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OPTIMISING REJECTION OF DIRT BY CANE HARVESTERS

by
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CONTENTS

SUMMARY

Basecutter designs and dirt in the cane supply

Field comparison of scalloped basecutter design with standard basecutter discs indicated that dirt levels in the cane supply were reduced when cutting below ground level. The scalloped discs also reduced stalling associated with build up of soil on the underside of the disc when cutting in sticky conditions.

No difference in dirt levels was found in a comparison between underslung and leg type basecutter drives under dry conditions.

Buttlifter and feed roller improvements

Detailed measurements of stool dirt rejection by the buttlifter and feed rollers using a test rig gave the following findings:

- dirt rejection was increased by slowing buttlifter speed;
- dirt rejection was increased by spring loading the top floating rollers in the feed train;
- dirt rejection was increased with open slatted rollers on the bottom of the feed train; Open slatted rollers had the added benefit of reducing dirt build up on both top and bottom rollers in wet field conditions.

It was not possible to confirm the above findings in field trials under relatively dry conditions with the BSES harvester but operator experience supports both the slowing of roller speed and the use of open slatted rollers.

Croplifter flotation and gathering wall design

Field observations indicated that croplifter flotation on current model harvesters is adequate to minimise ploughing of soil by the croplifters and a similar design is recommended for modified harvesters. Similarly, gathering wall design was found to be adequate on modern harvesters and narrowing of floating shoes on some older model harvesters is being recommended to reduce intake of dirt.

Knockdown angle at harvesting

The knockdown angle of a range of standard harvesters was recorded together with the improvements achieved by either removing/adjusting the knockdown roller or moving the basecutter forward. A trial conducted with the BSES harvester, comparing the standard knockdown angle of 42° with a reduced knockdown angle of 60°, gave a small but non-significant reduction in dirt levels. It was noted that a number of harvesters operating in north Queensland have been modified to reduce knockdown angle and it is claimed that maintenance costs related to wear from dirt are reduced. Harvesters are able to operate in lodged cane in the absence of a knockdown roller to aid feed into the machine.

Automatic basecutter height control

Load sensing on the basecutter hydraulic circuitry was investigated as a means of sensing basecutter height but this approach was found to give inadequate discrimination. The use of ultrasonics was therefore investigated as an alternative for sensing and controlling basecutter height. This was found to be successful in lodged, burnt cane in the Burdekin but not in green cane where the sensing signals appeared to be reflected from green leaf material in the cane. The commercial ultrasonic height sensors used in this investigation were unable to discriminate between signals reflected from leaf material and true ground level. Ultrasonic sensing may warrant further investigation, using improved electronic filtration of the return signals or multiple head sensors.

Natural radiation measurement of dirt in cane

During this project, dirt levels in rakes of cane from the harvester evaluation trials were measured using two techniques - ash and natural radiation determinations on samples of prepared cane. It was found that the two techniques showed close agreement and similar precision in estimating dirt levels in cane. The natural radiation technique is very convenient for determining relative soil levels within the one soil type, but requires calibration for different soil types.

1.0 BACKGROUND

Reduction of dirt (or soil) levels entering the cane supply to mills during the harvesting operation is seen as having major importance to the sugar industry. Dirt causes serious maintenance problems in mills and harvesters due to its abrasive properties. Estimates of total costs in Queensland mills attributable to dirt in cane range as high as $30m annually. While it is likely that the potential reduction in maintenance costs is a much lower figure, there will be substantial benefits from reduced dirt intake by the harvester.

Previous research in project BS19S `Assessment of sugarcane harvester performance' indicated that in dry conditions a high proportion of loose dirt is rejected by the basecutter/buttlifter/bottom roller system in most harvesters. In moist conditions dirt rejection was less effective. Overall rejection of stool-attached dirt was less than for loose dirt and modifications such as spider basecutters, and open slatted or cage type barred rollers were found to increase rejection of stool-attached dirt. These studies pointed to the need for reducing potential intake of soil by harvesters in the field and modification of harvester design to increase soil rejection. Knockdown angle, floating shoe design, basecutter design, basecutter height setting and buttlifter and feed roller design were identified as potential areas for improvement.

