



## FINAL REPORT – SRDC PROJECT BSS270

# REGIONAL ADOPTION OF ALTERNATIVE HARVESTER CONFIGURATIONS FOR SUSTAINABLE HARVESTING EFFICIENCY

by  
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**SD08005**

**BSES Limited**



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## CONTENTS

	Page No
<b>SUMMARY.....</b>	<b>i</b>
<b>1.0 BACKGROUND.....</b>	<b>1</b>
<b>2.0 OBJECTIVES.....</b>	<b>3</b>
<b>3.0 IMPACT OF KNOCKDOWN AND BASECUTTER DAMAGE ON CROP DAMAGE AND YIELD .....</b>	<b>4</b>
<b>3.1 Methods .....</b>	<b>4</b>
<b>3.1.1 Site selection and layout.....</b>	<b>4</b>
<b>3.1.2 Stubble-damage assessments.....</b>	<b>5</b>
<b>3.1.3 Harvester-loss assessments.....</b>	<b>7</b>
<b>3.1.4 Stalk numbers and cane yields.....</b>	<b>7</b>
<b>3.2 Results .....</b>	<b>7</b>
<b>3.2.1 Bingera trial.....</b>	<b>7</b>
<b>3.2.1.1 General .....</b>	<b>7</b>
<b>3.2.1.2 Harvest losses.....</b>	<b>8</b>
<b>3.2.1.3 Stool damage .....</b>	<b>11</b>
<b>3.2.1.4 Shoot counts .....</b>	<b>19</b>
<b>3.2.1.5 Cane yields .....</b>	<b>20</b>
<b>3.2.2 Mackay trial.....</b>	<b>21</b>
<b>3.2.2.1 General .....</b>	<b>21</b>
<b>3.2.2.2 Harvest losses.....</b>	<b>22</b>
<b>3.2.2.3 Stool damage .....</b>	<b>26</b>
<b>3.2.2.4 Shoot counts .....</b>	<b>30</b>
<b>3.2.2.5 Cane yields .....</b>	<b>32</b>
<b>3.3 Conclusions .....</b>	<b>33</b>
<b>3.4 Farming factors affecting harvester performance .....</b>	<b>33</b>
<b>3.4.1 Filling-in and hilling-up .....</b>	<b>34</b>
<b>3.4.2 Hill height.....</b>	<b>35</b>
<b>4.0 REFINEMENT OF CROP-HANDLING COMPONENT-SPEED AND GROUND-SPEED SYSTEM .....</b>	<b>36</b>

4.1	Definition of performance envelope for crop-handling components with respect to ground speed.....	36
4.1.1	Spirals.....	37
4.1.2	Basecutters.....	38
4.1.3	Feedtrain/Chopper.....	39
4.1.4	Conclusions.....	40
4.2	Prototype system.....	41
5.0	PROMOTION AND ADOPTION.....	48
5.1	Baseline Survey versus Output Survey.....	48
5.2	Focus groups.....	53
5.3	Field days.....	55
5.4	Publications.....	55
5.5	Intellectual property.....	55
6.0	OUTPUTS AND OUTCOMES.....	56
7.0	RECOMMENDATIONS.....	56
8.0	ACKNOWLEDGEMENTS.....	57
9.0	REFERENCES.....	57
	APPENDIX 1 – Field trial layouts.....	59
	APPENDIX 2 – Hyteco flow-control manifold used in the gathering-system hydraulic circuit.....	61
	APPENDIX 3 – Survey outputs.....	62

## SUMMARY

Maintaining economic sustainability of the Australian sugar industry through increasing crop-size and the move to green-cane harvesting has placed increased pressure on the harvesting sector. This has resulted in a significant increase in harvester pour rates throughout the Australian sugar industry in recent years, even where harvest contract sizes have not increased. This increase in pour rate has been facilitated primarily by an increase in harvester engine power. However, machine performance levels measured by extraneous-matter content in the cane supply must be reduced to enable the industry to meet sugar-quality targets and minimise CCS losses. Similarly, cane loss and stool damage must be reduced to more acceptable levels for the continuing viability of the industry.

The project aimed to improve harvester efficiency in a range of crops sizes and conditions by:

- Establishing site-replicated strip trials to investigate and quantify the impact of knockdown and basecutter damage on crop yield
- Synchronising harvester component speeds with ground speed
- Promoting cost-effective and improved retrofit harvester designs
- Ensuring adoption by providing information for the next generation of the *Harvester Best-Practice Manual*, including impact of harvesting on ratooning and crop yield.

The impacts of machine design and operating parameters on stool damage, crop loss at harvest, subsequent ratooning rates and final yields were assessed over a crop cycle in two field trials. This was achieved utilising a modular experimental harvester modified by BSES such that both a standard gathering/feeding system with aggressive 45° knockdown angle and an enhanced feeding module with virtually no knockdown effect can be operated within the same trial.

The monitoring of stool morphology over 3 crop years did not established any clear or consistent impact of the selected harvester-management treatments on stubble damage or the dynamics of shoot development. The observations, photographs and data demonstrated that major damage was caused to the stool by mechanical harvest, and this allowed the ingress of rots to at least one internode below the penetration of damage. This damage did not prevent the development of similar final stalk populations across treatments, indicating the value of the built-in redundancy associated with high shoot populations after ratooning. However, the upward movement of the point of development of ratoon shoots as the cycle progressed was quantified. The hypothesis was proposed that sucker shoots developing from deep in the stool may play a role in stool longevity. The second-ratoon harvest at both sites showed that treatments with no knockdown produced higher yields than did knockdown treatments.

An adaptive on-the-go control system, designed to enable variable speed control of the crop-handling components during the harvest operation, was developed. This system ensures that the cane harvester maintains a consistent feedrate and optimum performance by enabling manual automatic crop-handling component-speed variation with ground speed to compensate for variations in the crop. The system control unit also has an inbuilt function that allows manual override of the system by the operator. This introduces a

completely new dimension of sophistication into the world of cane harvesting, bringing it into line with many other agricultural harvesters.

Promotion and adoption of the project's outputs was facilitated through two focus groups and mini field days. An article for the *BSES Bulletin* is currently being written. The trial results will provide input to a revised version of the *Harvesting Best-Practice Manual* (an update of Sandell and Agnew 2002), and have demonstrated the importance of both machine operation and of crop presentation.

Whilst trial results and the enhanced module have been shown to industry representatives through the focus groups, no technical details or drawings have been or will be made available to anyone at this stage. The current plan is to maintain contact with aftermarket manufacturers such as EHS to make the most of any commercialisation opportunities to benefit the industry. If commercial opportunities arise with the potential to create adoption of this project's intellectual property, then the terms and conditions of releasing information would be developed between the researchers' organisations, SRDC and commercial partners.

## 1.0 BACKGROUND

The Australian sugar industry is now presented with a major challenge of maintaining industry profitability as it seeks to meet its international competitors. All sectors across the value chain, including the harvesting sector, are faced with this challenge.

Maintaining economic sustainability through increasing crop-size and the move to green-cane harvesting has placed increased pressure on the harvesting sector. This has resulted in a significant increase in harvester pour rates throughout the Australian sugar industry in recent years, even where harvest contract sizes have not increased.

This increase in pour rate has been facilitated primarily by an increase in harvester engine power. Increases in harvester pour rates are essential for the continuing viability of mechanical harvesting, and subsequently the whole of industry. However, machine performance levels measured by extraneous-matter content in the cane supply must be reduced to enable the industry to meet sugar-quality targets and minimise CCS losses. Similarly, cane loss and stool damage must be reduced to more acceptable levels for the continuing viability of the industry.

The technological evolution of the cane harvester in Australia has been a unique blend of developments among innovative growers, small manufacturers, and the research and development teams of larger corporations. The Australian Government has committed considerable resources and industry, through the Sugar Research and Development Corporation (SRDC), as funded projects that addressed improved machine design and performance. Davis and Norris (1998), Norris *et al.* (2000), Hockings *et al.* (2000) and Davis and Schembri (2004) have developed significant retrofit and machine design modifications, including the BSES single-spiral system, chopper/feedtrain optimisation and enhanced forward-feeding geometries. These have been extended into the next generation of cane harvesters. In addition, Whiteing and Norris (2000) and Sandell and Agnew (2002) have made a significant contribution to whole-of-system gain through best-practice machine setup and operation.

During normal operation of the majority of industry harvesters (CNH 7000/7700 and pre-1997 Cameco CH2500), operators can not the speeds of the crop-handling components (gathering, forward-feeding, basecutters and feedtrain/choppers). On post-1997 Cameco CH2500 harvesters, the operator can adjust the speed of the basecutters from zero to maximum in set increments. This means that the operator cannot compensate for crop load on the crop-handling components, except through the operator manually reducing ground speed.

This project sought to investigate the impacts of machine design and operating parameters on stool damage, crop loss at harvest, subsequent ratooning rates and final yields over the crop cycle. This was achieved using a modular experimental harvester modified by BSES, such that both a standard gathering/feeding system with aggressive 45° knockdown angle and an enhanced feeding module with virtually no knockdown effect can be operated within the same trial sites to measure basecutter damage levels at harvest and investigate subsequent crop development over four harvests.



Kroes and Harris (1994) found that a major cause of damage to the cane is contact between the basecutter disk and the stalk prior to the completion of the cut. Cane damage due to disk contact is attributed to excessive harvester ground speeds or feed rates, as basecutter speed remains fixed regardless of harvester operating speeds. Current harvesters probably cause damage at normal field speeds (Kroes and Harris 1994).

Kroes and Harris (1995) investigated the quality of cut as affected by the basecutter parameters of incline angle, speed, knockdown angle, feed rate, blade shape, and lateral cane position. The severity of damage and modes of failure were classified and sensitivity analysis undertaken on the different parameters. Knockdown angle, basecutter speed and feedrate had high impacts on the severity of damage. The apparent correlation between the feed rate and the number of damaged stalks led to the development of a model by Kroes and Harris (1995) that describes the basecutter kinematics. The model calculates the maximum permissible velocity ratio (feedrate/disk rotational speed) to maintain total blade coverage of the cane crop and to prevent contact between the disks and uncut stalks for a given basecutter and crop parameters.

For a given ground speed, an overly high basecutter rpm will result in stool being cut by the blades multiple times. When the basecutter rotational speed is too slow for the forward speed, then a tearing cut results, and stalks are torn off by the disc before a blade reaches the stalk; this causes severe damage to the stool.

Davis and Norris (2002) in trials undertaken in northern New South Wales identified that an increase in the feed efficiency so that choking or glut feeding is minimised is required to achieve the requirements of harvesting heavy green cane. Evenness in feed is essential, otherwise any increase in volumetric capacity gives only a proportional gain. An important concept in maximising feeding efficiency is the ability to control feedrate. They found that by reducing the rotational speed of the forward-feeding system, such that their surface speed was similar to ground speed, feeding ability was increased.

This project investigated a major opportunity to implement harvesting best-practice through the development of a speed-control system for cane-harvester crop-handling components. Other agricultural crop harvesters, including grain combines, cotton pickers and forage harvesters, all have some form of feedrate control system on their critical crop-handling components. John Deere has developed an advanced adaptive on-the-go control system for combines designed to enable automatic ground speed control during harvest operation. This system assures that a combine maintains a consistent crop load by automatically changing the ground speed to compensate for variations in crop that are not readily visible to the operator.

In evaluating solutions for improved machine performance, the associated symptoms of unmatched machine crop-handling speeds and harvest speed on performance indicators need to be identified, considered and addressed. Thus, criteria for machine performance should include feeding ability, stool damage, effect on subsequent yields, reduced overloading of crop-handling components, reducing cane loss, lower EM after cleaning, and less operator stress.

## 2.0 OBJECTIVES

The project aimed to improve harvester efficiency in a range of crops sizes and conditions by:

- Establishing site-replicated strip trials to investigate and quantify the impact of knockdown and basecutter damage on crop yield
- Synchronising harvester component speeds with ground speed
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The monitoring of stool morphology over 3 crop years did not established any clear or consistent impact of the selected harvester-management treatments on stubble damage or the dynamics of shoot development. The observations, photographs and data demonstrated that major damage was caused to the stool by mechanical harvest, and this allowed the ingress of rots to at least one internode below the penetration of damage. This damage did not prevent the development of similar final stalk populations across treatments, indicating the value of the built-in redundancy associated with high shoot populations after ratooning. However, the upward movement of the point of development of ratoon shoots as the cycle progressed was quantified. The hypothesis was proposed that sucker shoots developing from deep in the stool may play a role in stool longevity. The second-ratoon harvest at both sites showed that treatments with no knockdown produced higher yields than did knockdown treatments.

An adaptive on-the-go control system, designed to enable variable speed control of the crop-handling components during the harvest operation, was developed. This system ensures that the cane harvester maintains a consistent feedrate and optimum performance by enabling manual automatic crop-handling component-speed variation with ground speed to compensate for variations in the crop. The system control unit also has an inbuilt function that allows manual override of the system by the operator. This introduces a completely new dimension of sophistication into the world of cane harvesting, bringing it into line with many other agricultural harvesters.

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manufacturers such as EHS to make the most of any commercialisation opportunities to benefit the industry. If commercial opportunities arise with the potential to create adoption of this project's intellectual property, then the terms and conditions of releasing information would be developed between the researchers' organisations, SRDC and commercial partners.

### **3.0 IMPACT OF KNOCKDOWN AND BASECUTTER DAMAGE ON CROP DAMAGE AND YIELD**

Stool damage and morphology and subsequent shoot development were quantified to determine whether harvesting treatments (harvester management) have a significant impact on stool health and development that may be reflected in cane yield over the crop cycle. It was hypothesised that damaged stools might be more prone to poorer ratooning, and there was little knowledge of the impact of harvester management on depth of ratooning and propensity for development of gaps in the stand. Over the course of the study, it became apparent that, whilst machine design and operation play a significant role in determining damage and ratooning rates, crop presentation appears to play an even greater role. This is discussed further in Section 3.4.

#### **3.1 Methods**

##### **3.1.1 Site selection and layout**

Project staff in Mackay and Bundaberg worked with local mill field staff to identify a number of potential sites with consistent yield and sufficient area of erect cane to conduct the trials. A site at Sandy Creek on Bundaberg Sugar's Bingera plantation (Q188<sup>(b)</sup>) and a site at Mackay owned by Ray Muller (Q157) were selected. Based on the site areas, row numbers and predicted yields, trial layouts were developed (Appendix 1) that enabled four replicates of the four harvester setups to be compared.

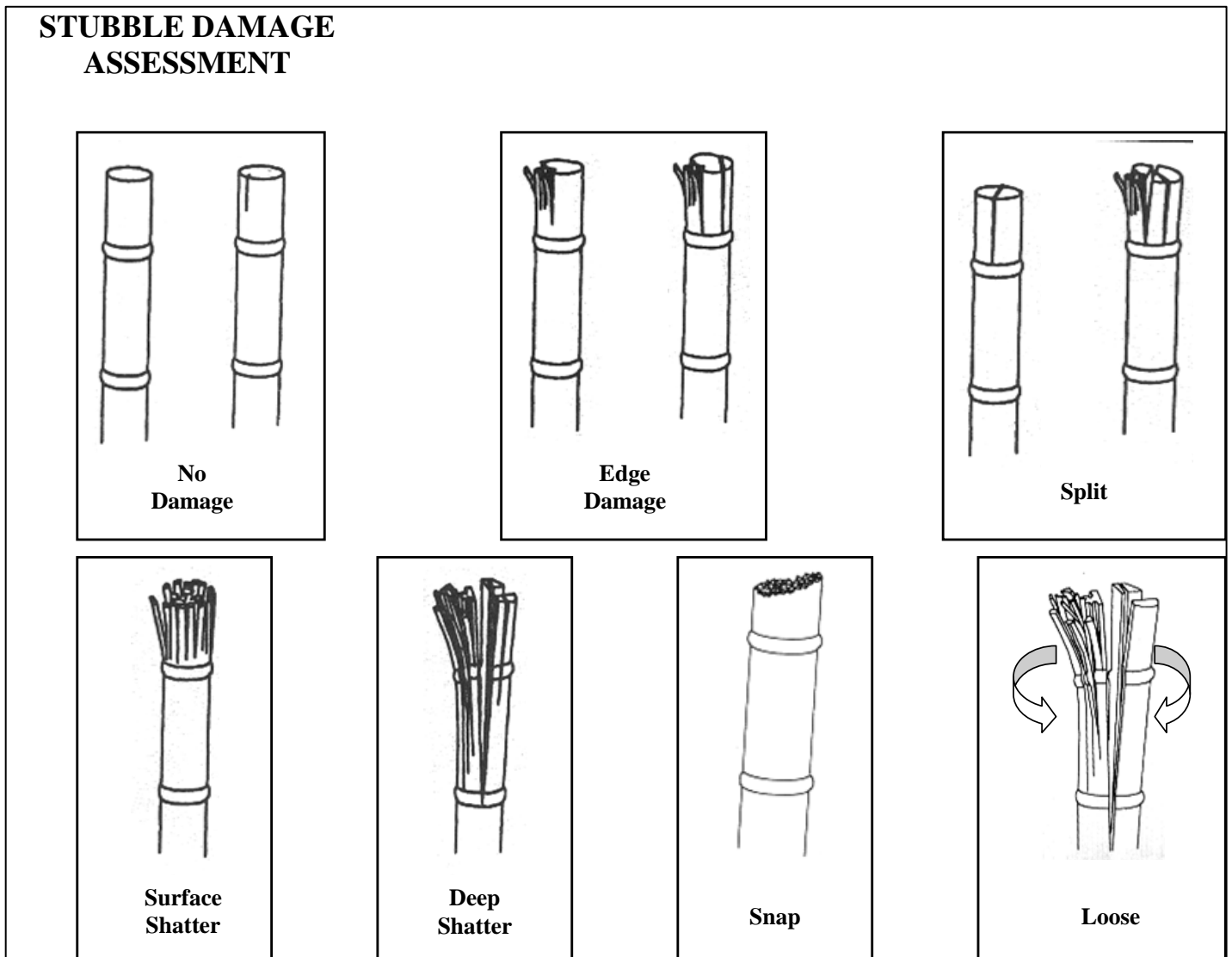
Prior to each harvest, individual plots of each treatment were marked and two random sites within each plot were selected for pre- and post-harvest assessment of shoot numbers and basecutter damage. Each random assessment site was marked by burying a radio marker ball in the centre of the site. Four 10-m sections of row were marked using the marker as the central datum point. This system enables project staff to pinpoint the exact location of each random assessment plot throughout the life of the project, as the markers are unaffected by harvesting or cultivating operations.

Each marker ball was used as a datum point, surrounding which were four 10-m lengths of row in which pre-harvest stalk levels were monitored to determine the rate of shoot development and final millable stalk numbers. As the trial sites were harvested, post-harvest damage and loss data were collected. The same sections of row were tracked from plant cane throughout the duration of the project to determine the cumulative effects of harvester damage on the crop.

Electromagnetic mapping, along with some soil sampling, was conducted at each site to identify any potential salinity issues.

### 3.1.2 Stubble-damage assessments

An intensive process of assessing stool damage resulting from the different harvester configurations was conducted immediately after each plot was harvested. The stubble-assessment team used the protocol in Figure 1 to grade damage levels from no damage through to deep shatters.



**Figure 1 Stubble-damage assessment categories**

Two of the four 10-m lengths of row were designated in each plot for non-destructive quantitative assessment of damage to the stool after harvest throughout the crop cycle. Damage was assessed after loose soil had been brushed away from the top of the stools

(Figure 2). Plots were also established in adjoining rows for destructive assessment of stool morphology some 8 weeks after harvest, when ratooning was well established. Four stools were exhumed from the soil in each plot with a mechanical digger and adhering soil was removed by soaking in water and air blasting (Figure 3). Stools were assessed for number of suckers, shoots, swelling buds, dormant buds, non-viable buds, length of roots and position of shoot development, relative to ground level.



