter are not significantly different (P=0.05). Low = 0 kg N/ha; Medium = 100 kg N/ha; High = 200 kg N/ha).

When the ground speed of the harvester is constant, the different cane yields and crop factors drive the pour rate conditions. Crop factors are influenced by fertiliser rates that impact on the quality and quantity of billets during harvesting (Anon. 2014), particularly sugar loss and trash mixing in the billet supply from the cleaning systems. We collected these residues, which were removed during the cleaning by the extractor fans, by the tarp test (De Beer et al. 1985; Whiteing 2013). Juice samples were measured by the colorimetric method (Campbell et al. 1999) using a Glucose and Sucrose Assay Kit from Sigma-Aldrich, USA to find the sugar lost by adhering to trash during harvesting. In the Bundaberg trial, the sugar loss appeared higher in the 75 kg N/ha rate but this was not significant different (P=0.05) from the other rates (Table 2). However, the sugar loss (7.09%) in the 75 kg N/ha rate was the highest (P<0.05).

**Table 2.** Sugar loss during cutting by the chopper harvester at Bundaberg trial.

<table>
<thead>
<tr>
<th>N rate (kg/ha)</th>
<th>Sugar yield (t/ha)</th>
<th>Tarp sugar loss (t/ha)</th>
<th>Sugar loss per sugar yield (%)</th>
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<tbody>
<tr>
<td>75</td>
<td>6.84&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.43&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.09&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>150</td>
<td>13.92&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.35&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.55&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>225</td>
<td>14.25&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.38&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.67&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Letters within a column followed by the same letter are not significantly different (P=0.05).

The different N rates impacted on the physical properties of sugarcane and crop production (Table 1). Physical properties such as weight and diameter directly relate to the bulk density of the sugarcane, with the lower densities easily discharged by the cleaning system. The billet range between 0-100 mm at the low N level (Fig. 2) had a lower proportion of billets than any other level but this was not, however, significant (P=0.05). Additionally, the proportion of sound billets for the low nutrient was significantly higher than for the other rates (P<0.05) (Fig. 3). We hypothesise that the small pieces that are
light and have a low bulk density are blown out by the extractor system during cleaning. Therefore, the proportion of sound billets increases in the lowest N level. Furthermore, the proportion of sugar loss evident in the low N rate was significantly greater than in the other two N levels (P<0.05) (Table 2).

In addition to crop production (Muchow et al. 1996; Wiedenfeld 1997) and sugar quality (Wiedenfeld 1995) attributes that are influenced by different N rates, the physical properties of sugarcane were also affected. This resulted in quality and quantity differences during machine harvesting. The EM and sugar loss resulting from the different pour rates that were driven by the N applications (with a fixed ground speed) are important impacts on cane supply that we have identified. Crop nutrient practises are important factors in improving cane supply during harvesting.

CONCLUSIONS

Crop condition is one of the important factors to impact on the efficiency of cane harvesters, especially on pour rate, cane cleaning and loss during cutting. We have shown that crop yield was driven by the rate of N fertiliser and resulted in the different physical properties of cane such as stalk length, diameter and weight, and the proportions of tops and brown leaves. When the ground speed of the harvester was constant during cutting, the pour rate was impacted by the different cane factors. As the pour rate increased, the capacity of the cleaning fan to efficiently differentiate trash from billets decreased, resulting in increased sugar loss. The billet length distribution test at the Macknade site indicated that 43.9% of cane billets from all fertiliser treatments were 100-150 mm long. The proportion of sound billets from the low nutrient plots during the cutting increased, whereas where cane received high levels of N fertiliser, it decreased. In addition, the proportion of damaged and mutilated billets tended to increase with an increase in N rate as billets hit the extractor fan during cleaning. This resulted in different sugar loss during harvesting from the different fertiliser rates. Trash samples blown out by the cleaning fan were collected from the field to test in a laboratory by the colorimetric technique. The proportion of sugar loss in the samples from the low fertiliser rate was higher than the loss in the samples from higher rates.

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REFERENCES


Influencia del rendimiento y otras características de la caña en pérdidas de caña y calidad del producto

Resumen. Las condiciones del campo y del cultivo afectan a las pérdidas de caña, la calidad de la caña suministrada y la cantidad de materia extraña que se mezcla con la caña suministrada al ingenio. El tamaño del cultivo también afecta al rendimiento de la maquinaria y las pérdidas durante la cosecha. Las propiedades físicas del cultivo y la composición del tallo de la caña son condicionadas por una amplia gama de prácticas agronómicas, nutrición incluida. El objetivo de este estudio es la investigación del impacto de diferentes condiciones del cultivo y cultivo y las pérdidas durante la cosecha. Las propiedades físicas del cultivo y la composición del tallo de la caña son condicionadas por una amplia gama de prácticas agronómicas, nutrición incluida. El objetivo de este estudio es la investigación del impacto de diferentes condiciones del cultivo y cultivo y las pérdidas durante la cosecha.

Palabras clave: Pérdidas de caña, cosecha de caña, tasa de vertido, condiciones de campo y cultivo