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Improving yield and cane quality through implementation of harvesting best practice - 2019 Herbert demonstration

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Abstract In 2019, the Australian sugarcane industry conducted a month-long demonstration with 12 trials to determine the commercial viability of harvesting best practice. Initiated by a small group of innovative growers and contractors from the Herbert region, the concept of a commercial demonstration sought to determine both agronomic and economic impacts of adopting HBP, including the assessment of possible yield gains without having a detrimental impact on extraneous matter, and economic implication for growers and harvesting contractors arising from revenue and harvesting cost changes. Two Herbert harvesting contractors participated in the demonstration comparing their standard harvesting practices to Sugar Research Australia Harvesting Best Practice (HBP or recommended practice). The results identified an average 4.8 t/ha increase in yield with no additional increase in extraneous matter for the recommended setting. A comprehensive economic analysis was conducted on each of the trials. Detailed harvesting costs and operational information, including machinery, labour, and fuel data, were collected from the respective harvesting operations. Harvesting costs and levies were $37/ha ($0.07/t) higher for the recommended setting due to higher yields, reduced harvester ground speeds and lower extractor fan speeds. Despite the higher harvesting costs, recommended settings obtained significantly higher total revenue ($151/ha, +4.7%). This resulted in an overall net benefit of $114/ha in the adoption of recommended settings (based on a 4.4% higher net revenue calculated as total grower revenue minus harvesting costs and levies). The Herbert demonstrations have proven instrumental in the acceptance of harvesting best practice for the region. The results again confirm that adapting and aligning commercial-scale harvesting practices to crop and paddock conditions have positive impacts on both yield and economic outcomes.

Key words Economic benefit, adoption, demonstrations, recommendation, harvesting practice, extraneous matter, cane loss

INTRODUCTION

Research conducted from the 1980s to early 2000s identified significant industry gains for operating within Harvesting Best Practice (HBP) parameters. A substantial part of this research showed HBP delivering significant yield improvements for green-cane operations. It also showed the greatest proportion of loss (5–25%) originated from operations of the primary and secondary extractor fans (Hurney *et al.* 1984; Ridge and Dick 1988; Linedale and Ridge 1996; Agnew *et al.* 2002; Whiteing 2002; Sandell and Agnew 2002).

Due to various limitations, real (e.g. increased operational time) and perceived (e.g. high extraneous matter levels from HBP), much of the industry continues with harvesting practices above machine-capacity flow rates and high fan speeds. Although it is acknowledged that contractors are generally trying to deliver the best outcomes for growers, there remains significant pressure to operate at high product-flow rates to ensure bin allotments are filled and throughput maximised during a season. It is also understood that harvesting groups remain concerned that a reduced machine flow rate will result in significant operational hour and cost increases (Patane *et al.* 2019a). The barriers to adoption of HBP have become more apparent over time and include four important factors for consideration:

- A limited understanding or belief in the expected yield gain.
- A limited understanding of the harvesting cost impact.
- Undervaluing the importance of payment incentives to harvesting groups (at increased operational times).
- Poor implementation of HBP resulting in no significant production or economic benefit.

To address these issues, Patane *et al.* (2020) undertook 95 harvesting trials across 12 sugarcane regions of Queensland and New South Wales during 2017 and 2018. The original program (Patane *et al.* 2019a) aimed to identify the extent of losses and opportunities for practice change, harvesting cost impacts, improved communication between stakeholders, industry pressures (e.g. filling bin allotments, bin weights) and time constraints. To address the economic concerns, Department of Agriculture and Fisheries (DAF) economists developed a detailed cost comparison model, expanding on work done by Ridge and Powell (1998) and Ridge and Hobson (2000). Economic evaluations complemented the trial work of Patane *et al.* (2020) undertaken during 2017 and 2018 (Thompson *et al.* 2019; Nothard *et al.* 2019).

