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Final Report – SRDC Project BSS227
A participatory approach towards
improving industry sector profits through
improved harvesting efficiency
by
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EXECUTIVE SUMMARY

The industry issue addressed and its relevance

Recent productivity gains through the introduction of high yielding varieties, green cane harvesting, improved drainage and irrigation have resulted in larger, mostly lodged crops with increased suckering. As a result, ccs levels have declined, dirt in supply and extraneous matter levels have increased, and stool damage at harvest is obvious. Growers do not always connect their role in crop presentation to ease of harvest and resultant cane quality. Failure to hill up plant cane adequately and match it to harvester basecutter angle; inconsistent row spacing and lack of attention to farm layout, headlands and haul roads are the main deficiencies. Harvester operators and harvest crews may also have goals conflicting with cane quality and quality of ground job. The standard system of harvester payment, which is based on \$/tonne, rewards speed of operation. Stool damage, cane loss and poor billet quality result. The mills' transport limitations and need for continuous supply may impose restrictions on harvesting where by the harvester must deliver a fixed quantity of cane within a short time frame. This can result in poor ground job and higher cane losses (because fan speed is increased in an attempt to achieve cleaning at high pour rates). Short and damaged billets can result from pressure to achieve high pour rates and high bin weights. Encouraging harvesting under wet conditions results in field damage. The viability of the north Queensland sugar industry is in jeopardy. Industry leaders believe there are large productivity and profitability gains to be made by adopting harvesting best practice (HBP).

How the project addressed the issue

The improved harvesting efficiency project goal was to extend known harvesting technology rather than undertake research. It did this using a participative approach to involve growers and cane harvester operators/crews in benchmarking harvesting quality and efficiency for individual blocks, farms and harvesting groups. By benchmarking the measurable aspects of harvesting, best practice techniques were identified and group-managed trials were set up as part of the adoption process. Data loggers and in-cab displays were fitted to participating harvesters to improve farm trial management and the quality and frequency of the data.

The HBP project worked closely with fifteen commercial harvesting contractors, associated farmers and mill staff, located between Mackay and Mossman. Over 50 farm demonstration trials were conducted during the 1999–2001 seasons.

Information gathered from farm trials and harvester research was incorporated into the publications *The Harvesting Best Practice Manual* and *HBP: The Money Issues* publications for use by harvester operators, growers, millers and industry. Extension activities including cooperator feedback meetings, group shed meetings, field days, information forums, media input and circulation of draft HBP manuals occurred in all regions from northern NSW to Mossman, although the focus was on central and northern districts.

The project outputs and outcomes

This project demonstrated that adoption of HBP (specifically, lower pour rate and lower extractor fan speed balanced against harvest time) could provide an extra \$100/ha plus to the industry. Several barriers to adoption of HBP have slowed progress. These include low sugar prices, wet weather, orange rust disease, system of harvester payment, insufficient cane quality feedback mechanisms and physical, time and safety constraints upon harvesting.

Information gathered from farm trials and harvester research was incorporated into a Harvesting Best Practice Manual and Harvesting Best Practice: The Money Issues brochure (a summary of the major issues influencing HBP). The manual brings together current harvester research and knowledge. It is a ‘how-to’ guide to achieve HBP. Subjects examined include harvester set-up and operational settings, field conditions, farm layout, farming practice and their effect on harvester performance, cane quality, sugar quality and industry profitability.

Outputs and outcomes related to specific aspects of the project investigations are detailed below.

Primary extractor fan

One of the key points demonstrated by trials was that the primary extractor is the principal cause of harvester cane loss. Increasing primary extractor rpm is an inefficient method of reducing extraneous matter (EM). Operating the primary extractor at higher rpm dramatically reduces grower/harvester returns because of excessive cane loss.

Pour rate/extractor fan speed

Although industry returns per **hectare** increased under lower pour rate and extractor fan speed, harvester returns per **hour** decreased because of extra time and fuel usage.

Billet length effects on losses, quality and cane transport

Billet length and quality assessments carried out as part of this project showed operators the disastrous effect that mismatching chopper and roller train speed has on billet quality. Field trials across a range of chopper makes demonstrated that the proportion of sound billets produced rarely exceeded 60-70%.

To make more efficient use of the cane transport system, mills have been encouraging higher bin weights via promotion of shorter billet length. The downside of this is that shorter billets are prone to more damage resulting in higher cane and juice losses as well as potential deterioration problems. Penalties for “low” bin weights are at odds with this strategy.

Harvest planning

The purpose of a harvest plan is to match the expected harvest operation to what is possible within the constraints of harvest price, field conditions, and workplace health and safety guidelines. Information is fed into the BSES Harvest Transport Model, which

estimates the time taken to complete the harvest under the specified scenario. Cost estimation calculations for crew hours, and harvester efficiency are developed. The process of harvest planning has been refined over the project life. Harvest model predictions for participating groups were checked against actual harvest data collected on log-books or logging equipment. Results show that the harvest model can accurately predict harvest time and cost.

Field efficiency

Harvester field efficiency is time spent cutting cane as a percentage of total harvest time. It is an important measurement in the analysis of harvest cost. The team has developed methods and definitions to facilitate this. There is interest in logging/recording harvester efficiency to assist with differential charging for harvesting which will remove the current market anomaly where farms achieving HBP are subsidising those that do not because all are charged a flat rate per tonne harvested.

Soil in cane supply

The project team worked with farmers to increase awareness of the importance of a consistent row profile matched to the basecutter configuration, because mismatch is a major cause of soil in cane. The BSES modified crop divider fronts promoted under the project exert a lower force on the stool, improve cane feeding and reduce soil in cane. Lower ground speeds promoted by HBP also result in less dirt entering the machine.

Cane loss feedback

Lack of real-time, accurate and consistent measurement of cane loss is a weak link in the HBP system. We trialed a new system (using a microphone mounted on an extractor blade to listen to the impact of billets and log the frequency of ‘hits’) developed by The National Centre for Engineering in Agriculture (NCEA). It showed potential to work reliably, but further testing is needed to relate hits cane loss. The robustness of the hardware in the longer term is unknown.

BSES cane-gathering fronts

Promotion of modified cane-gathering fronts on harvesters, developed by BSES resulted in increased awareness of this equipment. Over 180,000 t were put through the BSES fronts in Mulgrave, Innisfail, Ingham, Burdekin and Mackay in 2001. Cooperators were satisfied with the improved gathering, feeding, operator vision and the reduction in front weight of the harvester over standard. Demands for the fronts led to commercial production in Mackay for 2001 season by EHS Manufacturing. Numerous copies of the BSES fronts are also present throughout the industry.

Optimised feed-train

BSS227 linked closely with MCB001. BSS227 was highly active in promoting the benefits of feed-train optimisation. This led to a significant uptake of the BSES feed-train optimisation service. Optimised feed-train rollers are all travelling at the same tip speed, which is adjusted to 65-70% of the chopper tip speed

Benefits include reduced juice and cane loss at choppers, consistent billet length, better billet quality and improved cane cleaning.

Widespread awareness of HBP

Widespread industry awareness of the effects of farm and harvesting practices upon productivity, sugar quality and harvester and milling profitability has been created by extension activities including shed meetings, cooperator feedback meetings, field days, information forums, media input and circulation of publications: HBP: The Money Issues and HBP Manuals. Extension activities have occurred in all regions from northern NSW to Mossman (although the focus was in central and northern districts).

The impact of the project findings on the sugar industry

The original project proposal stated the following expected outcomes: improvement in ccs in the order of 0.5 unit, reduction in extraneous matter (including soil) levels in the cane supply by 3%; reduction in cane loss by 1%; and a reduction in stool damage resulting in improved growth of ratoon crops.

By adopting best practice harvesting technology (specifically lower pour rate and fan speed) an extra \$100/ha plus should be available for the industry. If 50% of farms adopt HBP then it is worth approximately \$20 million per year to the industry. This benefit is primarily due to reduced cane loss because of lower primary extractor fan speed. The slower machine forward speed produces a lower flow of cane through the harvester, which gives more opportunity for cleaning and a reduction in extraneous matter. This usually results in a higher ccs being achieved. The lower forward speed also means less opportunity for intake of soil in supply.

Other benefits include reduced cane loss through adoption of modifications like the extractor paddle, lower soil in cane through matching row profile to basecutter angle, lower soil intake and less stool damage and better cane quality through the promotion of new BSES harvester fronts, better understanding of the costs of harvesting through logging and individual block assessments.

Per cent soil in supply at Tully fell from 2.1 in 1999 to 1.88 in 2001. Mud solids per cent cane fell from 0.82 in 1999 to 0.76 in 2001 at Mackay Sugar.

CCS, in isolation of other parameters, increased by 2.06, 1.36 and 1.26 units at Mulgrave, Tully and Mackay Sugar, respectively, between 1999 and 2001. However, tonnes of cane per hectare decreased by 16.5, 4.0 and 18.2, respectively, over the same time frame. Other factors including excessive rainfall, damage from wet 1998 harvest, rats and orange rust disease had a dominant impact on northern and central production.

1.0 BACKGROUND

Declining ccs levels in north Queensland have been linked to increased extraneous matter (EM) by a number of authors (Brotherton and Pope, 1995; Pope, 1997; Wilson and Leslie, 1997). Extraneous matter is defined as tops, trash, suckers, stool, soil and any materials other than millable cane in the supply.

Growers and harvesting operators are generally aware of the impact of EM on ccs. However, attempts to reduce EM by increasing extractor fan speed resulted in increased cane loss. Linedale and Ridge (1996) conducted a statewide extension campaign that substantially reduced harvesting loss and developed a simple method to measure losses. However, there was a trend to increased EM associated with the reduction in cane loss. Cane quality projects in Tully and Mulgrave identified a number of HBP solutions to optimise cane loss and EM.

Harvester forward speed and crop size combine to produce pour rate. Pour rate has a major impact on cane quality, EM, stool damage and harvesting economics. Powell (1997) discussed the factors involved in determining the optimum forward speed while minimising stool damage and cane loss. Chapman and Grevis-James (1998) discussed a differential charging system for harvesting to encourage improvements in efficiency and to optimise pour rates.

Stool damage and soil compaction are affected by cultural practices such as row width (Braunack and Hurney, 2000), harvester basecutter settings and maintenance (Kroes, 1997) and harvester forward speed (Kroes and Harris, 1997).

Sugar mills such as Tully and Mulgrave have installed equipment to monitor cane quality. The ability to measure the quantity of soil in cane and individual fibre levels in the cane supply has enabled these mills to provide some feedback to operators and growers on the quality of cane supply.

