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FINAL REPORT

Project NCE 004

IMPROVEMENTS IN BASE CUTTER DESIGN AND CANE FEEDING

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Objectives

To reduce base cutter damage to the cane stool, reduce dirt entrainment and improve feeding of cane

Final Report

Due 30/08/02

Status

PROJECT COMPLETE



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TABLE OF CONTENTS

1 Summary	4
2 Background to the Project.....	5
3 Project Objectives	6
4 Methodology	8
5 Detailed Results	8
6 Summary of Results	9
7 Assessment of Likely Impact.....	13
8 Project Technology	13
9 Recommendations.....	14
10 Publications.....	16



1 Summary

This project followed on from Project US2 (Cutting of sugarcane), which showed that conventional basecutters and knockdown angles contributed to cane damage and loss by way of disk contact, multiple layered cuts and stalk bending.

This project proposed that removing the use of knockdown as a primary process for feeding, and replacing the impact type cut with alternative means involving slicing cuts and serrated blade edges, would improve basecutting and feeding, and reduce the problems identified in project US2. The outcomes would be in the form of cutting and feeding modules available for retrofit or as original equipment.

The project planned to proceed by way of laboratory tests using an existing single cut device, modified to simulate the effects of harvester forward speed, followed by development of feeding means using a dedicated tractor based harvester. The laboratory trials were completed as planned, but the field trials were abandoned because of the take-up of initial results by industry innovators, and the logistical difficulties of supporting a research harvester in the commercial environment.

The research undertaken in this project was primarily aimed at creating an understanding of the processes involved in cutting cane, and then using this understanding to propose and develop modifications to the conventional basecutter. The hypothesis of this research was that it is possible to improve the base cutting process in sugar cane (reducing force, energy and damage) by making a slicing cut instead of the conventional impact cut, where the cutting edge contacts the cane with its velocity oriented in the same direction as the radius to the point of contact. In Project US2, it was demonstrated that a slicing cut, when attempted using a curved edge, would push the cane aside without cutting, so serrated edges were suggested to avoid this problem.



A comprehensive program of experimental investigations was planned and carried out. Both backwards and forward curved blades were manufactured, and equipped with serrations of three different pitches and a smooth edge as a reference. The oblique angle (which defines the amount of slicing) and blade speed were the other variables investigated, and their effects on force, energy, damage and losses were measured.

Only the oblique angle did not show significant effects on the measured variables, and so the hypothesis that slicing would improve cutting was not proven.

Further tests were carried out to consider the effects of knockdown, and to define the effects of blade edge angle on the cut. These tests did not show significant differences between backward and forward blades, but in the presence of knockdown the forward blade shows some advantage, causing less damage.

The laboratory tests were used to plan a series of field tests to measure the performance of serrated and slicing blades in the field. The field tests started with backward serrated blades, and at the same time the Mossman Mill contractors undertook independent field trials based upon these ideas using standard blades set at a forward angle.

2 Background to the Project

The research carried out in Project US2 showed that current basecutter arrangements and working speeds are causing damage to the stool and stalk due to disk contact and inadequate cutting mechanics.

Disk contact occurs at ground speeds greater than 9kmh, which is a working speed commonly used in the industry. At speeds greater than this, the combination of knockdown and disk contact cause stool tipping, root damage and excess soil in the cane supply. Multiple cuts and knockdown were shown to cause major splitting damage to the stalk, which leads to partial billets that are more easily removed in the cleaning section of



the harvester. Cutting by impact was shown to inevitably result in splitting of the stool, which may be followed by the entry of organisms that cause further stool damage and the loss of ratoons.

Project US2 showed that current arrangements for gathering, knockdown, cutting and feeding of cane are responsible for stool tipping and splitting, breakage of stalks and substantial loss of cane due to multiple cuts and split billets. It was also known that the basecutter is the major source of the dirt that enters the cane supply.

This project therefore proposed that this area of the harvester should be reconsidered, with the aim of removing knockdown, replacing the impact cuts with an alternative process to avoid stalk and stool damage, improving the kinematics to remove the limit on ground speed, reducing the intake of dirt, and improving the feeding.

3 Project Objectives

The objectives as stated in the Project Description were

1. to investigate and evaluate alternative means for basecutting and feeding that will avoid the disadvantages shown to exist with the current system, and reduce cane loss, dirt entry, stool damage and stool tipping, while increasing the allowable ground speed and improving the feeding.
2. to combine these new components and demonstrate their operation in the field
3. in collaboration with a harvester manufacturer, to develop a prototype, and to make this modification available for retrofit to the existing fleet, and as a standard fitment on new harvesters.



