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Investigating losses from green and burnt cane harvesting conditions

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Abstract Despite much research into the impact of high harvester pour rates and fan speeds on harvested cane yields, there has been low adoption of HBP (harvesting best practice) across the industry. Full adoption across the Australian sugarcane industry could increase industry revenue with no necessity for horizontal expansion (increase in cane land). In order to inform industry of the potential for significant gains, 95 replicated harvesting trials and workshops were undertaken during 2017 and 2018 across 12 sugarcane regions in Queensland and New South Wales. The performance of settings recommended by HBP was compared with each harvesting operation's standard practice by assessing yield, CCS, bin mass, extraneous matter (EM), fibre, sugar loss and revenue. To highlight the strong relationship between cane loss and excessive pour rates and fan speeds, treatments with higher pour rates and fan speeds and lower pour rates and fan speeds were also trialled. Cane loss, production and revenue data from the fully replicated and randomised trials were analysed to identify differences between industry standard harvesting practices and those recommended by HBP. Harvesters typically operate at ground and fan speeds at on average of 0.9 km/h and 95 rpm above those recommended under HBP parameters. The higher ground speed overloads the cleaning capacity of the harvester in delivering an average 21 t/h more cane though the machine. Consequently, fan speeds are increased to remove the additional EM (extraneous matter) entering the machine, which then removes additional cane via the extractor. This cane often disintegrated in the process, making much invisible. Trials indicated the average sugar loss out of the extractor increased by 0.15 t/ha over the HBP settings. However, there was no significant improvement in EM or bin mass. As a result of cane loss though the extractor, less cane per hectare was delivered to the mill. Mill analyses across the trials identified cane and sugar yields for the recommended practice were 4.9 t/ha (cane yield) and 0.7 t/ha (sugar yield) higher than standard practice. Neither CCS nor fibre levels were significantly different. Increased cane and sugar yields generated by the recommended practice translated to an increase in grower gross revenue of $181/ha., but reduced ground speeds increased the cost of harvesting by $61/ha. Subtracting the additional harvesting costs and levies from the additional grower revenue leaves a net benefit of $116/ha for the grower. Preliminary results of "good" burn trials indicate an improvement of $207/ha in grower gross revenue with lower fuel. Based on the green-cane results, full adoption of HBP could improve annual industry revenue by $44 million for growers at an additional cost of $17 million for harvesting (excluding incentives). Milling revenue would also improve by $25 million per year but this does not account for additional milling or transport costs.

Key words Harvesting best practice, cane loss, fan speed, pour rate, extraneous matter

INTRODUCTION

Improving harvesting efficiency has been a focus of the sugar industry since mechanised harvesting began in the 1970s. Numerous projects were undertaken in the 1980s though to the early 2000s in an effort to understand

and minimise harvesting losses (Hurney *et al.* 1984; Ridge and Dick 1988; Linedale and Ridge 1996; Agnew *et al.* 2002; Whiteing *et al.* 2001; Sandell and Agnew 2002). That research identified that the greatest source of cane loss when harvesting was though the primary and secondary extractors, estimated at 5–25% of weight in green cane and 5–8 t/ha in burnt cane (Agnew *et al.* 2002; Hurney *et al.* 1984). The size of harvester cleaning chambers influences their capacity to extract EM above a certain flowrate threshold (Ridge and Hobson 1999). However, harvesting is commonly undertaken at ground speeds that deliver flowrates above the threshold, overloading the chamber and limiting its ability to extract EM effectively. Ordinarily this would increase EM levels but, in an attempt to offset this, operators typically increase extractor fan speeds above recommendations. While EM levels are generally offset, the higher fan speeds also extract cane, although these unintended cane losses are not visible as they are shattered by the fan blades on discharge. The amount of harvesting loss depends on harvester settings, field conditions, varieties and time of harvest (Ridge and Dick 1988). Interest in harvesting losses regained focus in 2013 and several projects followed (Pollock 2013; Sugar Research Australia 2014; Larsen *et al.* 2017; Keeffe 2017).

