BUREAU OF SUGAR EXPERIMENT STATIONS

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EVALUATION OF THE CHOP-THROW SYSTEM FOR INCORPORATION IN A TWO-ROW HARVESTER

by
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SD00020

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EXECUTIVE SUMMARY

This report outlines a three-year project to develop a two-row, chop-throw harvester in conjunction with a Bundaberg innovator and evaluate its performance under commercial conditions. The role of the BSES in this project was to provide some technical input into cleaning system design, and to evaluate field performance.

The first version of the harvester was completed prior to the 1993 harvest season and it was used commercially in cutting mainly burnt cane during the 1993 season. This version incorporated many of the features of the semi-commercial Cannavan harvester developed in the Burdekin. Performance in terms of cutting rates and billet quality was satisfactory initially, but cleaning with gravitational separation of cane components was relatively poor. There were also difficulties with wrapping of green cane leaves on the chain feed top roller system, and damage to the chop-throw mechanism by foreign objects.

The harvester was extensively modified in the first half of 1994 to include a conventional top roller system, a shorter thrower chute, a safety shear device on the thrower, and a blower cleaning system injecting a narrow jet air just above the thrower. The location of the air jet was based on parallel studies with a single-row machine in which billets were shown by video photography to be oriented parallel to the thrower for a short distance after chopping. Testing of harvester performance in the 1994 season showed that feeding of cane was excellent and very high pour rates could be achieved. Loss of cane due to breakage of stalks of the brittle variety Q141 was reduced by the flat feed train, and visual soil levels in the cane supply were very low. However billet quality was poor and the cleaning system was relatively ineffective in removing leaf and trash from the cane supply. The poor billet damage was in part due to damage to the chop-throw mechanism. Parallel evaluation of the performance of several prototype single-row harvesters showed that improved billet quality could be achieved in a correctly adjusted chop-throw system. Several cleaning systems were evaluated in these harvesters and cleaning efficiency was satisfactory at relatively low pour rates.

Tests at the end of the 1994 season showed that the design air velocities were not being achieved at the blower outlet, and that the thrower draft was diverting airflow up the thrower chute. The poor fan performance was attributed to excessive backpressure on the fan due to the outlet duct shape and a grate at the outlet. As a result of these tests the blower system was re-designed for the 1995 harvest season to upgrade air output, improve the directional control of air flow, and reduce back pressure on the blower. Tests conducted with no cane present showed that fan output was significantly improved. The safety device on the thrower system was upgraded to an electro-magnetic system.

Limited testing of the improvements was possible in the 1995 season due to repeated breakdowns, but cleaning was observed to be improved significantly. However, it was still inferior to current commercial single row harvesters. The modified chop-throw device with a safety mechanism was not robust enough for commercial operation in difficult field

conditions and this led to the eventual abandonment of the chop-throw principle by the harvester developer.

It was evident during this project that background research under non-commercial conditions was required to perfect the chop-throw device and design a suitable cleaning system. The various cleaning systems tried on prototype chop-throw harvesters were not optimised due to commercial pressures, and it is recommended that modelling of the chop-throw cleaning system be carried out to assess cleaning potential before further commercial development is attempted.

1..0 BACKGROUND

Trials over a number of years with conventional harvesters have shown that cane losses through the cleaning extractors in green cane range from 2-15%, depending on variety, crop conditions and harvester settings. Several SRDC funded projects conducted by BSES (Ridge and Pearce, 1996; Linedale and Ridge, 1996) have shown that cane losses can be reduced with current systems, but there is a penalty of increased leaf and trash in the cane supply. The extraneous matter problem is particularly serious at high harvester pour rates. It is expected that improvements in extractor chamber design will give only marginal improvements in leaf and trash rejection at low cane loss levels.

Project BS26S (Ridge *et al.* 1994) on harvester modifications for improving dirt rejection has shown that only minor improvements can be expected with the current harvester single-row harvester feed train. Two-row operation allows reduced ground speeds for the same cane output, and this combined with a flatter feed train in the chop-throw harvester, offers the opportunity for further reduction of dirt levels.

The chop-throw system was initially developed and tested for single-row operation. The initial prototype single-row machine developed by the Cannavan family was operated semi-commercially in the Burdekin area for several years in conjunction with a conventional chopper harvester. In burnt cane this harvester was capable of cutting at high rates and handling large lodged cane. The chop-throw principle shows promise for more efficient separation of cane from leaf and trash than the current chopper harvester cleaning system. The potential contributing factors are the alignment of billets leaving the thrower, and the high initial velocity of cane and extraneous matter, possibly allowing use of higher air velocities in the cleaning system without excessive cane loss. It is believed that the chop-throw system has more potential for effective cleaning with minimum cane loss than the conventional harvester. In addition, development of a two-row machine would allow relatively low material flow rates within a wider feed train for a given pour rate, aiding the cleaning process.