Results from Patane *et al.* (2019b) identified a yield gain of 4.9t/ha (0.7t sugar/ha) in changing from standard to recommended (HBP) harvesting practice. After subtracting levies and harvesting costs, this equated to an additional $116/ha for the grower (net benefit). Based on the results, full adoption of HBP has potential to 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 annum, but this did not account for additional milling or transport costs (Patane *et al.* 2020). Despite the demonstrated financial benefits of HBP, there remain concerns about its commercial practicality.

Over the same period (2017 and 2018), Herbert contractors and growers embarked on harvesting 'fact-finding' tours to the Isis region, a region well advanced in HBP. Although participants acknowledged a disparity existed between contractor standard and recommended harvesting practices, they identified an urgent need to address cultural behaviours that were impacting harvesting group (contractors and growers) performance in the Herbert (e.g. perceptions of blame and cynicism) (Patane *et al.* 2020). The tours successfully stimulated open discussions around HBP. As a result, tour participants indicated that for wider change to occur in the Herbert region, vital knowledge gaps and barriers to adoption in three key areas should be addressed. These included:

- The assumption that cane-loss estimates and potential economic benefits for the Herbert region were similar to those identified in industry-wide trials.
- An ability to confirm harvesting practices were performed as agreed by contractors (e.g. live cane-loss monitoring).
- The perception that harvester operators will spend a significantly longer time in the field when operating at HBP.

Both growers and contractors from the Herbert expressed a desire to validate research outcomes under commercial conditions. This paper presents the results from 12 commercial demonstration trials conducted in the Herbert during 2019. With support from Wilmar Sugar, Herbert Cane Productivity Services Limited and Herbert River Canegrowers, the Sugar Research Australia (SRA)/DAF harvesting team delivered the industry's first month-long commercial harvest demonstration round for the Herbert region.

METHODOLOGY

The principal objective of the 2019 Herbert demonstration was to increase acceptance of the commercial benefits of HBP by moving from controlled trials to a larger-scale commercial environment. The initial program developed by Patane *et al.* (2019a) addressed the benefits of HBP adoption through research trials, trial economic analyses and presentation of results further validated by Patane *et al.* (2020). Despite statistically significant results, Herbert stakeholder tours of the Isis region identified a gap between program delivery and adoption uptake. To address this gap, the Harvesting team applied the ADKAR ® framework of change. Hiatt (2006) states the ADKAR model represents the essential five elements that effect change (or adoption): awareness, desire, knowledge, ability, and reinforcement. Despite awareness of earlier research identifying significant gains from HBP, including the desire to explore recommended practice, adoption rates remained relatively low. This was likely driven by limitations in some forms of knowledge (e.g. cost change information), restricted access to decision-support tools (e.g. cane-loss monitoring equipment to improve confidence in the adjustment of practices), and a lack of reinforcement that practice change would deliver tangible benefits for harvesting groups.

To validate production and revenue differences of standard and recommended harvester settings, the demonstration trial methodology follows that of Patane *et al.* (2019b) with exception of the control and aggressive treatments. The Infield Sucrose Loss Measurement System (ISLMS) was also excluded. Trial protocols were block-specific, and all treatments were adapted for prevailing block and machine conditions. Two harvesting groups alternated between contractor-standard and recommended (HBP) settings for their entire contract over a single round during the 2019 harvesting season (round three of four rounds or 25% of the growers' crops). This included a total of 12 demonstration trials (trials) for 9 growers. Operational time, block size, row length/width and yield determined the number of replications completed for each treatment, which varied among the demonstration trials. Relatively even blocks were selected to minimise the impact of yield variability. Other block-selection criteria included a minimum 400 t of cane for replication purposes and a single variety and crop class. The two harvesting treatments for the demonstration trials were labelled 'recommended' (HBP), and 'contractor's standard' (standard). A full rake was analysed to compare yield data between standard and recommended settings.