The cane-loss problem requires a whole-of-value chain approach to ensure improved industry profitability, which is ultimately finding a balance between cane loss, cane quality (e.g. EM) and harvesting costs (Sugar Research Australia 2014). To achieve this balance, HBP recommends maintaining pour rates and extractor-fan speeds within specified guidelines depending on extractor-fan type, fan hub, variety, field conditions, etc. While using HBP reduces cane loss and increases cane yields and revenue, it generally entails reducing ground speeds, thus increasing harvesting time and costs per hectare. The additional revenue obtainable has been quantified (Agnew *et al.* 2002; Sugar Research Australia 2014) and models have been developed to estimate changes in harvesting costs (Ridge and Powell 1998; Antony *et al.* 2003; Sandell and Prestwidge 2004). However, limited research has evaluated both the revenue and cost implications using replicated trial data to determine the net impact on industry profitability.

Despite past research, there was little use of HBP when this project commenced and a deterioration in cane quality had been noted (Larsen *et al.* 2017). Reasons for the slow uptake of HBP are complex and include, among others, a lack of recognition of the scale of losses and opportunities to minimise them, expectations of higher harvesting costs, lack of communication, and time pressures to fill bin allotments. Overcoming these issues requires a strategic approach that targets harvesting groups, considers both economic and social constraints and involves milling companies.

During the 2017 and 2018 seasons, the harvesting adoption project (SRA Project 2016/955 – Adoption of practices to mitigate harvest losses) undertook demonstration trials with 95 harvesting groups located across 12 sugarcane regions spanning Queensland and New South Wales. The trials were designed to demonstrate the production and revenue implications from using HBP. Initial 2017 trial results presented by Patane *et al.* (2019) showed a statistically significant improvement in cane yield (5.4%), sugar yield (5.7%) and grower revenue ($220/ha) when moving from a standard to recommended practice. Thompson *et al.* (2019) further determined the average net benefit ($163/ha) of the 2017 trials in adoption of the recommended settings based on the average grower revenue change less the estimated change in cost at $61/ha (Nothard *et al.* 2019).

That research was extended to 2018 where a further 23 trials were included in the green-cane results. Here, we present updated results on the combined green-cane data set together with preliminary results from the 'good' burn trials.

METHODOLOGY

Trials were designed to demonstrate the production and revenue implications from using HBP instead of standard harvester settings. Trial protocols were block and machine specific and all treatments were adapted for the prevailing conditions. All treatments were replicated (at least three times) and randomised. Cane yields were assessed using a mass-balance protocol including mill weighbridge and NIR (Whiteing *et al.* 2016). Cutting distances, ground speeds and flow rates were derived from GPS time-stamped waypoints. Due to the varied bin capacities among mills, bin mass data were aggregated to a nominal 10-t bin capacity. Billet quality and lengths and EM levels were also measured.

For the green-cane trials, the Infield Sucrose Loss Measurement System (ISLMS) protocol was used to measure cane and sugar loss from the extractors and total biomass (Whiteing *et al.* 2016). Four harvester settings (or treatments) were trialled: a 'control'; 'recommended' (HBP); 'contractor's standard'; and 'aggressive'. The 'control' treatment was designed to provide the best possible estimates of total yield and biomass available in the field by using a low flow rate (60 t/h) and primary fan speed settings (<600 rpm) with the secondary fan turned off. The 'recommended' treatment targeted the HBP flow rate of 80–90 t/h, subject to cleaning-chamber size, and recommended fan speeds varied, subject to variety, field condition and fan blade and hub type. The 'contractor's standard' treatment was the operator's nominated settings, while the 'aggressive' was designed to demonstrate more aggressive practices (increasing flow rates by 15+ t/h and fan speed by 100+ rpm). Ground speeds were set to maintain the targeted flow rates.

The burnt cane trials examined thee harvester settings: a 'control'; 'moderate'; and 'aggressive'. With the exception of one trial, ground speed was kept the same for all treatments. For the 'control' treatment, both the primary and secondary extractor fans were turned off as burnt cane has much lower EM levels than green cane. Primary fan speeds for the 'moderate' treatment were between 550–650 rpm and were subject to the quality of the burn. 'Aggressive' fan speeds were set 200 rpm above moderate. Secondary fans were turned on for the 'moderate' and 'aggressive' treatments.