This report deals with the development of a two-row commercial chop-throw harvester and discusses parallel work with single row machines.

2.0 OBJECTIVES

- Incorporate the chop-throw system in a two-row harvester.
- Develop a suitable cleaning system for minimising EM levels with the chop-throw system.
- Evaluate the performance of the chop-throw system in terms of billet quality, cane loss and extraneous matter separation.
- Evaluate the benefits of the flatter feed train for minimising stalk breakage in brittle varieties and increasing dirt rejection.

3.0 METHODOLOGY

In Year 1 of the project, the chop-throw system was to be incorporated into a two-row harvester by the commercial partner Mr D J Young for use in a large commercial harvesting contract in the Bundaberg district. The harvester was to be modified to give a flatter feed train, with the chop-throw system being used to lift cane onto the elevator for delivery to mill bins. A suitable cleaning system was to be incorporated in the thrower chute to complete partial separation of leaf and trash from cane achieved in the thrower.

Any necessary adjustments and modifications to the chop-throw system were to be carried out in consultation with the inventor Mr Chris Cannavan and the potential manufacturer Bonel Limited.

Preliminary testing of the performance of the chop-throw mechanism was to be carried out during the 1993-harvest season. This was to include measurement of billet quality and length, and extraneous matter levels in green and burnt cane. The effectiveness of the modified feed train in reducing stalk breakage in brittle varieties and dirt levels in the cane supply was also to be assessed.

The chop-throw mechanism and cleaning system was to be modified, depending on trial results in the 1993 season.

Final evaluation of the harvester was to be carried out during the 1994 harvesting season with testing and modification being completed by December 1994. Testing extended into 1995 to evaluate modifications of the cleaning system.

4.0 RESULTS AND DISCUSSION

4.1 Commercial development stages

Construction of the dual row harvester was completed on schedule prior to the 1993 season, allowing preliminary evaluation during the season. The layout of the chop-throw mechanism and thrower chute is shown in Figure 1. The harvester was used commercially during the 1993 season, mainly in burnt cane. It was noted that extraneous matter levels were unacceptably high in green cane. In addition it was noted that the floating chain-driven top feeding device initially fitted in the chop throw harvester (similar to that in the prototype Cannavan harvester) was subject to wrapping of leaves and stalling in green cane. Part of the commercial contract involved cutting in rocky conditions, and this resulted in damage to the chopper system, including twisting of the thrower blades. The susceptibility to damage led to considerable time being spent developing a safety shear device to limit such damage. At this stage the harvester had limited cleaning ability associated with natural separation of cane and leaf and trash by gravity during the throwing operation.

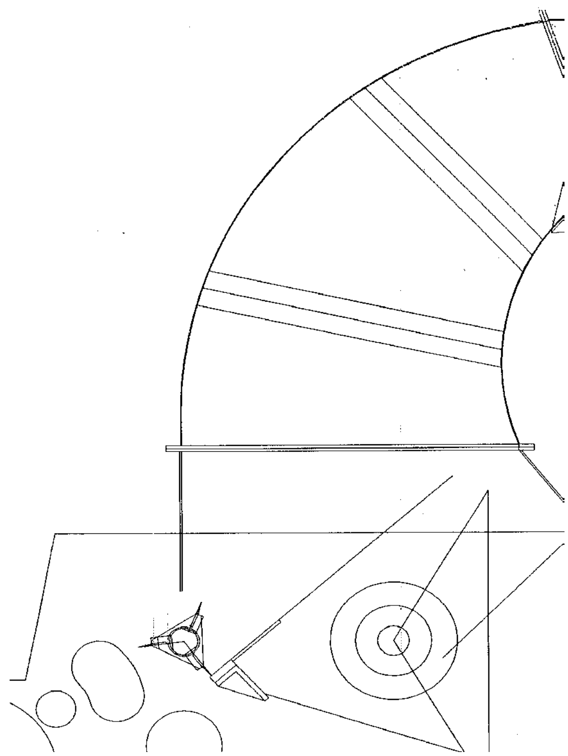

Figure 1 **Diagrammatic representation of the chop-throw mechanism showing the chopper drum, thrower drum and thrower chute in relation to the top of the feed train**

After the 1993 season the harvester was extensively modified to reduce the chute height, provide a blower cleaning system close to the chop-throw mechanism, and replace the chain and slat top feeding device with rollers. The safety device on the chop-throw mechanism was also modified. These modifications were completed in September 1994.

