PERFORMANCE TESTING OF CHOPPER CANE HARVESTERS FOR CANE QUALITY

T. G. Fuelling
Bureau of Sugar Experiment Stations
Tully, Queensland, Australia

ABSTRACT

The impact of mechanical harvesting on the quality of cane supply in Queensland is outlined and aspects of mechanical harvester design which have an influence on this are discussed.

INTRODUCTION

In times of excess supply of any commodity, buyers normally discriminate between sellers on the basis of quality (Kelly20). It is, therefore, essential that the export oriented sugar industry in Australia strives to meet the highest standards of sugar quality. One factor affecting the quality of output from a sugar mill is the quality of the input — the cane supply.

This paper describes the impact of mechanical harvesting on cane quality and performance testing of sugar cane harvesters carried out by BSES (Bureau of Sugar Experiment Stations) aimed at further improvement of the quality of the cane supply.

IMPACT OF MECHANICAL HARVESTING

Background

More than a decade has passed since the development and acceptance of the mechanical chopper harvester in Australia. As with mechanical harvesting of other crops, field layout and cultivation practice have had to be adjusted to make mechanical cane harvesting efficient and economical (Baxter1 and Gaunt and Zagorski14). Conversion from harvesting whole stick cane to chopped cane created problems of cane deterioration (Price and Blyth24) but Egan4 showed that one of the key factors in reducing deterioration of chopped cane was to minimize the delay between harvest and crush. Detailed studies of transport scheduling such as those of Murry23 and of rostered harvesting (James and Hayes19) enabled mills to reduce the normal cut to crush delays to between two and 20 hours.

The Australian cane crop is not cut almost exclusively by chopper harvesters, the design of which has improved to the extent that lodged cane can now be
harvested with minimum loss of cane. Manual pick-up of sugar cane is no longer required. Harvesting is normally carried out in daylight hours only. Any further reductions in harvest to crush delay could only be achieved with extended harvesting hours (Foster). In 1973 and 1975, Australia’s sugar cane growing areas had extremely wet harvest season. These extreme conditions caused harvesting delays (due to inability to operate in wet fields) and subsequent deterioration of cane burnt for harvest (McNeil and Inkerman). Fuelling noted that the design of the infield transport system restricted cane harvesting in wet fields and has reported on high flotation infield transport using weight transfer and large flotation tyres (Fuelling). The deterioration of standing burnt cane also stimulated new investigations of all aspects of green cane harvesting: (deterioration Foster), harvesting (Foster et al.), processing (Foster), trash disposal (Ridge et al.).

Deterioration results in the conversion of sugar to polysaccharides, mainly dextrans (Egan). Experiments by Henderson and Kirby and Irvine and Bevan showed the rise in dextrans was much more significant than the fall in sugar content (c.c.s.). Although under normal harvest delays the decline in c.c.s. is a comparatively minor loss to the farmer, higher dextran levels are very deleterious to milling operations and sugar quality.

Even with cut to crush delays of less than 20 hours, the experiments of Henderson and Kirby, Irvine and Bevan also showed more rapid deterioration of damaged billets and billets less than 250 mm long compared with undamaged billets greater than 250 mm. Foster also showed less deterioration with green cane billets than burnt cane billets.

Extraneous matter in cane supply, (BSES) i.e. tops, trash, roots and dirt, has increased with mechanical harvesting of the crops. Tops frequently comprise approximately two-thirds of the extraneous matter (Fuelling et al.). They contain little sucrose and increase sugar production costs (Kirby and Kingston). Trash increases fiber levels and reduces the crushing rate (Scott) and lowers sugar quality in terms of color and filterability (Sloane and Rhodes).

Dirt is normally only a small proportion of extraneous matter and the system of fines and bonuses is comparatively insensitive to significant changes in dirt levels which may be significant in the factory. As harvesters have improved to handle lodged crops and wet conditions, the amount of dirt in the cane supply has increased. The increase in the amount of dirt is of major concern to millers (Burgher and Nix).