Henkel *et al.* (1979) found that basecutter height setting had a significant effect on dirt levels in the cane supply and dirt levels were minimised if cane could be cut at ground level. Work by Musumeci (1989) suggested that cutting torque on the basecutter may be a useful index of basecutter height and allow automatic control of basecutter height.

This project addressed the above aspects of harvester design which influence dirt intake by the harvester and subsequent rejection within the harvester. While the work on basecutter height control was predominantly an SRI responsibility, the majority of the project was conducted jointly by BSES and SRI and a combined report has been prepared.

2.0 PROJECT OBJECTIVES

∃ Determine the effect of different basecutter designs on the level of dirt entering the cane supply.
∃ Research improvements to the buttlifter and feed train rollers to increase dirt rejection.
∃ Evaluate the potential for improving croplifter flotation and gathering wall design to reduce channelling of dirt onto the basecutters.
∃ Determine whether further reductions in knockdown angle prior to basecutting are feasible and whether this has potential for reducing dirt intake.
∃ Determine whether sensing of load on the basecutter or ultrasonic sensing of ground level can be used to control basecutter height setting.

3.0 METHODS

3.1 Preliminary surveys of harvester modifications

Early in the 1989 harvest season, SRI and BSES engineers visited north Queensland to survey harvester modifications for reducing soil intake and to observe field operating conditions which may influence the success of different modifications.

A further survey of modifications for soil removal during harvesting was carried out during the 1990 season in north Queensland.

3.2 Roller test facility studies

Detailed testing of roller performance in removal of soil was carried out in three stages.

3.2.1 Stage I (August-December 1989)

The BSES Austoft 7000 harvester was used to test dirt rejection by various combinations of rollers in the feed train. Rollers evaluated included a two-bladed buttlifter, and two- bladed open and tangential rollers at positions 3, 4 and 5 on the bottom of the feed train. In early tests, loose soil was mixed in with cane on the BSES test facility conveyor and fed into the harvester. Soil rejection by the basecutter, buttlifter and later rollers was measured using a specially designed tray placed under the harvester. In some tests dirt rejection by the elevator and primary extractor was also measured.

In later tests, a combination of loose soil and stools of cane with attached soil was fed with cane into the harvester. Stools of cane with attached soil were dug for use in testing using a specially designed digger mounted on the three point linkage of a tractor. Soil was again recovered from the basecutter, buttlifter, later rollers, extractor and elevator, and from the delivery bin to complete the mass balance for soil recovery. Soil moisture levels were recorded because it had been noted previously that soil rejection was higher in dry soil. Cane was irrigated where necessary to provide moist soil conditions.

3.2.2 Stage II (May-June 1990)

A duplicate of the roller train in the Austoft 7000 was constructed to allow video photography and physical measurement of dirt rejection by different roller combinations. The roller train was powered by a hydraulic test rig which allowed variation of roller speed through a control circuit.

Detailed testing of the efficiency and pattern of dirt rejection was carried out with various combinations of roller speed and roller type. Tests were carried out with whole stools of cane with attached soil. In some tests the floating top rollers were spring loaded to increase the break up of dirt attached to cane stools. Combinations included finned rollers, top and bottom immediately behind the buttlifter, slowing of the top finned roller and spring loading of the top finned roller.

3.2.3 Stage III (April-June 1991)

Following field trials in the 1990 season, a comprehensive series of tests was carried out with modified roller designs during the pre-season period in 1991, again with and without spring loading of the top floating rollers. In these tests the buttlifter roller speed was also varied and dirt rejection by the buttlifter and other rollers was recorded. Roller designs tested included a modified finned roller, a cage type roller, the tangential roller tested previously and open rollers throughout the bottom of the feed train. Video photography of the mechanism of dirt rejection was also carried out.

3.3 Field trials

Field trials were carried out with the BSES harvester in the Tully and Mulgrave mill areas during the 1990 and 1991 seasons to evaluate roller combinations developed in the bench testing program at Bundaberg. This region was selected for the tests because of the greater availability of stool tipped cane with attached soil and the likelihood of wetter harvest conditions. These tests were also used to evaluate a modified basecutter disc (scalloped disc) and to compare the standard Austoft 7000 knockdown angle for cutting cane with a reduced knockdown angle.

A trial was also carried out at Bundaberg to compare dirt rejection by the standard underslung basecutter on the Austoft 7000 harvester and a new leg basecutter developed for this harvester.