The need to implement a “Best Practice Plan” was identified by the Australian Cane Harvesters Association and the Queensland Mechanical Cane Harvesters Association, who initiated the Best Practice Search Conference conducted by Macarthur Agribusiness (1996). Among the strategies incorporated in the best practice plan, under the broad goal of improving quality of performance, was education and training of operators and growers.

The harvesting loss, soil in cane and best practice projects have provided simple tools to measure some aspects of harvester and haulout performance. This information needs to be linked to other industry productivity data to obtain an overall picture of the harvesting operation and the links with farming practice, productivity and profitability. The collection, analysis and use of this benchmarking information provides an opportunity to use a participative extension approach with grower-managed groups. Participation in activities provides an action-learning environment because growers trial and adopt the best practice options identified. Also the linking of projects currently underway in several districts will result in a sharing of knowledge on best practice harvesting.

2.0 OBJECTIVES

The aim of the project was to increase farm, harvesting sector and factory profitability through the adoption of best practice harvest related farm activities and harvesting operations. This was achieved by:

- collating current research results relating to harvester and haulout performance, harvester design, field conditions and operation settings to ccs, extraneous matter, soil in cane, cane and sucrose loss, billet quality and stool damage;
- conducting two way briefing sessions for research/extension officers, cane inspectors and CPPB staff likely to have involvement in the project;
- establishing participating grower/harvester groups;
- establishing a benchmarking procedure with the groups to establish baseline performance data;
- adjusting harvesting equipment, operating methods, farming practices and mill activities to improve farm and harvester performance;
- comparing and reporting the performance of groups;
- developing a Manual of Harvesting Best Practice;
- creating widespread industry awareness of the effects of farm and harvesting practices upon productivity, sugar quality and grower, harvester and mill profitability;
- instigating and promoting modification of cultural practices, harvester componentry and best harvesting practices to halt, and where possible reduce, the increasing soil levels in the cane supply within three years.

The Improved Harvesting Efficiency project has achieved all of its objectives, which has been a substantial achievement given the difficulties (weather, pest, disease and sugar price) encountered during its lifespan.

3.0 METHODS

Harvester and haulout performance, harvester design, operational settings, field conditions and the effect of crop presentation on ccs, extraneous matter, soil in cane, cane and sucrose loss, billet quality and stool damage were discussed in an industry workshop. Consequently, a draft manual of harvesting best practice was produced as a guide for extension. The manual included suggestions for improving practices from the harvester operator's and the grower's points of view.

Extension and cane quality officers formed groups centred around harvester operators that were perceived as pro-active and were willing to experiment with different options to improve performance. The project team supplied equipment to and worked closely with fifteen commercial harvesting contractors (five in Mackay, two in the Burdekin, four in Tully, two in Mulgrave and two in Mossman.), associated farmers and mill staff. Harvester operators included contractors, farmer-contractors and co-operatives.

Each harvester was fitted with logging equipment developed under the project to measure and record machine performance once during every minute of operation. Operator feedback was enhanced with the inclusion of a forward speed display. A display of top roller opening position indicated machine pour rate and feeding characteristics. Apart from the standard extractor rpm, some of the machines also displayed basecutter rpm, chopper rpm and roller rpm. Feedback devices also allowed operators to undertake farm

demonstration trials. Groups formulated and assisted with conducting farm trials to evaluate different practices. Trials were carried out to test the effect of farming and harvester practices on CCS, EM, soil in the cane supply, cane and sucrose loss, billet quality, stool damage, harvesting efficiency and profit. Each trial generally contained 2-3 treatments by 2-3 replicates while some were observation only. A typical trial included the harvesting of approximately 300 tonnes of cane with individual rep/rake sizes being a minimum of 30 tonnes. Each trial took approximately seven man-days to complete, excluding data analysis and interpretation. Criticism of scientific rigor by some quarters failed to comprehend the nature of this project, which was extension rather than research based.

A list of trial types carried out during the project follows.

1999: 12 farm trials

Nine fan speed/pour rate trials, one basecutter modification, one extractor modification and one topper.

2000: 18 farm trials

Two pour rate/fan speed (standard practice versus best practice), two extractor paddle, two basecutter, two fan speed/cane loss, four roller-speed/chopper speed billet length and quality, two Austoft prototype versus standard machine cane cleaning, two field efficiency, counter-rotating fans and dew versus dry.

2001: 21 farm trials

Five billet length, seven angled blade basecutter, three Austoft prototype (two cleaning/cane loss and a ratooning), dew versus dry, forward speed versus ratooning, extractor/cane loss, BSES front cutting one way versus two way/ratooning, harvesting efficiency and the NCEA Streamline Billet Counter.

Prior to the start of each harvesting season, participatory harvesting groups met to discuss practices and modifications they believed might improve machine performance and the quality of cane supplied for crushing. Modifications to equipment, operating technique or changes in cultural practices were always part of the agenda. Through consensus, they decided on priorities needing investigation, design of trials and who would host the trials. Some were involved with data collection and the majority participated in discussion of the results.

As new information either from project trials or harvester research came to light, the Harvesting Best Practice Manual was updated. Several drafts were circulated to cooperating groups, interested growers/contractors, mill staff, extension officers and researchers over the past two years, and feedback was sought from the industry to improve the content and readability of the document. Industry players outside our participatory groups received contact with HBP information through newspaper and radio articles, grower shed meetings, information forums, BSES field days, QMCHA Harvesting and Transport Expos, and specific project publications such as HBP: The Money Issues and the HBP Manual.

Harvester field efficiency is the ratio of time spent cutting cane to harvest time (harvest time includes cutting, turning, in-field service and maintenance, downtime, waiting for bins and rest/meal breaks). An elevator hour-meter was used to measure cutting time. This information was combined with a log-book to record block data, fuel use and other

variables. A database was used to record and analyse these data for calculation of cost of harvest on a block-by-block basis. The information collected provided an accurate data set for entry into the BSES Harvest/Transport Model. The model compares alternative scenarios to determine the optimum economic machine settings and operation. Cost constraints can be identified and possible solutions found. This process was used to produce harvest plans that are mutually acceptable to the harvester and grower, and growers define what they are prepared to pay to achieve a certain quality job.

The aftermath of the wet 1998 did make harvesting conditions difficult in 1999 due to bad wheel ruts, very light crops, large tangled standover and rat damage, particularly in far north Queensland. These problems did affect the attitude of harvest crews, performance of harvest machinery and in many cases, reduced cane quality. Conditions were not always conducive to large-scale harvester trials. In the Mackay and Tully districts, the large drop in crop estimate (20%) reduced the season length and limited the time available to do field trials.

The wet and low sunshine growing season of 2000, in combination with orange rust disease, devastated Q124, which was 45% of Queensland's crop. Districts like the Central (87% Q124) and the Herbert (62% Q124) suffered record losses. Small crops (av. 56 t/ha in Central District) made demonstration and testing opportunities rare.

In 2001, the majority of mill areas cut 7%-18% below estimate. The Central District averaged 65 t/ha. This poor result was due to unprecedeted November 2000 rainfall that decimated the large area of late planted cane, caused waterlogging, nitrogen deficiency and delayed weed control. Q124 was still the dominant variety and its yield was greatly reduced by orange rust. Lack of decent sized crops meant harvesters often travelled at high speed, covering large areas to fill allotments. Uniform blocks of adequate tonnage for trials were rare and time constraints made it difficult to conduct trials even in good blocks.

The logistics of locating large, uniform blocks for demonstration trials, during 1999-2001, harvesting them without breakdown or other disruption and achieving feedback from the mill (excluding lost or joined rakes) proved a mighty challenge.

See Appendix 1 for more details on trial methods including data logging used and cooperating harvester specifications.

4.0 RESULTS

Extractor fan

One of the key points demonstrated by trials was that the extractor fan is an inefficient method of reducing EM but it dramatically reduces grower/harvester returns when operated at higher rpm because of excessive cane loss. In a replicated Mackay trial, a 150 rpm increase in fan speed (from 1,100 to 1,250 rpm) reduced grower and harvester returns by \$177/ha and \$86/ha, respectively. Cane loss was determined by mass balance and tarp (Linedale *et al.*, 1993) methods and CCS determined using individual fibres.

Pour rate/extractor fan speed

A prime example of the benefits of HBP is shown in Figure 1. This replicated Tully trial was carried out in a 90 t/ha crop of second ratoon Q135. The field sector return is increased by \$174/ha at the lower pour rate/fan speed. All Tully trials in 1999 showed improvements in grower returns per hectare by slowing pour rate/fan speed. Grower returns from best practice, calculated using individual fibres, ranged from \$45-\$114/ha above standard practice. Grower return is gross income minus harvest and levies and harvester return is payment to the harvester based on the contract rate per tonne of cane harvested. Work by Stainlay in Tully in 2000 indicated that groups wanting to operate at best practice would have to switch from a 13 out of 15 to a 14-15 out of 15 day roster. This meant that an extra crew member was required to keep work hours within Workplace Health and Safety (WPHS) guidelines. This would cost an extra \$0.50/t.

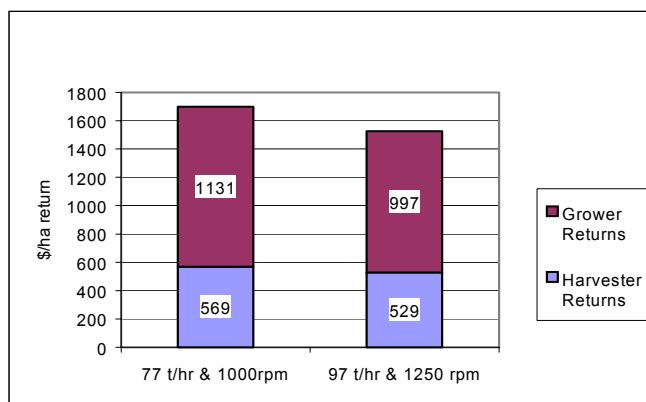


Figure 1 - Effect of varying pour rate and primary extractor fan speed on grower and harvester returns (Agnew *et al.*, 2002).

In another Tully pour rate/fan speed trial, evaluating best practice versus standard, industry returns per hectare increased under HBP, but harvester returns per hour decreased because of extra time and fuel usage (Table 1). Best practice (7 km/h @ 1,000 rpm fan) gave over \$200/ha extra for the industry compared to standard (9 km/h @ 1,200 rpm fan).

Table 1 - Effect on returns of best practice pour rate/fan speed versus standard (Agnew *et al.*, 2002).