In order to provide a financial incentive to supply clean cane, in many areas the value of cane is adjusted by the imposition of penalties on the payment of bonuses related to extraneous matter levels.
HARVESTER TEST PROGRAMS

In 1977, BSES commenced performance testing of sugar cane harvesters with a view to defining factors which affected the quality of the cane supply (Henkel et al.\textsuperscript{16}). These tests were designed to investigate harvester performance in green and burnt cane in terms of:

1. billet length (average length and distribution)
2. billet damage (degree and type)
3. extraneous matter (levels and composition)

MATERIALS AND METHODS

The testing so far has been carried out in the northern region of Queensland using the variety Q90 which comprised 63% of the crop in 1978. This variety has a heavy green top, is relatively free trashing and has a sprawling habit which may lead to lodging in the cane field. Crop yields normally averaged between 80 and 100 t ha\textsuperscript{-1}. The crops were grown in rows spaced 1.4 to 1.5 m apart.

The cane supply is sampled with a portable chute (Fig. 1) directly from the harvester while operating. This chute is hooked on to the rear of the transporter bin and a flap above the bag diverts any extraneous material until a sample is required. To collect a sample, the transporter driver is signalled to speed up momentarily bringing the chute under the elevator outlet. The flap is opened by an operator following the bin and the sample collected in a bag. A quick release mechanism allows the operator to drop off the bag and replace it while the transporter is in motion. Samples are obtained without any interference with the operation of the harvester. Harvester ground speed is monitored with a wheel dynamometer attached to the rear of the harvester.

Due to variations along the row of the condition of the crop in terms of erectness, burnt quality, stalk length, etc., the stream material entering the bin is somewhat variable. It was found that, for samples of 15 to 20 kg, coefficient of variation for sound billets and extraneous matter varied from 7 to 14 and 22 to 31 per cent, respectively.

As a compromise between workload and precision, a standard of five samples each 15 to 20 kg has been adopted for each observation in harvester tests. Even with this density of sampling, it is necessary to repeat the test several times before general conclusions can be drawn regarding harvester performance.

Millable cane left in the field (scrap) is assessed from three plots each of approximately 0.008 ha randomly located within the trial area. Cane removed by the topper and cane spilled from the transporters is excluded. The remainder is divided into billet cane (less than 500 mm) and whole stalk cane (greater
than 500 mm). The amounts in each category are adjusted for juice losses due
to damage by extractors and traffic (e.g. run over by harvester or transporter).

Cane samples are sorted according to data required for a particular test.
Billet length is normally measured by sorting a sample of billets into size
categories and calculating the mean length from the number in each category.
Although this gives a reasonable assessment, it can be biased and for precise
work, the length of each billet is measured.

Billet damage is a much more subjective assessment. Guidelines for distin-
guishing a sound billet from a damaged billet have been developed and are
as follows:

A cane billet is classified as a damaged billet if –

1. It is broken or squashed such that there are numerous rind cracks
   and a portion of the cane is reduced to a pulpy condition, or

2. It has more than 400 mm² of rind removed exposing the interior of
   the stalk, or

3. It has “splits” (not including growth cracks) in the rind totalling
   more than 80 mm. However, rind cracks less than 40 mm are not
   regarded as “splits”.

FIGURE 1. Portable chute attached to transporter for collecting cane samples.
For extraneous matter analysis the components are defined thus:

**Tops** — that part of the section of the stalk above highest developed internode which can readily be broken off by hand. Normally of billet or part billet length.

**Trash** — dry and green leaves and leaf sheaths (not included in tops). This category includes weeds, grass etc.

**Roots** — true roots (excluding dirt) which extend from the internodes of the cane stalk above or below ground.

**Dirt** — all soil and stones included free within the sample plus similar material removed from the roots or billets.

**RESULTS**

**Harvester performance**

In 1977, the Toft 4000, Toft 6000, Massey Ferguson 205, and Class Libertadora 1400 were tested in green and burnt cane. The tests were generally carried out in erect crops (yields 70 to 105 t/ha\(^{-1}\)) with well maintained machines and good operators.