3.3.1 Field trials - 1990

During the 1990 season, the BSES harvester fitted with modified finned top and bottom rollers immediately behind the buttlifter was tested in the Tully and Mulgrave mill areas beside unmodified contractor machines. The top floating roller was spring loaded. Basecutter settings were maintained as consistently as possible between machines. Three rakes of cane were cut with each machine in a randomised pattern across the block. A composite prepared cane sample was subsequently taken from each rake in the mill for determination of soil content. Soil levels were estimated by ashing duplicate samples of prepared cane and measuring natural radiation levels on a bulk sample of prepared cane.

Four sites were selected for comparative tests between harvesters in each district and a further two trials were carried out at Tully to compare dirt intake with standard and scalloped basecutters fitted to the BSES harvester. Where possible, tests were carried out in cane which was partially lodged and stool tipped to accentuate potential dirt intake by the harvester. It was intended that tests would also be carried out in wet conditions but the small falls of rain at the start of the test period were followed by dry conditions.

3.3.2 Field trials - 1991

In 1991, a trial was again carried out in the Mulgrave Mill area with the BSES harvester to compare standard configuration of the harvester with decreased knockdown angle (knockdown roller removed) and with slower buttlifter speed combined with spring loading of the first top roller. The trial was carried out in partially stool tipped cane in relatively dry conditions.

A second trial was carried out to compare standard and scalloped basecutters in partially stool tipped cane.

Samples of prepared cane were again taken at the mill for ash and natural radiation determinations.

A small field trial was also carried out at Bundaberg comparing dirt rejection by the BSES harvester and a standard Austoft 7000. Samples for soil determination by ashing were taken from representative bins for each harvester.

3.3.3 Field trial - 1992

A trial was conducted on Fairymead Plantation early in the 1992 season to compare dirt intake with a standard underslung basecutter and a prototype leg type basecutter in an Austoft 7000 harvester. Samples for soil determination by ashing were taken from representative bins from each harvester.

3.4 Basecutter torque studies

The pressure drop across the hydraulic motor driving one of the two basecutter discs on an MF305 harvester was monitored during harvesting using pressure transducers linked to a datalogger. Results of three cutting conditions (about 50 mm above ground, ground level and about 50 mm below ground) were recorded. Results for a slow forward speed of harvesting were also recorded. Whole body modes of harvester vibration were monitored for correlation with the pressure fluctuations. Measurements of cutting resistance of the ground and cutting height of the harvester at test sites were also carried out.

3.5 Computer modelling

Survey data on row height and interspace height were taken in several blocks for use as inputs to a computer model of an automatic basecutter height control system. The model used various locations for a height sensing device and varying speeds of height response to sensor outputs. The model calculated indices of the amount of dirt cut by the basecutter and cane left in the field and the power required to operate the height control system.

3.6 Ultrasonic sensing of basecutter height

Trials were conducted with two commercial ultrasonic height control systems fitted to harvesters. These systems were supplied by K Eldredge Electronics Pty Ltd and Southcott Pty Ltd. Tests were conducted at Bundaberg and in the Burdekin, respectively. Both systems were evaluated by observation of operation under automatic control during harvesting of cane. Data in the form of reflections sensed by the K Eldredge Electronics system were recorded. The other system was evaluated by measurement of fuel consumption by the harvester and measurement of juice turbidity at the mill to provide an index of dirt in harvested cane. Manual harvester operation and automatic setting of basecutter height were compared.

4.0 RESULTS AND DISCUSSION

4.1 Preliminary surveys of harvester modifications

The preliminary surveys of harvester modifications identified several interesting roller designs which were included in subsequent trials. It was noted that most harvesters which had been retro-fitted with double croplifters for green cane harvesting had spring loading on the croplifters to minimise digging into soil during operation. This is a standard fitting on Austoft 7000 harvesters. It was also noted that while some old Toft 4000 and 6000 harvesters retained wide floating sidewalls to pick up lodged cane, which encouraged ploughing of soil onto the basecutter, later harvesters were operating effectively with narrow floating side walls. Several types of modified basecutter designs were also noted including scallops, spider basecutters and domed basecutter discs.

Other modifications noted included moving the basecutter forward in tracked machines and several wheeled machines to reduce the knockdown angle prior to basecutting, combined with changes to the buttlifter positioning; and removal of the knockdown roller to reduce knockdown angle.