Total grower revenue was calculated using the respective cane-payment formulae, levies, harvesting cost, trial production data and the 5-year average sugar price ($423/t). The overall net benefit to industry for both growers and contractors was then considered by subtracting the change in harvesting costs and levies from the change in total grower revenue (net benefit = ∆ grower revenue – ∆ harvesting costs) between the average standard and recommended treatments. The average change in harvesting costs were applied at 22 c/t or $61/ha as determined by Nothard *et al.* (2019) when moving from standard to recommended based on changes in ground speeds and yields. The methodology used for the net benefit analysis was given by Thompson *et al.* (2019). It does not account for rail/road transport and milling costs.

For the statistical analysis, data were pooled from all regions into a single analysis. A linear mixed-model was fitted to the data using Proc Mixed of SAS Analytical software package (SAS Institute 2013). The model applied to the data for each harvest output was:

Trait ~ Treatment + Location (Replicate) + Grower/contractor + ε,

where Trait was the harvested output of interest. Treatment was considered a fixed effect and replicate nested within location was treated as a random effect. The random component effect was grouped by block/contractor to account for this variation. Tukey's multiple comparison test was used to identify differences among means at a significance level of 5%. From the 95 harvesting trials, 51 complied with the trial protocols and met the requirements for analysis.

GREEN-CANE RESULTS

Table 1 shows the mean harvester settings, elevator pour rates and flow rates for the four treatments (2017 and 2018). To achieve the recommended (HBP) settings, harvester ground speeds and primary extractor fan speeds were reduced on average by 0.9 km/h and 95 rpm, respectively, compared with the contractor's standard. Consequently, the mean product flow rate into the harvester dropped by 20.6 t/h. This was partially offset by reduced cane loss though the primary extractor and resulted in the elevator pour rate decreasing by a lower 12.5 t/h. Table 1 also outlines the EM levels in the delivered cane, bin fill rates and average bin masses. While EM levels and average bin masses were similar between the standard and recommended practice, the control treatment had significantly higher mean EM levels (~3% higher) and lower average bin masses (by 1.5 t per 10 t bin) than both of these practices. The trend observed showed elevated EM levels to reduce overall bin mass. Given the lower elevator pour rate, recommended practice on average filled 0.6 fewer bins per hour (-8%) than standard (statistically significant difference).

Table 1. Average harvester performance under different practices.

Parameter	Practice			
	Control	Recommended	Standard	Aggressive
Ground speed, km/h	3.3	4.7	5.6	6.1
Primary fan speed, rpm	592	703	798	934
Elevator pour rate, t/h	57.4 a	76.1 b	88.6 c	92.5 d
Flow rate**, t/h	65.2 a	89.0 b	109.6 c	119.6 d
Extraneous matter, %	14.3 a	11.6 b	11.3 b	10.1 c
Bin fill rates, bins/h	6.9 a	7.2 a	7.8 b	8.0 b
Average bin mass, t/10 t bin	7.31 a	8.78 b	8.84 b	9.27 c

*Common letters within a row indicate no statistically significant differences among treatments (p = 0.05).
**Estimated flow rate using results from the ISLMS and delivered product.

Table 2 shows the sugar loss and total biomass results for each treatment as measured by the in-field ISLMS trials. Recommended practice had significantly lower mean in-field sugar loss (–0.15 t/ha) and total biomass (–1.7 t/ha, cane and EM) left in the paddock than standard practice. These results identified a strong positive relationship between ground/fan speed settings and sugar loss (speeds above harvester capacity equated to greater sugar loss).

Table 2. In-field residues under different practices.

Parameter	Practice			
	Control	Recommended	Standard	Aggressive
Sugar loss, t/ha	0.38 a	0.55 b	0.70 c	1.05 d
Total biomass, t/ha	13.7 a	17.0 b	18.7 c	21.9 d

*Common letters within a row indicate no statistically significant differences among treatments (p = 0.05).

The mean production and revenue results for each harvester treatment setting are given in Table 3. The control and recommended settings obtaining significantly higher cane and sugar yield than standard practice, while the aggressive settings obtained the lowest yields; recommended practice obtained 4.9 t cane/ha (+5.2%) and 0.7 t sugar/ha (+5%) more than standard practice. Both CCS and fibre levels were very similar between recommended and standard practice (no significant differences), which showed that the increased sugar/ha was driven largely by increased cane yield. The control and recommended settings obtained significantly higher total grower revenue than standard practice, while the aggressive settings obtained the lowest average revenue. Recommended practice delivered $181/ha (+4.8%) more total grower revenue than standard practice.