In each test the harvester was initially operated at the normal harvest speed selected by the operator for the particular condition. This ranged from 5 to 7 km/hr\(^{-1}\) in burnt cane and 4 to 6 km/hr\(^{-1}\) in green cane. Where possible, harvesters were then operated at 2 km/hr\(^{-1}\) above and below the normal harvest speed.

Fig. 2 gives a break-up of the cane supply harvested at the normal speed in terms of sound billets, damaged billets and extraneous matter.

The results of the tests reported by Fuelling et al\(^{11}\) can be summarized as follows:

1. Over the range of speeds tested, speed of operation had little effect on the quality of the cane supply for well maintained machines with sharp chopper knives.

2. Speed of operation had no effect on the amount of millable cane left behind. This was mainly dependent on ground conditions.

3. Large variations in billet length were primarily due to different chopper gearing fitted to the harvester. With the Massey Ferguson 205 some shortening of billets was noticeable when cutting green cane.
4. Operator attitude to maintenance and operations was a key factor in determining the quality of the cane supply.

5. Cultivation practices and field conditions had a large influence on the quality of the cane supply.

6. The Claas 1400, Massey Ferguson 205, Toft 4000 and Toft 6000 were all capable of harvesting erect crops of Q90 cane in green condition with extraneous matter levels similar to those of burnt cane. However, output was reduced by 30 to 40 per cent.

**Effect of basecutters setting on dirt in the cane supply**

In 1978, a series of case studies (Henkel *et al.*[17]) were carried out with a Toft 6000 harvester which had twin horizontal basecutters (similar to those fitted by Massey Ferguson and Claas). These were operating in ratoon crops in which soil in the row is hilled up at least 50 mm above the interspace. The machine had adequate power to cut below ground level. In the earlier testing (Fuelling *et al.*[11]) it was noted, that, in physical sorting of cane samples, a significant amount of dirt adhered to the cane billets was not included in the extraneous matter assessment. A washing step was therefore introduced. The results in Table 1 show that:

1. Cutting below ground level considerably increased the amount of dirt in the cane supply;

2. Normal physical analysis of cane samples measured less than half the total quantity of dirt;

3. Dirt levels increased significantly in wet and lodged crop conditions; and

4. Cutting below ground significantly reduced loss of millable cane in lodged conditions.

**Knife life studies**

There are two different systems for chopping cane used in cane harvesters in Australia. Massey Ferguson and Claas machines are fitted with a drum chopper which gives a scissor-type cut. The Toft machines are fitted with the single rotating chopper knife which gives a chop-type cut. The blades on the drum choppers scrape together at each cut giving a self-sharpening action when correctly adjusted. The rotating chopper used in the Toft system is not self-sharpening but has a simple change procedure allowing regular replacement.

The change in billet quality with tonnage cut after new chopper knives that have been fitted was used as an indicator in knife studies carried out on current model harvesters in 1978.
**TABLE 1.** Test conditions, measured dirt levels (% of the total sample) and cane left in the field (t/ha⁻¹)

<table>
<thead>
<tr>
<th>Study</th>
<th>Crop condition</th>
<th>Soil condition</th>
<th>Soil type</th>
<th>Basecutter setting *</th>
<th>Dirt (%) of sample</th>
<th>Cane left in field (t/ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Physical analysis</td>
<td>Wash analysis</td>
</tr>
<tr>
<td>1</td>
<td>erect</td>
<td>dry</td>
<td>yellow</td>
<td>A</td>
<td>0.03</td>
<td>0.19</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>earth</td>
<td>G</td>
<td>0.08</td>
<td>0.31</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>B</td>
<td>0.63</td>
<td>1.08</td>
</tr>
<tr>
<td>2</td>
<td>erect</td>
<td>wet</td>
<td>yellow</td>
<td>A</td>
<td>0.04</td>
<td>0.50</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>earth</td>
<td>G</td>
<td>0.00</td>
<td>0.68</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>B</td>
<td>2.30</td>
<td>4.15</td>
</tr>
<tr>
<td>3</td>
<td>lodged</td>
<td>dry</td>
<td>yellow</td>
<td>G</td>
<td>0.16</td>
<td>0.41</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>earth</td>
<td>B</td>
<td>3.09</td>
<td>2.01</td>
</tr>
<tr>
<td>4</td>
<td>erect</td>
<td>dry</td>
<td>red</td>
<td>A</td>
<td>0.00</td>
<td>0.55</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>volcanic</td>
<td>G</td>
<td>0.00</td>
<td>0.31</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>B</td>
<td>0.04</td>
<td>0.52</td>
</tr>
</tbody>
</table>