Separate blowers with a common drive shaft fed air across the thrower chute from front to back, just above the thrower. The delivery vent was 100 mm x 686 mm, and was fitted with a barred grid at the entry to the thrower chute. Airflow into the chute was directed at a downward angle of approximately 30 degrees. The harvester operated in this configuration in the Bingera mill area until the end of the 1994 season, and cut a substantial tonnage (Plates 1 and 2).

Plate 1 - Side view of the Young dual row, chop-throw harvester

Plate 2 - Rear view of the Young two row, chop throw harvester showing the outlets of the twin blower cleaning system

At the end of the 1994 season it was evident that the cleaning system required re-design to improve cleaning, and that there were problems with excessive billet damage and the safety mechanism on the thrower. The latter problem was leading to frequent failure of the chop-throw mechanism.

Prior to, and during the 1995 season, the blower system capacity was upgraded and the delivery chute modified to straighten airflow into the thrower chute. The grates on the blower outlets were removed to reduce backpressure on the blowers and improve airflow. An electromagnetic lock was fitted to the thrower to protect it against damage by foreign objects. The blade keepers on the chopper were also modified in an attempt to reduce billet damage. The outlet of the cleaning system was also modified to prevent trash falling into the delivery elevator. The harvester was used intermittently during the 1995 season, again with relatively poor cleaning performance in green cane and frequent breakdowns of the chop-throw system.

4.2 Blower and cleaning chute design tests

During the 1993 season it was noted that trash was not clearing the thrower chute outlet despite the fitting of a roller at the outlet to help prevent catching of trash on the bottom edge of the outlet. Following the 1993 season experiments were conducted with varying thrower speeds to determine the optimum height of the thrower chute to give effective trash clearance, and to observe gravitational separation of billets and leaf and trash. The height of the thrower chute was subsequently reduced to improve separation of billets and trash.

Video photography was conducted on a single-row prototype harvester to determine billet orientation and trajectory of different cane components in the thrower chute. The single-row machine was most suitable for these studies due to ease of access. Frame by frame slow speed replay of the video indicated that billets were oriented parallel to the thrower blades for a significant distance after leaving the thrower. This suggested that supplementary cleaning by a blower or extractor should take place as close as possible to the thrower to take advantage of the preferential orientation of billets. The flow of air should be directed from front to rear in a backwards-curved thrower chute to take advantage of natural gravitational separation of cane components. The blower outlet was located adjacent to the thrower as a result of these trials.

The initial blower system fitted prior to the 1994 season was calculated to produce an air velocity across the thrower chute of 21.6 m/s through the 0.07 m^2 outlet vent, assuming a back pressure on the blower equivalent to 75 mm of water. The blower used was designed to operate with minimal backpressure. It was noted at the time that the blower system on the Claas green cane harvester delivered 20-40 m/s through a 100 x 1200 mm outlet (0.12 m^2)

As a result of the poor cleaning performance in the 1994 season tests were conducted in December 1994 to determine actual air flows from the blowers, and the fan back pressure. It was found that the back pressure on the blower was 187 mm of water with the outlet grid in place, and 134 mm of water with the grid removed. The measured air velocity from the fan outlet with the thrower operational was 1.5 m/s with the grid removed, and 0.8 m/s with the grid in place. The grid bars were estimated to reduce the effective outlet area of the fan vent by approximately one third. With the thrower non-operational and the grid removed, the air velocity was 5 m/s. The main conclusions drawn from these tests were that the outlet grid should be removed, fan capacity boosted significantly, and the blower delivery chute reshaped to deliver air at right angles to the flow of cane. It was felt that this would help overcome the obvious interference of the updraft from the thrower with the blower air flow.

Following fitting of new backward curved fans with a nominal outlet air velocity of 40 m/s at up to 500 mm of water back pressure further tests of fan performance were conducted in March 1995. It was found that the air velocity averaged 31.3 m/s across the original 0.17 m^2 outlet vent with the thrower non-operational. Further testing in April using a smoke generator showed that the air trajectory was improved with and without the thrower operating. For an enlarged fan outlet 0.11 m^2 in area the fan back-pressure was 50 mm of water. With the thrower operating the outlet air speed was approximately16 m/s. The harvester designer, Doug Young, planned to increase this to 32 m/s by increasing the blower drive speed.