**Figure 2** Cleaning 10-m plots with air blast prior to damage/loss assessments in the Mackay trial



**Figure 3** Sequence of assessment of stool morphology

The standard harvester-management treatments were assessed in all experiments, but a hand-cut treatment was included in each plot at the Bingera site for comparison with the mechanical-harvest treatments. An additional four stools per plot were exhumed from the hand-cut row at the Bingera site for comparison against the mechanical-harvesting treatments.

### **3.1.3 Harvester-loss assessments**

Loss measurements were made during each trial harvest. This involved finding and weighing all cane pieces and stalks associated with basecutter damage and pickup loss. Two categories of cane loss were considered in these trials: firstly, the small fragments and short butts associated with basecutter shattering and underground snaps that leave a small section of cane stalk butt; and secondly, the whole cane sticks that have not been effectively gathered and fed into the machine. The small pieces are referred to as ‘ground losses’ and the whole sticks are ‘pick-up losses’.

### **3.1.4 Stalk numbers and cane yields**

Stalk counts were conducted throughout the growing season to track ratoon development. Severe weather and/or lodging meant that some counts could not be conducted up until harvest.

At the onset of the project it was identified that variations in planting density prior to any mechanical harvesting needed to be taken into account when comparing ongoing shoot populations and resulting yields. To do this, raw data on shoot populations are adjusted to account for the original variations in shoot populations due to planting-rate variability.

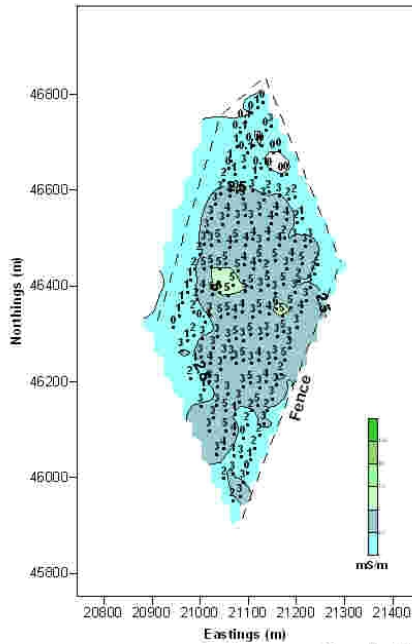
## **3.2 Results**

### **3.2.1 Bingera trial**

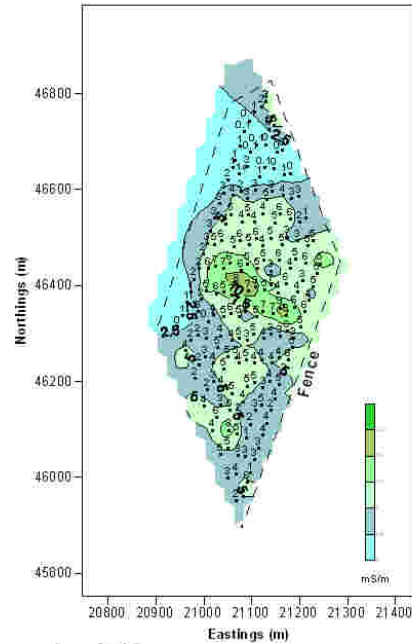
#### **3.2.1.1 General**

The three EC maps developed from the Bundaberg trial site (Figure 4) indicated no serious salinity issues, except slightly higher salt levels in the centre of the block at a deeper level that could create restrictions in the root zone.

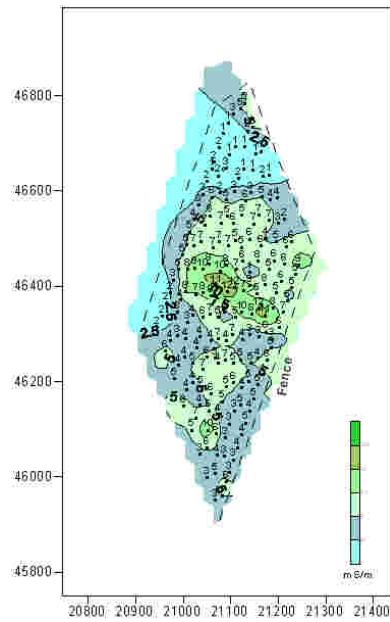
Sandy Ck. Bingera - November 2005  
 apparent electrical conductivity to approx. 0-5 m depth



Sandy Ck., Bingera - November 2005  
 apparent electrical conductivity to approx. 1 m depth



Sandy Ck., Bingera - November 2005  
 apparent electrical conductivity to approx. 1.5 m depth

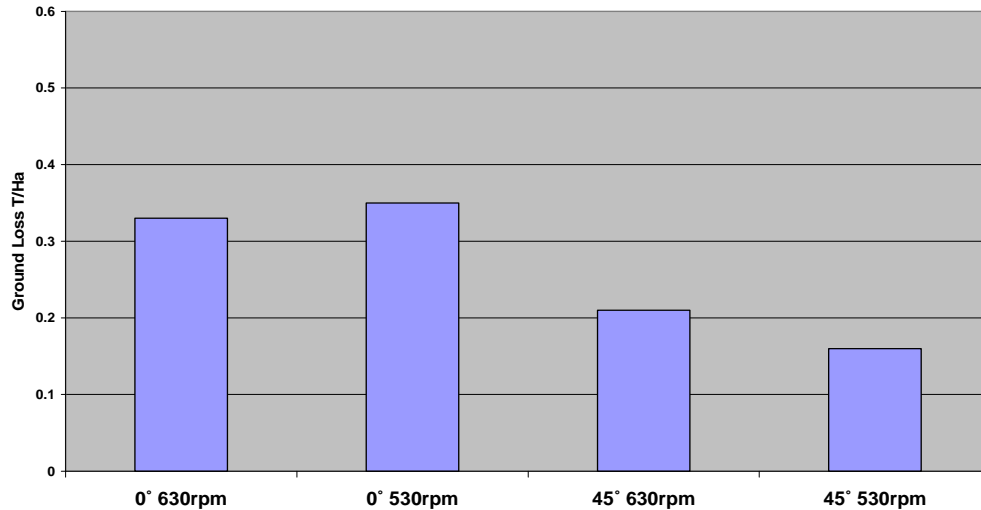


**Figure 4** Bingera trial – Electrical conductivity maps

### 3.2.1.2 Harvest losses

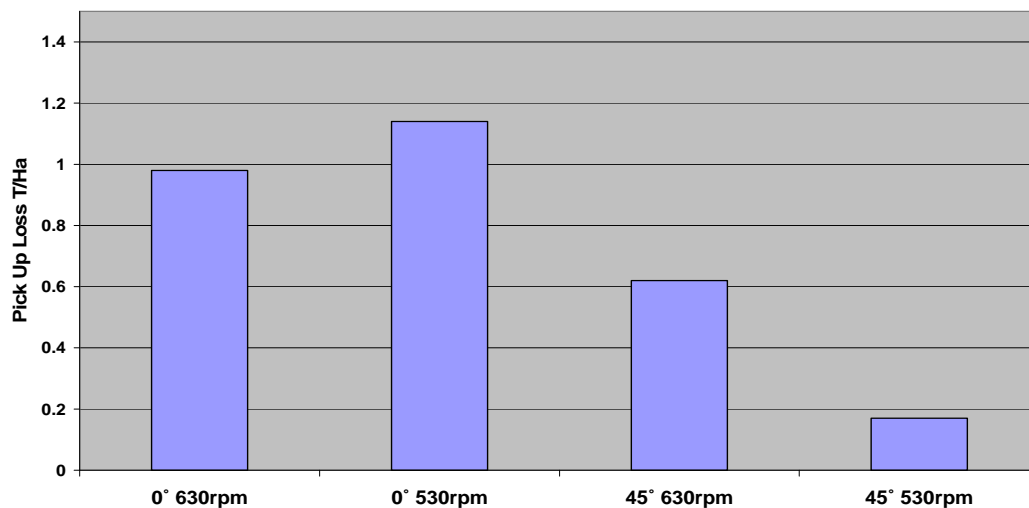
#### *2004 harvest*

There were no major differences in ground losses in the Bingera trial, with low levels of loss from both modules (Figure 5).



**Figure 5** Bingera trial – Ground losses from the 2004 harvest

There appeared to be higher losses in the zero-knockdown module (Figure 6), which was unexpected. Discussions with the harvester operator and the engineering team questioned the matching of buttlifter shape to basecutter discs and minor changes to the buttlifter profile were made prior to the 2005 harvest to better fit the discs and possibly reduce pick-up losses.

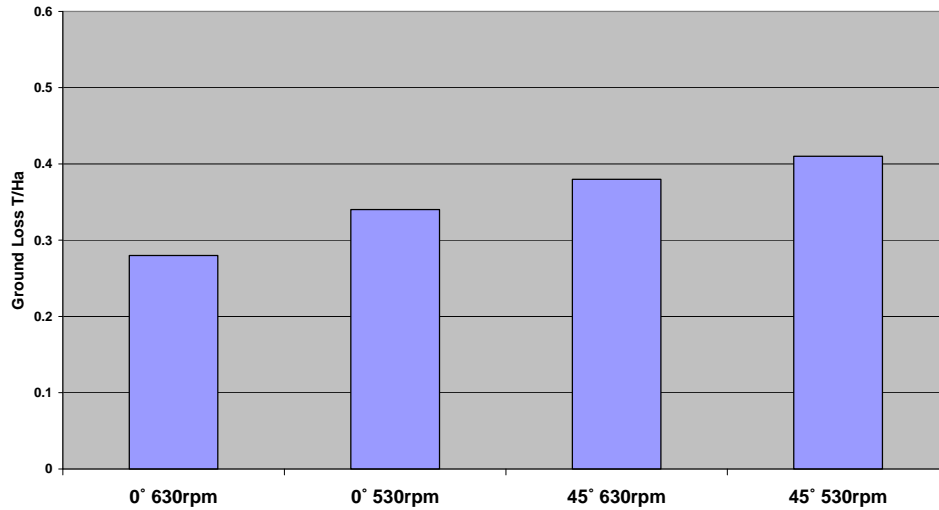


**Figure 6** Bingera trial – Pick-up losses from the 2004 harvest

### *2005 harvest*

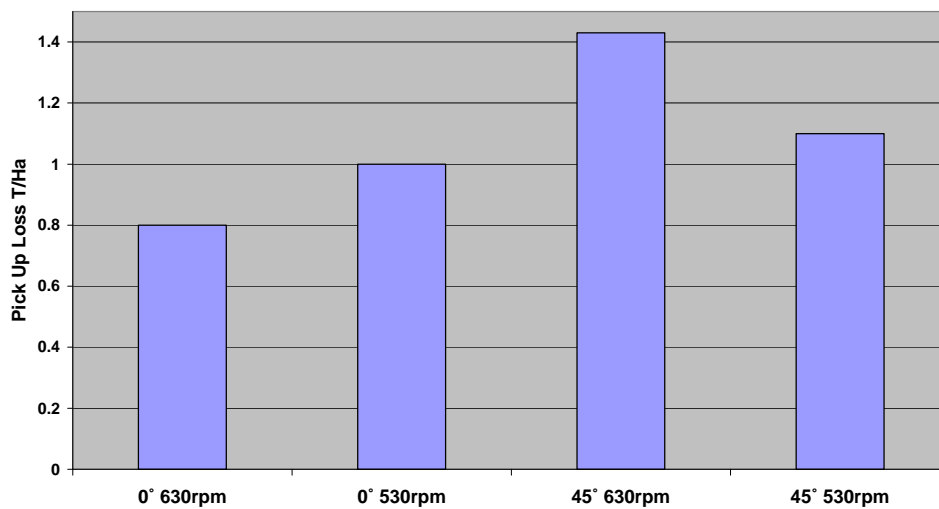
There were no significant differences in ground losses (Figure 7), with the standard module producing only slightly higher figures than the modified system.





**Figure 7** Bingera trial – Ground losses from the 2005 harvest

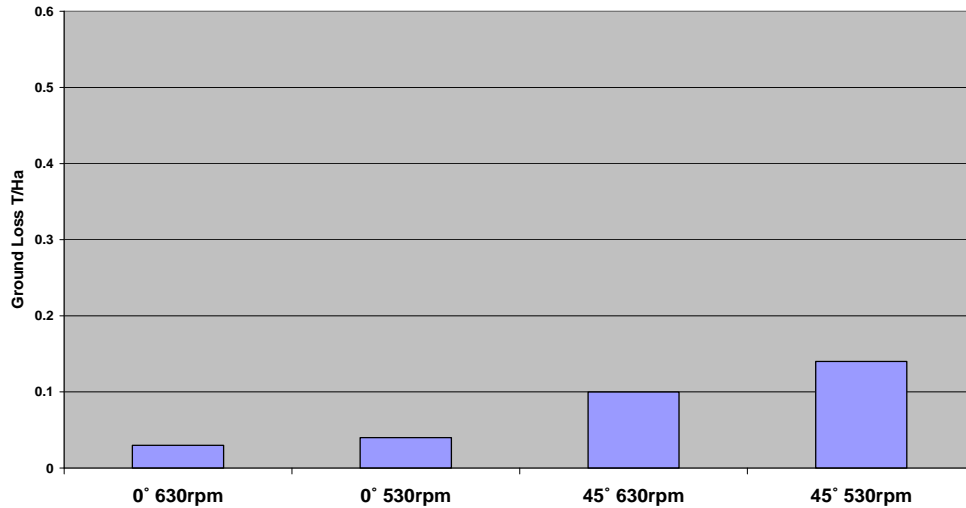
Some reduction in pick-up loss was observed with the enhanced feeding module (Figure 8), though these were not as significant as seen in the Mackay trial.



**Figure 8** Bingera trial – Pick-up losses from the 2005 harvest

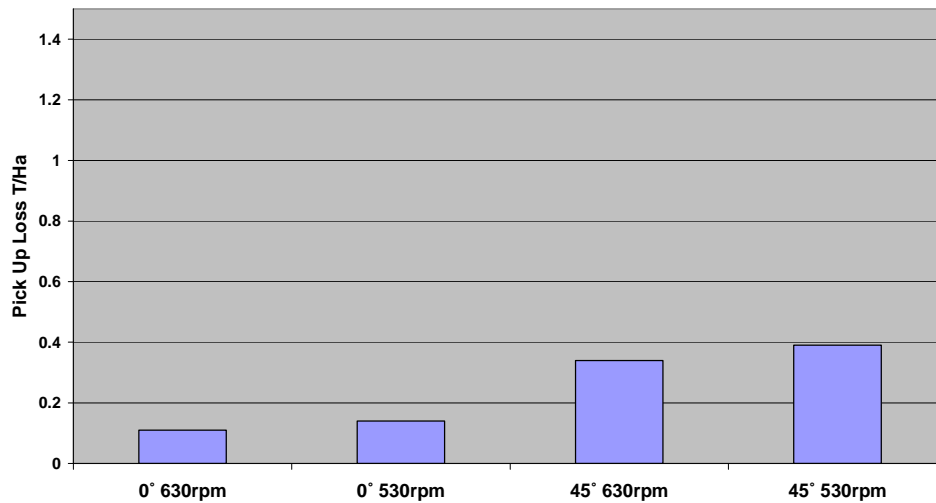
### *2006 harvest*

Ground-loss levels were low due to the very light crop (Figure 9), with no significant differences.



**Figure 9** Bingera trial – Ground losses from the 2006 harvest

Some reduction in pick up loss was observed with the enhanced feeding module (Figure 10), although not as significant as seen in Mackay.

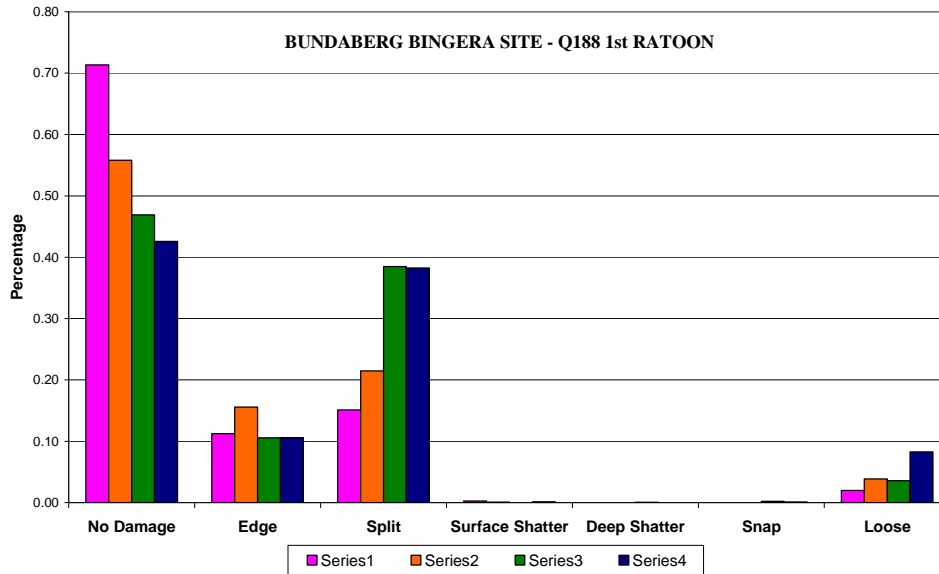


**Figure 10** Bingera trial – Pick-up losses from the 2006 harvest

### 3.2.1.3 Stool damage

#### *Following the 2004 harvest*

There was a significantly higher proportion of undamaged stools associated with the zero knockdown angle on the enhanced module (series 1 and 2) than on the standard module (Figure 11). Interestingly, much of the damage caused using the standard module (series 3 and 4) was in the form of splits propagating down into the stool. This is most likely due to the aggressive knockdown angle causing pre-stressing of cane stalks prior to being cut.



**Figure 11** Bingera trial - Stool damage assessment following the 2004 harvest. Series 1: Zero knockdown; Standard basecutter speed - Enhanced module, K2B1; Series 2: Zero knockdown; Optimum basecutter speed – Enhanced module, K2B2; Series 3: Standard knockdown; Optimum basecutter speed – Standard module, K1B2; Series 4: Standard knockdown; Standard basecutter speed – Standard module, K1B1

There were highly significant treatment effects on total damage of stubble and for split and loose stubble effects ( $p=0.03$ ,  $0.01$  and  $0.02$ , respectively). The no-knockdown treatment (K2B1) with 81% undamaged stubble pieces was significantly better than knockdown treatment (K1B2) with 40% undamaged stubble. The other treatments were intermediate (57-59%) and not significantly different from the previous values. Both knockdown treatments had more split stubble than did the no-knockdown treatments, but only treatment K1B2 was significantly worse than all other treatments (56% versus 6-19%). Treatment K1B1 had the most loose stubble (4%) but this was not significantly different ( $p=0.02$ ) from K2B2 (3%); other treatments had no loose stubble.

There were no significant harvester treatment effects within depth zones for the origin of ratoon shoots at Bingera, possibly because of the dominance of ratooning from deeper layers (Table 1).

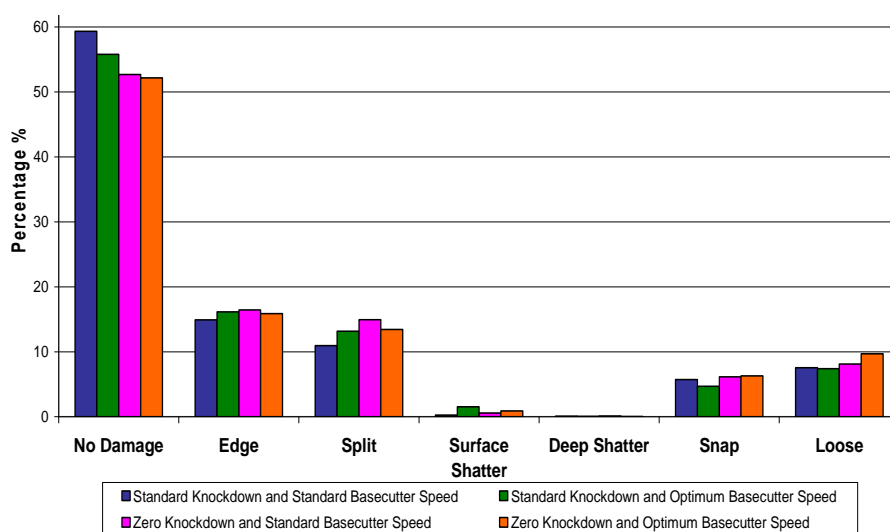
**Table 1** Percentage of viable buds on stubble Q157 and Q188<sup>Ⓛ</sup> at Mackay and Bingera, respectively, that produced shoots in four depth intervals

Depth (cm)	Q157 - Mackay	Q188 <sup>Ⓛ</sup> - Bingera
0-5	12.9	7.8
5-10	34.1	18.0
10-15	39.6	25.2
15-20	13.4	49.1

There were significant treatment effects on the percentage of buds, either viable or total, that produced shoots or suckers in the Q188<sup>Ⓛ</sup>. Surprisingly, knockdown treatment K1B1 had a significantly higher proportion of total buds (39%) represented as shoots than other mechanical treatments (24-27%), but the K1B1 value was not significantly different ( $p=0.02$ ) from hand-cut cane 31%. Hand-cut and no-knockdown treatments contained more suckers than did the knockdown treatments, with hand-cut and K2B2 only, being significantly greater than K1B1.