4.2 Roller test facility studies

4.2.1 Stage I

The first trial in the initial series in 1989 involved comparison of a two-bladed buttlifter with a standard buttlifter for rejection of both loose soil and stool-attached soil. The design of the two-bladed buttlifter is illustrated in Figure 1. Results are given in Table 1. These show no significant benefit in soil rejection with the two-bladed buttlifter despite indications in an earlier project that the two-bladed buttlifter gave some break up of stool-attached soil. There was an obvious but non-significant increase in cane loss through the roller feed train with the two-bladed buttlifter.

Field evaluation is moist red soil showed that there was less build up of soil on the two-bladed buttlifter than on a standard three-bladed buttlifter but there again appeared to be more loss of cane in brittle varieties.

Table 1

Comparison of soil rejection between two-bladed and standard buttlifters for loose soil and stool-attached soil

Treatment	Soil rejection %		Cane loss %
	buttlifter	total	
Loose soil			
standard	6.6	29.8	1.7
two-bladed	5.9	30.3	2.4
lsd	ns	ns	ns
Loose plus stool-attached soil			
standard	11.3	63.0	3.1
two-bladed	11.7	69.7	4.0
lsd	ns	ns	ns

The second comparison in the roller tests on the BSES harvester was between standard bottom rollers and a combination of two- and three-bladed and tangential rollers in positions 3, 4 and 5, respectively. The tangential roller and three-bladed roller are also illustrated in Figure 1. Results are summarised in Table 2. These show a small but non-significant improvement in soil rejection by the modified rollers compared to standard rollers. There is a corresponding small but non-significant increase in cane loss through the roller train. The test roller combination corresponds to modifications noted in the initial field survey which were designed to increase soil removal in the roller train. The small improvement in soil removal, combined with additional cane loss suggests that this modification is not worth pursuing.

Because of the difficulty in assessing the mechanism of soil rejection by rollers in these initial tests with the BSES harvester it was decided to build an open roller test rig to allow high shutter speed video photography to be carried out during trials.

Table 2

Comparison of soil rejection between standard rollers on bottom of feed train and a combination of a two-bladed roller, open roller and tangential roller in positions 3, 4 and 5 behind the two-bladed buttlifter

Treatment	Soil rejection %		Cane loss %
	buttlifter	backrollers	
standard	11.4	21.2	4.0
modified 3, 4, 5	9.4	25.1	4.6
lsd	ns	ns	ns

4.2.2 Stage II

The pre-season trials in 1990 concentrated primarily on assessment of the effectiveness of sharksfin rollers in breaking up and rejecting stool-attached soil. Results of the first series of trials with sharksfin top and bottom rollers fitted immediately behind the buttlifter are summarised in Table 3. In these trials the top sharksfin roller was run at three speeds: 150, 90-97 and 56 rpm. The sharksfin roller is illustrated in Figure 1.

Table 3

Effect of top roller speed on rejection of stool-attached soil using sharksfin rollers behind the buttlifter

% dirt rejection	Top roller speed (rpm)			lsd 5%
	150	**90-97**	**56**	
Total	75.4	77.0	81.8	16.6
Rollers only	51.5	52.2	59.1	34.3

There was a trend for dirt rejection to increase as top roller speed was reduced particularly in moist soil, but this was not statistically significant.

In the second series of trials, the top sharksfin roller was run at a slower speed of approximately 60 rpm and it was spring loaded to increase breakdown of stool-attached soil. Table 4 summarises measurements of soil rejection.

Table 4

Effect of spring loading and slowing the top floating sharksfin roller on rejection of stool-attached soil

	% dirt rejection		lsd 5%
	spring loaded	**no springs**	
total	80.2	78.7	5.7
rollers only	65.3	53.6	15.4

Again there was a trend to greater soil rejection with spring loading of the top sharksfin roller but this was not statistically significant.

The third series of trials involved further evaluation of the effectiveness of spring loading the top floating roller both with and without sharksfins on top and bottom rollers. Results are summarised in Table 5. These tests utilised relatively moist soil compared to earlier trials.