Parameter	Best practice	Standard practice
Fibre % (individual)	15.7	15.6
CCS (relative)	13.9	13.8
Cane yield (t/ha)	80	74
Tarp cane loss (t/ha)	1.4	4.7
Industry return (\$/ha)	2,567	2,356
Grower return (\$/ha)	1,375	1,253
Harvester return (\$/ha)	478	443
Mill return (\$/ha)	713	661
Harvester return (\$/hour)	334	360

Basecutters

Most basecutter trials were associated with trial blades that were raked forward around the outer bolthole so that the blade was angled forward into the cut (12-30 degrees). In the majority of trials no differences were evident in machine feeding, soil in cane, ratooning or cane quality. However, the trial blades wore more evenly, kept a squarer edge and lasted longer.

The poor crops of 2000/2001 meant ground speeds were maximised. The ability to increase basecutter rpm in line with forward speed reduced stool damage. Standard machines have fixed basecutter rpm, which means increased potential for stool damage at low forward speeds in large crops and at high forward speeds in small crops.

Billet length effects on losses, quality and cane transport

As a result of the many billet length and quality assessments carried out as part of this project, operators are more aware of the disastrous effect that mismatching chopper and roller train speed has on billet quality. Roller tip speed should be 60-70% of chopper tip speed (Norris *et al.*, 2000). Harvesters with slowed feed-trains to produce shorter billets achieve roller tip speeds from 30% to less than 60% of chopper tip speed. Field trials across a range of chopper makes demonstrated that the proportion of sound billets produced rarely exceeded 60-70% (Figure 2).

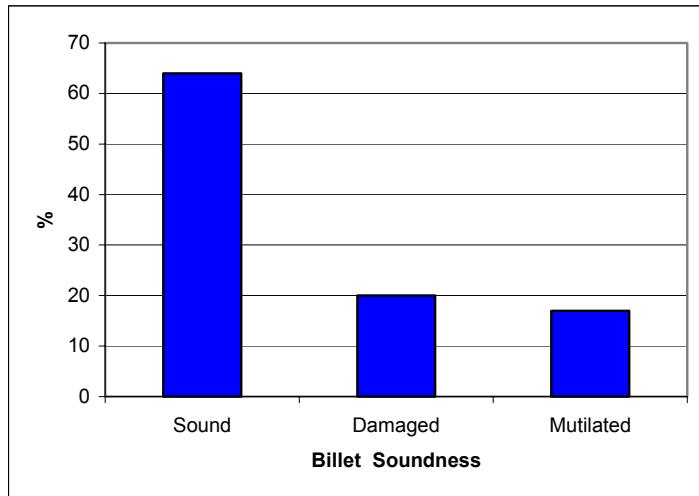


Figure 2 - Typical billet quality produced by non-optimised, late model harvesters in farm trials during 1999-2001 (Agnew *et al.*, 2002).

ISSCT standard criteria used to classify billet quality are as follows. Sound billets had no splits greater than 80 mm (other than growth cracks) through one end, rind cracks less than 40 mm, less than 400 mm² of rind removed and no squashed ends. Damaged billets included those that were less than 100 mm long, had individual splits greater than 40 mm and totalling more than 80 mm/billet, sections of rind removed 400-2,000 mm² and no squashed ends. Mutilated billets were broken, squashed, split, pulpy and/or had greater than 2,000 mm² of rind removed.

To make more efficient use of the cane transport system, mills have been encouraging higher bin weights via promotion of shorter billet length. The downside of this is that shorter billets are prone to more damage resulting in higher cane and juice losses as well as potential deterioration problems. Mossman trials (James unpublished) showed that a longer billet (204 versus 175 mm) produced 10% lighter bins but CCS was increased by 0.22-0.32 unit and sugar yield was 0.5 t/ha higher. Penalties for “low” bin weights are at odds with this strategy. More operators are adopting BSES roller train/chopper box research recommendations. BSES has developed a computer package to assess roller train/chopper relationship and give recommended changes.

Billet length distribution

In the majority of Mackay trials billet length was recorded for each treatment. Two important trends were observed. Harvesters were producing short billets, well below the award. Secondly, there was considerable length variation in the samples of billets produced. Figure 3 is part of the data from a 1999 pour rate/fan speed trial, which typifies the variation in billet length produced and highlights the trend towards short billets.

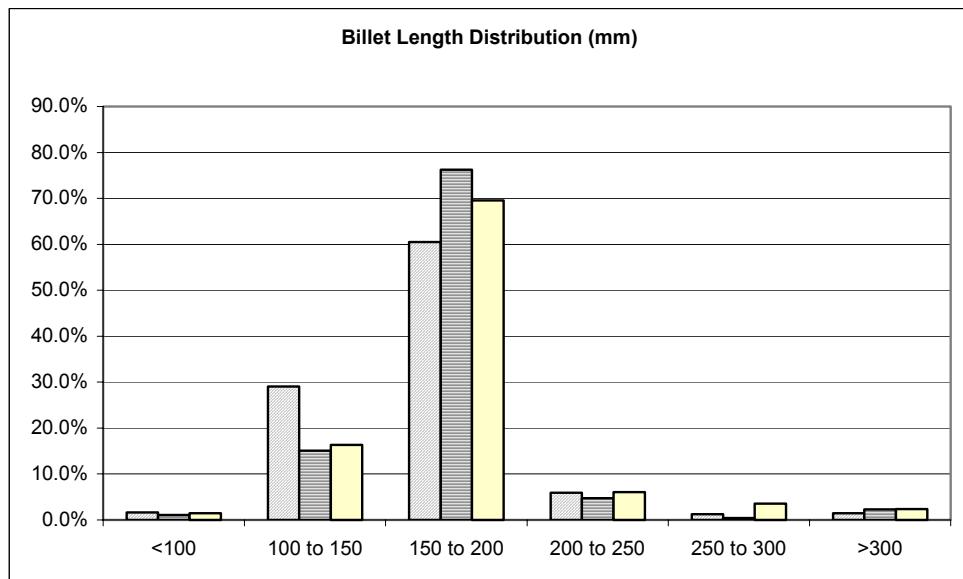


Figure 3 - Typical billet length distribution of modern commercial chopper harvesters. 1997 T7700 with 6-blade, 15" differential chop (Agnew and Sandell, unpublished).

Harvest planning

Applying harvesting best practice is not easy. Many factors exist limiting the implementation of HBP. Longer crew hours due to lower pour rates are not easy to negotiate due to WPHS guidelines. The tonnage-based payment system for harvest contractors (and employees in some cases) may not facilitate a best practice harvest operation. The fluctuations of crop yields and prices make analyses of best practice scenarios difficult. An ideal harvest will strike a profitable balance between harvest price and harvest job quality.

The first step to achieving best practice harvesting is to *plan* the harvest. The growers and the harvest contractor should develop a harvest plan *together*. It is important that all parties be clear and up front from the start. To develop a harvest plan, the group needs:

- a clear definition of the harvesting job the growers expect of the contractor;
- a harvest price quote from the contractor based on the harvesting job description outlined by the grower;
- tools such as the BSES harvest transport model to enable the variables of harvest quality and price to be assessed;
- negotiations between the growers and contractor to find the optimum balance between harvesting job, harvest price, and grower returns.

Points to consider strongly are field conditions, farm harvest efficiency, daily harvester allocation, and season length and harvest days. These points are all related to crop yield, farm layout, haul distance, mill crushing capacity, group tonnage, area tonnage, and rostered days off for the harvesting crew.

The BSES Harvest Transport Model (Ridge *et al.*, 1996) is a computer model developed by BSES. The model is used to assess different management options for harvesting. Row length, cart distance, crop size, labour costs, fuel use, capital costs and other details are entered into the model. The model provides estimates for pour rate, delivery rate, and harvest time for different combinations of harvest equipment, mode of operation, rostered days off, and field conditions. As with all models the information generated is dependant on the accuracy of the data entered into the model.

For example, a harvest group currently cutting with an average daily allocation of 600 tonnes, in an average day of 11 hours, operating a five out of seven day roster, can enter their details into the harvest transport model to determine the parameters effecting the harvest operation and benchmark the current practices. Changes in one or a combination of factors can then be run through the model and the effect examined against the benchmark. Used in this way the harvest transport model provides the information to develop costing for various scenarios. The model can also be used for assessing risk in the harvest operation. Examples are: “What effect does a 20% drop in crop yield have on day length and variable costs?” and “What effect does picking up extra tonnage have on crew day length?”

The main criteria for the group to use in deciding on adopting a harvest plan are as follows.

- Is the planned “job” quality satisfactory?
- Does the planned harvest comply with WPHS guidelines?
- Does the planned harvest allow the crew an opportunity to carry out the best possible “job”?
- Is the harvest price reasonable for the quality of the “job”?

The BSES harvest transport model outputs together with the experience of the harvester owners/operators and harvest record data from previous seasons will provide enough information to develop prices for the harvest plans developed. The harvesting group uses this information to decide on the type of harvest job for the season.

The key to implementation of the plan in the field is ensuring that the plan has the support of the harvest crew. Generally, harvest plans that have realistic expectations of “job” quality and crew work conditions will be received well by the crew.

Record keeping completes the planning and harvest management circle by providing feedback on the harvest and measures the effectiveness of the harvest plan.

The harvest plan selected must provide the highest possible job quality with fair and safe working conditions for the crew at a price that is acceptable.

Harvest performance is recorded with log-books/data logging systems to measure actual field performance with planned performance. This will allow more accurate planning in the future.

The Tully Cane Quality Project undertook a trial process for the implementation of HBP with four volunteer harvest groups in the Tully area during the 1999, 2000 and 2001 seasons. The groups were cooperative groups (groups where the growers that make up the group own the harvesting business that cuts the group’s cane). The project was funded by local industry with some SRDC support via the BSES Improved Harvester Efficiency project.

Adopting HBP by managing machine pour rate and fan speed was the main goal of the trial process. To obtain this goal, a harvest planning process was developed. The centrepiece of the harvest planning process was the BSES Harvest Transport Model.

Main barriers to implementation of harvest plans in 1999 were:

- actual tonnage cut was substantially lower than the estimate used in the planning process. The harvest plans were developed using the estimated figure. A change in crop yield will cause a large change in the time and cost of harvesting. A drop in tonnage will reduce the relevance of the harvest plans. This highlighted the fact the information entered into the harvest transport model must be as accurate as possible;
- group average data were used initially for model inputs when individual block data should have been used. Future harvest planning processes have to use individual block data as inputs into the model to increase the relevance of the planning process;
- the planning process did not involve the harvesting group members enough to promote ownership of the process. The lack of ownership of the harvest planning process translated to poor adoption of the harvest plan in the field. Not enough attention was paid to the harvest crew and the ramifications of working conditions and crew payment on a piece-rate systems.