#### *Following the 2005 harvest*

Surprisingly, the stool damage assessments at Bingera following the 2005 harvest indicated slightly higher (but not significantly) levels of damage with the zero-knockdown treatments (Figure 12). This was an apparent reversal of the results seen in the 2004 harvest, and was supported the operator's difficulty in matching the machine cutting height to the variable row profile with constant adjustments required in an effort to achieve a consistent result. However, infield variability, such as inconsistent row spacing and hill-up, the emergence of a grass problem (Figure 13) and water-logging in some sections of the block following unusual wet periods and leading to high levels of rots (Figure 14), appeared to be interfering with results and could explain the reversal of damage trends seen earlier.



**Figure 12** Bingera trial - Stool damage assessment following the 2005 harvest



**Figure 13** Bingera trial - Grass infestation in some sections of the trial



**Figure 14** Bingera trial - Rots and split stubble following the 2005 harvest

There was a significant treatment effect ( $p=0.10$ ) on the proportion of total viable buds that produced sucker shoots, where the 3.7% of viable buds that produced suckers in K1B1 was significantly less than the average of 11.3% for K2B2. Hand-cut, K1 B2 and K2B1 were intermediate and not significantly different from either of the two preceding groups.

There were also significant treatment effects on the proportion of viable buds that produced shoots and proportion of buds still at the swelling stage (Table 2). However, treatment rankings were different from those for Mackay, with the two no-knockdown treatments having significantly different proportions of buds as shoots. The hand-cut treatments appeared to be slowest in producing ratoon shoots.

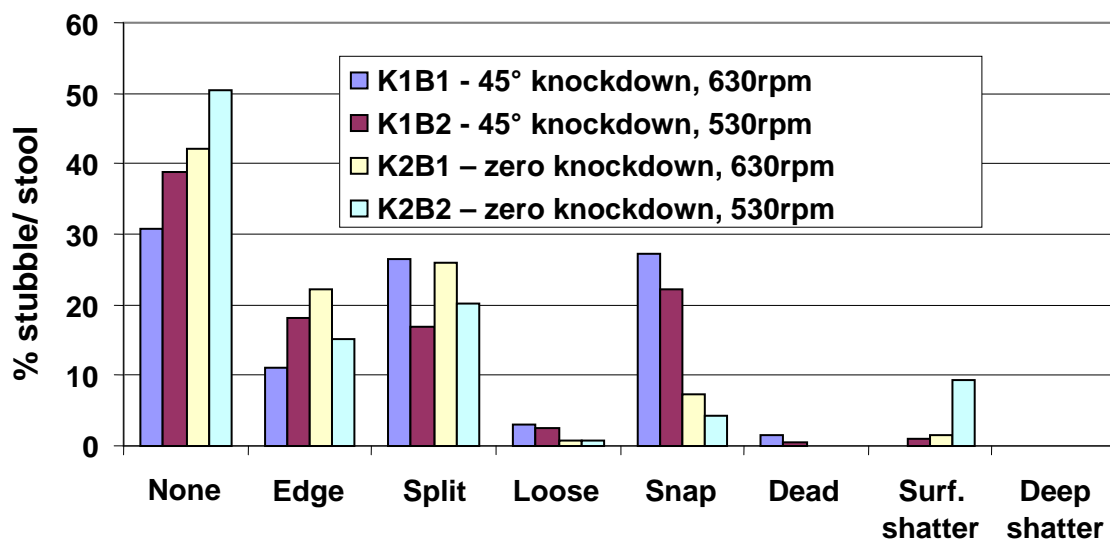
**Table 2** Bingera trial - Proportion of viable buds producing shoots and swelling buds

Treatment	% viable buds as shoots		% viable buds – swelling stage	
	Mean	Homog. groups	Mean	Homog. groups
K1B1	70.5	A <sup>x</sup>	0	B
K2B1	62.6	AB	0.8	B
K2B2	62.3	AB	0	B
K1B2	58.7	B	5.2	A
Hand-cut	55.1	B	4.9	A
p value		0.09		0.16

<sup>x</sup> values followed by the same letter are not significantly different

**Following the 2006 harvest**

Significantly higher levels of damage were seen in the 45° knockdown treatments (Figure 15), with much of this damage due to snapping. This supports the project hypothesis that aggressive knockdown angle places stalks under pressure prior to cutting, leading to excessive stalk snapping. Despite infield variability, such as inconsistent row spacing and hill-up, plus the emergence of a grass problem, there was a link between damage levels and machine setup.



**Figure 15** Bingera trial - Stool damage assessment following the 2006 harvest

The no-knockdown treatments (K2) had lower overall damage levels than did knockdown treatments (K1). Effects of basecutter speed within knockdown treatments was not significant (Table 3), and only the K2B2 treatment had significantly less damage than did K1B1. The values in Table 3 show that, overall, a relatively low proportion of stubble pieces were undamaged. Edge damage, slits and shattering allows the ingress of rots, which were observed again, generally down to one internode below the extent of damage.

**Table 3** Bingera trial - Percentage of undamaged stubble pieces per stool following the 2006 harvest

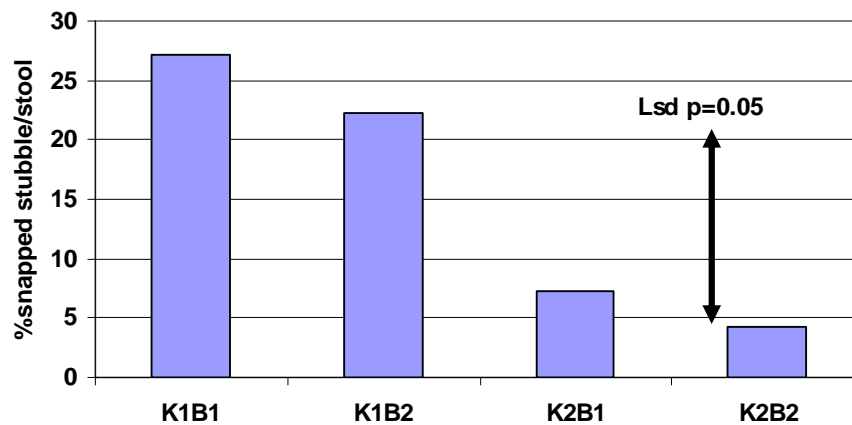
Treatment	% undamaged stubble	Homog. groups
K2B2	50.5	A
K2B1	42.1	AB
K1B2	39.0	AB
K1B1	30.9	B
lsd p=0.05	12.9	

There were no significant treatment effects for edge damage, splitting or deep shattering. There was apparently higher surface shattering in the K2B2 treatment ( $p=0.15$ ) than all other treatments at Bundaberg (Table 4). This was associated with 18.6% of stools affected by surface shattering in two of the four replicates of this treatment, when all other surface shatter damage was zero to very low. This may have been associated with higher-than-desired basecutter setting in these replicates due to the uneven row profile and the trash blanket.

**Table 4** Bingera trial - Percentage of stubble pieces showing surface shatter damage following the 2006 harvest

Treatment	% undamaged stubble	Homog. groups
K2B2	9.3	A
K2B1	1.6	B
K1B2	1.0	B
K1B1	0	B
lsd p=0.15	6.2	

Knockdown caused significantly more snapping than no-knockdown (Figure 16). However, this damage was not reflected in consistent treatment effects on the ratoon-shoot population.



**Figure 16** Bingera trial - Effect of knockdown treatments on snapped stubble damage following the 2006 harvest

There were few significant effects of the harvester treatments on stool morphology parameters (Table 5).

**Table 5** Bingera and Mackay trials - Summary of significance levels for stool-morphology parameters following the 2006 harvest

Morphology parameter	Mackay	Bingera
Stubble/stool	p=0.03	p=0.02
Shoots/stool	p=0.15	NS
Suckers/stool	NS	p=0.06
Shoots+suckers/stool	p=0.08	NS
Buds swelling	NS	NS
Buds non-viable	NS	NS
Total viable buds/stool	NS	NS
Shoots% TVB	NS	p=0.16
Sucker% TVB	NS	NS
Buds swelling% TVB	NS	NS
Shoot depths	NS	NS
Sucker depths	NS	p=0.05

p=probability value for significance, NS = not significant

The significant effect of stubble pieces per stool is the result of a much higher stubble population in one replicate of the K2B1 treatment.

The effects of treatments on the percentage of viable buds that resulted in shoots approached significance (Table 6). The K2B2 treatment (no-knockdown and optimised basecutter) had the lowest proportion of viable buds as shoots. There was no difference between the K1B2 (knockdown and optimised basecutter) and the hand-cut cane.



**Table 6** Bingera trial - Percentage of viable buds producing shoots following the 2006 harvest

Treatment	% TVB as shoots	Homog. groups
K1B2	73.6	A
Hand cut	71.3	A
K1B1	66.3	AB
K2B1	62.6	B
K2B2	60.7	B
Lsd ( $p=0.15$ )	8.2	

There were no significant treatment effects on the depth from which ratoon shoots emerged. However, there was a pronounced upward movement in the depths from which ratoon shoots emerged (Table 7). An average of 85.2% of all ratoon shoots in the third ratoon came from the 0-5 cm zone, and none from below 15 cm. In fact, 3% of shoots (very small in size) were established on above ground stubble sections due to high placement of the basecutter.

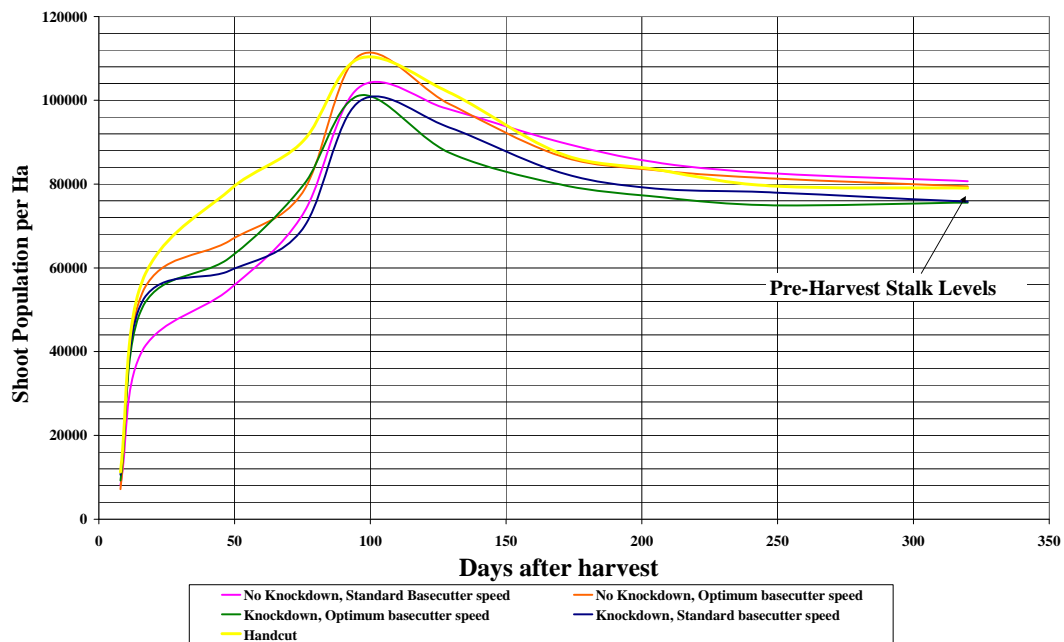
**Table 7** Bingera and Mackay trials - Comparison of proportion (%) of ratoon shoots emerging from different depth intervals for three ratoon crops. Data are means across harvester treatments

Depth zone (cm)	Crop class	Mackay	Bingera
Above ground	1R	0	0
	2R	0	0
	3R	0	3.0
0-5	1R	12.9	8.0
	2R	10.1	80.6
	3R	41.6	85.2
5-10	1R	34.1	17.9
	2R	38.5	16.5
	3R	37.7	11.3
10-15	1R	39.5	25.2
	2R	36.5	2.6
	3R	11.0	0.8
15-20	1R	13.3	48.8
	2R	14.8	0.4
	3R	3.2	0
>20	1R	-	0
	2R	-	0
	3R	2.7	0

### 3.2.1.4 Shoot counts

#### *Following the 2004 harvest*

Of interest was the rapid spike in shoot numbers from the hand-cut cane as opposed to those from the machine cut (Figure 17). This was a result of red/black/brown rot (Figure 18) and shows what can be achieved under ideal (hand-cut) situation. However, it is interesting to note that the maximum number of 160,000 shoots/ha and final number 80,000 shoots/ha were the same for both 'hand-cut' and 'zero knockdown, optimum basecutter speed'. The total number of shoots/ha for the 'standard knockdown' was 4000 less than the 'zero knockdown' harvester front.



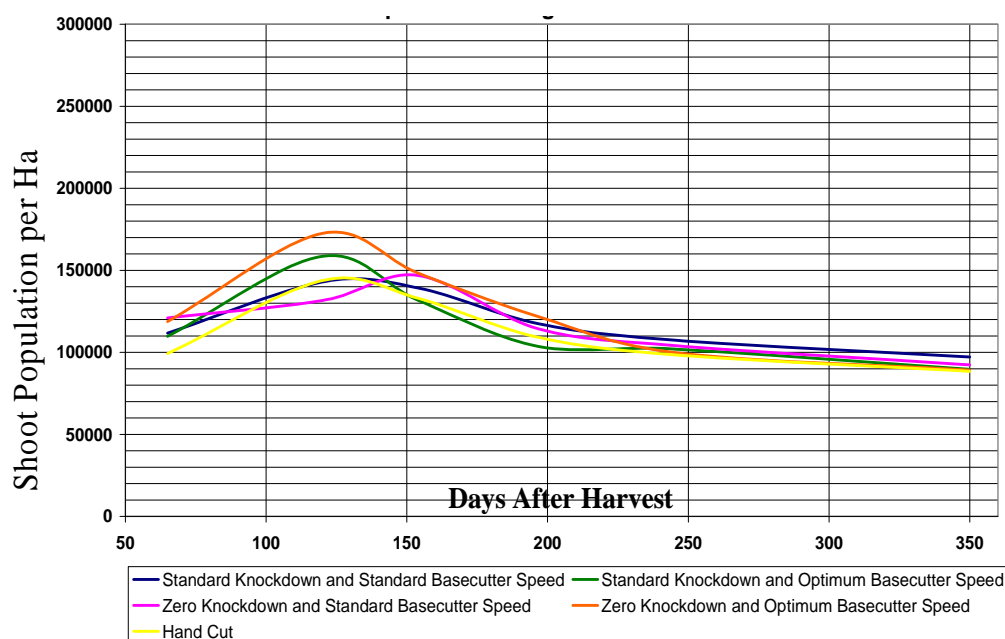
**Figure 17** Bingera trial - Shoot populations following the 2004 harvest



**Figure 18** Bingera trial - Deep ingress of rots into plant-cane stubble and development of suckers and shoots from deep below damaged stubble

### *Following the 2005 harvest*

The impact of wet conditions could be seen even from the start of these shoot counts (Figure 19), with hand-cut sections starting with the lowest shoot population despite the minimal damage. Stool-morphology assessments showed surprising levels of rots, even in hand-cut sections, which seemed to be linked more to position within the field than the level of damage. After some good early shoot development in the zero-knockdown/optimal-speed treatments, the populations ended up being fairly similar by harvest, with 90290 shoots/ha for standard-knockdown/optimal-speed, 89140 shoots/ha for zero-knockdown/optimal-speed, 88450 shoots/ha for hand-cut sections, 87610 shoots/ha for zero-knockdown/standard-speed, and 86150 shoots/ha for standard-knockdown/standard-speed.



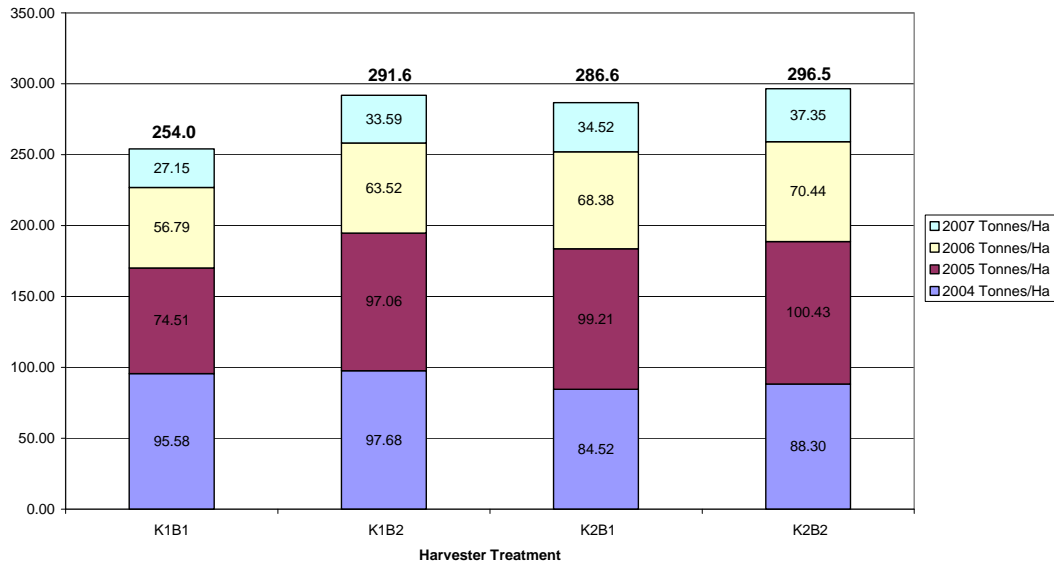
**Figure 19** Bingera trial - Shoot populations following the 2005 harvest

### *Following the 2006 harvest*

No shoot counts were attempted because of the high variability amongst plots.

#### **3.2.1.5 Cane yields**

The yield data for the 2007 was indicative of the very poor stand of cane due to grass competition and dry weather. The cumulative yield over the four harvests at the Bundaberg trial site is shown in Figure 20. Overall, the 'zero knockdown, standard speed' treatment appeared to give lower yields, although the variability at this site makes interpretation difficult.



**Figure 20 Bingera trial - Four-year cumulative cane yield data**

### 3.2.2 Mackay trial

#### 3.2.2.1 General

The heavy lodging that occurred at the Mackay trial site prior to the 2005 harvest negated the knockdown effect for that year. Fortunately, the crop was erect for the other harvests.

The three EC maps from the Mackay trial site at depths of 0.5 m, 1 m and 1.5 m (Figure 21) indicated no major salinity issues, except a slight build-up of salt at the bottom end of the paddock due to a change in soil type.