Table 5

Effect of spring loading of the top roller on soil rejection with and without sharksfins on top and bottom rollers

Roller configuration	% dirt rejection	
	total	rollers only
fins + springs	78.7	65.3
standard rollers + springs	69.3	49.6
standard (no springs)	56.6	39.1
lsd 5%	10.9	10.2

In this series, spring loading of either finned or standard rollers gave a significant reduction in soil rejection. Finned rollers also proved superior to the standard rollers where both were spring loaded. These results led to field testing of spring loaded finned rollers in north Queensland on the BSES harvester during the 1990 season.

4.2.3 Stage III

A number of variations of roller speed and roller type were tested during the 1991 pre-season period at the Bundaberg test facility.

Buttlifter speed tests

The effect of varying the buttlifter speed on dirt rejection was tested first using speeds in the range 40-80 rpm, with 80 rpm being the standard speed on the Austoft 7000 harvester at that stage. Trial results are given in Table 6.

Table 6

Effect of buttlifter speed on total soil rejection and soil rejection by the buttlifter roller

Buttlifter roller speed (rpm)	% dirt rejection	
	total	buttlifter roller
80	52.1	15.1
60	58.1	17.9
40	67.4	24.9
lsd 5%	13.6	8.8

The trials indicate a significant increase in soil rejection as the buttlifter roller speed is reduced, partly through more rejection by the buttlifter itself, and partly by increased rejection by other rollers.

Open versus closed bottom rollers

A comparison of soil rejection by open and closed bottom rollers at the 40 rpm buttlifter speed was carried out following the buttlifter trials. Video photography of the mode of rejection of soil by open and closed rollers was also carried out. Results of the trials are summarised in Table 7.

Table 7

Comparison of soil rejection by open and closed bottom rollers at a buttlifter speed of 40 rpm

Bottom roller type	% dirt rejection	
	total	buttlifter roller
open	71.2	28.9
closed	61.8	19.6
lsd 5%	11.2	13.3

Soil rejection was greater with open bottom rollers compared to closed rollers, but the difference was not statistically significant. Video photography indicated that soil fell into the gap between the slats on the open rollers and then dropped out below, giving an apparent potential for greater soil rejection.

Finned versus non-finned rollers

A similar trial was carried out comparing finned versus non-finned rollers immediately behind the buttlifter in combination with a buttlifter speed of 40 rpm. Results are summarised in Table 8.

Table 8

Comparison of dirt rejection by finned and non-finned rollers in combination with a buttlifter speed of 40 rpm

Roller type	% dirt rejection		
	total	buttlifter	roller 2
fins	67	23.8	15.2
no fins	66	24.8	13.8
lsd 5%	4.9	6.1	3.3

There was no significant improvement in dirt rejection with finned rollers compared to standard rollers.

Combined test of open versus closed rollers with and without fins

A combined trial was carried out to compare soil rejection by open and closed bottom rollers with and without fins on the first top roller to break up stool-attached dirt. Results are summarised in Table 9.

Table 9

Comparison of dirt rejection by open and closed bottom rollers, with and without fins on the first top roller

Roller combination	% dirt rejection		
	total	buttlifter	roller 2
open bottom rollers	67.0	24.5	14.0
closed bottom rollers	59.2	18.1	14.6
open rollers + fins	67.7	28.4	13.0
closed rollers + fins	56.7	16.2	12.8
lsd 5%	11.9	14.3	4.0

There was a trend to greater total dirt rejection with open bottom rollers but there was no apparent benefit from the finned top roller.

Standard rollers versus finned rollers and cage roller combination

A second combined trial was carried out to compare standard rollers with finned rollers and a cage top roller in place of the fins. The cage roller and finned roller are illustrated in Figure 2. Trials were carried out with a buttlifter speed of 40 rpm. Results of this trial are given in Table 10.

Table 10

Comparison of dirt rejection by standard, finned and cage rollers

Roller combination	% dirt rejection		
	total	buttlifter	roller 2
standard	80.2	36.2	21.1
finned	82.5	37.0	19.9
caged	79.1	41.0	17.8
lsd 5%	7.3 (ns)	9.3 (ns)	2.9

This trial showed no benefit from the finned roller or cage roller combination compared to standard rollers.

Springs versus no springs on top rollers

The final trial, pre-season in 1991, compared spring loaded top rollers with standard free floating rollers. The method of spring loading the top roller is shown in Figure 3. Results are given in Table 11.