Subsequent HBP adoption trials in the 2000 and 2001 seasons saw further refinement of the harvest planning process with efforts to address the shortcomings outlined above. The harvest planning process was improved to allow block-by-block harvest planning for growers within groups. Provisions were made to account for harvest contractors to input costs. This improved the accuracy and relevance of the planning process but the increased scope slowed the planning process making it a time consuming task in the current format.

Despite these efforts, adoption of harvesting planning process and best practice by the group was still poor. The barriers to adoption identified above proved to be persistent and hard to overcome. Advances were made in countering these problems. However, a lack of solutions to a number of important problems still remained. In particular, the harvest planning process lacked the ability to quickly and efficiently develop broad scale harvest plans. Fast and accurate harvest planning will allow groups to find the optimum harvest plan for their situation and allow an assessment of risk by running “what if” scenarios for their plan. For example, a fall or increase in crop estimate can be evaluated for the effect on the harvest plan.

Shifting the BSES Harvest Transport Model from a spreadsheet to a database format may be an option to increase the efficiency of the model as a planning tool. Database harvest planning tools designed to be compatible with input data from mill databases could be continually updated as variables change through the season, such as changes in estimate. This feature will make harvest plans more dynamic and relevant. Additionally, mill system compatibility would increase the scope of harvest planning to include group equity, delivery point, and transport schedule management.

Harvest record keeping has been and is successful when paper-based log-books are used to keep harvest records. This method can be prone to human error and time consuming but has proved to be successful. Reliability problems with electronic harvest logging equipment continued in the 2000 and 2001 seasons. The benefits of electronic record keeping equipment are accuracy, potential compatibility with feedback loops for the harvest plan and online cane quality measurement.

The process of harvest planning has been refined over time within the Tully Cane Quality Project. Harvest model predictions for participating groups were checked against actual harvest data collected on log-books or logging equipment. Results show that the harvest model can accurately predict harvest time and therefore cost (Table 2).

Table 2 - Comparison of the harvest plan with actual results on a Tully farm in 2001 (Stainlay pers. com. 2002).

Variables	Planned outcome	Actual outcome
Estimate (tonnes)	14,886	14,992
Harvester engine hours	257	243
Tonnes/elevator hour	97	86
Tonnes/harvester engine hour	58	62
Total fuel use (litres)	21,146	18,043
Fuel use (litres/tonne)	1.4	1.2
Days to harvest farm	28.3	30
Av. Day length (hrs)	9.8	8.6

Field efficiency

Harvester field efficiency is the percentage of the total harvest time that is actually spent cutting cane.

$$\text{Harvester field efficiency} = \left(\frac{\text{Total time that the choppers process cane}}{\text{Total time spent harvesting}} \right) \times 100\%$$

Field efficiencies are an important measurement in the analysis of harvest cost and harvest transport systems. The team has developed methods and definitions to facilitate this. There is interest in logging/recording harvester efficiency to assist with differential charging for harvesting. This will remove the current market anomaly where farms achieving HBP are subsidising those that do not because all are charged a flat rate per tonne harvested.

Efficiency gains from improving farm layout are possible and can help to make the harvesting viable into the long-term future. Row length and haulout turn around time are two of the most important factors affecting operating costs.

Record keeping

Record keeping is important because it enables the contractor to calculate the cost of harvest for each block in the contract. Once this is known, profit and loss blocks can be identified and inefficiencies rectified. The record keeping process requires the operator to complete a paper log-book as the harvest progresses. A convenient log-book is the QMCHA Log-book.

At the start and completion of each block or day, the following variables are recorded:

- date;
- farm number;
- block number;
- engine hours;
- elevator hours.

Optionally, other variables can be recorded:

- green/burnt;
- number of bins;
- haul conditions;
- crop conditions;
- downtime;
- consumables;
- comments.

At the end of each day or upon leaving the farm fuel use is recorded. Time-sheets are used to calculate total harvest time. It is important that the time-sheets are accurate and properly account for rest time. Mill data are also required. Haul distance and row length are calculated electronically using mill maps. Rake weights by block are required. All of the above data are entered into a database.

For each block these variables can be calculated:

- total cutting time;
- total harvest time;
- field efficiency;

- elevator pour rate;
- delivery rate;
- tonnes per engine hour;
- total cost of harvest.

Time spent cutting is simply measured by installing an hour-meter into the elevator on/off electric circuit. The hour-meter will ‘tick over’ only while the elevator is delivering cane. Because the harvester is cutting cane whenever the elevator is operating, the elevator hour-meter will therefore record cutting time.

However, there are times when the elevator is running and the machine is not cutting cane such as at the end of the row. Conversely, the harvester may be cutting cane with the elevator off such as cutting into a new row or changing haulouts. BSES studies have shown that these types of error do in fact cancel out on average. Using an hour-meter on the elevator is an accurate method of measuring daily cutting time. A breakdown of one day of harvesting in a Mackay farm trial in 1999 is shown in Figure 4. The chart shows the proportion of the day consumed by each activity. The harvesting field efficiency was 45% (6.15 hours out of 14 hours). Total harvest time includes time spent servicing and repairing the machine, turning and other downtime such as no haulouts. It does not include wet weather, moving or idle times. In Australia, field efficiencies typically range between 30-50%. How does this compare with Brazil, which is seen as an industry leader in harvesting efficiency?

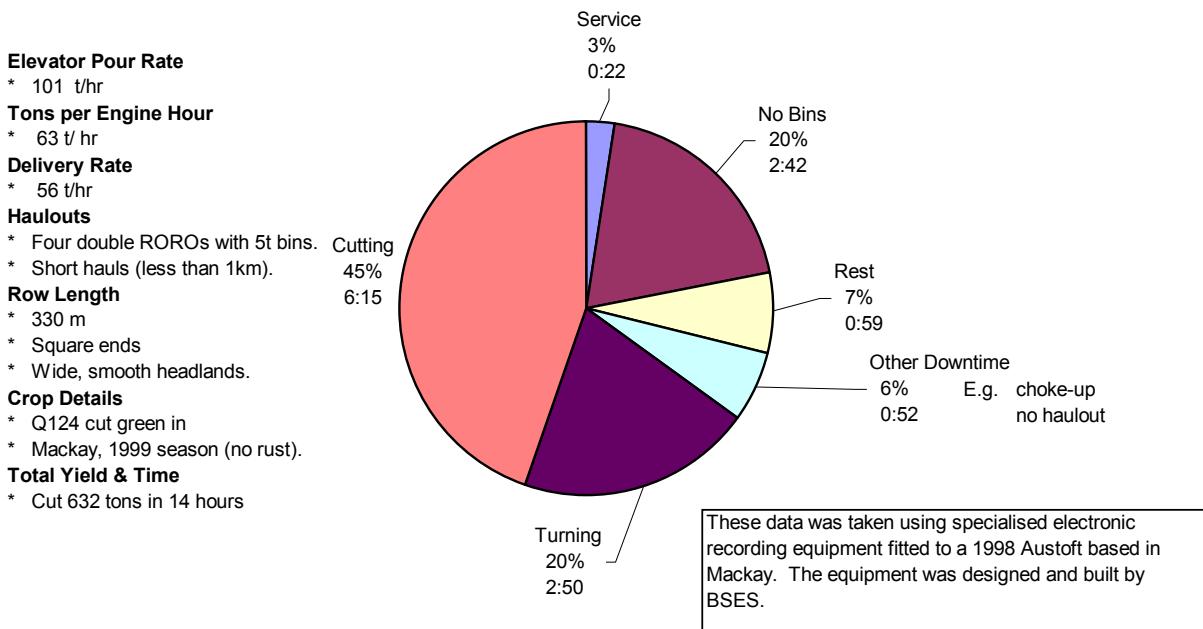


Figure 4 - Breakdown of one day of harvesting in a Mackay farm trial in 1999.
The chart shows the proportion of the day consumed by each activity
(Sandell and Agnew 2002).

The Brazilian operation is extremely time efficient which allows harvesting at a lower elevator pour rate. The Brazilian industry believes that 50 to 70 t/hr elevator pour rate is the limit of harvester cleaning capacity. As well as improved cleaning, harvesting at low pour rates has the advantages of low soil levels and more even feeding. Improved cleaning means lower fan speed and lower cane loss. This improves sugar yield, milling efficiency and sugar quality. These factors equate to a more profitable operation.

Brazilian machines are not turned off. They work continuously, 24 hours a day. Certainly, their machines experience downtime for servicing and repair, and non-cutting time spent turning and clearing choke-ups. The overall result is Brazilian machines are cutting for 63% of the total possible time available to them.

An Australian machine will typically cut cane for fewer hours per day and at high elevator pour rates of 100 to 150+ tonnes per hour. In a direct comparison between Brazilian and Australian harvester efficiency, the 45% efficiency quoted in Figure 4 is reduced to only 26% of the total available time, on a 24-hour basis.

Soil in cane supply

The project team worked with farmers to increase awareness of the importance of a consistent row profile matched to the basecutter configuration, because mismatch is a major cause of soil in cane. The modified crop divider fronts promoted under the project exert a lower force on the stool, improve cane feeding and reduce soil in cane. Lower ground speeds promoted by HBP also result in less dirt entering the machine. The project team also worked with contractors on basecutter configuration and operation. Improved basecutter operation minimises soil intake, improves ratooning and continuity of cane supply. Table 3 shows that soil levels in cane delivered to mills has either declined or remained relatively static between 1999 and 2001.

Table 3 – Soil in supply in selected central and northern mills (1999-2001).

Mill	Soil levels		
	1999	2000	2001
Tully (% soil)	2.1%	2.05%	1.88%
Mulgrave (NIR Ash)		3.13	2.03
Mackay Sugar average (mud solids % cane)	0.82	0.75	0.76
Farleigh	0.89	0.70	0.76
Marian	0.87	0.81	0.72
Pleystowe	0.68	0.59	0.73
Racecourse	0.82	0.89	0.81

Cane loss feedback

Lack of real-time, accurate and consistent measurement of cane loss is a weak link in the HBP system. The National Centre for Engineering in Agriculture (NCEA) is developing a system using a microphone mounted on an extractor blade to listen to the impact of billets and log the frequency of ‘hits’. The aim of the system is to provide an in-cab display of cane loss and automatically adjust fan speed to keep loss below a nominated level. Tests of the cane loss counter were made in 2001. This occurred in burnt and green Q124 ranging in yield from 45-70 t/ha. The initial hardware failed in the field. Suggestions for

improvement of robustness resulted in a second version being tested. The new system showed potential to work reliably, but further testing is needed to properly calibrate the machine in terms of the hits recorded and cane loss. The robustness of the hardware in the longer term is unknown.