Table 3. Mean production and revenue results under different practices.

Parameter	Practice			
	Control	Recommended	Standard	Aggressive
Gross cane yield, t/ha	100.7 a*	99.2 a	94.4 b	89.6 c
CCS, units	14.08 a	14.31 b	14.31 b	14.37 b
Fibre levels, %cane	14.86 a	14.45 b	14.54 ab	14.32 b
Sugar yield, t/ha	14.57 a	14.40 a	13.71 b	13.15 c
Total grower revenue, $/ha	4,037 a	3,968 a	3,787 b	3,656 b

*Common letters within a row indicate no statistically significant differences among treatments (p = 0.05).

BURNT-CANE RESULTS

The mean results from the initial three conforming or ‘good’ burnt cane trial sites for each harvester treatment setting are presented in Table 4. The aggressive treatment is representative of standard fan speed settings used by operators in the burnt-cane industry. The shift from aggressive to moderate and control treatments reduced the average primary extractor fan speeds by 200 rpm and 859 rpm, respectively. Reducing the extractor fan speed by 200 rpm decreased fuel consumption by 3.2 L/h (6.2%), while turning the extractor off resulted in a 9.8 L/h (19.1%) decrease. Reductions in extractor fan speed produced a marginal increase in EM levels of 1.8% and 0.7%, respectively.

Table 4. Average harvester performance under different practices (burnt cane).

Parameter	Practice*		
	Control	Moderate	Aggressive
Primary fan speed, rpm	0	659	859
Fuel burn, L/h	41.5 c	48.1 b	51.3 a
Flow rate*, t/h	138.5 a	146.8 a	145 a
Extraneous matter, %	4.7 a	5.8 a	4.0 a
Average bin mass, t/10-t bin	10.2 b	10.3 ab	10.4 a
Bin fill rates, bins/h	9.2 a	9.6 a	9.3 a

*Common letters within a row indicate no statistically significant differences among treatments (p = 0.05).

The change from aggressive treatment fan speed to moderate and control resulted in a 100 kg (1.0%) and 200 kg (1.9%) respective decrease in bin mass (based on 10-t rail bin). The bin fill rate for the moderate treatment was 0.3 and 0.4 bins per hour (based on 10-t rail bin) higher when compared to the aggressive and control treatments, respectively.

Table 5 shows the production and revenue results from the burnt-cane trials. There was a significant yield difference between control and aggressive treatments. The gross harvested yield increased from aggressive to moderate and from aggressive to control treatments by 1.3 t cane/ha and 5.1 t cane/ha, respectively. CCS decreased from aggressive to moderate and control treatments by 0.4% and 1.5%, respectively, while fibre levels increased by 0.6% and 7.8%. The sugar yield increased from aggressive to moderate and control treatments by 130 kg/ha and 480 kg/ha, respectively. Yield improvements from the aggressive to control treatment showed a $206/ha ($1.66/t) improvement in grower gross revenue, although this difference was not statistically significant (due to the large variability in CCS among sites).

Table 5. Mean production and revenue results for each treatment (burnt cane).

Parameter	Practice		
	Control	Moderate	Aggressive
Gross cane yield, t/ha	128.4 a	124.6 ab	123.3 b
CCS, units	15.48 a	15.65 a	15.71 a
Fibre levels, %Cane	14.02 a	13.08 b	13.00 b
Sugar yield, t/ha	20.88 a	20.53 a	20.40 a
Total grower revenue, $/ha	$6,098 a	$5,983 a	$5,892 a