It was not known how the flow of cane and trash across the path of the air jet would influence air flow and cleaning performance.

4.3 Billet quality testing

The performance of the double row machine was assessed in relation to concurrent work with different models of single row machines. Billet quality of single row chop-throw harvesters is summarised in Table 1. It should be noted that these machines had cut limited tonnages and the chop-throw mechanism was not worn or damaged. Also these trials were conducted at relatively low pour rates of 40-60 tonnes per hour.

TABLE 1
Single row, chop-throw harvester tests of billet quality, billet length and chopper loss

Harvester	% Sound billets	% Damaged billets	% Mutilated billets	Billet length mm	Chopper loss %
Cannavan*	57.7	30.8	11.5	158	2.7
Bonel (1994)*	77.3	22.7		249	
Bonel (1996)**	55.1	34.9	10.0		

* Three trials
** Four trials

Results of similar tests on the 2-row machine conducted in late 1994 are given in Table 2.

TABLE 2
Double row, chop-throw harvester tests of billet quality and billet length

Trial details *	% Sound billets	Billet length mm
Trial 1 Q141- Chop throw	40.1	
Q141- Walker Mizzi	76.8	
Trial 2 Q141	39.5	191
Trial 3 CP51-21	54.3	195
Mean- Chop throw	**44.6**	

* Trials conducted in burnt cane at pour rates of 190-200 tonnes per hour

These trials indicate relatively poor billet quality in the two-row, chop-throw machine compared to single row chop-throw harvesters, and the commercial two-row Walker Mizzi harvester fitted with a drum chopper. Inspection of the two row harvester at the time of the tests indicated some damage to the cutting anvil on the thrower, and some twisting of the thrower arms, giving uneven meshing of the chopper blades and thrower cutting anvil. This points to the need for a readily replaceable cutting anvil on the thrower, and a robust safety device on the thrower to minimise damage by foreign objects passing through the harvester. Later development of safety mechanisms led to loss of some of the robustness of the original fixed system, and there is an inherent difficulty in developing such a system with the high momentum of the thrower, and the forces generated.

4.4 Extraneous matter removal

The billet quality trials outlined above included an assessment of extraneous matter levels with single and dual row harvesters, and the results are summarised in Table 3.

The Bonel single row machines tested in 1993, 1994 and 1996 represent three types of cleaning systems, and the Cannavan (Plate 3) was tested with only gravitational separation of cane components. These are all different in configuration to the Young dual row, chop-throw.

TABLE 3
Extraneous matter levels for single and dual row, chop-throw harvesters, the Austoft 7000 and the Walker Mizzi dual row harvester

Trial Details		Final EM %	Pour rate t/h
Cannavan single row chop-throw (G)		11.9	60
Bonel (1993) S/R chop-throw	Q141	4.2	40
	CP51-21	7.9	40
Austoft 7000	CP51-21	8.0	80
Bonel (1994) single row chop-throw (G)		4.5	30-60
Bonel (1996) single row chop-throw (G)		6.5	40-50
Young dual row chop-throw (Q141a) (B)		5.0	190
Walker Mizzi dual row	(Q141a) (B)	3.5	180
Young dual row chop-throw (Q141b) (B)		5.0	200
Young dual row chop-throw (CP51-21) (B)		7.5	200

* G = green, B = burnt

Plate 3 - Cannavan single row, chop throw harvester without a blower cleaning system fitted

The 1993 Bonel harvester (Plate 4) had a blower mounted midway in the thrower chute directing air from front to rear at a downward angle of approximately 30 degrees. This system and the Cannavan harvester gave only moderate cleaning efficiency as demonstrated in Table 3, considering the relatively low pour rates. In the 1993 tests the cleaning efficiency was approximately equivalent to that in a commercial Austoft 7000, but at half the pour rate.

Plate 4 - The 1993 Bonel single row, chop-throw harvester, constructed in the Burdekin by R Gendrolius, and fitted with a blower cleaning system

The 1994 Bonel harvester (Plate 5) had an extractor mounted at the top of the thrower chute. Cleaning was very effective at the relatively low pour rates used in the trials with very little trash remaining in the cane supply (Table 3). The high cleaning efficiency was attributed to a partial mechanical separation of billets in the thrower chute by deflection of billets downwards at the bend in the top of the chute. This principle is used in the Santal chop-throw harvester developed in Brazil. This design was not persisted with due to height limitations set by potential export clients.