BSES cane-gathering fronts

Promotion of modified cane-gathering fronts on harvesters, developed by BSES (Norris *et al.*, 1998) resulted in increased awareness of this equipment. Over 180,000 t were put through the BSES fronts in Mulgrave, Innisfail, Ingham, Burdekin and Mackay in 2001. Cooperators were satisfied with the improved gathering, feeding, operator vision and the reduction in front weight of the harvester over standard. Demands for the fronts led to commercial production in Mackay for 2001 season by EHS Machinery. Copies of the BSES fronts are also present throughout the industry.

The Burdekin cooperators harvested approximately 80,000 t with the BSES front in 2001, cutting the majority of blocks two way. This is a massive departure from standard practice in the Burdekin of cutting the majority of blocks one way. The estimated commercial cost of a new BSES front is \$15,000.

Optimised feed-train

Promotion of the benefits of optimising the harvester feed-train led to demand outstripping supply for this BSES fee-for-service consultancy.

Widespread awareness of HBP

Widespread industry awareness of the effects of farm and harvesting practices upon productivity, sugar quality and harvester and milling profitability has been created by extension activities including shed meetings, cooperator feedback meetings, field days, information forums, media input and circulation of draft HBP manuals. A participatory approach has been used in the development of The Harvesting Best Practice Manual, an important tool in the wider extension of harvesting R&D outcomes. A twelve-page document focusing on the essence of harvesting best practice (HBP: The Money Issues) was also produced. This document was launched in April 2002 coinciding with a series of central and north Queensland HBP information meetings. The HBP Manual was published in July 2002. Extension activities have occurred in all regions from northern NSW to Mossman (although the focus was in central and northern districts).

4.1 Summary of farm demonstration trial results

1999 Season

Mackay

1. Fan speed/pour rate (Galea/Powell)

The aim of this trial was to investigate the effects of fan speed and ground speed on cane loss, cane quality and grower/harvester returns. The crop was erect, first ratoon Q124 at 110 t/ha. The machine was a 1996 tracked Austoft.

- Pour rates were not significantly different between treatments (100 t/hr).
- There was no statistical difference in CCS or EM between treatments.
- Cane loss increased by around 12 t/ha for a 150 rpm increase (from 1,100-1,250 rpm) in fan speed at a constant ground speed of 5.6 km/hr.
- The net result was a drop in grower return of \$165 /ha and a drop in harvester return of \$110 /ha.
- Billet quality was typical of modern machines with up to 40% damaged and mutilated. Billets were of a consistent length (85% 150-200 mm). There was no difference in billet quality between treatments. This result was virtually the same across all machines tested and matches the findings of the 1999 Mackay Sugar Cane Quality Survey.

2. Trial basecutter blades (Hamilton/Froyland)

The aim of this trial was to investigate the effects of a trial basecutter blade set-up. The crop was burnt, erect to sprawled first ratoon Q124 yielding 110 t/ha. The machine was a 1994-tracked Austoft travelling at 7.2 km/hr with a primary fan speed of 1,100 rpm. The soil type was a black earth.

- The trial blades were raked forward 12° around the outer bolthole so that the blade leant forward into the cut.
- No differences were evident in machine feeding, soil in cane, ratooning or cane quality.
- The trial blade wore more evenly, kept a squarer edge and lasted longer.
- There was no difference in billet quality between treatments.

3. Forward speed (Hamilton/Vezzoli)

The aim of this trial was to investigate the effects of ground speed on cane quality, cane loss, stool damage and grower-harvester returns. The grower, who was concerned that the harvester's ground speed was too high and caused excessive pick-up losses and stool damage, instigated the trial. The crop was a burnt block of erect Q124 plant (90 t/ha). The soil was black earth and hill-up was consistent.

- No significant difference in pour rate or ground speed; therefore, no conclusions may be made regarding machine performance.
- Results allayed the grower's fear that the higher ground speed (7.1 km/hr) was causing more cane loss and stool damage than the lower speed (6.4 km/hr), in this case.

4. Forward speed/ratooning (Crossley/Knudsen)

- No reliable results were obtainable from this trial.

5. Fan speed/pour rate (Oakenden Harvesting/Muscat)

The aim of this trial was to investigate the effects of ground speed and fan speed on cane loss, cane quality and grower-harvester returns. The crop was erect Q124 older ratoons, at 80 t/ha. The machine was a 1997 tracked Austoft.

Treat	Fan speed rpm	Ground speed km/hr	Elevator pour rate t/hr	CCS	EM%	Mass balance cane loss	Eight week shoot count	Grower returns \$/ha	Harvester returns	
									\$/ha	\$/hr
1	1050	6.4	72	14.39	16	-6.5	152	1,346	555	425
2	1050	8.4	103	14.30	18	-9.5	137	1,445	603	561
3	1200	8.4	91	14.46	19	-1.5	134	1,300	531	498
NF	0	5.5	72							

- A 150 rpm increase in fan speed resulted in an increase in cane loss of 8.0 t/ha. Mass balance figures are negative due to crop variability in the NO FANS (NF) treatment which underestimated potential cane yield. That is, other treatments harvested more cane than the NO FANS treatment. Although the cane loss value is negative, the relative increase in cane loss (as fan speed increases) is realistic.
- Grower returns dropped by \$145 /ha and harvester dropped by \$72 /ha or \$63 /hr due to increased fan speed.
- Trash levels increased by 2% as pour rate increased from 72 to 103 t/hr.
- There was no statistical improvement in cane quality for increased fan speed.

6. Primary fan cone (Crossley/Manicaro)

The aim of this trial was to investigate the effects of fitting a fan nose cone to the primary extractor. The crop was erect Q124 that yielded 65 t/ha.

Treatment	Fan speed rpm	Ground speed km/hr	Tarp cane loss t/ha
Cone Fitted	1,100	6.5	5.0
Cone Removed	1,100	6.5	3.3

- Fitting the cone increased cane loss by 1.7 t/ha and reduced EM by 1.3%.
- This device made the fan work more efficiently. A reduction in fan rpm is needed to ensure that cane loss does not increase.

7. Topping (Oakenden Harvesting/Muscat)

The aim of this trial was to investigate the effects of topping. The crop was erect Q117 at 65 t/ha harvested on 12 October.

Topper	CCS	Leaf removal (t/ha)	Tops removal (t/ha)	Grower returns (\$/ha)
OFF	16.23	11.0	0.0	1,415
ON	16.31	12.2	0.6	1,377

- The topper on treatment removed 0.6 t/ha of tops and 1.2 t/ha of leaf. The net result of topping was to reduce EM by 2.1%.
- The small crop with small tops suffering from dry conditions and cut late in the year, masked any potential ccs improvements from topping.

8. Delva board hill-up (Steve Webb)

In Mackay, a hill-up trial was established in 1998 replant Q124 on Steve Webb's Racecourse farm. The effect on cane loss and soil in supply was to be measured in spring 1999. Unfortunately an accidental cane fire occurred on 6/8/99, and the trial site was burnt. Because a large percentage of the farm had to be harvested quickly there was no opportunity to organise field and laboratory sampling.

FNQ trials

Mulgrave

1. Fan speed/pour rate (Malaponte/Reghenzani)

The treatments evaluated included 3.5 km/hr @ 1,200 rpm and 5 km/hr @1,350 rpm. This trial was in badly lodged Q127 with an extremely large sucker population. The block had been flooded twice and was loaded with silt. Slowing down pour rate and fan speed gave no advantage in this particular situation. There was no difference in EM between the two treatments. That is, the glut/starve feeding was exactly the same, as confirmed by the top roller opening sensor. This machine was fitted with a custom-made paddle in the extraction chamber, which managed to keep cane losses low, even at the high extractor fan speeds.

Tully

The **pour rate trials** were a comparison between current harvesting practices and an example of best practice harvesting. Typically this involved slowing the harvester ground speed to reduce the instantaneous pour rate and a reduction in the primary extractor speed.

All of the trials showed improvements in the grower returns per hectare by slowing the ground speed and primary extractor speed of the harvester (the Khon Road trial was inconclusive due to variable crop yield). The reduction in harvester ground speed and primary extractor speed increased the yield in the trials between 2 to 6 t/ha. This reduction in cane loss is due to the decreased primary extractor speed and possibly a reduction in other harvester loss areas. The reduced extractor speed had little effect on EM levels due to the lower harvester instantaneous pour rates allowing better cleaning of the cane at the slower extractor speed. As a result, the increases in grower returns ranged from \$45/ha to \$114/ha (returns calculated on individual fibres). The grower is benefiting from the increased cane in the bin, without compromising EM levels and therefore payment. The harvester is gaining from the increased tonnage. The question is, does this extra tonnage compensate harvesters for the expense involved in slowing down.

2000 Season

Mackay

Four trials were conducted during a difficult season, hampered by poor crop, short season length, stressed operators working long days to fill allotments, and industrial action by

Mackay Sugar workers. Only 59% of Mackay Sugar's original estimate of 7.8 million tonnes of cane was realised, with 4.6 million being crushed. The district averaged 56 t/ha at 12.6 ccs, mainly due to orange rust in Q124 and a protracted overcast/wet late summer/autumn period.

1. Dew versus dry (Hamilton/Froyland)

The farmer/operators identified early harvest under dew conditions as an issue, with respect to the effect on ccs, EM, soil levels and profitability. This burnt cane trial was replicated by conducting it on two different days. The orange-rust ravaged Q124 was small, yielding between 45 to 65 t/ha. Day one dew treatment had 0.8 unit less ccs but an extra 7 t/ha of cane and 0.7 t/ha of sugar. Dew had 9.5% EM and 1% dirt in cane versus 7.5% and 0.4%, respectively, for dry conditions. No difference in gross return minus harvesting cost was noted. Day two saw no dew in the early morning rake but light rain before and during the later rake harvest. There was no difference in production or quality parameters between dry and moist conditions. Further investigation into this issue is warranted.