*A = 50 mm above ground level; G = ground level; B = 50 mm below ground level*
FIGURE 3. The relationship between percent sound billets and the tons of cane cut follow chopper blade replacement

Manufacturers advised their recommended change interval for the knives and the tests were extended well beyond these intervals. All tests were carried out in stone-free, clay loam soils in the northern region (Fuelling and Henkel13). Fig. 3 shows levels of sound billets found in typical tests on each make.

The conclusions from the tests were:

1. Massey Ferguson harvester produced the most consistent supply of sound billets.

2. The Claas Libertadora 1400 harvester produced a lower level of sound billets. This could be due to:
   (a) the combined feeding and chopping function of the chopper
   (b) the wider throat of the machine
   (c) the position of the chopper system close to the basecutter
   (d) the action of the side cutter knife used in lodged crops

3. Of the three types of machines tested, the Toft harvester gave the lowest level of sound billets. The importance of regular knife replacement was obvious.
4. Lodged crops reduced the percentage of sound billets in the cane supply.

DISCUSSION

As the quality of the cane supply affects sugar quality, the importance of producing cleanly cut, undamaged billets of a length optimum for the area cannot be overlooked. Harvester design must be such that these criteria can be met without undue maintenance problems for the machines.

Tests have shown that current model harvesters can achieve a very low rate of cane loss in the field, when cutting erect crops. However, significant losses occur in badly lodged cane. Although these losses can be reduced by cutting below ground level, the increase in the amount of dirt in the cane supply can not be tolerated.

No matter what system are used for gathering up the crops it seems likely that the harvest of any heavily lodged crops must result in a certain amount of stalk damage and breakage even before the cane reaches the cutting mechanism of the machine. In erect crops, however, damage to the billets can be minimized by harvester design characteristics.

From the work reported in this paper, it is obvious that machines with self-sharpening double drum choppers can produce billets of high quality with long periods between blade replacement under reasonably stone-free conditions. This was not the case with machines utilizing the single rotating knife system. While frequent replacement of the latter type overcomes the billet damage problem to some extent, operators of the machines must be prepared to make the knife exchange at the appropriate intervals. Frequently, this does not happen in commercial practice.

However, it may be argued by some that in fields where stones are a problem the single rotating chopper with its simplicity of change is a better proposition as operators of the drum choppers would be less likely to halt the harvest to attend to minor blade damage. Limited tests indicated that with minor blade chips with MF205 could still produce billets of reasonable quality.

However, it is considered that easy adjustment and replacement of chopper knives should be an important aspect of design of all harvesters. Operators should be able to keep their machines in top condition with minimum of lost time due to knife maintenance essential for a high quality cane supply.

CONCLUSIONS

There have been tremendous advances in harvester design since mechanical harvesting became accepted into the Queensland sugar industry. Machines now have the power and ability to cut heavy lodged crops, to remove much of the extraneous leaf material from the crop and to produce cane billets of acceptable quality. However, to achieve the level of efficiency of which harvesters
are capable, attention must be made to the condition of the field and harvester operators must have a full appreciation of the requirements for a clean cane supply.

REFERENCES


PRUEBA DE FUNCIONAMIENTO DE LA MAQUINA COSECHADORA CON RELACIÓN A LA CALIDAD DE LA CAÑA DULCE OBTENIDA.

T. G. Fuelling

RESUMEN

El efecto en la calidad de caña dulce cosechado en Queensland por medio de una maquina cosechadora se delinea en esta presentación, y se discuten además otros aspectos en el diseño del mecanismo de la cosechadora que influye tal calidad.