DISCUSSION

Green cane

Figure 1 shows differences between standard and recommended practice in terms of ground speed, fan speed, flow rate, sugar loss, elevator pour rate and cane yield. Compared with standard harvester settings, using recommended settings required operators to reduce ground speeds by an average of 0.9 km/h and decrease primary extractor fan speeds by 95 rpm. Our trials identified that reducing ground speeds to those recommended, decreased the flowrate to within the threshold recommended for the cleaning chamber size. Consequently, the primary fan could operate at the recommended speed to effectively clean the cane with minimal losses. Compared with standard practice, the recommended ground and fan speeds increased the amount of recovered cane by 4.9 t cane/ha (5.2%) on average and had no detrimental impact on EM levels, fibre levels or CCS, and no significant effect on nominal bin mass. These results support the 2017 trial results presented in Patane *et al.* (2019) as well as that of Whiteing (2002). Given no difference in CCS, the improvement in sugar yield and grower revenue followed a similar trend to cane yield with recommended practice obtaining 0.7 t/ha more sugar and $181/ha more grower revenue. Harvesting cost evaluations undertaken for nine of the trials identified that using recommended settings increased harvesting costs by $61/ha on average (Nothard *et al.* 2019; Thompson *et al.* 2019). Taking these additional harvesting costs and levies into account, the overall net benefit in changing from standard to recommended settings is estimated at $116/ha.

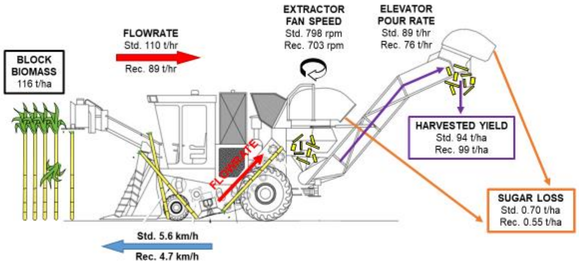

Figure 1. Differences in speeds, flow rate, sugar loss, pour rate and cane yield between standard (Std.) and recommended (Rec.) practices.

In-field testing (ISLMS) identified that significantly less material was extracted from the cleaning chamber when using recommended practice – standard practice had significantly greater sugar loss (+0.15 t sugar/ha or 21.6% increase). This type of test also enabled growers to verify the increased sugar loss first-hand by touching and smelling each sample and feeling that samples from more aggressive harvesting practices were moister, stickier and sweeter in aroma. Using recommended settings did have its drawbacks.

Lower ground speeds decreased the quantity of cane distributed to haulouts by 15 t/h on average and frequently increased harvesting time. The aggressive and control treatments were unviable with aggressive practices significantly reducing cane and sugar yields. Ground and fan speeds lower than recommended practice significantly increased fibre and EM levels and significantly decreased CCS and nominal bin mass, which would have implications for transport logistics, crush rates and sugar recovery and make it commercially impractical.

Figure 2 shows the estimated changes in production and revenue from full industry-wide adoption of HBP. The standard treatment was calculated as the benchmark using 5-year average cane yields, CCS and total harvested area data from all Australian green-cane harvested areas (SRA QCANESelect® 2018). We assumed that the same production differences measured in the trials are obtained across the entire Australian green-cane harvested area. The modelling estimated that an additional 1.16 million tonnes of cane could be generated each year from full adoption of recommended settings.

This increase translates to an additional 164,480 t of sugar, valued at over $69 million for the industry (an additional $2.86/t of cane). For growers, this amounts to an additional $44 million in gross revenue (an additional $1.81/t of cane). Considering an average increase of $61/ha in harvesting costs, the net benefit to growers in the green-cane industry is estimated at $26 million (moving from standard to recommended settings). The overall revenue increase to mills is estimated to be $25 million per annum.