The recommended treatment targeted HBP flow rates of 80-90 t/h. This was based on work derived from Ridge and Hobson (1999) who determined an optimal material flowrate of 69 t/h through a 1.37 m (4'6") diameter cleaning chamber. Ground speed was set to maintain the targeted flow rate (generally observed with a tolerance of plus or minus 1 km/h). The recommended fan speed varied between 650 and 750 rpm, subject to harvester make and model, fan blade and hub type, cane variety and field conditions (wet or dry). The standard practice was the operator's nominated harvester settings for the block and conditions. Both harvesters were fitted with SCHLOT® Live cane-loss monitors to allow the live (real-time) observation of cane loss by harvesting groups during the demonstration.

Total grower revenue was calculated with the commercial cane sugar (CCS) cane-payment formula using trial production data and the 5-year average sugar price ($421/t) inputs. Harvesting costs were collected during contractor group interviews. This included information on in-season and pre-season labour, harvester and haulout depreciation, interest, repairs and maintenance, fuel and oil, and overheads. The DAF cost-comparison model (Nothard *et al.* 2019) was used to estimate total costs per tonne and per hectare on both standard and recommended practice.

Net grower revenue was determined by subtracting harvesting costs and levies from total grower revenue. The overall net benefit to industry for both growers and contractors was calculated by subtracting the standard from recommended net grower revenue (Thompson *et al.* 2019). The net benefit calculation excluded rail transport and milling costs.

For statistical analysis, data from randomised-complete-block-design trials were pooled together for 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 + Replicate (Contractor) + Error,

where Trait was the harvested output of interest, Treatment was considered a fixed effect and replicate nested within Contractor was treated as a random effect. Each Contractor could have a different error, and this was taken into account in the linear mixed model. Tukey's multiple comparison test was used to identify differences among treatments.

RESULTS

The mean harvester settings and elevator pour rates for the standard and recommended practice are presented in Table 1. These include the average results for the 12 trials undertaken during the 2019 harvesting season. The average ground and primary extractor fan speeds for standard practice were 7.1 km/h and 710 rpm, respectively. The average ground and primary extractor fan speeds for recommended practice were lower at 6.0 km/h and 657 rpm, respectively.

Table 1 also outlines the extraneous matter (EM) levels in the delivered cane and average bin mass (using an average of 6, 8 and 10 tonnes bins for the Herbert region). EM level and average bin mass were very similar between the standard and recommended practice, with no significant difference. However, at a lower ground speed, recommended practice harvested at an average rate of 0.78 ha/h, slower when compared to 0.90 ha/h for standard practice. This represents a statistical difference in time taken to harvest and is accounted for in the average cost difference listed in Table 2.

Table 1. Mean harvester performance results between contractor standard and recommended practice based on 12 trials conducted in the Herbert during 2019.

Parameter	Practice	
	Standard	Recommended
Elevator pour rate, t/h	95.4 a	84.5 b
Extraneous matter, %	15.7 a	15.9 a
Average bin mass, t/bin	6.2 a	6.4 a
Average harvest rate, ha/h	0.90 a	0.78 b

*Means followed by the same letter are not significantly different ($p > 0.05$).

The mean production results for each harvester treatment setting are outlined in Table 2. Recommended settings resulted in significantly higher ($p < 0.05$) cane and sugar yields when compared to standard practice. The average increase was measured at 4.3 t cane/ha (+4.9%) and 0.6 t sugar/ha (+5.2%). Both CCS and fibre levels were very similar between recommended and standard practice (no significant difference), demonstrating that increased sugar yields (t sugar/ha) were driven largely by increased cane yields.

Table 2. Mean harvester agronomic and economic results between contractor standard and recommended practice based on 12 demonstration trials conducted in the Herbert during 2019.

Parameter	Practice	
	Standard	Recommended
Gross cane yield, t/ha	87.4 a	91.7 b
CCS	14.2 a	14.2 a
Fibre levels, %Cane	16.2 a	16.2 a
Sugar yield, t/ha	11.68 a	12.29 b
Total grower revenue, $/ha	$3,173 a	$3,324 b
Total harvesting/Levy cost, $/ha	$613	$650
Net grower revenue, $/ha	$2,560 a	$2,674 b

*Means followed by the same letter are not significantly different ($p > 0.05$).