2. Extractor cone and paddle (Crossley/Manicaro)

The paddle consists of a series of diamond-shaped plates mounted on a rotating horizontal shaft (50 mm hollow), located between the chopper box and the primary fan. The diamonds have 150 mm by 300 mm long sides, are 5 mm thick and are spaced 100 mm apart, each one offset by 45°. The difference between this paddle and a conventional one is that it has been proved to reduce cane loss without impeding airflow. Consequently it does not have a negative effect on EM.

The cone and paddle showed similar tarp cane loss (very low) and cane quality to the control. The small crop (67 t/ha) meant a relatively low pour rate (90 t/hr). This in combination with free-trashing, orange-rusted Q124 meant easy cleaning and low cane loss.

3. Fan speed and extractor loss in orange-rusted Q124 (Oakenden Harvesting/Muscat)

Growers concern over potentially high extractor losses in orange-rusted Q124 prompted this trial. The orange rust caused the production of light stalks that tapered dramatically from half-way to two-thirds of the way up the stick. Cane loss was very low when operating below 1,100 rpm. Commercial extractor losses were generally low as operators realised the cane was easy to clean and 800-1,000 rpm was the norm throughout the district.

4. Forward speed versus variable basecutter speed (Troy Kane)

Q124 averaged 56 t/ha in the Mackay district. Harvesters had to travel at high speed to cut their allotments. This trial was prompted by growers concerns that the high ground speed would cause poor ratooning. The observation trial used three different basecutter speed settings (700, 640 and 500 rpm) at 7 km/hr and 9.2 km/hr ground speed. The greatest stool damage occurred at the higher ground speed with low basecutter rpm. Kroes (1997) recommends increasing basecutter rpm above standard settings when forward speed exceeds 8 km/hr.

Burdekin

1. Matching roller speed to chopper speed (HCL/Cacciola)

The 1R Q127 crop was burnt and cut one way on 14 August and it yielded 143 t/ha. The '95 wheeled Cameco harvester had a 12" Trail Bros chopper box and travelled at 8 km/hr with a fan speed of 770 rpm. Long chop (200 mm) and short chop (160 mm) were produced at roller speeds of 215 and 164 rpm, respectively. There was no difference in bin weights, ccs, cane or sugar yield between the treatments. However, long chop produced 6.5% more sound billets. Recent work by BSES Bundaberg has shown that billet quality is maximised when roller tip speed is set to about 70% of chopper tip speed. Improving billet quality reduces chopper box juice loss. In best practice, chop length is reduced by adding more blades to the chopper drums, not by slowing rollers.

2. Harvester field efficiency (HCL/Lando)

The crop was erect, 4R Q127, cut burnt and yielding 120 t/ha. Two identical '95 wheeled Cameco harvesters were cutting one way in the same block. Data logging equipment was fitted to one harvester. Four haulout trucks serviced the harvesters, each with two 5 tonne bins. Row length was 1km, cart distance 5.4 km round trip, elevator pour rate 155 t/hr and delivery rate was 46.2 t/hr.

In this trial, a manual check verified that the BSES logging equipment could be used to accurately measure harvester field efficiency. Harvester field efficiency is total time choppers are processing cane divided by total time spent harvesting, expressed as a percentage. Burdekin trial harvesters spent about 30% of their total operating time actually cutting cane. On a 24-hour basis, the time spent cutting is reduced to 13%. Brazilian harvesters aim to achieve 66% of a 24-hour day actually cutting cane. This is a best practice benchmark. By using the harvester for more hours per day, the unit cost of ownership is reduced. Trial machines had an elevator pour rate that was relatively high (155 t/hr). Brazilian machines harvest at 60-70 t/hr elevator pour rate. These relatively low pour rates produce less cane loss in the field and a cleaner product at the mill.

3. Harvester field efficiency: cutting one way (HCL/Chandler/Hyne)

The 90 t/ha crop of Q117 plant was cut green using the same harvesting equipment as the previous trial. The row length was 445 m, cart distance was 1 km round trip, elevator pour rate was 95.4 t/hr and delivery rate was 37.4 t/hr.

Harvester efficiency improves as row length increases and cart distance decreases. The percentage of total time spent cutting increased from 55% to 65%, as row length increased from 445-1,080 m. Percentage of total time spent waiting for carters decreased from 14 to 3.5% as cart distance fell from 5.4 km to 1 km round trip.

Tully

The combination of light crops, mill crush rate, and large harvesting group areas reduced the capacity of harvester crews to operate at best practice without modifications to harvesting rosters.

1. Best practice versus standard (pour rate/fan speed)

In a 90 t/ha crop, operating at best practice gave over \$100/ha extra for the industry.

2. Extractor paddle

The trial was conducted in an 80 t/ha crop of Q152 ratoons, under damp and weedy field conditions.

The paddle reduced extractor cane loss by 7 and 17 t/ha at primary fan speeds of 1,100 and 1,200 rpm, respectively, without worsening EM. Installing the paddle returned an extra \$194/ha and \$261/ha for the industry, at 1,100 and 1,200 rpm, respectively.

3. Angled basecutter discs

This modification (discs were designed with blade keepers rotated forward to the direction of travel by 30°) produced similar cane quality and ratoon shoots as standard basecutter discs. More testing is required.

4. Best practice versus compromise versus standard (pour rate/fan speed)

In an 80 t/ha crop of 3R Q152, operating at best practice (7km/hr @ 1,000 rpm) gave over \$200/ha extra for the industry (\$122/ha for grower, \$52/ha for miller and \$35/ha for harvester) over standard practice (9 km/hr @ 1,200 rpm). However, the harvester was \$26/hour worse off under best practice operation due to longer cutting time. So although the "pie" becomes bigger when operating at HBP, the harvester operator's share may not be sufficient to compensate for having to spend more hours in the field.

A change in harvesting practices in Tully would have to be cost effective and within WPHS guidelines. These two factors were leading harvesting groups wanting to operate at HBP to switch from the current 13 out of 15 day roster to 14 or 15 out of 15 day rosters. An extra crew member would be needed to keep work hours within WPHS guidelines. The extra man was going to cost around \$0.50 per tonne on top of increases in fixed and other variable operating costs per tonne.

The harvest would have to be planned to produce best practice harvesting (otherwise best practice would be the current standard operation).

Meringa trials

The statewide trend of low yields left operators faced with the challenge of achieving viable pour rates in very testing conditions. These pressures did not leave much scope for extensive field trials; it was, however, a good season to promote some aspects of best practice harvesting. We were able to do small tests with growers and contractors concerned about light crops and thin stalks. A couple of contractors wanted to get a better calibration on their cane loss monitors with the light stalks.

1. Counter-rotating extractor fans (Eric Archibald)

This extractor modification is designed to minimise "dead-spots" in the cleaning chamber. It should give better cleaning, but what are the effects on cane loss? The 1999 Austoft fitted with this modification showed similar results to a standard 2000 Austoft in a side-by-side test. The crop was light and more testing is required.

2. Austoft prototype versus 2000 standard Austoft

The prototype had a modified front, wide throat, jetclean extractor and auto basecutter height control. In limited trials beside an Austoft 2000 (standard) and 1999 Austoft (counter-rotating fans), there were few differences in performance. Crops ranged from light/lodged (70 t/ha) to sprawled, difficult to feed/cut Q113 (100 t/ha).

3. 2000 Cameco (5', 4-blade extractor) fan speed/cane loss

This system showed a consistent relationship between cane loss and fan speed, but the entire curve was shifted to the left. About 750 rpm gave minimal cane loss (Figure 5).

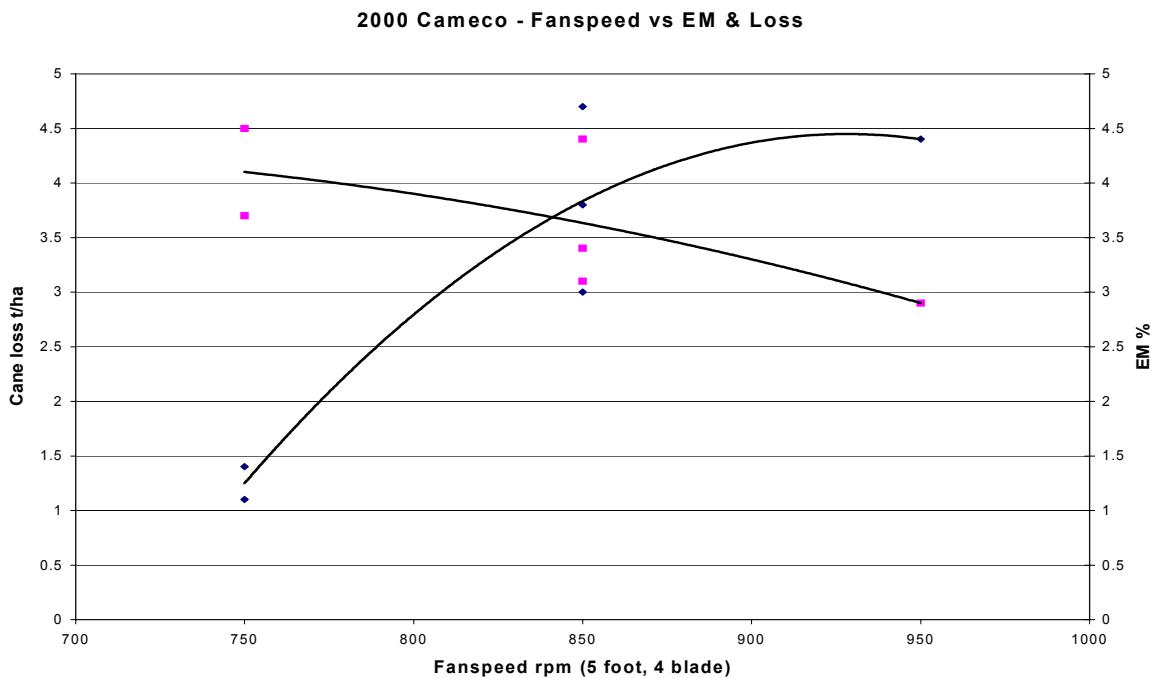


Figure 5 - Relationship between primary extractor fan speed cane loss and EM using a 5' 4-blade Cameco fan (Whiteing, pers com).

2001 Season

Mackay and Burdekin

1. Austoft prototype harvester: cane loss/fan speed (Bruce Davies)

The 2001 prototype has a modified primary extractor fan incorporating a larger diameter hub and four shorter blades. A plastic cone is mounted on the hub. The first test was in small (55 t/ha), erect Q124 at 800, 900 and 1,000 rpm. Cane loss was low. Cane loss and

cleaning characteristics were similar to modern commercial machines; however, the fan must be run at lower rpm to achieve comparable results.