Table 11

Comparison of spring loaded top rollers with standard free floating rollers

	% dirt rejection		
	total	buttlifter	roller 2
springs	84.8	41.6	20.8
no springs	76.4	34.5	18.4
lsd 5%	8.2	10.0	3.6

This trial showed a significant improvement in total soil rejection where the top rollers were spring loaded.

As a result of the 1991 pre-season tests, the following combination of settings was selected for field trials in north Queensland with the BSES harvester in the 1991 season: buttlifter speed 40 rpm, first two top rollers spring loaded, open slatted bottom rollers. These three factors showed significant improvements in dirt rejection in the pre-season tests compared to the standard settings.

4.3 Field trials

4.3.1 Field trials - 1990

Feed roller evaluation

Results of the four comparative trials between the modified BSES harvester and `standard' commercial harvesters at Tully and Mulgrave are summarised in Table 12.

Table 12

Comparative trials between BSES and standard machines in stool tipped cane at Tully and Mulgrave Mills

Location	Trial	Harvester	Ash % cane	Total radiation count
Tully	1	BSES	3.23	10 912
		GP20	3.22	10 652
	2	BSES	1.11	4 714
		GP20	1.28	5 569
	3	BSES	1.18	5 940
		GP4	1.11	5 823
	4	BSES	2.76	11 075
		GP12	3.10	12 106
	Mean	BSES	2.07	8 160
		Other	2.18	8 538
Mulgrave	1	BSES	3.68	7 994
		GP20	3.06	7 083
	2	BSES	1.23	5 968
		Other	1.47	6 672
	3	BSES	2.98	6 327
		GP200	2.89	6 296
	4	BSES	2.74	6 714
		Galeano	3.29	7 581
	Mean	BSES	2.66	6 751
		Other	2.68	6 908

There were no significant reductions in dirt levels (as indicated by either ash readings or natural radiation counts) with the finned rollers fitted to the BSES harvester despite the promising results with the test facility. Subsequent tests with finned rollers suggest that any improvement in soil rejection will be only minor, contrary to the earlier findings. It was noted during the field trials that the feed of cane in the BSES harvester was slightly inferior to the commercial machines, in part due to the finned rollers. They were subsequently modified to improve feeding ability prior to pre-season testing in 1991. The modified finned roller is shown in Figure 4.

Readings of ash % cane and natural radiation on prepared cane samples in the field trials showed good agreement and similar precision.

Basecutter evaluation

Two trials were carried out at Tully in 1990 to compare dirt rejection with standard and scalloped basecutters. The scalloped basecutters are illustrated in Figure 5. Results of the Tully trials and a similar trial at Mulgrave in 1991 are given in Table 13.

Table 13

Comparative dirt levels with standard and scalloped basecutters when cutting below ground level

Trial	Basecutter	Ash % cane	Total radiation count
1	standard	5.7	19 637
	scalloped	3.1	11 843
	lsd 5%	ns	
2	standard	2.3	8 757
	scalloped	2.1	7 759
	lsd 5%	ns	
3	standard	3.8	14 140
	scalloped	2.4	8 156
	lsd 5%	0.4	
Mean	standard	3.9	14 178
	scalloped	2.5	9 252
	lsd 5%	0.9	

There was a significant reduction in dirt levels with the scalloped basecutters over all trials and a trend to lower dirt levels in each of the three trials. In addition, it was observed that the scallops assisted in reducing problems associated with dirt build up under the basecutter discs in sticky soils.

Knockdown angle

During the 1990 season, knockdown angle was recorded for a range of harvesters to determine the scope for reducing stool tipping at harvest and results are summarised in Table 14.

Table 14

Knockdown angles for modified and standard harvesters

Harvester type	Modification	Knockdown angle
Austoft 7000	standard	42□
	no knockdown roller	60□
	no knockdown roller, basecutter forward	62□
Toft 6000	standard	30□
	basecutter forward	35□
Alfarm Mizzi	standard	55□

4.3.2 Field trials - 1991

Mulgrave

Only one feed roller evaluation trial was completed in Mulgrave in 1991 due to the difficulty in locating stool tipped cane and rapid drying out after the only major fall of rain. In this trial three treatments were compared using the BSES harvester. These included normal operation, slow buttlifter speed plus spring loading of the top rollers and normal roller operation with the knockdown roller removed. Adjustment of buttlifter roller speed was achieved by using two small hydraulic motors (12" and 1:") as a flow divider. This gave a buttlifter speed of approximately 45 rpm. Results are given in Table 15.