Table 2 presents the average changes in revenue, levies and harvesting costs. With no significant difference in CCS, the improvement in grower revenues followed a similar trend to cane yields with recommended practice giving a $151/ha (4.8%) significantly higher ($p < 0.05$) average total grower revenue. Where lower ground speeds and pour rates increased harvesting costs (longer operational hours), costs per tonne were partially offset by the resultant yield gains associated with reduced extractor fan speeds. On average, actual harvesting costs were $35/ha (excluding levies) higher for the recommended setting. This translated to a marginal $0.07/t higher cost due to the higher yields produced by the recommended treatment, i.e. total cost per hectare divided by a higher tonnage. Despite a higher harvesting cost, recommended settings obtained a significantly higher ($p < 0.05$) overall net benefit of $114/ha.

DISCUSSION

Following the 2017 and 2018 Isis tours, the SRA/DAF harvesting team with the support of Wilmar Sugar, Herbert Cane Productivity Services Limited and Herbert River Canegrowers delivered the industry's first month-long commercial harvest-demonstration round for the Herbert region in 2019. The intent of the project was to align outcomes of the original program (Patane *et al.* 2019a) to cultural drivers such as values, execution, and behaviours. This aimed to address the disparity between current harvesting practices and recommended harvesting practices, as well as embedded cultural behaviours that remained a barrier to adoption.

Conversations with the Isis region tour participants indicated that whilst awareness and some desire existed for change, barriers to adoption included a lack of knowledge (full practice change impacts), resource availability to guide change, and reinforcement for change that would bring tangible benefit. The demonstration trials addressed these gaps by measuring harvester setting change outcomes under commercial conditions for an extended period (improved knowledge). Harvesters were also fitted with SCHLOT® Live cane-loss monitors that provided real-time cane-loss measurements to further minimise loss. SCHLOT® Live monitors also had the ability to monitor harvester parameters to satisfy growers that recommended practices were adhered to by the contractor. If field conditions changed within the block, the Live monitors allowed the operator to adjust practice to remain within HBP parameters. An economic analysis determining the net benefit (revenue less costs) of recommended practice reinforced and validated meaningful outcomes to both the grower and contractor.

Figure 1 shows the differences between standard and recommended practice for the Herbert commercial demonstration trials in terms of ground speed, fan speed, elevator pour rate and cane yield. The commercial demonstration followed trial results from Patane *et al.* (2019b) and identify recommended settings as more economical than standard practice. Results show a 4.9% improvement in recovered cane for the recommended practice with no detrimental impact on EM levels, fibre levels or CCS, and no significant effect on nominal bin mass. Given no difference in CCS, the improvement in sugar yield and grower revenue follow a similar trend to cane yield with recommended practice obtaining 5% more sugar.

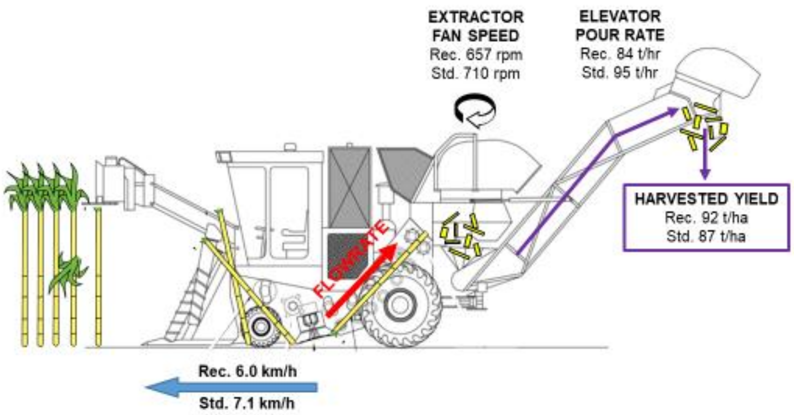

Figure 1. Graphical depiction of different speeds, pour rate and cane yield between standard (Std.) and recommended (Rec.) settings.