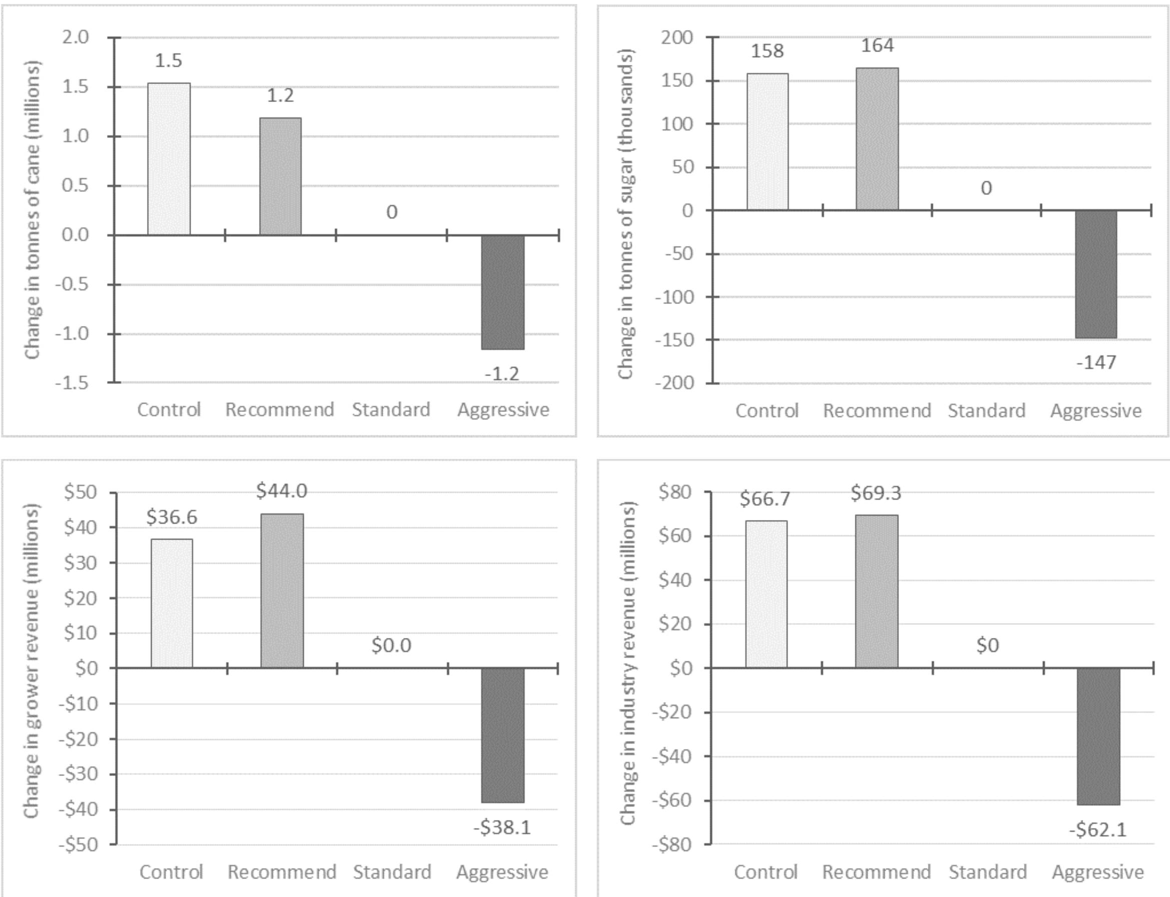

Figure 2. Impact across industry to cane and sugar production as well as grower and industry revenue from adopting recommended harvesting practices.

Sugar prices vary year to year and as harvester settings are tailored to requirements on any given day it is informative to understand the revenue implications at different sugar values. While the preceding analysis used the 5-year average sugar value, Table 6 shows the grower and industry revenue implications from using recommended harvester settings at different sugar values. In isolation, a high sugar price would generate a relatively larger revenue benefit, while a low price below would obtain a smaller benefit.

Table 6. Changes in total grower and industry revenue at different sugar values.

Parameter	Sugar value, $/t					
	350	390	424	430	470	510
Change in total grower revenue, $millions	36.7	40.8	44.2	44.9	49	53
Change in total industry revenue, $millions	57.6	64.1	69.7	70.7	77.3	83.9

Burnt cane

Figure 3 show the differences in fan speed, elevator pour rate and cane yield between aggressive and control treatment means. The trials demonstrated that turning off the primary extractor fan and maintaining current practice ground speed under 'good' quality burn conditions produced an immediate fuel saving of 9.8 L/h. The production impact of this change was also a 5.1 t cane/ha increase in cane yield and a 480 kg/ha increase in sugar yield. The EM level increased by 0.7% with an associated 200 kg reduction in bin mass (based on 10-t rail bin). The minimal increase in EM level and decrease in bin mass is outweighed by the associated fuel savings and gains in cane and sugar yields.