Table 15

Ash and natural radiation levels with different modifications to the BSES harvester

Treatment	Ash % cane	Natural radiation count
1. Standard	1.85	6 588
2. Slow buttlifter plus springs	1.68	6 116
3. Knockdown roller removed	1.55	5 694
lsd 5%	ns	ns

There was a trend to lower dirt levels with both the slow buttlifter and springs and the knockdown roller removed but this did not reach statistical significance. Tests were carried out in only slightly moist conditions and this may have minimised the expected differences with different harvester settings.

Bundaberg

The trial comparing the modified BSES harvester with a standard machine was also carried out under dry conditions and only a small but non-significant difference in dirt levels was noted. Ash % cane was 0.75 and 0.85%, respectively, for the BSES and standard harvesters. Both machines gave low dirt levels.

4.3.3 Field trial - 1992

The field trial in 1992, to gather information on the difference between leg and underslung basecutters in dirt rejection, was again conducted under relatively dry conditions. No significant difference was detected between the two basecutter types with ash levels of 1.47 and 1.55% for leg and underslung basecutters, respectively.

4.4 Basecutter torque studies

Recorded hydraulic pressure drop across the basecutter motor for three different basecutter height settings and slow harvester speed is shown in Figures 6, 7, 8 and 9. The pressure drop showed greater fluctuation as the height was lowered and an overall increase in magnitude. Reducing the harvester forward speed reduced the amount of fluctuation in measured torque (Figure 9). There appeared to be no correlation between hydraulic pressure drop signals and vibration measurements on the harvester chassis. The increase in pressure drop as the basecutter is lowered suggests that pressure drop may be useful for sensing basecutter height but it was felt that signal fluctuation was too great for control purposes.

It was also felt that in addition to harvester speed variable resistance of the cane crop to cutting may influence basecutter torque. Another problem in using basecutter torque for height control was the wavelength of approximately 0.5 seconds of the torque signal. With additional averaging this would produce a long delay between successive control signals for changing basecutter height. Frequency analysis of the torque signal failed to identify any mechanical interference or possibilities for more rapid upgrading of successive torque readings.

In the early stages of the investigation attempts were made to characterise cutting resistance of the soil using a Scala dynamic cone penetrometer. Readings showed a wide spread and it is thought that this is an indication of the variability in resistance to penetration in the soil. This means that a height sensor which is dependent on cutting resistance may require considerable averaging to give a reliable indication of cutting height.

Two techniques were used to check basecutter cutting heights as an index of performance of a controller. Both the dumpy level and a profile meter lacked precision in some circumstances due to the difficulty in locating the true basecutter cutting position in loose soil.

4.5 Computer modelling

The preliminary data collected on height of the row and adjacent interspaces indicated that the height of the row relative to the mean of the interspaces varied by up to 50 mm with a wavelength of 2 m. This makes manual adjustment for such variations impractical where the harvester forward speed may be 2-3 ms^{-1}. It also means that an automatic control system needs to be updated rapidly for fine control of basecutter height.

The computer model was written to calculate indices of `dirt' and `air' to show cutting below or above ground, respectively, for either manual or automatic basecutter height control. The model was tested using measured row and interspace profiles from four field sites to show the effect of sensor positioning relative to the basecutter on height control, and the speed of adjustment required to optimise cutting height. Results indicated that height sensing should be as close to the basecutter as possible and that speed of height adjustment should be at least 25 mm per second to minimise the air or dirt index.

Engine power requirements for height adjustment calculated with the program were shown to be small and not significant.

The model was also used to calculate whether the air/dirt indices would be reduced with effective automatic control compared to manual control. Automatic control generally produced a significant reduction in the dirt index without a significant increase in the air index (indicating high cutting) for the measured field profiles. This suggests that effective automatic control with rapid signal upgrading should reduce dirt levels compared to manual control.

4.6 Ultrasonic sensing of basecutter height

The echo recordings from the K Eldredge Electronics ultrasonic system when harvesting burnt and green cane are shown in Figures 10 and 11, respectively. The true height of the sensor corresponded with the strong band of echoes recorded in burnt cane (Figure 10) but a number of false echoes were recorded in green cane (Figure 11).