Plate 5 - The 1994 Bonel single row, chop-throw harvester fitted with an extractor cleaning system at the top of the thrower

The 1996 Bonel harvester (Plate 6) had an extractor mounted on the front of the thrower chute just above the thrower, drawing trash forward through the mat of cane. This configuration was convenient for mounting of the extractor, but airflow is in the opposite direction to natural forces acting to separate cane components. Cleaning efficiency was inferior to the 1994 harvester (Table 3).

Plate 6 - The 1996 Bonel single row, chop-throw harvester fitted with an extractor cleaning system at the front of the thrower chute, just above the thrower

The trials with the Young dual row machine were conducted at commercial cutting rates equivalent to 90-100 t/h per row in burnt cane late in the 1994 season. With the initial blower design cleaning was relatively poor and inferior to the Walker Mizzi harvester. The poor cleaning was found to be due to very poor air flow through the mat of cane as discussed in section 4.2.

No testing was carried out in the 1995 season after modification of the cleaning system, due to difficulties in arranging access to the harvester while operating. The machine was frequently out of action for repairs during the 1995 season. Reports from the Bingera mill cane inspectors and Mr Doug Young indicate that cleaning efficiency was improved, allowing operation in green cane, but was still inferior to commercial single row harvesters.

It was evident from the above work with different cleaning systems that modelling of different design options would be beneficial in developing an effective cleaning system. Some experimentation with blower (or extractor) design would also be required in a non-commercial situation to optimise airflows for cleaning, both in terms of directional control and velocity of the air. It was apparent that the blower designs used in both the 1993 Bonel harvester and the Young harvester were giving insufficient air flow, and the air jet was considered to be too narrow for effective cleaning.

4.5 Cane pick-up losses, soil in cane

One important feature of the dual row, chop-throw harvester is the relatively flat feed train, made possible by the vertical throwing action after the chopper. The trials conducted in the brittle variety Q141 in burnt cane gave an opportunity to assess any benefit of the flat feed train in reducing cane loss in the feed train. Cane loss was measured at approximately 2 t/ha in the Young dual row, chop-throw compared to 4 t/ha in the conventional Walker Mizzi dual row. This is a significant advantage and was clearly evident in sections of cane blocks cut with the respective machines.

In the burnt cane trials no significant soil levels were evident in the cane supply for the chop-throw harvester, compared to visible soil in the conventional harvester under the same conditions. Again the flat feed train appeared to be giving a positive benefit.

4.6 Commercial limitations

At the current stage of development the chop-throw system has some serious limitations for commercial development. The main limitation is developing a robust chop-throw system with protection against serious damage from foreign material entering the cane supply, such as rocks and metal. The chop-throw device has not been developed to operate commercially with replacement of chopper components as required to maintain billet quality. The second limitation is in the cleaning system, with some experimental and modelling work required to determine whether the apparent advantages of high initial billet velocity and control of billet orientation will give better cleaning. Commercial systems tested in this project, with the exception of the 1994 Bonel single row harvester, were relatively ineffective in removing leaf and trash.

5.0 DIFFICULTIES ENCOUNTERED DURING THE PROJECT

The main difficulty encountered in this project was the limited opportunity for experimental work to develop the cleaning system. The commercial operation of the harvester meant that blower modifications were carried out between cutting seasons, and the modified system was then used commercially without prior field-testing. Problems with the thrower system occupied much of the development time put in by the designer, Mr Doug Young, and this further reduced emphasis on improving cleaning.

6.0 RECOMMENDATIONS FOR FURTHER RESEARCH

Further research on the chop-throw system should address three issues:

- The development of a robust chop-throw device, with in safety mechanisms to limit damage by foreign objects. This work should include development of the blade holding mechanism on the thrower and a replaceable thrower anvil to improve billet quality.
- Modelling work to optimise design and location of the cleaning system
- Experimental work to design a suitable blower or extractor to give the directional air flow required for effective cleaning (bearing in mind the effect of the thrower air draft on air flow)

While the flat feed train possible in a chop throw harvester gave some apparent advantages in reducing cane breakage and soil levels the above program would need to be weighed in terms of the probability of success.

7.0 APPLICATION OF RESULTS TO THE INDUSTRY

The project results have limited direct application in the sugar industry, but have highlighted the issues involved in developing the chop-throw principle. The chop- throw mechanism was shown to be one avenue for giving higher billet velocity after chopping, and controlled orientation of billets. Modelling studies in conventional cleaning systems suggest that this would allow use of high air velocities for cleaning with minimal cane loss.

8.0 PUBLICATIONS ARISING

There were no publications arising directly from this project.

9.0 REFERENCES

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