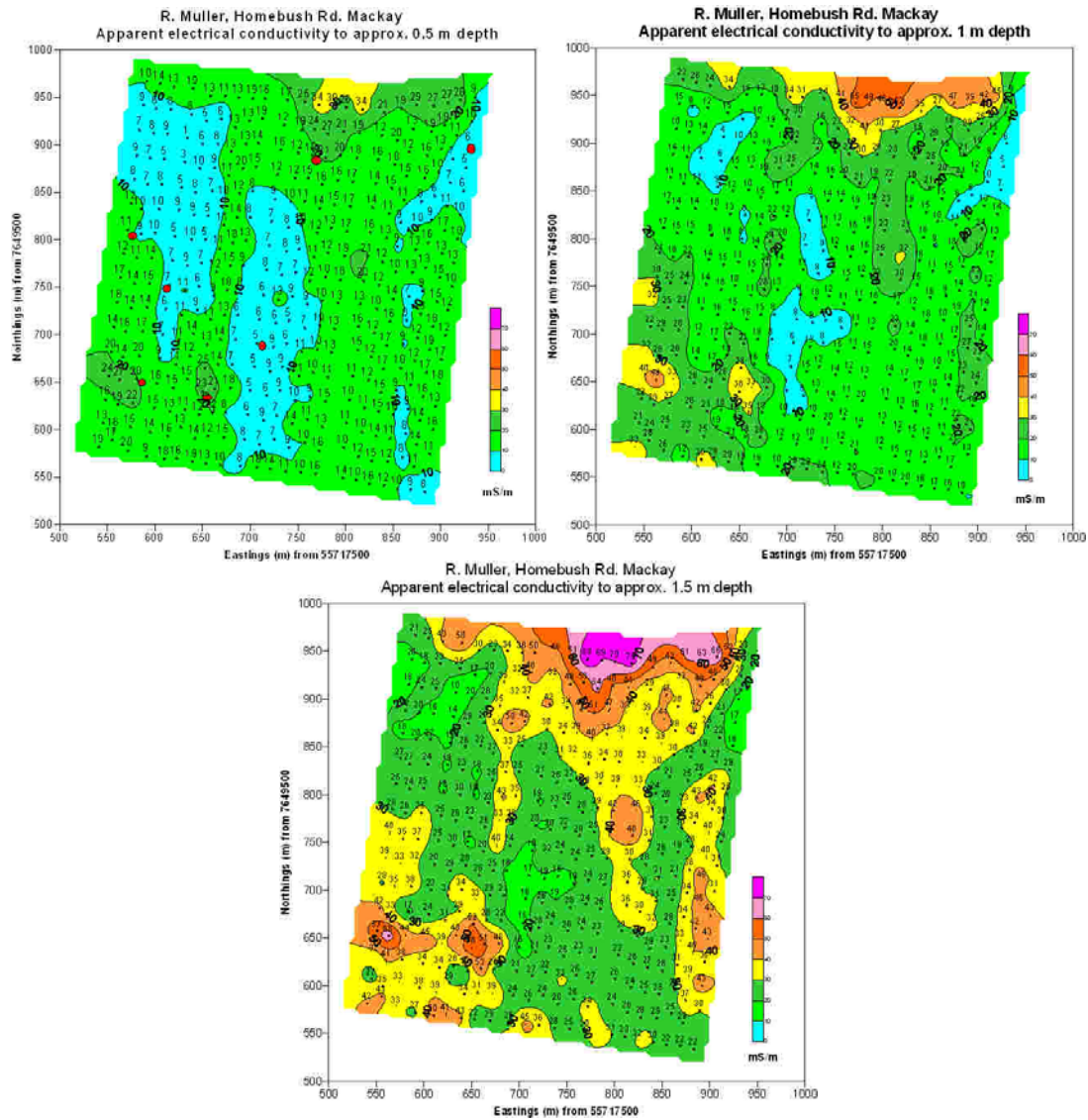
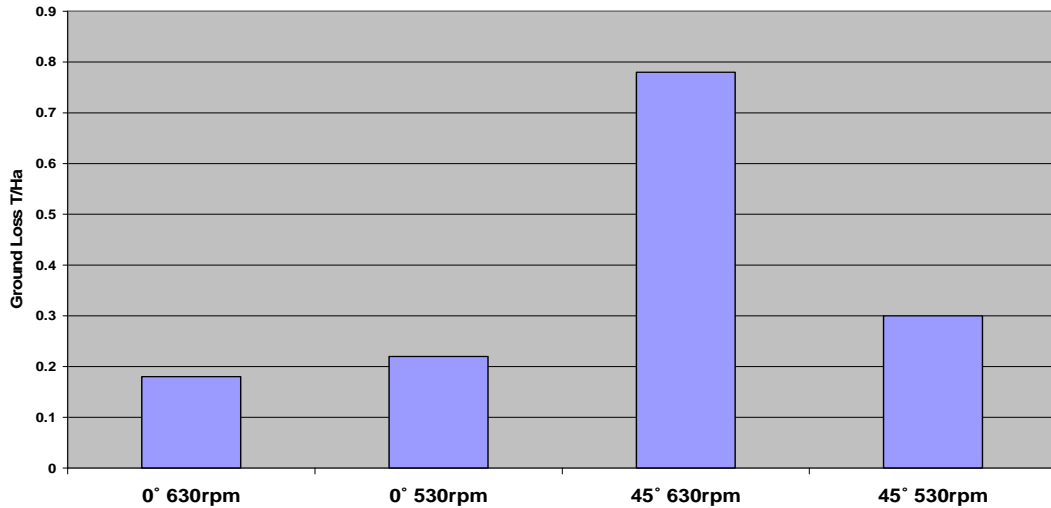


Figure 21 Mackay trial – Electrical conductivity maps

### 3.2.2.2 Harvest losses

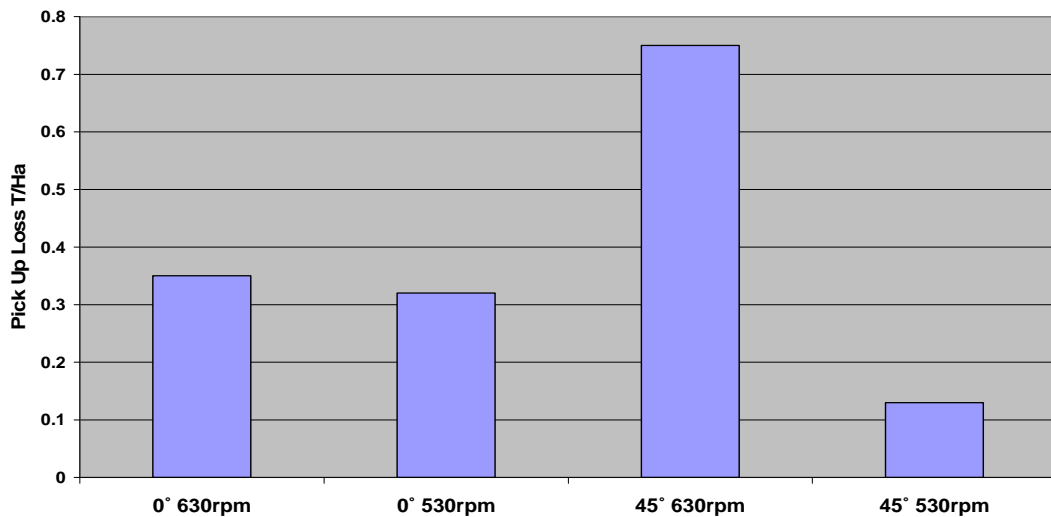
#### 2004 harvest

There were lower ground losses from the zero-knockdown module than from the standard knockdown (Figure 22), but no consistent differences between the two basecutter speeds.



**Figure 22** Mackay trial – Ground losses from the 2004 harvest

Pick-up losses depend not only on the harvester gathering system configuration, but also the crop condition immediately surrounding the inspected plots, so there is a degree of variability in the results. There were no major differences in the pick-up losses of the two modules (Figure 23) and the level of loss was very low for both systems due to the erect crop. Harvesting lodged cane would cause much higher losses and might highlight differences between modules not seen in erect cane.

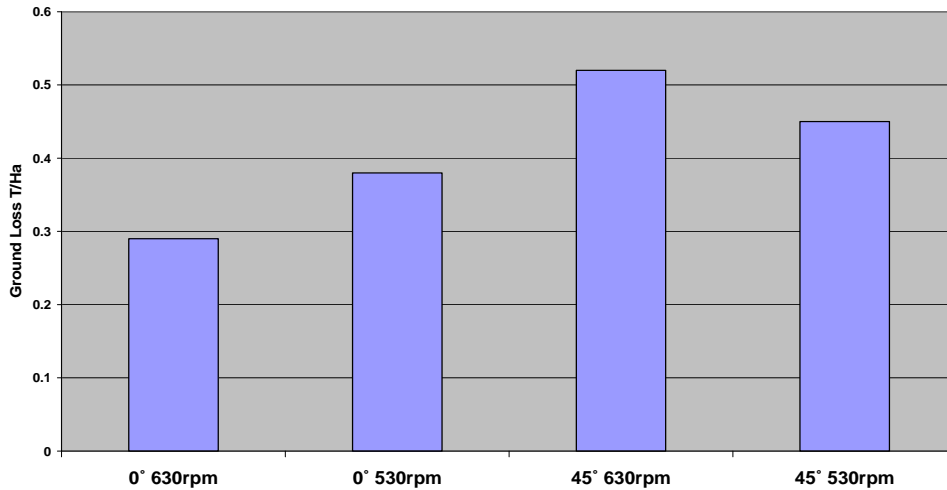


**Figure 23** Mackay trial – Pick-up losses from the 2004 harvest

### 2005 harvest

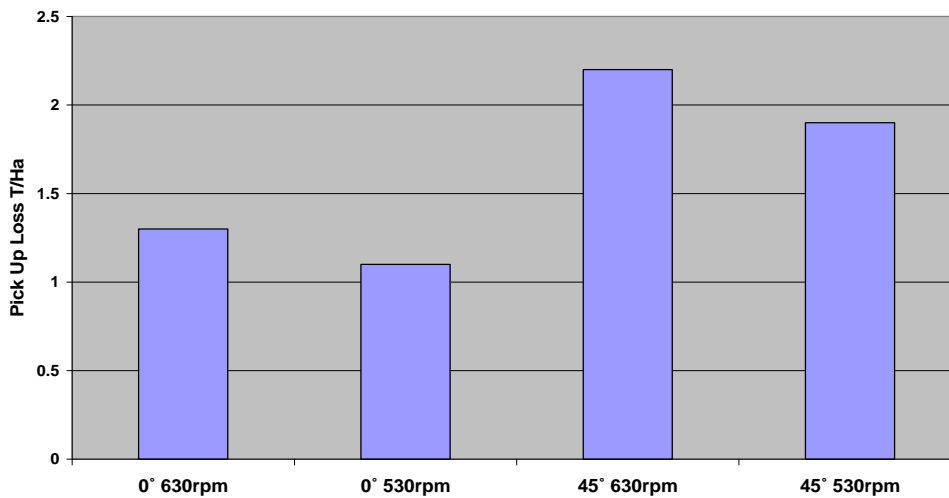
Lodging of the block prior to harvest made the gathering and feeding process more difficult for the harvester and it was expected that pick-up losses in particular would be lower for the enhanced feeding/zero knockdown module.

Ground losses were not much higher for the standard knockdown setup (Figure 24), which was not unexpected, given the reduced knockdown effect due to lodging.



**Figure 24** Mackay trial – Ground losses from the 2005 harvest

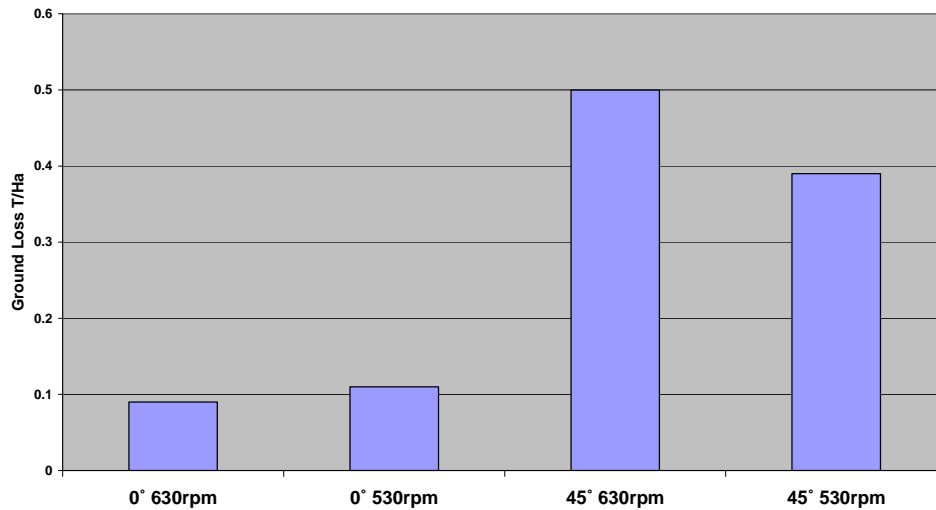
Pick-up losses were lower with the enhanced feeding module (Figure 25), due to its improved gathering and positive feeding design. This reduction in pick-up losses, especially in lodged cane, is a significant benefit to be gained from correct gathering system geometry and a more positive forward-feed system.



**Figure 25** Mackay trial – Pick-up losses from the 2005 harvest

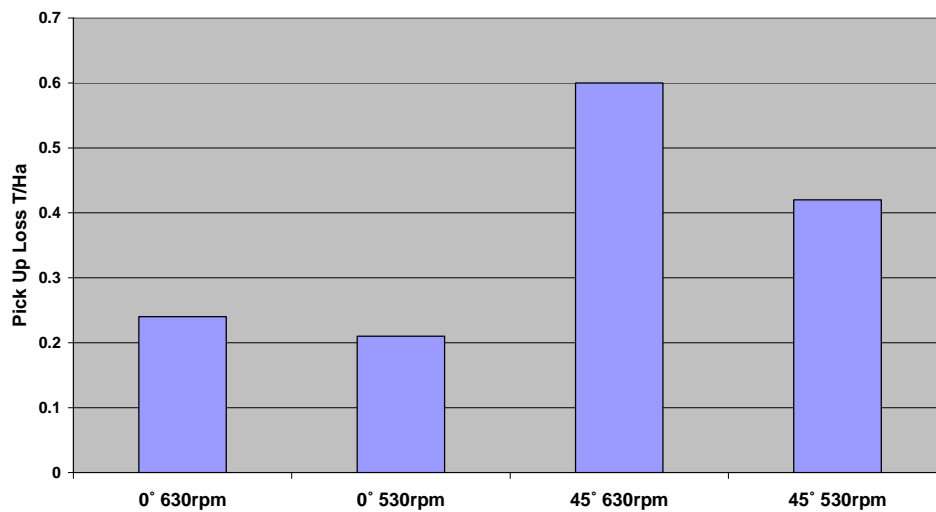
**2006 harvest**

The crop at Mackay was quite tall and erect, which highlighted the differences between the standard aggressive knockdown angle and the reduced knockdown module in the 2006 harvest. Ground losses were higher with the more aggressive 45° knockdown angle (Figure 26), due to the pre-stressing caused by forcing cane stalk downwards before being cut by the basecutters.



**Figure 26 Mackay trial – Ground losses from the 2005 harvest**

Pick-up losses were lower with the enhanced feeding module (Figure 27), due to its improved gathering ability and positive feeding design. This reduction in pick-up losses is a significant benefit to be gained from correct gathering system geometry and a more positive forward feed system, especially in brittle or lodged cane.



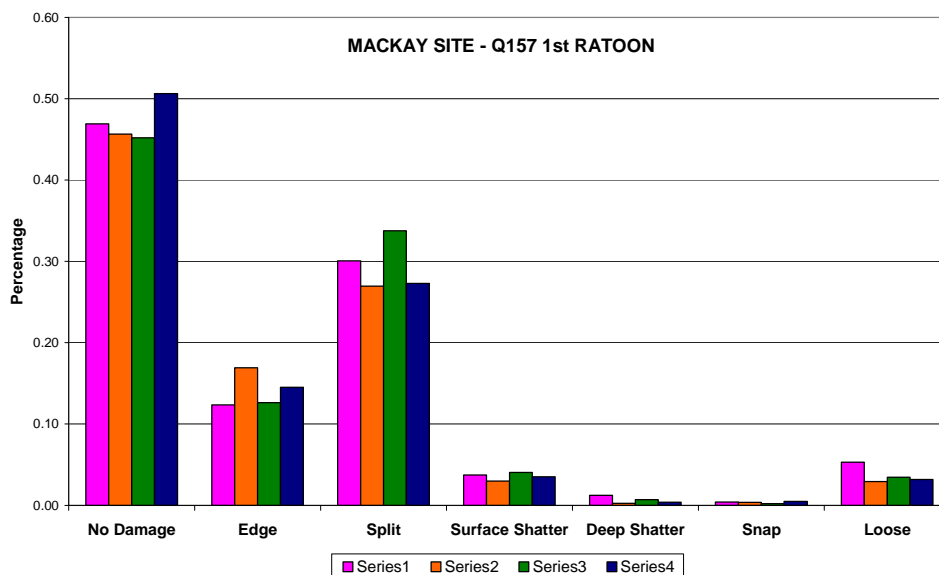
**Figure 27 Mackay trial – Pick-up losses from the 2006 harvest**



### 3.2.2.3 Stool damage

#### *Following the 2004 harvest*

There were no significant differences amongst treatments in stool damage following the harvest (Figure 28).

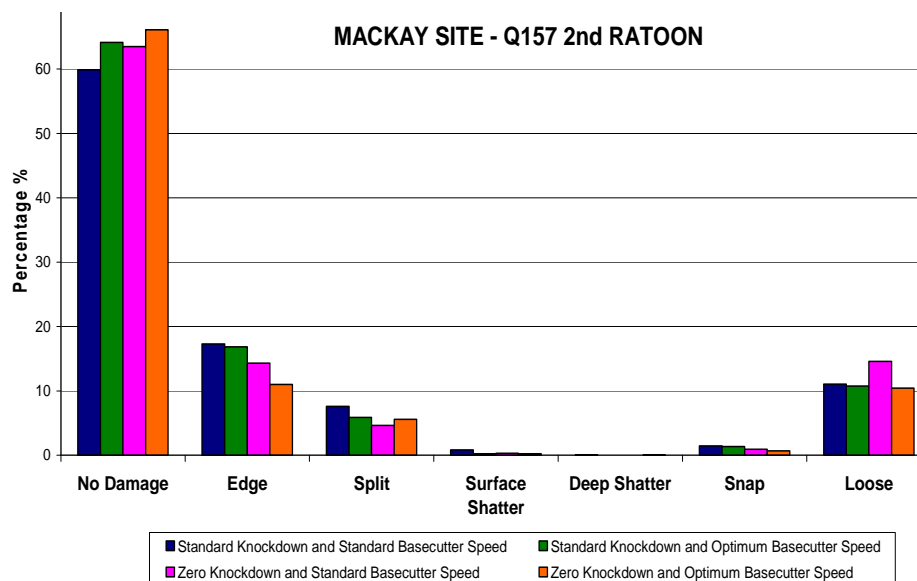


**Figure 28** Mackay trial - Stool damage assessment following the 2004 harvest. Series 1: Zero knockdown; Standard basecutter speed - Enhanced module, K2B1; Series 2: Zero knockdown; Optimum basecutter speed - Enhanced module, K2B2; Series 3: Standard knockdown; Optimum basecutter speed - Standard module, K1B2; Series 4: Standard knockdown; Standard basecutter speed - Standard module, K1B1

There were no significant treatment effects on stubble damage or stool morphology in this crop.

#### *Following the 2005 harvest*

The Mackay trial site has remained a consistent block with no weed/grass problems and reasonable consistency in terms of hill-up and row spacing. Damage assessments conducted following the 2005 harvest showed slightly higher (but not significantly) levels of edge damage and splits down into the stool from the standard aggressive harvester configuration (Figure 29).