The extent of the false echoes was found to depend on position of the sensor in the throat of the harvester. The compromise position to minimise false echoes was 0.7 m above ground and 1.2 m ahead of the basecutter.

Trials were conducted in burnt cane with each ultrasonic system automatically controlling the cutting height of a test harvester. Solenoid controlled hydraulic valves were fitted to the basecutter height control circuit to allow automatic control from the sensor. Generally, height control was considered satisfactory by the harvester operators but there was occasional loss of control by both systems leading to either deep cutting or cutting above ground. Both systems showed susceptibility to false echoes from green leaf when operating in cane which had been only partially burnt. Operators commented favourably on the good performance of the systems on entry or exit from cane rows.

Tests of the effect of automatic basecutter height control on harvester fuel consumption and dirt in the cane supply showed a possible fuel saving compared to relatively deep cutting under manual operation, but no apparent reduction in dirt levels.

The presence of the height sensor in the throat of the harvester gave some impedance of cane feed but this was not severe under the test conditions.

5.0 DIFFICULTIES ENCOUNTERED DURING THE PROJECT

The main difficulty encountered during the project was in maintaining standard test conditions for harvester modifications, both for bench and field tests. It was found that soil moisture levels strongly affected dirt rejection and discrimination between modifications was less in dry soil than in moist to wet soil.

While every effort was made to standardise moistures for bench tests by irrigating test cane there was considerable variability between replicates in these tests. In both the 1990 and 1991 seasons, the field evaluations of harvester modifications in north Queensland were hampered by dry conditions.

The field trials were conducted prior to the development of the cane loss monitor and there was also difficulty in standardising settings between harvesters, both in terms of basecutter height and cutting speed. Recent experience suggests that monitoring of both basecutter height and harvester speed is critical for such field comparisons.

The major difficulty encountered in the basecutter height control program was the use of commercial ultrasonic height sensors for which details of control algorithms were commercially sensitive. This limited the amount of input which could be made towards optimising performance.

6.0 RECOMMENDATIONS FOR FURTHER RESEARCH

∃ **Investigate effect of harvester forward speed/feed rate on dirt rejection**

In the course of the current investigations, field trial results did not conform well to test facility results and it is felt that this may be linked to harvester throughput. If this factor was found to be critical, it would provide support for double row harvesting as an avenue for reducing forward speed for a given throughput and thereby reducing dirt levels.

∃ **Investigate both harvester feeding characteristics and dirt rejection with reduced roller speeds**

One of the main factors found to improve dirt rejection in the test facility trials was roller speed. The current major harvester types have a graded increase in roller speed along the feed train to aid dirt rejection but maintain feed of cane at high throughputs. The effectiveness of the reduced roller speeds at the start of the feed train in rejecting dirt has been confirmed in recent trials with a prototype harvester and further gains may be possible through slowing other rollers. Also some guidance is needed on the impact of changing roller speeds to shorten billet length as there may be some benefit in improved soil rejection as billet length is shortened.

7.0 APPLICATION OF RESULTS TO THE INDUSTRY

Information on benefits from various modifications to both older model and current model harvesters has been widely circulated in the industry through BSES information meetings, roving field tours, the ASSCT Conference and the BSES Bulletin. These include spring loading of croplifters, use of narrow sidewalls on floating shoes, reducing knockdown angle of cane, slowing buttlifter speed, use of scalloped basecutters, use of open rollers on the bottom of the feed train and spring loading of top rollers.

There has been gradual adoption of some of these recommendations such as spring loading croplifters, use of narrow sidewalls, reducing knockdown angle and use of open rollers. One current model harvester has reduced bottom roller speed to improve dirt rejection. The reduction in roller speed is achieved by replacing the 24 cuin motors with a 30 cuin motor. Roller speed is reduced from 80 rpm to 64 rpm. Similar adjustments can be made for other harvester configurations where oil flow and motor size in the feed train may differ.

Similarly there has been semi-commercial adoption of the ultrasonic basecutter height control system and this may become fully commercial depending on operator acceptance.

8.0 PUBLICATIONS ARISING

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APPENDIX

ROLLER CONFIGURATIONS