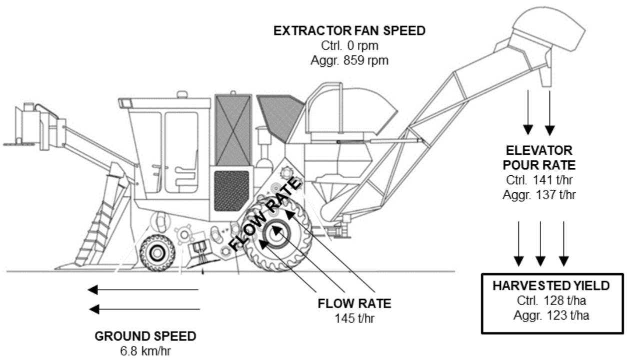

Figure 3: Differences in fan speed, pour rate and cane yield between aggressive (Aggr.) and Control (Ctrl.) treatments.

The unnecessary and often excessive use of primary extractor fans in blocks with good quality burns requires reviewing. Turning the extractor fan off had no significant difference on harvesting bin-fill rates, suggesting no potential impact on season length. In an operating environment increasingly concerned with the excessive use of fossil fuels and climate change, the ability to effect fuel savings with no major adverse effect on industry profitability is a great benefit.

Based on trial fuel consumption recordings, fuel savings from an aggressive to both moderate and control fan settings were $3/h and $11/h, respectively. The incorporation of fuel consumption, treatment yields, bin weights, ground speeds, haulout size, and other measured variables into the green-cane harvesting cost model showed little difference in overall harvesting costs between treatments. The average net benefit accruing to the growers was calculated at $203/ha, which included a $202/ha change in revenue net of levies, and an 88 c/ha estimated change in cost for moving from an aggressive to no-fan setting.

From the preliminary burnt cane results, it is anticipated that under good burn conditions, growers may benefit from turning off their extractor fans, despite the improvement in total revenue not having statistical significance (due to CCS variability increasing the F Probability statistic marginally to 0.06). This is based on an improved yield result against an anticipated negligible change in harvesting cost where the fuel savings would likely offset the costs of an increase in haulout trips (due to lower bin densities). The uncertainty around cane quality would thus be the determining factor and any significant drop in CCS would negate the improvement in yield. This requires further investigation given the variability in CCS among sites. There is added uncertainty for 'poor' burn scenarios where an increased level of EM would likely have more impact on the overall CCS. It is anticipated that the extractor fan would still be necessary in the removal of EM, but further research is required under these conditions.

CONCLUSIONS

Harvesting is commonly undertaken at ground and fan speeds above those recommended by HBP, which overloads cleaning chambers and emits cane from the extractor. These unintended cane losses are not visible as they are shattered by the fan blades on discharge. HBP recommends maintaining pour rates and fan speeds within specified guidelines to minimise losses, while balancing increased harvesting costs to maximise industry profitability. To engage industry and draw attention to the available gains, 95 harvesting trials were undertaken collaboratively with harvesting groups across 12 regions. Pooled results identified the production and revenue gains from using HBP along with the associated harvesting cost changes. For green cane, standard harvester ground speeds, flowrates and primary fan speeds were reduced by 0.9 km/h, 21 t/h and 95 rpm, respectively, to bring them within the recommended thresholds. These changes resulted in statistically significant increases in cane yield (+4.9 t cane/ha), sugar yield (+0.7 t sugar/ha) and grower revenue (+$181/ha). No statistically significant differences were observed in EM, CCS, fibre or bin mass, indicating little, if any, impact.

However, there were some trade-offs including decreased bin fill rates (-6 t/h) and higher harvesting costs due to slower groundspeed. Past research indicated an average harvesting cost increase of $61/ha (or 22c/t at an average recorded yield improvement). Assuming full adoption across industry, grower revenue was estimated to increase by $44 million. Subtracting the additional harvesting costs and levies ($18 million), growers were left with an annual net benefit of $26 million. The milling sector would also gain (~$25 million per annum in revenue), but the additional transport and milling costs that would be incurred are unknown.

Further research is required in burnt cane regions, but preliminary indications are that unnecessary use of primary extractor fans, often at excessively high fan speeds, has revealed an opportunity for growers to improve harvested yields by up to 5.1 t/ha with little impact on overall harvesting costs.