**Figure 29** Mackay trial - Stool damage assessment following the 2005 harvest

There was no effect of treatment on the proportion of total viable buds that produced sucker shoots in 2005. Effects of treatment on the proportion of viable buds producing second-ratoon non-sucker shoots (shoots) were significant (Table 8). The knockdown treatments (K1) had significantly more of the total viable buds represented as shoots at the time of assessment than in the K2B2 treatment. K1B1 was intermediate. The corollary of this observation was seen in the proportion of buds still at swelling stage, where the K2 treatments had more buds in this category than did K1B2. There were no treatment effects on the total number of viable buds per stool and final shoot emergence may well not show any treatment effects. It is difficult to determine a logical mechanism for the apparent early emergence effect, as there were no treatment effects on total stubble damage levels, and the largely sprawled nature of the first ratoon should have nullified effects of the knockdown treatment.

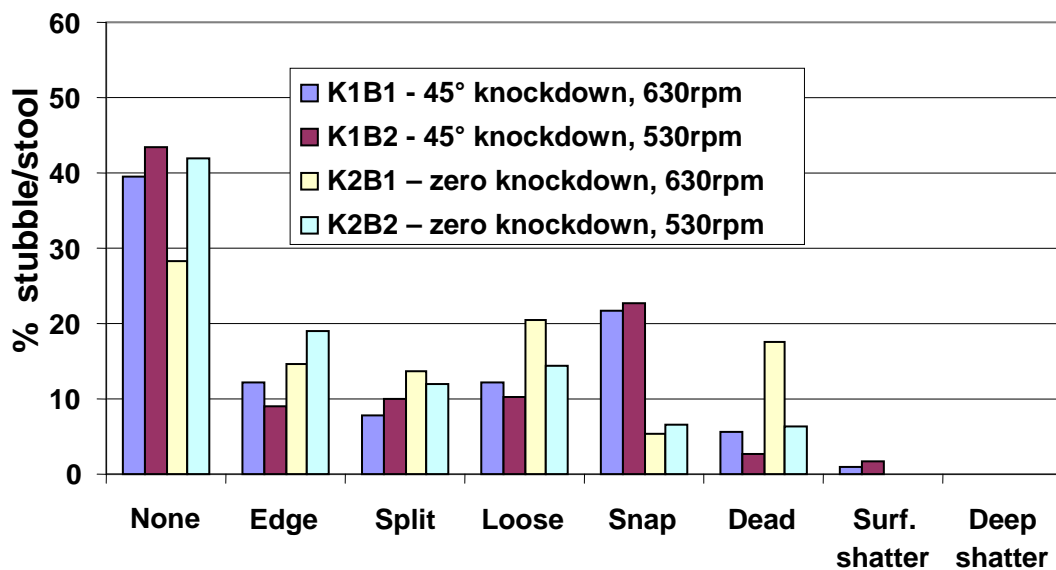
**Table 8** Mackay trial - Proportion of viable buds producing shoots and swelling buds

Treatment	% viable buds as shoots		% viable buds – swelling stage	
	Mean	Homog. groups	Mean	Homog. groups
K1B2	69.3	A*	24.8	B
K1B1	58.9	AB	33.6	AB
K2B1	54.4	B	38.5	A
K2B2	53.4	B	36.5	A
p value		0.09		0.16

\* values followed by the same letter are not significantly different

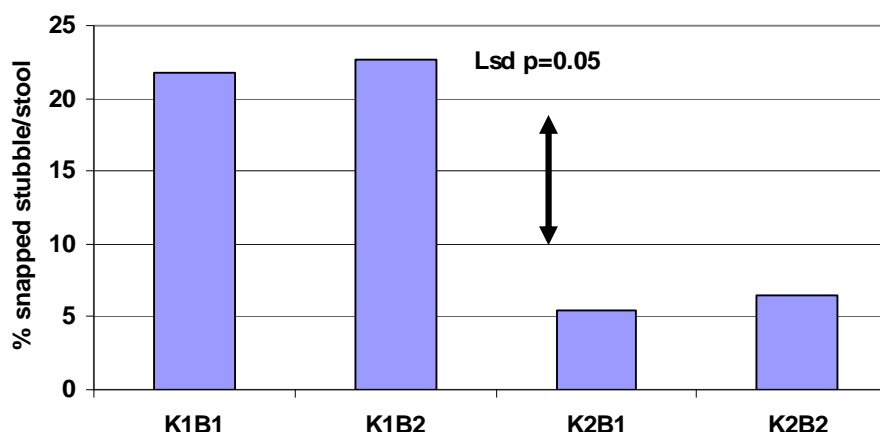
### *Following the 2006 harvest*

The Mackay trial site remained a consistent block with no weed/grass problems. A degree of variability in terms of hill-up and row spacing is thought to have had an impact on data collected, although some trends supported the hypothesis that reduced knockdown angle should decrease the level of snapped stalks (Figure 30). Other types of damage such as shattering, edge splits and loosened stool appear to be a product of hill height and profile in combination with machine design that played the lesser role in determining damage levels. There was a strong link between knockdown angle and the level of damage due to snapping when harvesting with the aggressive knockdown module. The connection between harvester treatment and other types of damage was more difficult to interpret due to the effect of crop presentation on splitting and stool loosening.



**Figure 30 Mackay trial - Stool damage assessment following the 2006 harvest**

There was no difference among treatments in the proportion of undamaged stubble pieces per stool, edge damage, splitting or deep shattering. Knockdown showed low surface shatter damage (1.05-1.8%), whereas there was no surface shatter damage recorded in the no-knockdown treatments. Knockdown caused significantly more snapping than no knockdown (Figure 31).



**Figure 31** Mackay trial - Effect of knockdown treatments on snapped stubble damage following the 2006 harvest

There were few significant effects of the harvester treatments on stool morphology parameters (Table 5). There were significantly more stubble pieces per stool in Q157 in the K1B2 (Knockdown and optimised basecutter speed) than all other treatments. This effect was consistent across all replicates and cannot be explained. The knockdown treatments had more shoots and shoots + suckers per stool than did no-knockdown treatments in the Q157 ratoons (Table 9). The difference between the lowest population treatment (K2B1) and both knockdown treatments approached significance ( $p=0.15$ ) for the shoots and was significant ( $p=0.08$ ) for the total above ground shoot population. This is a counter-intuitive result, given the adverse impact of knockdown on snapped stubble damage, but even the lowest number of shoots/stool in the K2B1 treatment would provide an acceptable stalk population if all survived. Thus, the above differences are unlikely to be reflected in yield.

**Table 9** Mackay trial - Population of shoots and shoots + suckers following the 2006 harvest

Treatment	Shoots/stool	Homog. groups	Shoots+suckers/stool	Homog. groups
K1B2	15.2	A	16.5	A
K1B1	14.5	A	16.1	A
K2B2	11.6	AB	12.5	AB
K2B1	9.4	B	10.2	B
lsd		$p=0.15$		$p=0.08$

The upward movement of the stool was not very apparent (Table 7), but there was a marked increase in shoots emerging from the 0-5 cm zone (Figure 32) and associated reductions in the 10-15 and 15-20 cm zones.

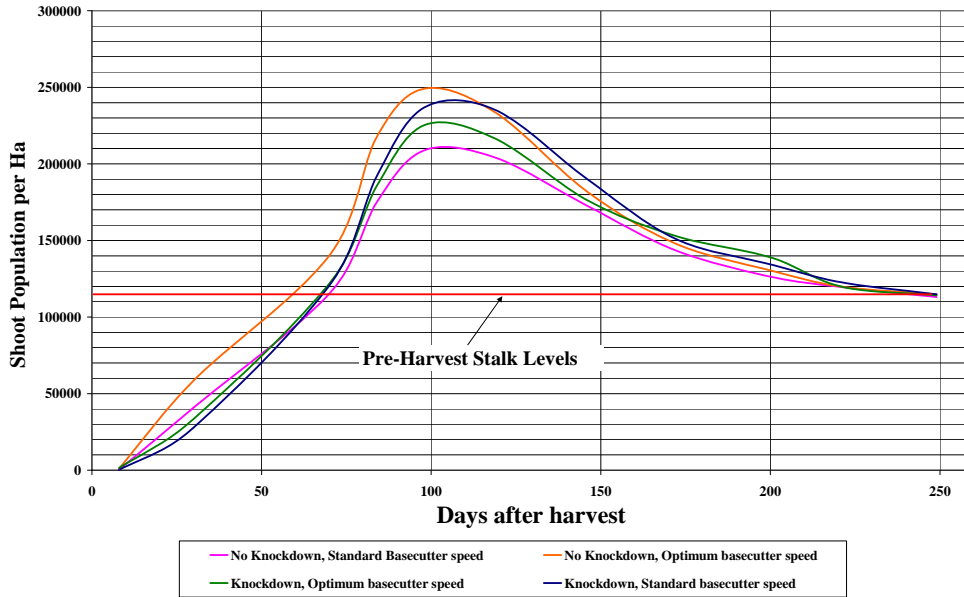


**Figure 32** Mackay trial - Emergence of suckers from deep in the stool. The black tie and pink tag are at ground level

#### 3.2.2.4 Shoot counts

##### *Following the 2004 harvest*

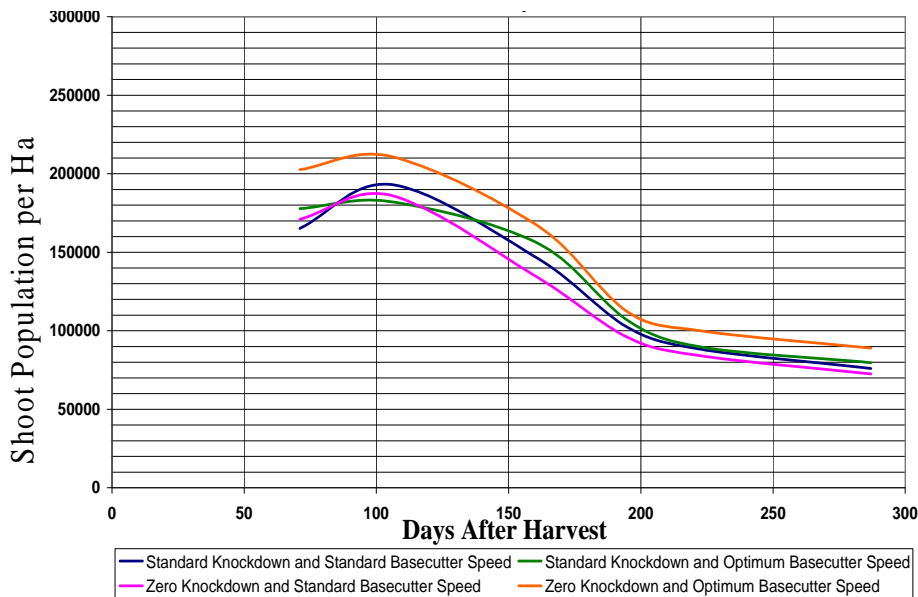
The 'zero knockdown, optimum basecutter speed' treatment had the fastest shoot ratooning and the highest overall shoots per hectare (250,000) (Figure 33). However, all treatments reached around the same shoot numbers at 18 April when lodging prevented further shoot counts (115,000 shoots/ha).



**Figure 33 Mackay trial - Shoot populations following the 2004 harvest**

*Following the 2005 harvest*

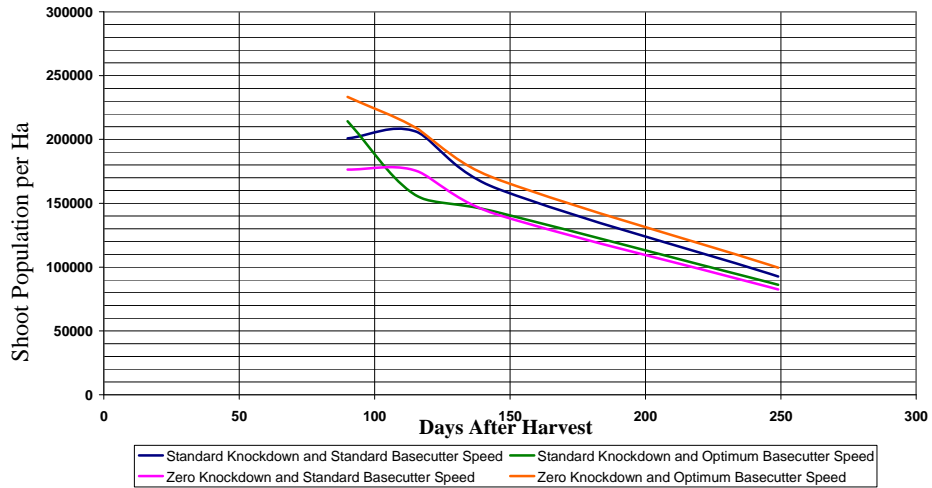
The zero knockdown/optimum basecutter speed treatments produced the highest shoot population and this continued through to harvest, with a final shoot population of 88,940 shoots/ha (Figure 34). Surprisingly, the two standard knockdown treatments had higher shoot populations (79680 shoots/ha at optimum basecutter speed and 76020 shoots/ha at standard basecutter speed) than the zero knockdown/standard basecutter speed (72460 shoots/ha). This could indicate that basecutter speed plays a critical role in determining damage and ratooning levels.



**Figure 34 Mackay trial - Shoot populations following the 2005 harvest**

**Following the 2006 harvest**

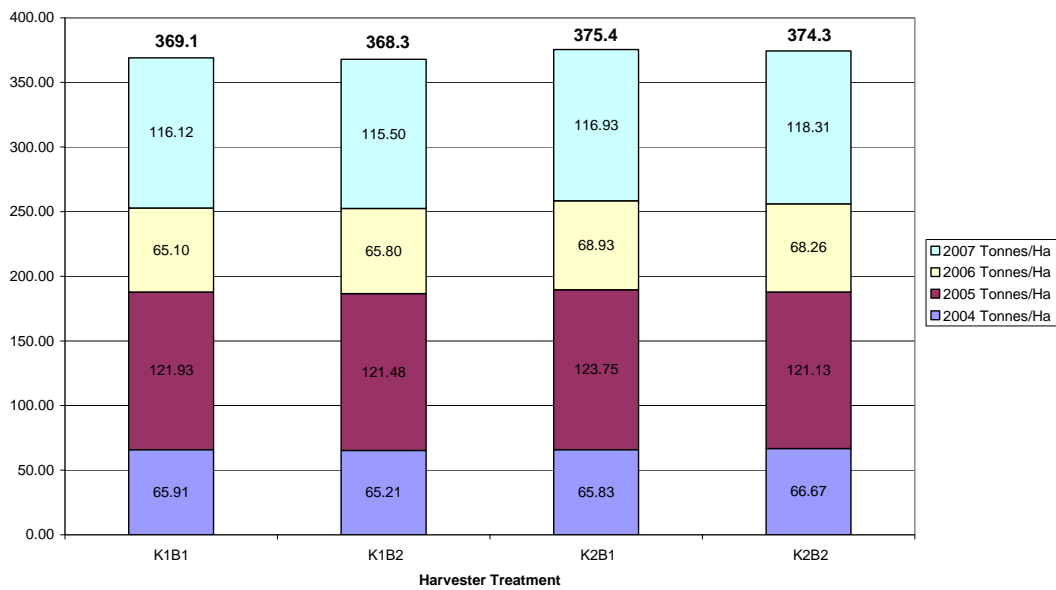
Similar to the post-2005-harvest shoot-population trend, the enhanced module with zero knockdown and optimal basecutter speed had the highest pre-harvest shoot population (Figure 35).



**Figure 35 Mackay trial - Shoot populations following the 2006 harvest**

**3.2.2.5 Cane yields**

Figure 36 shows the cumulative yield for each harvester treatment over the four harvests from 2004 to 2007. There appears to be a slightly better yield performance in the zero-knockdown treatments, which may have been more significant if the knockdown effect had not been negated by lodging prior to the 2005 harvest.



**Figure 36 Mackay trial - Four-year cumulative cane yield data**

### **3.3 Conclusions**

The monitoring of stool morphology over 3 crop years did not establish any clear or consistent impact of the selected harvester-management treatments on stubble damage or the dynamics of shoot development. The observations, photographs and data demonstrated that major damage was caused to the stool by mechanical harvest, and this allowed the ingress of rots to at least one internode below the penetration of damage. This damage did not prevent the development of similar final stalk populations across treatments, indicating the value of the built-in redundancy associated with high shoot populations after ratooning. We did, however, quantify the upward movement of the point of development of ratoon shoots as the cycle progressed. The hypothesis was proposed that sucker shoots developing from deep in the stool may play a role in stool longevity. The second-ratoon harvest at both sites showed that treatments with no knockdown produced higher yields than did knockdown treatments.

The marked upward movement of the genesis of the stool would appear to have potential to limit the productive life of the crop cycle. How then is it possible for long ratooning cycles to be practised in some areas of Australia and particularly in southern Africa? Certainly lower levels of stool damage associated with manual harvest may be a factor in Africa, but capacity to produce six to eight ratoons is not uncommon in the Central region of Queensland. We offer the hypothesis that sucker shoots that originate deep in the stool may provide a mechanism for renewal of the deeper bud zones to maintain a viable stool. We were unable to quantify the proposed mechanism, and this may be due to the variability in sucker numbers and the relatively small samples used. However, it does raise a question about the potential positive value of suckers in the rationing process, as opposed to the generally held view that suckering is counter-productive, especially when suckers develop early and are included in harvested cane.

### **3.4 Farming factors affecting harvester performance**

During these trials, it became increasingly clear that there are a number of interacting factors that determine levels of basecutter damage, ratooning rates and subsequent crop yields. The key hypothesis for this project was that aggressive knockdown angles in current commercial cane harvesters place undue stress on cane stalks prior to being cut by the basecutters, resulting in significant levels of stalk splitting and snapping. Additionally, work conducted in earlier basecutter research indicated that a mismatch between harvester forward speed and basecutter speed results in excessive shattering of stools. We have clearly observed many instances of this occurring during the field-trial phases of this project, but there have been major inconsistencies in the damage levels recorded within individual plots due to external, non-harvester related variability. As a result, data collected on stool damage, ratoon development and crop yield has been highly inconsistent with the expected outcomes. This section seeks to explain the nature of in-field variations observed during this project and their impact on stool damage levels. Whilst the impact of this variability has significantly compromised the data collected during this project and made it difficult to prove the initial hypothesis, it does indicate that farmers have a real opportunity to reduce the levels of 'harvester damage' experienced through improved crop presentation. If crop presentation issues have been able to override the expected effects of a significant harvester design improvement, this indicates



that attention to detail in preparing cane crops for harvest is even more vital than previously suggested.

### 3.4.1 Filling-in and hilling-up

Probably the most significant of these crop presentation variables is the row profile left after filling-in and hilling-up operations. To achieve successful crop presentation in terms of 'fill-in' and 'hill-up', farming operations should aim to produce a consistent hill shape that closely matches the profile left by the basecutter blade action after harvest. Where farming operations have been successful in filling-in and hilling-up to form a consistent mound that peaks in the centre of the row, a well-operated harvester tends to give a high-quality basecutter job - the blades have skimmed the surface of the soil across the full width of the hill profile with stalks being supported by surrounding soil to give a clean cut with minimal shattering. To maintain consistency in machine operation for our trials, basecutter height was set at an appropriate height to skim the soil surface whilst cutting guard rows and then that height maintained throughout the trial using the in-cab sight gauge.

An incomplete hill-up that leaves a hollow in the centre of the row results in stalks being cut above ground level. This causes significant shattering of butts, as well as a degree of stalk snapping due to a lack of supporting soil. Another side-effect of this V-shaped stool profile is the loosening of the stool below the surface due to agitation of unsupported stalks being impacted by basecutter blades. Figures 37 and 38 show the difference in basecutter damage between a properly filled-in section of row and an incomplete fill-in resulting in a V-shaped profile, respectively. Note that both sections of row are within the same plot, cut at the same machine height and in the same direction and yet the stool appearance following harvest is very different, simply due to the variation in hill profile.