2. Austoft prototype harvester: cane loss/fan speed (John Powell)

The crop was erect Q135 at 100 t/ha. Fan speeds were 900, 1,000 and 1,150 rpm. Cane loss at 1,150 rpm was unacceptable. Gross return (minus harvesting) to the grower was the same at 900 and 1,000 rpm but dropped almost \$700/ha once fan speed reached 1,150 rpm.

3. Austoft prototype harvester: automatic basecutter height controller on ratooning (Galea/Powell)

In this observation trial, three rows each were cut by the prototype and a standard T7700 using the same contractor operator. Each machine had a leg box with five blades (each 5 mm thick) per disk. Shoot counts were taken at 2, 4 and 6 weeks post harvest. There were no differences between the two machines. The operator commented that the hydraulics should respond faster at ground speeds above 7 km/hr and the display should be in the centre of the operator's vision. The designer, Matt Schembri (SRI), said that the final version would incorporate these changes.

4. Billet length effect on ccs, bin weights, cane loss and EM (Devin Bowman)

In a 97 t/ha, sprawled, 2R crop of Q124, the 4-blade, 12", Austoft choppers produced two billet lengths (188 and 232 mm) by adjusting roller train speed. Choppers were sharpened between each treatment. Bin weight decreased 9% as billet length increased. Longer chop had a positive effect on billet quality (5% more sound billets).

5. Harvesting in dew versus dry conditions (Oakenden Harvesting/Muscat)

In an erect, 100 t/ha, Q124 crop, there was no difference in ccs or EM between the early morning (5am) dew treatment and late morning (11am) dry treatment. Tarp cane loss was low across treatments but was higher under dew (0.7 versus 0.35 t/ha). Replication was achieved by repeating the treatments over two days. Similar levels of dew occurred on each day.

6. Forward speed on ratooning (Crossley/Manicaro)

The effect of three forward speeds (9.2, 7.0 and 5.0 km/hr) on stool damage and ratooning was carried out in 85 t/ha, Q121 plant cane. Stool damage was worse as harvester speed increased. However, there was no difference in shoot counts between the treatments six weeks after harvest. The block was irrigated post harvest, which may have helped mask the results. The harvester was a 1996 T7700 with standard 5-blade leg basecutters.

7. Primary and secondary extractor cane loss (Oakenden Harvesting/Camilleri)

Cane loss increased by 3.5-4.5 t/ha as primary extractor rpm increased from 1,100-1,250 rpm. The crop was erect, 100 t/ha, Q135 replant. The harvester was a 1997 T7700 with a 4'6", vertical arm, primary extractor with standard blades. An extractor paddle was also fitted. The steady forward speed (5.8 km/hr) and good crop conditions (EM 9.5-10.5%)

combined with the action of the extractor paddle combined to produce a relatively low cane loss.

8. Effect on ratooning in a grub-damaged block, by cutting one way versus two way when using the BSES modified fronts (HCL/Tasselli)

In this Burdekin trial there was no difference in ratoon shoot counts between cutting one way versus two ways. Cutting up and back improved harvesting efficiency by 25% in this block. The 115 t/ha crop of Q127 ranged from erect (80%) to sprawled (20%) and had obvious stool tipping due to grub damage.

9. NCEA cane loss counter (P Borg)

NCEA developed a system using a microphone mounted on an extractor blade to listen to the impact of billets. The system attempts to provide continuous “on-the move” cane loss measurement. The ultimate aim of the system is to provide an in-cab display of cane loss and automatically adjust fan speed to keep loss below a nominated level.

This trial evaluated the ability of the system to measure cane loss and its robustness in the field. Testing occurred in burnt and green harvested Q124 ranging in yield from 45-70 t/ha. The initial hardware failed in the field. Suggestions for improvement of robustness by Gary Sandell resulted in Mark 2 being tested. The system showed potential to work reliably. Billet loss (measured by the number of hits/second and confirmed by tarp test) increased as fan speed increased. Further testing is needed to properly relate the hits recorded to represent cane loss in t/ha. Also the robustness of the hardware over the longer term is unknown.

10. Field efficiency variation with different turning strategies

This Burdekin trial examined the effect of different turning strategies on harvesting efficiency. Cutting one way took 9.9 hours to harvest the block. Cutting round and round saved 1.5 hours, while two way cutting saved 1.7 hours.

Mulgrave

Perforated elevator flights for dirt rejection

Jim Fapani and John Piccolo were interested in determining if their perforated elevator flights rejected significant amounts of dirt at the siding. Under dry harvesting conditions the perforated flights dropped out 55 kg of dirt per 9 tonne load. The conventional flights only rejected 10 kg. It was estimated that the innovation would have reduced the amount of dirt processed by the mill by 25%.

BSES modified fronts

Considerable progress was made with cooperators and contractors in Mulgrave, Innisfail and Ingham. Initially H J Way was concerned that the fronts needed small outer spirals fitted and that saws were necessary. However, after a week of operating under difficult conditions (viney and grub-damaged blocks) he changed his mind.

The Innisfail group had steep terrain and numerous washouts to contend with. They were impressed with the lightness and flexibility of the fronts.

The Ingham group had a large area of dual-row cane to harvest and was delighted with the ease with which the fronts handled the job.

Almost half the contractors in the district travelled to see the fronts in operation.

Isis

Fan speed, cane loss and EM trials

Cane loss tests were carried out on five harvesting groups in Childers. Loss varied from 5-20 t/ha as fan speeds were operated between 1,200-1,350 rpm! There was some lack of operator awareness with regard to the small effect fan speed has on EM and the large impact it has on cane loss. Trials demonstrated that cane loss could be minimised without a large increase in EM.

Tully

Basecutter trials

Six trials were carried out to evaluate angled blade basecutter discs and their effect on ground job and stool damage. The blade keepers of the trial basecutter discs were rotated forward into cut by 30 degrees. Discs were angled down to stop clashing.

In high wear conditions angled blades had more even wear. This reduced the need to square blades up by cutting the blade back. In many cases there was no difference in stool damage or soil levels between standard and modified. Damage between modified and standard varied with soil conditions. Loosely supported stool suffered more damage from modified. Damage from modified was due to the outside corner leading. Cutting back the outside corner did reduce damage in soils, which loosely supported the stool. However, shoot counts four weeks after harvest showed no differences between treatments.

5.0 OUTPUTS

Technology transfer

The following is a list of major technology transfer activities held during the life of BSS227.

1999

- BSES Field Days: Central District, Ingham, Meringa and Mossman
- Articles: Bush Telegraph, Sugar Times, “Sugar 2000” Publication, and QLD Country Life
- Mackay BSES Newsletter
- BSES Corporate Video

- BSES information meetings in the far north and in the Burdekin
- QMCHA - Harvester and Transport Expos
- Harvesting Best Practice Manual (Draft 1)
- Mackay Cooperators workshop for feedback of trial results
- South Johnstone, Mourilyan and Mulgrave Productivity Awards
- Tully Post-Season Harvester Workshop for harvester owners and operators
- Mackay trial results booklet

2000

- BSES Bulletin January 2000
- Mackay district pre-season farmer shed meetings
- SRDC Review: Best Practice Projects
- Tully Harvest Information day for advisors
- Burdekin Greyback Cane Grub Consultative Committee Meeting
- Herbert Cane Harvesting Forum: harvester owners/operators and growers
- Extension package to Tableland Mill harvester crews and their growers
- BSES Field Days (Central, Ingham, Tully and Meringa)
- Articles: Bush Telegraph and Sugar Times Supplements for Central District Field Day
- Modified Fronts Field Days (Ilbilbie and Dalbeg)
- Harvesting Information Meeting (Mulgrave Mill)
- CP2002 Best Practice project leaders meetings
- Harvesting Best Practice Cooperators Feedback Meeting (Mackay/Burdekin)
- QMCHA Harvesting and Transport Forums
- Harvesting Best Practice Manual (Draft 2)
- Mackay and Burdekin trial results booklet

2001

- Isis Clean Cane Committee Harvesting Efficiency and Cane loss Information meetings
- Stakeholders Meetings: Bundaberg and Sugar Mackay
- Northern Harvesting Information Forums: Ingham, Innisfail, Mossman, Tablelands and Inkerman
- Northern NSW (Harwood) Harvesting Information Forums
- Articles: Bush Telegraph, QCL, Sugar Times and Bush Telegraph, CANEGROWER magazine and BSES Newsletter and Central District Field Day Supplements
- BSES Field Days: poster presentations at Meringa, Burdekin and Mackay
- FNQ Grower Shed Meetings
- Tully Cooperators Information Meeting
- BSES/EHS Machinery Harvester Front Field Day
- Burdekin BSES Front Field Day
- ISSCT presentations at Mackay
- Wang Kanai Sugar presentation at Mackay
- Farmer information meetings: Mackay District
- QMCHA Harvesting and Transport Expos
- BSES Newsletter
- Mackay/Burdekin Cooperators Feedback Meeting
- Mackay and Burdekin trial results booklet

2002

- CSR Productivity review: supply of project outcomes
- HBP: The money Issues “handout” distributed at central and north Queensland HBP Information Forums
- Harvesting Information Forums at Koumala, Mackay, Proserpine, Ayr, Ingham, Tully, Innisfail, Mulgrave, Mossman and Walkamin
- Presentation of paper (Increased sugar industry profitability through harvesting best practice) at ASSCT in Cairns
- HBP issues discussed at central district Prosper farmer discussion groups in May. HBP also featured in Burdekin, Herbert and far north Queensland farmer discussion groups in May/June with 50-90% grower attendance
- Publication of The Harvesting Best Practice Manual

6.0 EXPECTED OUTCOMES

The original project proposal stated the following expected outcomes: improvement in ccs in the order of 0.5 unit, reduction in extraneous matter (including soil) levels in the cane supply by 3%, reduction in cane loss by 1% and a reduction in stool damage resulting in improved growth of ratoon crops.

By adopting best practice harvesting technology (specifically lower pour rate and fan speed) an extra \$100/ha plus should be available for the industry. If 50% of farms adopt HBP then it is worth approximately \$20 million per year to the industry. This benefit is primarily due to reduced cane loss because of lower primary extractor fan speed. The slower machine forward speed produces a lower flow of cane through the harvester, which gives more opportunity for cleaning and a reduction in extraneous matter. This usually results in a higher ccs being achieved. The lower forward speed also means less opportunity for intake of soil in supply.

Other benefits include reduced cane loss through adoption of modifications like the extractor paddle, lower soil in cane through matching row profile to basecutter angle, lower soil intake and less stool damage and better cane quality through the promotion of new BSES harvester fronts, better understanding of the costs of harvesting through logging and individual block assessments.