The net benefit improvement of $114/ha for the recommended treatment shows a lower overall net benefit when compared to the $163/ha determined by Thompson *et al.* (2019) from industry-wide trials. This was mainly due to a lower average primary extractor fan speed reduction and yield gain for one of the harvesting groups. The net benefit gain is largely determined by the harvester setting change (cost impact) combined with the resultant yield change (revenue impact).

Using the recommended instead of standard harvester settings required operators to reduce ground and extractor fan speeds by an average of 1.1 km/h and 53 rpm, respectively. The impact to industry would be an increase in harvesting time, requiring an increase in harvesting hours per day and/or an increase in season length. For the demonstration, harvesting time increased by an average 8.1 minutes for every 100 t of cane harvested using the recommended settings. This additional time would increase fuel consumption, labour hours, machine depreciation, and wear and tear costs per hectare (Nothard *et al.* 2019). However, due to the additional grower revenue ($151/ha), paying additional compensation to harvesting contractors that cover both added costs and an incentive would allow them to improve their returns while harvesting less area or increasing their operational hours.

The 2019 Herbert project strategically followed a change framework that targeted the needs of individual stakeholders resulting in strong outcomes for the Herbert region. This includes one of the participating Harvesting contractors successfully negotiating an incentivised payment arrangement to harvest at HBP. The harvesting contractor stated "The project has allowed the group to identify where there are potential gains with different harvesting practices at a commercial scale". Through live cane-loss monitoring (facilitated by the installation of SCHLOT® Live on the harvester), growers can also validate contractually agreed harvester settings. The grower spokesperson stated "the project has been very beneficial not only for myself but also for the group in allowing us to identify revenue benefits from adopting HBP, this has led to the group paying the contractor an incentive to harvest at HBP and install the latest technologies". The demonstration round delivered an increase in awareness of the need to incentivise harvesting contractors and improved acceptance of the yield improvement potential of HBP. The communication of the demonstration was also instrumental in reaffirming the benefits of HBP in a commercial setting. Information dissemination included face-to-face grower workshops during the season, presentation of results to individual contractor groups and establishing “champion” harvesting contractors to advocate the benefits of HBP. This has led to the Herbert region investing in cane-loss monitors to assist in minimising loss.

The project has been pivotal in identifying losses on a commercial scale, heightening awareness which led to contractors being incentivised for HBP and installing in cab tools to assist in implementation. This was prevalent and led to the Herbert region installing the greatest number of cane loss monitors in the Australian sugar industry.

CONCLUSIONS

The Herbert commercial demonstration trials supported industry-wide green-cane-harvesting trial results by identifying recommended practice (HBP) as economically superior to standard practice on a commercial scale. The demonstration identified an additional 4.3 t cane/ha (+4.9%) for recommended practice, with no detrimental impact on EM levels, fibre levels or CCS, and no significant effect on nominal bin mass. With no difference in CCS, the improvement in sugar yield and grower revenue followed a similar trend to cane yield with recommended practice obtaining 0.6 t (+5.2%) more sugar per hectare. These results confirm that HBP delivered more cane per hectare to the mill without significantly impacting quality. There was a significant gain in production and profitability to industry under commercial conditions even when considering the impact on harvesting costs.

The Herbert demonstration has proven instrumental in the acceptance of HBP for the region. Contractors involved in the program have been incentivised to adopt HBP, and practice change dialogue between Contractors and Growers has noticeably increased. The results again confirm that adapting and aligning harvesting practices to crop and paddock conditions have positive impacts on both yield and economic outcomes on a commercial scale. Since conducting the demonstration, multiple harvesting groups have commenced incentivising harvesting contractors to change practice and install cane-loss monitors.

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