**Figure 37** Hill profile matching the basecutter disc action very well, resulting in minimal damage to stools in terms of shattering or loosening. The scenario was observed many times at both trial sites with both harvester setups



**Figure 38** Hill profile where the hollow left in the centre of the hill resulted in basecutter blades impacting stalks above the level of the soil causing higher levels of shattering, deep splits propagating into the stool and stool loosening that would obviously result in poorer ratoon development

Whilst this type of variation in hill shape has obvious effects on stool damage, it also creates problems for harvester operators trying to minimise soil intake and stalk pickup losses. If cane grown in a V-shaped hill lodges, it leaves operators with two unsatisfactory options: (i) set basecutter height to skim the extremities of the hill profile to minimise soil intake, resulting in stalks laying in the centre of the V being left behind with significant yield loss and stool damage affecting subsequent ratoons; or (ii) set basecutter height lower to pickup all cane stalks, resulting in large quantities of dirt being fed into the cane bundle by the basecutters, which reduces cane quality and creates higher levels of wear damage within the harvester and mills that is a significant cost to the industry. Cutting lower can also result in the total removal of stools growing in the outer edges of the hill profile.

### 3.4.2 Hill height

Previous discussion has emphasised the impact of cutting height on basecutter damage, whereby cutting above the soil level creates excessive shattering/splitting and cutting too far below the soil level can result in stool removal and high levels of soil in the cane supply. On many occasions, variations in cutting height were observed at both trial sites. Checks of the harvester's operation showed that the machine's basecutter height setting was not being varied at all from row to row or between plots. We observed that apparent cutting height variability was being caused by two crop-presentation variables. The first was simply differences in actual hill height created during the hilling-up process, where variation in the volume of soil being moved into the centre of row resulted in a higher hill where more soil was moved and a lower hill where less soil was moved into the cane row. The latter scenario of insufficient soil being displaced into the row centre often resulted in both a low hill height and the V-shaped profile creating the cane pickup, stool damage and soil intake problems discussed previously. Areas where more soil had been moved into

the cane row would cause a higher intake of soil in the plant cane harvest, but without the same basecutter issues and subsequent harvests would not be as badly affected with the basecutter action creating a better hill profile/basecutter match. These variations in hill profile have always been considered an 'inconvenience' to operators with some impact on cane-pickup losses. However, the corresponding impact on basecutter damage levels observed during this project suggests that filling-in and hilling-up operations are critical factors impacting on damage levels and ratoon development.

Data collected during this project indicated some differences in damage and ratooning due to knockdown effect. However, there was no clear basecutter-speed effects observed. Sub-optimal basecutter speeds were expected to generate higher levels of stool shattering, edging and splitting, but these categories of stool damage are also caused by cutting above the soil level. This leads us to conclude that the cutting height variations due to crop presentation discussed above has overridden any basecutter speed effects. The fact that in-field variation was able to significantly override major machine-design effects indicates that farming practices in preparing plant cane for harvest play a much more significant role in determining levels of harvesting damage than previously thought.

#### **4.0 REFINEMENT OF CROP-HANDLING COMPONENT-SPEED AND GROUND-SPEED SYSTEM**

A major opportunity to implement harvesting best-practice presents itself through the development of a speed-control system for cane-harvester crop-handling components. Other agricultural crop harvesters, including grain combines, cotton pickers and forage harvesters, all have some form of feedrate control system on their critical crop-handling components. John Deere has developed an advanced adaptive on-the-go control system for combines designed to enable automatic ground speed control during harvest operation. This system assures that the combine maintains a consistent crop load by automatically changing the ground speed to compensate for variations in crop that are not readily visible to the operator.

In evaluating solutions for improved machine performance, the associated symptoms of unmatched machine crop-handling speeds and harvest speed on performance indicators need to be identified, considered and addressed. Thus, criteria for machine performance should include feeding ability, stool damage, effect on subsequent yields, reduced overloading of crop-handling components, reducing cane loss, lower EM after cleaning, and less operator stress.

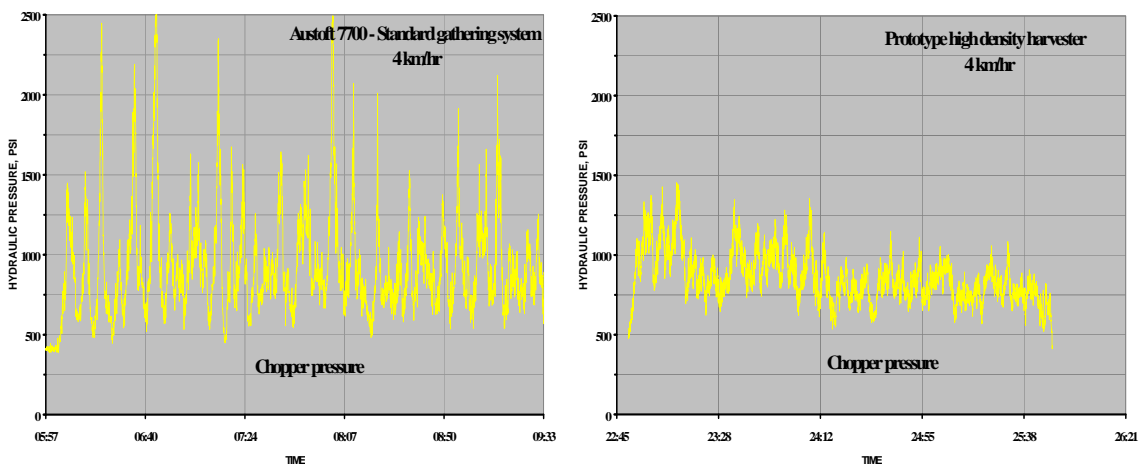
##### **4.1 Definition of performance envelope for crop-handling components with respect to ground speed**

The three key crop-handling components identified in SRDC-supported projects BSS165 and BSS252 as having a significant impacts on harvesting efficiency are the spirals, the basecutters and the feedtrain/chopper systems. That research indicated that linking crop-handling components to ground speed could give significant improvements in terms of improved feeding and reduced damage and loss. To develop performance envelopes for

each component, we conducted trials at Bundaberg Sugar's Fairymead plantation in a heavily lodged block of Q188<sup>b</sup>. The modular harvester had hydraulic systems that allowed component speeds to be controlled individually. Trial runs were conducted at a range of ground speeds and component speeds. This enabled us to identify optimum speeds for each crop-handling component as ground speed varied.

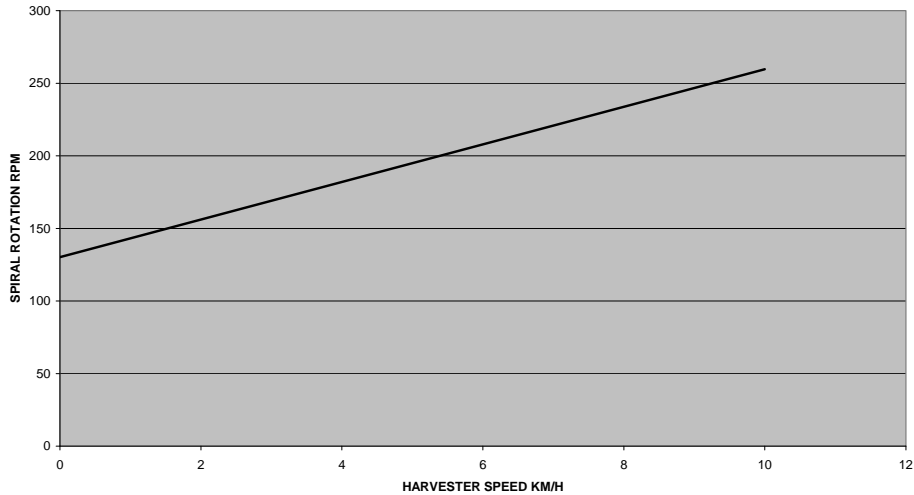
#### 4.1.1 Spirals

Significant improvements in green-cane feeding were made with the development of the BSES single-spiral retrofit for standard harvesters. Uneven feeding causes large gluts of cane to pass through the harvester, causing chopper and cleaning system overloads. These overloads cause pressure spikes in the chopper hydraulic circuits, as seen in the left-hand section of Figure 39 that shows chopper pressure over time as gluts pass through the system. The graph on the right of Figure 39 shows the smoothing of chopper pressure in the same 160 t/ha block of cane resulting from a combination of single spirals and optimal feedtrain/chopper setup to give more even feeding.



**Figure 39** Chopper pressure in (left) a standard harvester, and (right) the prototype harvester

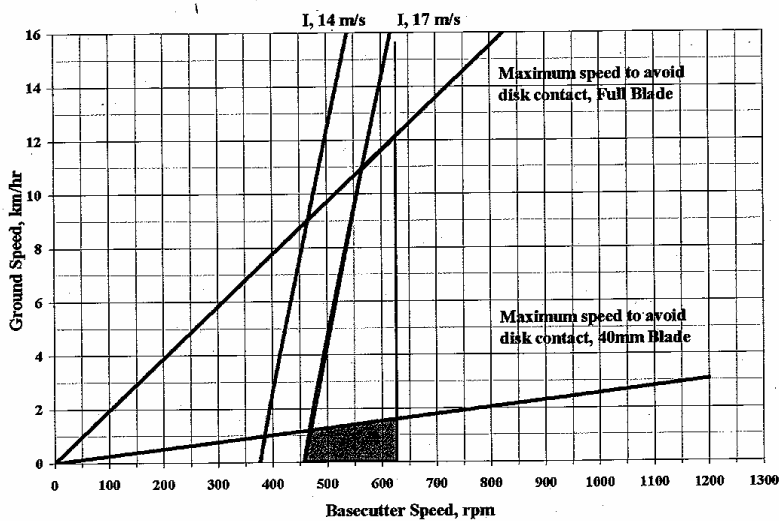
In a standard harvester, spirals rotate at a constant speed set by the manufacturer's choice of motor size. In our trials with the modular harvester, we observed that if the spirals remained at a constant speed, the number of stools being torn out increased as groundspeed was reduced. This was due to the cane moving too quickly up the spirals relative to the forward motion of the harvester. Reducing spiral rotational speed as ground speed reduced avoided this problem. The trials identified an optimum performance range for spirals relative to ground speed (Figure 40). Note that spiral speed variation is limited by the hydraulic setup of current harvesters, but the available range of speeds is more than adequate to match the range of harvesting speeds.



**Figure 40** Effect of harvester speed on spiral rotation

#### 4.1.2 Basecutters

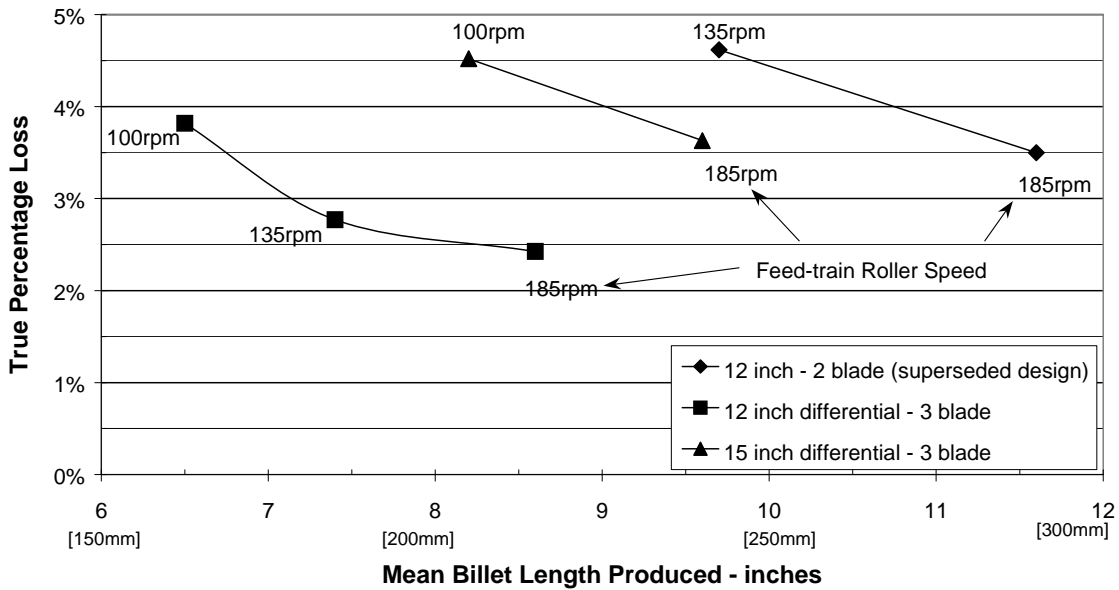
An in-depth study of the relationship between basecutter speed and harvester ground speed was undertaken by Sander Kroes of SRI. That work examined issues such as each stalk receiving multiple cuts if basecutter speed is too high relative to ground speed. Multiple blades hitting each stalk cause stool shattering that leads to poor ratooning. If the reverse situation of basecutter speed being too low relative to ground speed occurs, there are serious damage issues caused by the basecutter disk bulldozing into stalks before they can be cut by the blades; this results in stools being removed from the ground. The relationship between basecutter speed and ground speed is shown in Figure 41. An automated speed control system would avoid this problem by increasing basecutter speed as harvester forward speed increases.



**Figure 41** Relationship between basecutter speed and ground speed

### 4.1.3 Feedtrain/Chopper

Extensive research by BSES into chopper losses and feedtrain/chopper relationships has identified the potential to significantly reduce the loss of sugar in the chopping process. Two key areas for improvement identified were matching the surface speeds of all feedtrain rollers to get even cane feeding and then matching chopper to feedtrain speeds to minimise the juice loss associated with mismatched feedtrain/chopper relationships. Figure 42 shows juice loss decreasing as feedtrain speed increases to match chopper speed.



**Figure 42 Relationship of billet length and juice loss**

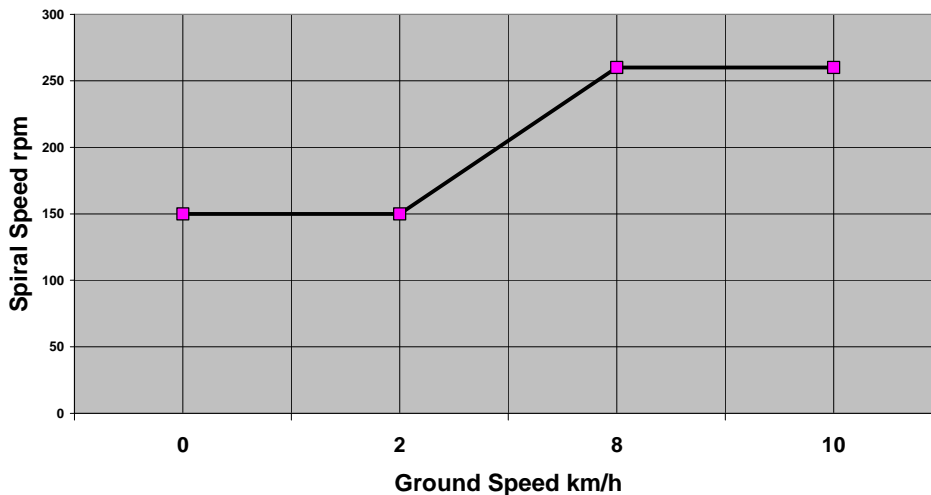
There are some practical limitations on the range over which chopper speeds can be varied. If choppers are slowed down too much (less than 180 rpm for a 12-inch chopper system), there is a poor throw velocity into the cleaning chamber, which can cause poor cleaning and recirculation of billets. This occurs when billets do not have the momentum to leave the choppers and so they continue to rotate around the chopper drum after they are cut and end up being dropped on the ground below the harvester. If chopper speed is too high, then billets move across the cleaning system too quickly for the fan to have sufficient cleaning time, resulting in high extraneous matter. The chopper test-rig identified that to minimise juice loss, the feedtrain-roller surface speed should run at 60-70% of the chopper-tip velocity, which implies that feedtrain speed variation is limited by the range of acceptable chopper speeds. In terms of linking ground speed to feedtrain/chopper speed, the key to achieving good cane feed into the machine is having the feedtrain-roller surface speed higher than the forward speed of the harvester, such that cane is actively pulled into the throat of the harvester.

#### 4.1.4 Conclusions

We believe that the feedtrain/chopper speed range is determined by three factors: practical limitations (recirculation), optimal throw velocities for cleaning, and feedtrain surface speeds higher than ground speed for positive feeding.

The relationship between harvester forward speed and crop-engaging components plays a vital role in the functionality of commercial harvesters in most crops (eg. grains), except sugarcane, where component speeds typically remain fixed at factory settings. Whilst the factory settings allow cane harvesters to process cane adequately, there is no ability to change forward-feeding or basecutter-component speeds to match harvester forward speed. The component speed ‘envelopes’ shown below were programmed into a programmable logic controller (PLC) and the system consistently achieved the desired component speed/ground speed match.

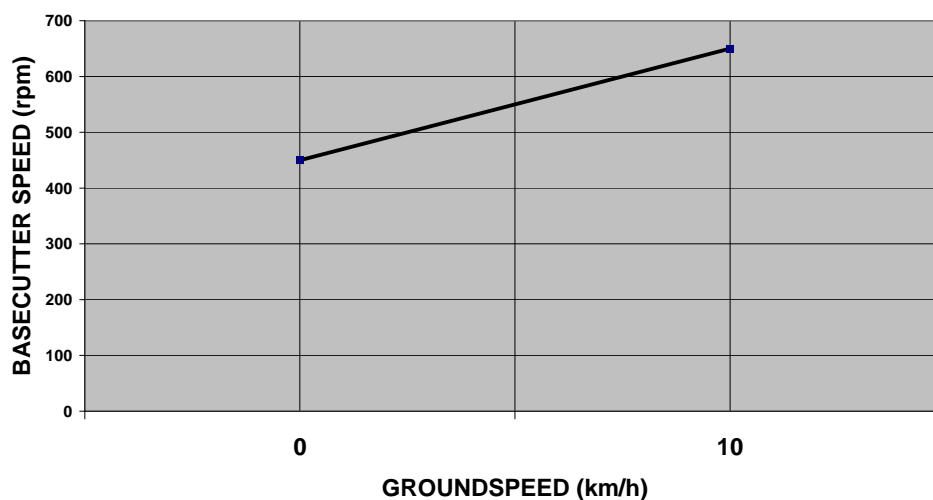
Factors taken into account when establishing the forward feed circuit response were the requirement to have a minimum rotational speed (150 rpm), which provided positive crop feed when first entering the cane row at speeds below 2 km/h with the Hyteco control valve progressively increasing oil flow to the feed components as harvester forward speed increases. Maximum oil flow from this hydraulic pump produces the upper spiral speed of 260 rpm once the harvester reaches 8 km/h (Figure 43), giving a wide range of component speeds within typical operational speeds.



**Figure 43** Spiral circuit response curve

The basecutter response curve (Figure 44) takes into account the minimum disc-rotational speed required to avoid disc contact with cane stalks prior to the blades severing stalks as harvester speed increases. On top of this, the practical requirements of the basecutter system were considered, whereby a minimum speed of 450 rpm was set to provide adequate momentum from the basecutter discs and legs to maintain cutting speed as the machine enters the cane row and cuts the first stool. The system progressively increases

oil flow to the basecutters via the Eaton proportional pump controller to achieve the maximum speed of 650 rpm at 10 km/h.



**Figure 45 Basecutter circuit response curve**

We believe that, as harvester forward speeds continue to rise, increasing basecutter speed is vital to avoid massive damage and stool removal due to disc/stalk contact. An automated system is an ideal way to maintain acceptable basecutter speeds across the full range of operating speeds.

## 4.2 Prototype system

The proof-of-concept prototype speed-control system for the crop-handling components of sugarcane harvesters was designed to allow for:

- Incorporation into the hydraulic layout of 'Beetle', the modified Austoft 7000 experimental harvester based at BSES Bundaberg, and
- The concept to be extended with slight design modifications into the hydraulic layout of CNH 7000/7700 and Cameco CH2500/CH3500 harvesters.

The proof-of-concept system provides electric-over-hydraulic control of each of the crop-handling-component pump-drives supplying oil to forward-feeding components and basecutters allowing an in-cab programmable PLC to constantly adjust component speeds to match harvester forward speed. Work by BSES, SRI and other researchers in the past has indicated that matching component speeds to ground speed would play a significant role in improving cane feeding performance and reducing basecutter damage. For a given ground speed, an overly high basecutter rpm will result in stool being cut by the blades multiple times. When the basecutter rotational speed is too slow for the forward speed, then a tearing cut results and stalks are torn off by the disc before a blade reaches the stalk; this causes severe damage to the stool.