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REFERENCES

Agnew J, Sandell G, Stainlay G, Whiteing C (2002) Increased sugar profitability though harvesting best practice. *Proceedings of the Australian Society of Sugar Cane Technologists* 24: 8 pp.

Antony G, Prestwidge D, Sandell G, Higgins A (2003) Scope for cost savings from harvesting rationalisation in the Australian sugar industry. *Proceedings of the Australian Society of Sugar Cane Technologists* 25: 8.

Hurney AP, Ridge DR, Dick RG (1984) Evaluating of the efficiency of cane harvesters in removing extraneous matter and in limiting cane losses during the cleaning process. *Proceedings of the Australian Society of Sugar Cane Technologists* 6: 11–19.

Keeffe EC (2017) *Sensors for improved harvesting feedback: evaluation of suitability*. Sugar Research Australia Limited, Brisbane.

Larsen PL, Patane PA, Asamoah I (2017) Benchmarking cane supply quality in the Herbert, Burdekin, Proserpine and Plane Creek Regions. *Proceedings of the Australian Society of Sugar Cane Technologists* 39: 77–88.

Linedale AI, Ridge DR (1996) A successful campaign to minimise harvesting losses within the Queensland sugar industry. *Proceedings of the Australian Society of Sugar Cane Technologists* 18: 1–5.

Nothard B, Thompson M, Patane P, Lander G, Norris CA, Poggio M (2019) A cost assessment of harvesting best practice. *Proceedings of the Australian Society of Sugar Cane Technologists* 41: 497–506.

Patane P, Landers G, Thompson M, Nothard B, Norris CA, Olayemi M (2019) Adoption of practices to mitigate harvest losses: 2017 results. *Proceedings of the Australian Society of Sugar Cane Technologists* 41: 488–496.

Pollock J (2013) *An examination of losses in the sugar industry value chain and opportunities to reduce them. Final Report: Sugar Industry Value Chain Analysis. JSP 1003.* Sugar Research and Development Corporation, Brisbane.

Ridge DR, Dick RG (1988) Current research on green cane harvesting and dirt rejection by harvesters. *Proceedings of the Australian Society of Sugar Cane Technologists* 10: 19–25.

Ridge D, Powell J (1998) *A Management Assistance Package for Optimising Harvester/Infield Transport Productivity. Final Report SD98005.* Sugar Research and Development Corporation, Brisbane.

Ridge DR, Hobson PA (1999) *Analysis of Field and Factory Options for Efficient Gathering and Utilisation of Trash from Green Cane Harvesting. SRDC Final Report SD99005.* Sugar Research and Development Corporation, Brisbane.

Sandell G, Agnew J (2002) *Harvesting Best Practice Manual for Chopper-Extractor Harvesters.* Bureau of Sugar Experiment Stations, Brisbane.

Sandell G, Prestwidge D (2004) Harvest haul model – the cost of harvesting paddocks of sugarcane across a sugar milling region. *Proceedings of the Australian Society of Sugar Cane Technologists* 26: 10.

SAS Institute (2013) *The SAS System for Windows. Release 9.4.* SAS Institute Inc., Cary.

Sugar Research Australia Limited (2014) *Harvesting Best Practice Manual. Technical publication MN14001.* Sugar Research Australia, Brisbane.

Sugar Research Australia Limited (2018) SRA *QCANESelect® database.* http://tools.sugarresearch.com.au/QCANESelect/default.aspx (accessed 1 February 2019).

Thompson M, Nothard B, Patane P, Landers G, Norris CA (2019) An economic evaluation of sugarcane harvesting best practice. *Proceedings of the Australian Society of Sugar Cane Technologists* 41: 507–511.

Whiteing C, Norris, CP, Paton, DC (2001) Extraneous matter versus cane loss: Finding a balance in chopper harvested green cane. *Proceedings of the International Society of Sugar Cane Technologists* 24: 276–282.

Whiteing C (2002) *Facilitation of best practice to reduce extraneous matter and cane loss.* https://elibrary.sugarresearch.com.au/handle/11079/988 (accessed 1 February 2019).

Whiteing C, Giddy L, Norris CP (2016) A cane-loss measuring system for machine-harvested sugarcane. *Proceedings of the International Society of Sugar Cane Technologists* 29: 959–967.