Per cent soil in supply at Tully fell from 2.1 in 1999 to 1.88 in 2001. Mud solids per cent cane fell from 0.82 in 1999 to 0.76 in 2001 at Mackay Sugar (Table 3).

CCS, in isolation of other parameters, increased by 2.06, 1.36 and 1.26 units at Mulgrave, Tully and Mackay Sugar respectively, between 1999 and 2001 (Table 4). However, tonnes of cane per hectare decreased by 16.5, 4.0 and 18.2, respectively, over the same time frame. Other factors including excessive rainfall, damage from wet 1998 harvest, rats and orange rust disease had a dominant impact on northern and central production.

Table 4 - Changes in ccs, tonnes cane per hectare and tonnes sugar per hectare between 1999 and 2001 for Mulgrave, Tully and Mackay sugar mills.

	Mulgrave	Tully	Mackay Sugar
CCS	+2.06	+1.36	+1.26
TCPH	-16.5	-4.0	-18.2
TSPH	-0.41	+0.40	-1.66

7.0 FUTURE RESEARCH NEEDED

Areas that require further research include:

- improving the cane quality feedback system for the harvester operator, grower and miller;
- harvester payment system: implementing change in the field;
- extended hours harvesting: case studies;
- improving the efficiency of cane harvesting and transport to the mill (CSIRO/BSES Project 2002/2005).

8.0 RECOMMENDATIONS

1. Lower pour rate and primary extractor fan speed operation will provide more profit for the industry.
2. System of harvester payment must be changed so that quality of harvest job is rewarded and growers with efficient farm layouts are rewarded.
3. Harvest planning (grower, contractor and mill) on a block- by- block basis should be adopted to match mill transport, harvest job quality, WPHS and growers reasonable expectation of harvest job.
4. A better system of cane quality feedback is required to grower and harvester. This includes real time in-cab feedback of harvest job as well as timely, detailed feedback from the mill.
5. Development of an economic, accurate and robust cane loss monitor for the harvester operator is a priority.
6. Forward speed monitor mandatory on cane harvesters.
7. Promotion of harvest crew record keeping using log-books and elevator hour-meter. This will help the contractor better understand costs as well as provide information for differential charging.
8. The role of farmers in presenting cane to maximise quality and quantity of cane harvested, needs to be better acknowledged. This will happen when growers are paid on individual cane quality supplied.
9. Ways of encouraging good operators (harvester and haulout) to stay in the industry needs investigating.
10. Support for scientific evaluation of harvester modifications, methods of operation and farming practices that are claimed to improve profitability.

9.0 LIST OF PUBLICATIONS

BSES Bulletin

1999-2000

Agnew, JR and Sandell, GR (2000). Harvesting Best Practice: Mackay experience. BSES Bulletin 69:14-15.

2000-01

Stainlay, GT (2001). Best is less. BSES Bulletin 73:16-17.

Sandell, GR (2001). New cane loss monitor. BSES Bulletin 75:12.

2001-02

ASSCT Paper

Presented at the 24th Conference of the Australian Society of Sugar Cane Technologists held in Cairns from 29 April to 2 May 2002 and published in the Proceedings of the Society for the 2002 Annual Conference.

Agnew, JR, Sandell, GR, Stainlay, GT and Whiteing, C. Increased Sugar Industry Profitability Through Harvesting Best Practice pp. 184-189.

Other Publications

The Harvesting Best Practice Manual

Sandell, GR and Agnew, JR Eds (2002). The harvesting best practice manual for chopper extractor harvesters. Bureau of Sugar Experiment Stations, Indooroopilly 2002.

Harvesting Best Practice: The Money Issues

Agnew, JR and Sandell, GR (2002). Harvesting best practice: the money issues. Bureau of Sugar Experiment Stations, Mackay 2002.

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APPENDIX 1

TRIAL METHODS

1. Methods

- Most trials were fully replicated.
- For each replicate we would measure the following.
 - Rake weights.
 - Individual fibre.
 - Individual ccs.
 - Dirt levels.
 - All machine data.
 - Crop data (eg variety, lodged, weeds etc.).
 - Field data (eg row profile, row width, soil type etc.).
 - Other data as appropriate.

Large samples of cane product were collected from the bins at the siding. These samples were used to determine the extraneous matter (EM) of each treatment. Each sample was sorted into millable cane, suckers, tops, stool, soil and other extraneous matter (see table below).

REP	EM by weight [%]				
	cane	tops	leaf	stool	Error
1	86.3%	5.7%	4.8%	3.0%	0.2%
2	82.8%	6.4%	4.0%	6.5%	0.2%
3	85.6%	5.8%	4.3%	4.1%	0.2%
No Fans	65.7%	10.4%	22.8%	1.1%	0.0%

- From these samples, millable cane billets were further sorted by length and then by billet quality classifications of sound, damaged and mutilated.
- A ‘No fans’ treatment was conducted. In this treatment, all extraction equipment (topper and primary and secondary extractors) was turned off. This treatment was used to determine the total crop present in the field. Extraneous matter samples (as outlined above) were used to convert total yield into total millable cane available for harvest.
- In the same way, total yield for each treatment was multiplied by % cane for each treatment. This determines total harvested millable cane for each treatment.
- Harvested millable cane for each treatment is subtracted from the total millable cane derived above. The difference between these figures is mass balance cane loss.
- The tarp method was also used to measure cane loss.

APPENDIX 2

THE DATA LOGGING SYSTEM AND MACHINE DATA

1. What does it do?

Monitors and records important machine variables for later download by lap top computer. Data are date and time stamped.

➤ These variables are as follows.

- Fan speed
- Ground speed
- Basecutter pressure
- Chopper pressure
- Elevator on/off
- Top roller opening position

➤ Example data

Date	Time	Fs rpm	Gs km/hr	Base psi	Chop psi	Ev off sec	Roller opening scale: 1.3 to 2.5
10 Oct 99	08:15:00	1,012	4.6	1,227	2493	2	2.035
10 Oct 99	08:15:20	312	0.3	308	397	20	1.300

➤ Trial machines had in-cab display of:

- ground speed;
- top roller position.

2. How is its used?

- Produce baseline data to compare machine performance.
- Calculate other important machine parameters such as field efficiency, downtime and turning time.
- Linked to mill data such as ccs, crop yield and variety.
- This system enables the team to perform accurate trials.
 - In-cab displays enable the operator to maintain a constant ground speed.
 - Logger system records ACTUAL machine parameters.

APPENDIX 3

HARVESTER SPECIFICATIONS (MACKAY AND BURDEKIN COOPERATING GROUPS)

1. Owner: Case Austoft

Make and model

- 2001 prototype tracked Austoft.

Chopper box

- Four-blade Austoft differential chop at 15" centres.
- Blades were in good condition.

Extractor

- 4' 6" vertical arm prototype extractor.

Basecutter

- Leg box fitted with automatic basecutter height control (Schembri, SRI). Discs have five blades per disc.

Other

- A wider front end for improved feeding.

2. Owner: HCL Harvesting, a grower co-operative

Make and model

- 1995 wheeled Cameco.

Chopper box

- Six-blade Trail Bros pinch chop at 12" centres.
- Trail Bros shafts with bevelled keepers.
- Blades were in good condition.

Extractor

- 4' vertical arm.
- Standard blades.

Basecutter

- Leg box.
- 6 mm hard-faced blades.

3. Owner: DC and FL Bowman

Make and model

- 1994 tracked Austoft.

Chopper box

- Four-blade (ie 2 blades per drum) Austoft chop at 12" centres.
- Blades were in good condition and were sharpened between replicates.

Extractor

- 4' vertical arm.
- Standard length $\frac{3}{4}$ pitch blades.

Basecutter

- Underslung box with increased horsepower and rpm.
- Six-blade scalloped discs.
- 5 mm blades in good condition (square ends).

4. Owner: Oakenden Harvesting, a grower co-operative group

Make and model

- 1997 tracked Austoft T7700.

Chopper box

- Westhill six-blade chop at 15" centres.
- Blades were in good condition.

Extractor

- 4' 6" vertical arm with a standard plastic hood.
- Standard primary blades.
- Extractor paddle fitted.
- Standard secondary extractor.

Other

- Six-blade basecutters with 6 mm blades.

Haulouts

- Two 35 m³ JCB/Corridinni elevated tippers.

5. Owner: Gary Crossley

Make and model

- 1996 tracked Austoft T7700.

Chopper box

- Eight-blade Trail Bros Experimental chop at 15" centres. These shafts have vastly increased clearance and increased overlap. It is claimed that this set-up reduces chopper pressure by as much as sixty per cent.
- Blades were in good condition.

Extractor

- 4' 6" horizontal arm.
- Standard blades that are 12 mm shorter.
- Standard blades on the secondary.

Other

- Five-blade base-cutters.

6. Owner: P Borg

Make and model

- 1994 wheeled Austoft.

Chopper box

- Six-blade Austoft differential chop at 15" centres.
- Blades were in good condition.

Extractor

- 4' 6" vertical arm extractor.

Basecutter

- A leg box.
- Five-blade discs and the blades were 5 mm blades.

7. Owner: Don Hamilton

Make and model

- 1995 tracked Austoft T7700.

Chopper box

- Six-blade Trail Bros chop at 12" centres.
- Blades were in good condition.

Extractor

- 4' horizontal arm.
- Standard blades that are 12 mm shorter.

Basecutter

- Leg box.
- Modified large discs with blades mounted 14° into the cut. 6 mm blades.

8. Owner: Kane Family**Make and model**

- 1997 tracked Cameco. 348 hp overrated Caterpillar engine.

Chopper box

- An eight-blade Westhill chop at 15" centres.
- Blade edges were average but the blades were bedded in well.

Extractor

- 4' vertical arm.
- Full pitch blades with a Greeves hood.
- Secondary.

Basecutter

- Leg box.
- Six-blade discs.
- 5 mm blades that were new at the start of the trial.

Other

- Variable basecutter rpm.
- Hydraulically adjustable basecutter angle.
- Variable chopper rpm.

9. Owner: Charlie Galea**Make and model**

- 1996 tracked Austoft T7700.

Chopper box

- Eight-blade Galea chop at 15" centres.
- Blades were in good condition.

Extractor

- 4' 6" vertical arm with a standard plastic hood.
- Standard primary blades.
- $\frac{3}{4}$ secondary extractor 20 mm short.

Basecutter

- A leg box.
- Five-blade base-cutters with 5 mm blades.