The development of an automated speed control system aimed to capture the benefits seen in this earlier work and the BSES experimental harvester provided an excellent platform for testing with interchangeable modules enabling comparisons between standard harvester setup and the enhanced feeding module. The experimental harvester 'Beetle' is a modified 1989-built production model Austoft 7000. The machine is fitted with a Komatsu SA6D108 engine, rated in excess of 180 kW and a manual cabin. The mainframe of this harvester has been modified to incorporate forward-feeding modules (Figure 46) with the enhanced feeding module fitted and the standard module placed in front.



**Figure 46** Experimental harvester modified to incorporate forward-feeding modules with the enhanced feeding module fitted and the standard module placed in front

A forward-feeding module is a discrete stand-alone unit that is a full-scale representation of a harvester front-end. When installed, the discrete module allows the harvester to operate as a fully functional machine. Several modules have been developed by BSES, including a standard leg basecutter module based on a 2000 production model CNH-Austoft 7000/7700 and an enhanced forward-feeding leg basecutter module.

The layout of the feedtrain forward of the second-bottom feedroller was updated from the original 1989 model layout to a 2000 production-model layout. The speed of the feedtrain rollers have been synchronised with the speed of the installed Austoft 12-inch differential rotary-pinch chopper system. This machine is an excellent test bed for comparing standard machine performance to any modified configuration. The conceptual design of this system was considered in the context of extending the principle and system to the

hydraulic layout and crop-handling components of current model CNH Austoft and John Deere Cameco harvesters. Where possible, off-the-shelf components were sourced and integrated into the system design.

The development of the speed-control system was completed during the 2006 harvest with earlier electric/hydraulic control problems being resolved following efforts of the project team with input from hydraulic experts at Berendsens Fluid Power and the development of new electronic control systems by Mark Conway at Control Unlimited. The system revolves around the PLC interface (Figure 47) that receives inputs from ground-speed radar and feed roller/basecutter speed sensors. The PLC is programmed to respond to different ground-speed inputs and then activate the two proportional electro-hydraulic flow controllers to increase or decrease oil flow to the harvester components to constantly optimise component speed to ground speed.



**Figure 47** PLC interface

After initial discussion, we decided to use a Koyo PLC and an E-Pad HMI (human machine interface) as the control equipment for the project. The project required the ability to read four high-speed inputs, spiral, basecutter, feedtrain and ground speed, as well as control three analogue (4-20 Ma) outputs to control the spiral, basecutter and feedtrain hydraulic circuits.

The Koyo DL06 PLC is a shoe-box PLC with four expansion slots. In its basic form, the PLC allows for 24 digital inputs, of which two can be high-speed counter inputs and 18 digital outputs. A two-channel high-speed counter module was fitted into slot 0 on the PLC and two two-2 channel 4-20 Ma output modules were fitted into slots 1 and 2 - this gave the required four high-speed inputs and three analogue outputs.

The PLC was mounted in its own enclosure, allowing it to be mounted out of the way in the cab and a harness was run out of the cab to pick up the sensors and valves. A toggle switch and delay on timer was fitted to invert the 4-20 Ma signal to the EPV controller on the basecutter pump so that the basecutter could be reversed to allow removal of any chokes.

The HMI, which incorporated a four-line 20-character LCD and five user-definable keys, was mounted within reach of the operator as to allow circuits to be turned on/off, change set points, and to monitor current speeds, target speeds and valve-open percentages.

The PLC program was written using Ladder format software developed by the PLC manufacturer. The high-speed counter inputs on both the PLC and expansion module were programmed to allow the sensors in the hydraulic motors and ground-speed radar to be scaled to display rpm and km/h on the HMI and used elsewhere in the program to act as feed back for the control circuits. The PLC software supports Pid loops; therefore, three loops were programmed to operate the spiral, basecutter and feedtrain circuits. The outputs of these loops were then written to the appropriate 4-20 Ma outputs. The Pid loops can be tuned by connecting a Computer to the PLC and either initiating an 'Auto Tune' or manually tuning the loops while the machine is running.

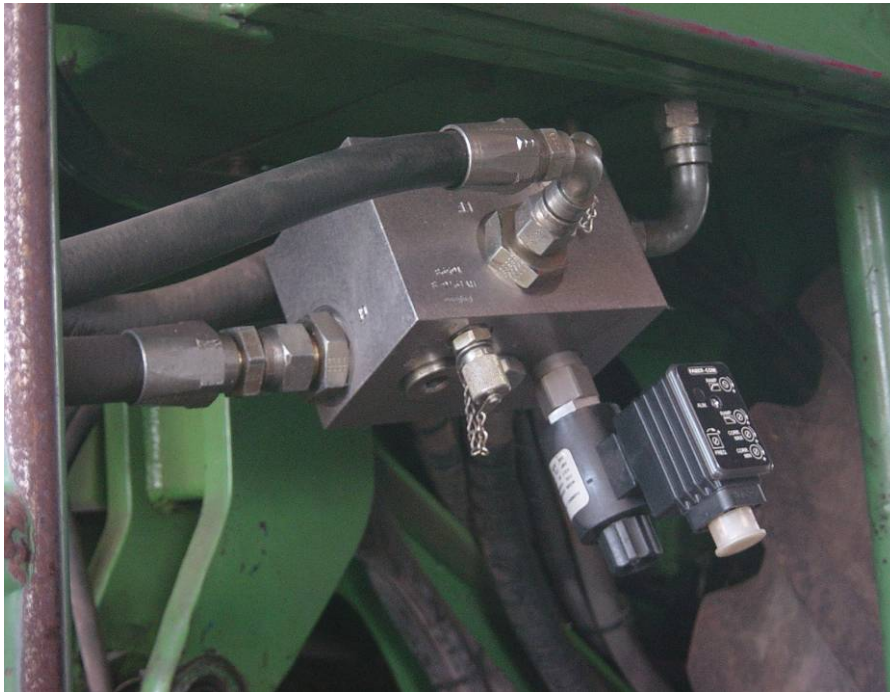


**Figure 48** Automated speed control system as installed in harvester cab showing: PLC interface between component speed sensors and the electric-over-hydraulic controllers (top box), the Dickey-John radar ground speed display (middle) and the operator feedback console (bottom box) as installed inside the harvester cabin



The HMI was programmed using the manufacture's software and communicates with the PLC using common addresses to both units. The HMI is connected to the PLC via a comms cable that allows the operator to select three control modes, 'manual' (enters a percentage valve open, i.e. 50%), 'set point' (sets a target speed, i.e. 280 rpm and controls the speed using the feedback sensor), or 'auto' (which varies a target speed according to ground speed and feedback sensor). Several screens are available to the operator to monitor the status of all circuits, alter control modes or change current set points. All circuits can individually turned off or on via illuminated rocker switches on the face of the HMI enclosure. Figure 48 shows the system installed in the harvester cabin.

In the initial design, we proposed to use proportion control valves in a manifold designed and build by Hyteco Hydraulics (Figure 49). Initial testing showed this design worked very effectively in the spiral/gathering system circuit, but created major pressure spikes in the feedtrain/basecutter circuits due to the much higher flows.



**Figure 49** Hyteco control valve/manifold installed in a spiral circuit

After major, but unsuccessful, efforts to modify the Hyteco design to control the basecutter circuit, we decided to move to a proportional electronic pump-control unit available from Eaton Hydraulic. This was expensive, but was guaranteed to function effectively. The component was sourced with advice from Berendsens and installed during 2006. Workshop testing showed none of the pressure-spike problems experienced with the Hyteco unit. The result was a fully functioning system incorporating the original Hyteco manifold/valve to control the spiral/gathering circuit and the Eaton proportional unit controlling the basecutter circuit (Appendix 2; Figure 50).



**Figure 50** Eaton electro-hydraulic proportional pump controller fitted to the experimental harvester

The system is an adaptive on-the-go control system, designed to enable variable-speed control of the crop-handling components during harvesting. This system ensures that the cane harvester maintains a consistent feedrate and optimum performance by enabling manual automatic crop-handling component-speed variation with ground speed to compensate for variations in the crop. The system control unit also has an inbuilt function that allows manual override of the system by the operator.

As the development of a new system to control the basecutter circuit took some time and there were enforced delays due to smut decontamination processes, there was limited time for field-testing in the 2006 season. However, the system was operated with some fine-tuning in 2007. Ongoing testing in the 2007 harvest season in Bundaberg focussed on the functionality and reliability of the system. The programmable PLC at the heart of the crop-handling component speed/ground speed system allows for the adjustment of a range of parameters by connecting to a laptop. This enabled fine-tuning on-the-go (Figure 51) to adjust component speeds and system response times to maintain a stable hydraulic circuit under field conditions where loads and pressures vary constantly.

To test the system's ability to maintain the correct ground-speed/component-speed relationship, we used it to harvest BSES plant-breeding trial sites that contained a wide range of variables that the system is required to process. These variables include variations in crop size that can increase or decrease hydraulic loadings requiring the PLC to interpret and respond quickly enough to maintain the correct component speeds without excessive hydraulic pressure spikes.

Another field variable faced by the system in testing was gaps within the cane row that cause a sudden reduction in basecutter load followed by an equally sudden increase back to full load as the machine moves into heavy cane again. The automated speed control system proved very effective in both these situations with us making small adjustments to system response time via the laptop software to provide stable basecutter/spiral speed throughout the field variations. This consistency in component speeds was achieved with the system still being able to respond to changes in harvester forward speed as the operator progressed from standstill through to full operating speeds.



**Figure 51 On-the-go adjustment of system parameters**

On-the-go adjustment of the PLC settings proved to be critical, as the variations in hydraulic circuit loads/pressures cannot be simulated in the workshop. It also enabled instantaneous feedback from the harvester operator on whether the speed control system was having positive/negative impacts on machine performance as small adjustments were being made. This introduces a completely new dimension of sophistication into the world of cane harvesting, bringing it into line with many other agricultural harvesters. The team was very happy with the performance of the unit, especially its ability to respond effectively to in-field variation.

## 5.0 PROMOTION AND ADOPTION

A broad group of industry stakeholders were involved in this project during its four-harvest lifespan. Growers, harvester operators, millers and a manufacturer had opportunity to observe the modular harvester in operation during the trials and have input into the research process through surveys and focus-group activities. The following section examines survey responses from the core group of 16 participants and discusses some of the broader focus-group activities. Survey data is shown in Appendix 3.

### 5.1 Baseline Survey versus Output Survey

The aim of the baseline survey was to gauge attitudes and knowledge of harvester basecutter damage in terms of the perceived impact on crop development and the factors affecting damage levels. Surveys 1 and 2 are shown below. This is followed by discussion and analysis of participants' responses.

#### **SURVEY 1: BASECUTTER DAMAGE/RATOONING EFFECTS**

1. Name:.....
2. Cane Growing Region:.....
3. Primary Occupation: .....  
(eg. Grower, harvester operator, miller, manufacturer)
4. Farm Size/Group Size:.....
5. How would you rate the importance of basecutter/knockdown damage as an issue affecting ratooning/productivity? (high, medium, low).....
6. Rate the following factors in order of their impact on ratooning: (1-most impact to 7-least impact)
  - knockdown angle
  - basecutter speed (rpm)
  - basecutter blade condition
  - crop lifter spiral design
  - hill height/shape
  - filling in of plant cane
  - harvester speed
7. If you are a grower, do you consider your hill height and shape in plant cane matches the basecutter profile left by your harvester?.....

8. If you are a harvester operator, what percentage of plant cane blocks have a hill profile well matched to your basecutter setup?.....
9. If you are a harvester operator, what angle is your basecutter box set at and what speed is it running (if known)?.....
10. Do you consider harvester damage associated with standard aggressive knockdown/basecutter setups is having an impact on yields?.....
11. Is harvester damage associated with a mismatch between stool profile and basecutter profile having an impact on yields? .....

Thank you for your time in completing this survey.

**SURVEY 2: BASECUTTER DAMAGE/RATOONING EFFECTS**

1. Name:.....
2. Cane Growing Region:.....
3. Primary Occupation: .....  
(eg. Grower, harvester operator, miller, manufacturer)
4. Farm Size/Group Size:.....
5. How would you rate the importance of basecutter/knockdown damage as an issue affecting ratooning/productivity? (high, medium, low).....
6. Rate the following factors in order of their impact on ratooning: (1-most impact to 7-least impact)
  - knockdown angle
  - basecutter speed (rpm)
  - basecutter blade condition
  - crop lifter spiral design
  - hill height/shape
  - filling in of plant cane
  - harvester speed
7. If you are a grower, do you consider your hill height and shape in plant cane matches the row profile left by your harvester?.....
8. Would information gained from this project create any changes in your farming operations with the aim to improve harvester performance?.....



9. If you are a harvester operator, what percentage of plant cane blocks you cut would you consider to be well matched to your basecutter setup?.....
10. Based on the outputs of this project, what do you consider has the most impact on harvester damage, ratooning and yields: knockdown/basecutter geometry or crop presentation?.....
11. This project investigated the potential to reduce harvester stool damage by eliminating aggressive knockdown angles and matching basecutter speed to harvester speed.
  - a. Did you consider this an area worth investigating?.....
  - b. Were you surprised at the impact of crop presentation on harvester damage?.....

Thank you for your time in completing this survey. If you have further comments on ratooning, harvester setups, etc, please include them below.

Sixteen industry stakeholders agreed to be part of the survey. The group involved were John Markley (Mackay Sugar), Ray Muller, Chris and Nathan Grech (Mackay growers and harvesting contractors), Steven Lawn (EHS Manufacturing), Renato, Carlo and Dario Germanotta (Mackay growers and harvesting contractors), John Powell (Mackay grower and QMCHA), Doug and James Young (Bundaberg growers and harvesting contractors), Ross McLean, Mike Smith and Keith Sarnadsky (Bundaberg Sugar millers, growers and harvesting 'contractors'), and Neville and Jason Loeskow (Bundaberg growers). Individual responses will not be identified to maintain confidentiality.

The analysis below examines responses question by question, comparing the differences between Survey 1 and Survey 2 to identify changes in perceptions/attitudes and knowledge gained from the project.

*Questions 1 to 4: General Information - Name, Region, Occupation, Farm/Group Size:*

This group comprised five growers, six grower/harvesting contractors, one harvesting contractor, three miller/growers and one manufacturer. Nine came from the Mackay region and seven from the Bundaberg region. Farm size ranged from 5000 t to 600,000 t, and harvesting business size ranged from 83 000 t to 200,000 t.

*Question 5. How would you rate the importance of basecutter/knockdown damage as an issue affecting ratooning/productivity? (high, medium, low):*

In the initial survey, basecutter/knockdown damage was rated as of high importance by 6 people, medium importance by 8 people, and low importance by 2 people. Having seen the project outcomes, only 3 people still rated it as high, 11 people rated it medium and 2 low. Discussions/comments indicated that, as farming practices play a critical role in determining levels of basecutter damage, knockdown damage was perceived to be less important.

*Question 6. Rate the following factors in order of their impact on ratooning: (1-most impact to 7-least impact) - knockdown angle; basecutter speed (rpm); basecutter blade condition; crop lifter spiral design; hill height/shape; filling in of plant cane; harvester speed.*

The overall ratings combine the responses of all 16 survey participants were:

<b>Overall Ratings – Survey 1</b>	<b>Overall Ratings – Survey 2</b>
1. Basecutter blade condition	1. Filling in of plant cane
2. Filling in of plant cane	2. Hill height & shape
3. Hill height & shape	3. Basecutter blade condition
4. Basecutter speed (rpm)	4. Harvester Speed (km/hr)
5. Harvester speed (km/hr)	5. Basecutter speed (rpm)
6. Knockdown angle	6. Crop lifter spiral design
7. Crop lifter spiral design	7. Knockdown angle

Initially, blade condition was rated as the most important factor, but having seen the trial results, where brand-new blades were used for each treatment, participants could see that poor row profile could cause significant damage even with sharp, long blades. They then ranked filling-in and hill-up as the most important factors in survey 2. Harvester speed and basecutter speed ranked fourth and fifth in both surveys, and discussions indicated an increasing awareness of the need to link basecutter speed to the harvester forward speed. Knockdown angle dropped to the least important factor in survey 2. Although knockdown angle plays a role in creating stool damage, participants realised that significant improvements in ground job quality could be made through improved presentation and operation before resorting to major machine design changes.

*Question 7. If you are a grower, do you consider your hill height and shape in plant cane matches the basecutter profile left by your harvester? Versus Question 8 (Q9 in Survey 2) If you are a harvester operator, what percentage of plant cane blocks have a hill profile well matched to your basecutter setup?*

In both surveys, 77% of growers considered that their row profile successfully matched the harvester basecutter setup. Interestingly, harvester operators felt that only 55% of row profiles were matched to their machine setup. This difference of opinion can be explained by a lack of communication between the parties to identify that a mismatch exists and improvements to row profile are needed. In addition, the basecutter blades tend to reshape

the existing profile, which makes the mismatch less obvious but still results in stool damage as well as increased soil intake by the harvester.

*Question 8.(survey 2) Would information gained from this project create any changes in your farming operations with the aim to improve harvester performance?*

Even though 77% of growers felt their row profile matched the harvester setup (i.e. only 23% had a mismatch needing attention), 85% of respondents indicated a willingness to adjust farming practices, namely filling-in and hilling-up, to reduce levels of basecutter damage at harvest. This shows an increase in awareness and understanding of the critical role that crop presentation has on harvester performance.

Very surprisingly, one grower who indicated in Question 7 that their row profile was mismatched to the harvester setup then answered “No” to Question 8. So, despite understanding that a mismatch existed and that it was impacting on stool damage and ratooning, they had no intention of making any changes in farming operations to rectify the situation. This is a classic example of one of the major impediments to adoption of best practice faced by researchers and extension officers.

*Question 9.(survey 1) If you are a harvester operator, what angle is your basecutter box set at and what speed is it running?*

Most operators had the basecutter angle set in the midrange (around 15°) to allow flexibility across the variable hill heights and shapes encountered. There was a good level of awareness amongst operators that higher basecutter speeds were needed with the ever-increasing pour rates needed to maintain viability. As a result, most basecutters were being run at around 630-640 rpm with one operator opting to use six blades per disc rather than the more typical five-bladed discs to avoid the stool damage caused by ‘disc contact’ where the disc hits uncut stalks before the next blade sweeps through to make the cut.

*Questions 10 & 11.(survey 1) Do you consider harvester damage associated with standard aggressive knockdown/basecutter setups is having an impact on yields? And is harvester damage associated with a mismatch between stool profile and basecutter profile having an impact on yields?*

Only 63% of participants felt that the standard knockdown angle was having an impact on yields, while 100% felt that the mismatch between row profile and harvester setup was impacting on the crop potential. This was an interesting result, considering knockdown angle was rated second lowest of the factors impacting on ratooning and yet it was perceived as impacting on yields.

*Question 10.(survey 2) Based on the outputs of this project, what do you consider has the most impact on harvester damage, ratooning and yields: knockdown/basecutter geometry or crop presentation?*

The unanimous response to this question was “crop presentation”. While knockdown/basecutter geometry was recognised as a potential problem, all participants accepted that better formation of consistent and suitable shaped hills was the key to reducing stool damage.

*Question 11.(survey 2) This project investigated the potential to reduce harvester stool damage by eliminating aggressive knockdown angles and matching basecutter speed to harvester speed. Did you consider this an area worth investigating? Were you surprised at the impact of crop presentation on harvester damage?*

All participants in the survey were fully aware that the duration and labour intensive nature of this project had made it an expensive exercise with the original hypothesis not being supported by the data gathered. Despite this, over 80% of respondents still considered it an area worth investigating, which indicated an acceptance that you won't know the answer unless you do the research work. Over a third of those surveyed were surprised at the impact of crop presentation on harvester damage.

*Comments:*

- Basecutter height control would be a great help
- Variable speed basecutters are important
- Filling-in plant cane to achieve better profile is important
- Project outcomes support move to guidance
- Increased focus on stool presentation important
- Expensive research, low chance of success (due to field variability)
- Six-blade discs enable higher ground speeds without disc contact
- Knockdown damage not a real issue in heavy lodged crops where knockdown actually assists feeding
- Previously had 45% under 1.8 m system but created problems with spraying and reduced stool life – because standard basecutter is not wide enough for dual row – normally run 6-8 years ratoon cycle but this was being reduced
- TechAgro have automated speed control in Brazil for a couple of years now.

## **5.2 Focus groups**

We contacted interested growers, operators and millers to communicate the aims of the project and discuss the potential of retrofits for harvesters to improve ratooning. The Mackay focus group consisted of contractors (Roy Pietzner, Barry Adair, Chris and Nathan Grech, James Bartello, Joe Muscat, Renato, Carlo and Dario Germanotta), growers (Ray Muller, Vince Germanotta), millers (Ian O'Hara, Ian Hunter and John Markley – Mackay Sugar), Queensland Mechanical Cane Harvester Association's John Powell and EHS Manufacturing's Eddie Simms and Steven Lawn. In Bundaberg, the focus group included growers (Neville and Jason Loeskow, Des Schulte, Doug Young),

mill staff (Keith Sarnadsky, Ross Maclean, Mike Smith) and harvester contractors (James Young, Chris Vella - Isis). Over the course of the project, some focus-group participants left the industry, an ongoing trend particularly in the harvesting sector, and some were not available for the survey. However, their input into the project was appreciated by researchers.

At Mackay, the group comprising harvester operators, growers and a local aftermarket machinery manufacturer (EHS Manufacturing) met at Ray Muller's farm during the 2005 harvest to discuss trial results and also to offer feedback on the machines performance. Initially, data on stool damage was presented, and issues such as crop presentation were identified as overriding factors affecting ratooning (whilst machine design will play an important role in determining stool damage, the machine cannot compensate for poor or inconsistent fill-in and hill-up operations).

The severity of stool damage due to harvesting came as a surprise to some of the group, especially when presented with pictures of the ensuing rots and poor shoot growth caused by stool splitting caused by excessive knockdown angle. The group saw the potential to maintain viable yields through the reduction in stool damage and hence better ratooning. After examining the data, the group was invited to observe the experimental harvester in operation with the enhanced forward-feed module fitted. The majority of people in attendance were impressed with the feeding ability of the enhanced module that was performing very well in cane which was severely lodged due to storms and high winds in Mackay. Despite having only 240 horsepower (versus 350 hp in new harvesters), the enhanced module was easily gathering and feeding the heavy lodged crop without the bulldozing and damage typically associated with challenging conditions. Over two days with the industry-standard front module fitted in exactly the same crop, the machine was suffering significant feeding problems with large bundles of cane building up in front of the machine and stalling out the feed components. This really highlighted the big gains in feeding performance with the enhanced feeding module. The group on the day consisted of Eddie Simms and Steven Lawn of EHS Manufacturing, Chris and Nathan Grech (harvester contractors), Charlie Galea (contractor/grower), Steve Vella (contractor) and Ray Muller (farmer).

It had been proposed to run a demonstration day/focus group meeting in Bundaberg during the 2005 trial harvest, but rain delays at Mackay meant that the Bundaberg trials had to be run immediately upon the team's return from Mackay without sufficient notice for industry to attend.

It was also planned to have formal feedback meetings with the Mackay and Bundaberg focus groups at the same time as the 2006 harvest, but the discovery of sugarcane smut created time pressures for the focus group members and the project team. Despite the disruption created by smut, the team continued to pass on information and receive feedback from the owners of EHS Manufacturing in Mackay (Eddie Simms and Steven Lawn), Mackay farmers Ray Muller, Vince, Renato, Carlo and Dario Germanotta, Chris and Nathan Grech, and John Powell. Joseph Muscat, who also works for BSES in Mackay, but is also an ex-harvester contractor, provided invaluable feedback from his own experience and contact with the wider harvesting community. Mackay's milling sector has maintained input into the project through Jim Crane, Ian O'Hara, John Markley

and Ian Hunter whose opinions and assistance in running the trial program have proven invaluable.

At Bundaberg, there was ongoing feedback from Bundaberg Sugar staff Keith Sardnasky (Bingera Farm Manager), Ross Maclean (Harvesting Operations Manager) and Mike Smith. Long-time harvester contractors Doug and James Young (Bundaberg) contributed opinions about the effectiveness of the enhanced feeding module and supported the team's view that farming practices to achieve consistency in hill-up and row spacing have a major role to play in determining the level of harvester damage. Bundaberg farmers Neville and Jason Loeskow and Des Schulte have observed the machine's operation during trials and, in the case of the Loeskows, saw the trial progress on their own farm.

Contact with aftermarket manufacturers such as EHS Manufacturing in Mackay were important linkages in terms of developing potential retrofits in the future.

### **5.3 Field days**

A mini-field day held on 29 July 2004 in Mackay attracted about 20 interested people. Having the modular harvester on site and cutting cane stimulated more discussion among industry people than would ever occur in a formal presentation.

### **5.4 Publications**

A *BSES Bulletin* article describing the conduct and outputs of the project is currently being prepared. The difficulties in drawing conclusions from the data created by field variations led researchers to hold off publishing results during the course of the project to avoid confusing or contradictory information. However, project participants were presented results throughout the duration of the trials. The knowledge gained on the impact of farming practices on harvester damage has been incorporated into the BSES Limited Harvesting Best Practices workshops.

### **5.5 Intellectual property**

There are two components of this project that represent quite valuable intellectual property - the enhanced forward feeding module fitted to 'Beetle' during these trials, and the automated speed control system. These concepts could be of great value to the sugar industry as we seek to advance harvesting technology. Therefore, it is important that this intellectual property is protected. The option to patent the enhanced feeding module was investigated and found to be both costly and quite difficult to fully define and therefore protect the concept.

Whilst trial results and the enhanced module have been shown to industry representatives through the focus groups, no technical details or drawings have been or will be made available to anyone at this stage. The current plan is to maintain contact with aftermarket manufacturers, such as EHS, to make the most of any commercialisation opportunities to benefit the industry. If commercial opportunities arise with the potential to create

adoption of this project's intellectual property, then the terms and conditions of releasing information would be developed between the researchers' organisations, SRDC and commercial partners.

## 6.0 OUTPUTS AND OUTCOMES

- The impacts of machine design and operating parameters on stool damage, crop loss at harvest, subsequent ratooning rates and final yields were assessed over a crop cycle in two field trials. This was achieved utilising a modular experimental harvester modified by BSES such that both a standard gathering/feeding system with aggressive 45° knockdown angle and an enhanced feeding module with virtually no knockdown effect can be operated within the same trial. These trials showed not only the importance of machine operation, but also of correct crop presentation to ensure effective harvesting.
- An adaptive on-the-go control system was designed to enable variable speed control of the crop-handling components during the harvest operation was developed. This system ensures that the cane harvester maintains a consistent feedrate and optimum performance by enabling automatic crop-handling component-speed variation with ground speed to compensate for variations in the crop. The system control unit also has an inbuilt function that allows manual override of the system by the operator. This introduces a completely new dimension of sophistication into the world of cane harvesting, bringing it into line with many other agricultural harvesters.
- Promotion and adoption of the project's outputs was facilitated through two focus groups and mini field days. An article for the *BSES Bulletin* is currently being written. The trial results will provide input to a revised version of the *Harvesting Best-Practice Manual* and have demonstrated the importance of both machine operation and of crop presentation.
- Whilst trial results and the enhanced module have been shown to industry representatives through the focus groups, no technical details or drawings have been or will be made available to anyone at this stage. The current plan is to maintain contact with aftermarket manufacturers, such as EHS, to make the most of any commercialisation opportunities to benefit the industry. If commercial opportunities arise with the potential to create adoption of this project's intellectual property, then the terms and conditions of releasing information would be developed between the researchers' organisations, SRDC and commercial partners.

## 7.0 RECOMMENDATIONS

- Outcomes of this project have been incorporated into the BSES Limited Harvesting Best Practice Workshops, with a focus on raising awareness amongst growers of the importance of improved crop presentation for harvesting.

- The message that filling in and hilling up operations are critical to minimising stool damage during harvesting needs to be promoted throughout the industry.
- Automated harvester component speed control system met with positive response from project participants and has potential to reduce basecutter damage, particularly at higher ground speeds. Promotion of this concept and the investigation of the system currently in use in Brazil would be worthwhile.

## 8.0 ACKNOWLEDGEMENTS

Thanks go to:

- The farmers (Bundaberg Sugar, Neville/Jason Loeskow, Ray Muller and the Germanotta family) who enabled these trials to take place over four harvests
- Bundaberg Sugar and Mackay Sugar for assistance with trial logistics and enabling comprehensive mill data to be collected
- All BSES Limited researchers and field staff involved in the often-challenging data-collection process
- Focus-group participants who gave their own time to observe the modular harvester in operation and provide feedback to the project team
- SRDC for co-funding this extensive research project and their patience when unforeseen challenges caused delays.

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**MACKAY TRIAL SITE: SRDC PROJECT BSS270250: REGIONAL ADOPTION OF ALTERNATIVE HARVESTER CONFIGURATIONS**

- 1 - Standard setup Knockdown and Standard Basecutter speed - Standard leg box module, K1B1
- 2 - Standard setup Knockdown with Optimum basecutter speed - Standard legbox module, K1B2
- 3 - Zero Knockdown with Standard basecutter speed - Enhanced leg box module, K2B1
- 4 - Zero Knockdown with Optimum basecutter speed - Enhanced leg box module, K2B2

**Trial Plan - FARM 4190A; Block 4, Paddock 1, Racecourse Mill, Mackay**

**Q157 - Planted End of July 2003**

Headland																												
B o o m	G u a r d	K 2 B 2	K 2 B 1	G u a r d	B o o m	G u a r d	K 1 B Y 1	K Y 1 B 2	K 1 B 2	K Y 1 B 1	K 2 B Y 2	K 2 B Y 2	G u a r d	B o o m	G u a r d	K Y 1 B 2	K Y 2 B 2	K 1 B 1	K 1 B 2	K 1 B 1	K Y 2 B 1	G u a r d	B o o m	G u a r d	K 2 B 2	K 1 B Y 2	G u a r d	B o o m
T r a c k	6	X 0	Y 1 0	6	2	X 1 0	1 0	Y 1 0	1 0	X 0	1 0	X 1 0	2	2	X 1 0	1 0	1 0	Y 1 0	X 0	1 0	Y 1 0	2	2	Y 1 0	X 1 0	3 6	3 6	
		R1T4	R1T3			R1T1	R1T2	R2T2	R2T1	R2T3	R2T4				R3T3	R3T4	R3T1	R3T2	R4T1	R4T3					R4T4	R4T2		
Headland - Fence - Tram Line												Headland - Fence - Tram Line																
Plot No	1	2				3	4	5	6	7	8				9	10	11	12	13	14				15	16			
Harvest Order	7	1				9	13	16	10	8	6				2	5	11	14	12	3				4	15			
Harvest Day	Day 3	Day 2	Day 1		Day 1	Day 5	Day 6	Day 6	Day 5	Day 3	Day 3	Day 1		Day 1	Day 2	Day 3	Day 5	Day 6	Day 5	Day 2	Day 1		Day 1	Day 2	Day 6	Day 1		

## APPENDIX 2 – Hyteco flow-control manifold used in the gathering-system hydraulic circuit

The flow control manifold comprises the following:

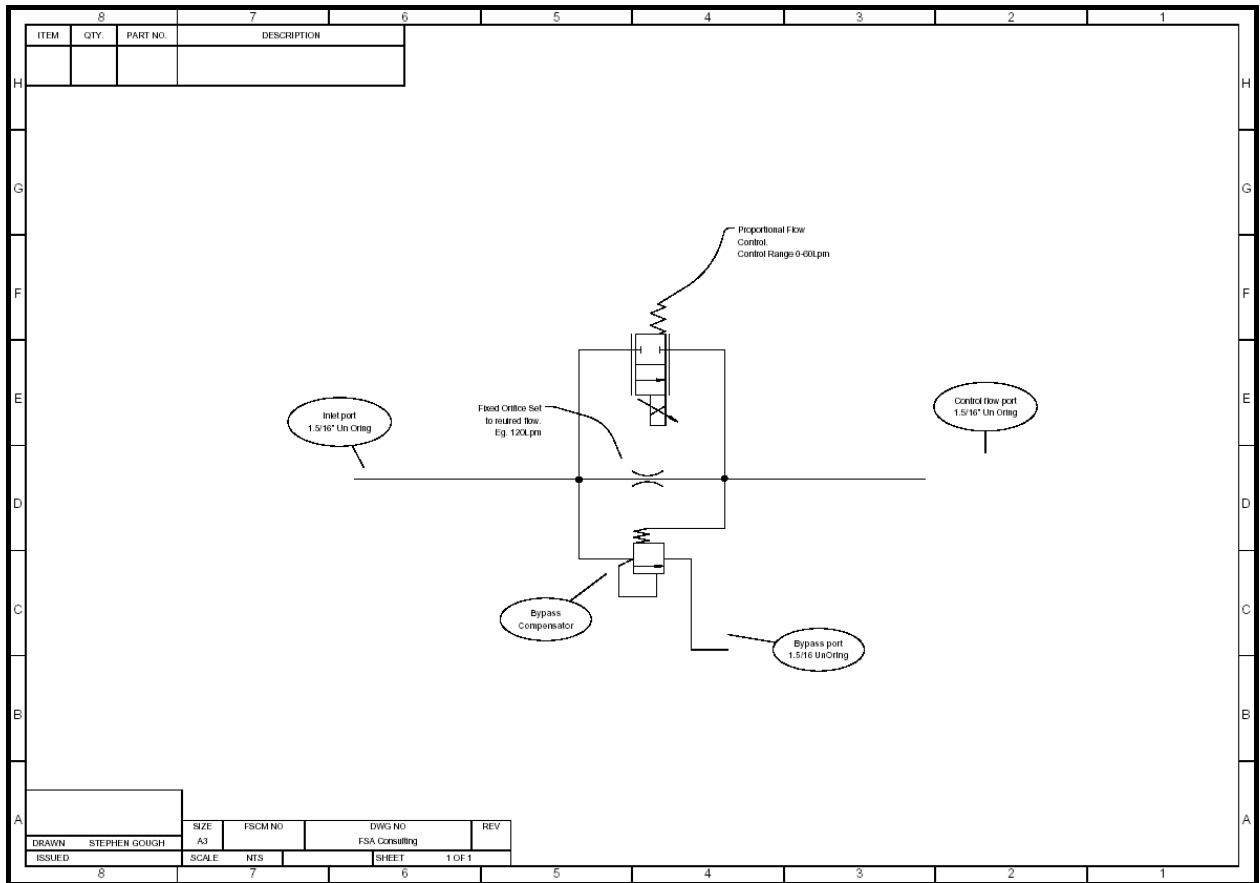
Cartridges: 1 x ELP 30/Q1, 1 x PSS 30/2202-Q, 1 x Orifice. For this application, the orifice is 8 mm diameter.

BSP Ports: 2 x 1/4" – These are test ports.

UNO Ports: 3 x 1 5/16". These are inlet, control flow and excess oil ports.

Material: Nickel-Plated Steel.

The hydraulic circuit for the flow control manifold is shown below.



## APPENDIX 3 – Survey outputs

### Survey 1

Region	G/M/H	Size(ha/t)	Q5	Q6 kda	bc rpm	blade	spiral	hillup	fillin	speed	Q7	Q8 %	Q9 angle	Q9 rpm	Q10	Q11
Mackay	M	na	Med	5	4	3	4	1	2	2	na	na	na	na	Y	Y
Mackay	G	68000	High	6	3	1	7	4	5	2	Y	na	na	na	Y	Y
Mackay	GH	140ha83000	High	2	3	1	2	1	1	1	Y	75	mid	variable	Y	Y
Mackay	GH	140ha83000	High	2	3	1	2	1	1	1	Y	75	mid	variable	Y	Y
Mackay	Man	na	High	3	2	1	2	5	5	3	na	na	na	na	Y	Y
Mackay	GH	450ha90000	Med	7	1	1	5	2	2	2	Y	60	mid	max	N	Y
Mackay	GH	450ha90000	Med	7	1	1	5	2	2	2	Y	60	mid	max	N	Y
Mackay	GH	450ha90000	Med	7	1	1	5	2	2	2	Y	60	mid	max	N	Y
Mackay	G	5000	High	7	4	1	3	5	2	6	Y	50	na	na	Y	Y
Bundaberg	GH	200000	Low	5	4	1	7	3	2	6	Y	50	mid	?	N	Y
Bundaberg	H	100000	Low	6	5	1	7	3	2	4	na	50	mid	?	N	Y
Bundaberg	GM	600000farm	High	4	5	3	6	2	1	7	N	10	mid	640/6bl	Y	Y
Bundaberg	GMH	8000ha	Med	3	6	4	7	5	1	2	N	50	?	?	Y	Y
Bundaberg	G	70000	Med	7	2	1	6	4	3	5	N	na	na	na	Y	Y
Bundaberg	G	1200ha	Med	1	2	3	7	4	5	6	Y	na	na	na	Y	Y
Bundaberg	G	600ha	Med	2	4	6	4	3	3	1	Y	na	na	na	Y	Y
Note: Lowest total = most impact on ratooning												Av%				
				74	50	30	79	47	39	52			54			

### Comments

knockdown damage not a real issue in heavy lodged crops; knockdown assists feeding in lodged crops

## Survey 2

Region	G/M/H	Size	Q5	Q6 kda	bc rpm	blade	spiral	hillup	fillin	speed	Q7	Q8	Q9 %	Q10	Q11a	Q11b				
Mackay	M		Med	5	4	3	4	1	2	2	na	na	na	crop	Y	N				
Mackay	G	68000	High	6	3	1	7	4	5	2	Y	Y	na	crop	Y	N				
Mackay	GH	140ha83000	High	2	3	1	3	1	1	2	Y	Y	75	crop	Y	N				
Mackay	GH	140ha83000	High	2	3	1	3	1	1	2	Y	Y	75	crop	Y	N				
Mackay	Man	na	Med	3	4	1	3	1	2	3	na	na	na	crop	Y	Y				
Mackay	GH	450ha90000	Med	7	1	1	5	2	2	2	Y	Y	60	crop	Y	Y				
Mackay	GH	450ha90000	Med	7	1	1	5	2	2	2	Y	Y	60	crop	Y	Y				
Mackay	GH	450ha90000	Med	7	1	1	5	2	2	2	Y	Y	60	crop	Y	Y				
Mackay	G	5000	Med	7	5	2	4	3	1	6	Y	N-wellmatched	50	crop	Y	N				
Bundaberg	GH	200000	Low	6	3	4	7	2	1	5	Y	Y	50	crop	Y/N	N				
Bundaberg	H	100000	Low	7	6	3	5	2	1	4	na	na	50	crop	N	N				
Bundaberg	GM	600000farm	Med	5	4	3	7	2	1	6	N	Y	10	crop	Y	N				
Bundaberg	GMH	8000ha	Med	3	6	4	7	5	1	2	N	Y	50	crop	N	Y				
Bundaberg	G	70000farm	Med	6	2	5	7	4	1	3	N	N	na	crop	Y	N				
Bundaberg	G	1200ha	Med	5	4	3	7	1	2	6	Y	Y	80	crop	Y	N				
Bundaberg	G	600ha	Med	5	3	5	3	2	2	1	Y	Y	na	crop	Y	Y				
Note: Lowest total = most impact on ratooning													Av%							
													83	53	39	82	35	27	50	56

### Comments

BC height control would be a great help

Variable speed BC, rollers, choppers are important.

Previously had 45% under 1.8 but created problems with spraying and reduced stool life (basecutter not wide enough for dual row - normally run 6-8 year ratoon cycle)

Tech agro have automated speed control in Brazil for couple years now.

Filling in plant cane to achieve better profile important

Project outcomes support move to guidance; expensive research, low chance of success.

Increased focus on stool presentation important