This project has been undertaken at a time when there have been major problems within the industry, due to low sugar prices, low yields, and shortened seasons. At the same time harvester sales have essentially collapsed. Consequently, it has been difficult to organize proper field trials, and the fieldwork that has been done has been more in the way of a demonstration rather than a full replicated trials. The effects of modifications have had to be judged more on anecdotal evidence, and this evidence is inevitably affected by the larger issues noted above as well as by the performance of the modification. The shortened seasons not only reduce the time available for fieldwork, but also make it difficult for co-operators to provide opportunities for installing and testing modifications.

There is also an increasing recognition that it is extremely difficult to measure changes in harvester performance with any acceptable statistical significance. Cane loss, dirt entry, stool damage and stool tipping can be assessed by comparing the difference between two appropriate measurements, but because those measurements are themselves subject to substantial natural variation, their difference (which is the effect of the modification) is statistically uncertain unless there is a large number of replicates.

A further factor that changed the course of the project was the adoption of forward facing blades by contractors in the Mossman mill area, who showed that these blades would operate without clogging, and appeared both to feed better and to reduce the soil in the cane. There was no opportunity for the project staff to be closely involved with this work, and to provide technical assistance and advice, because of the shortened seasons, lack of time and the expense involved. Consequently, these developments continued down a separate path, seeking practical solutions to adapting forward blades to the standard basecutter configuration.

When the project was initially proposed, it was expected that backward facing blades would compromise feeding, and that alternative feeding means would be required. It was proposed that this work could be undertaken with a simple tractor based harvester, where the basecutter and feeding means could be modified conveniently. As the project progressed, it became obvious that developing improved feeding would be a major



project in itself, that forward blades improved feeding in any case, and that a concurrent BSES project on gathering and feeding was making substantial progress on improving these processes in harvesters. Consequently, this aspect of the project was not pursued.

The project has therefore

- achieved the first objective apart from developing the feeding arrangements
- has demonstrated improved basecutting means in the field (part of second objective)
- and facilitated the manufacture of new basecutter disks and blade arrangements (third objective)

4 Methodology

The project involved a student, and his Dissertation (attached as a CD-ROM) includes a complete justification and description of the methodology involved and the research tasks undertaken.

5 Detailed Results

The PhD Dissertation included with this report contains all the results, including statistical analyses and discussion of the results.



6 Summary of Results

The hypothesis of this research was that it is possible to improve the base cutting process in sugar cane (reducing force, energy and damage) by making a slicing cut instead of the conventional impact cut, where the cutting edge contacts the cane with its velocity oriented in the same direction as the radius to the point of contact. More precisely, an impact cut occurs when the line normal to the cutting edge is in the direction of motion of the knife and is directed towards the center of the cane. The “oblique” angle is the angle between the line normal to the cutting edge and the direction of motion, and it is zero for an impact cut. If there is a non-zero oblique angle, a slicing cut occurs. Kroes (Project US2) demonstrated that a slicing cut, when attempted using a curved edge, will push the cane aside without cutting, so serrations were suggested to avoid this problem

The project commenced with a kinematic analysis of the combined rotary and linear motion of the blade, to investigate the circumstances that maximise the average ratio (V_t/V_n) between tangential velocity V_t (which produces slicing) and normal velocity V_n (which produces impact). This analysis showed that θ_r , the (angle subtended at the centre of the disk by the root and the tip of the blade) was the factor that has most influence on this ratio. In other words, the greater the angular extent of the blades, the greater is the average ratio of tangential velocity to normal velocity, and the greater the relative degree of slicing.

This analysis was based on curved blade edge shapes for convenience, and a distinction was made between “backward” blades, whose radius decreases in the direction of rotation, and “forward” blades, whose radius increases in the direction of motion. Forward blades act to “hook” the cane as they cut it, while backward blades act to push the cane away as they cut. It appeared that backward blades might have problems with feeding, while forward blades may have problems with the buildup of trash in the re-entrant corner between the root of the blade and the basecutter disk.



A comprehensive program of experimental investigations was planned and carried out. Both backwards and forward curved blades were manufactured, and equipped with serrations of three different pitches and a smooth edge as a reference. The oblique angle and blade speed were the other variables investigated, and their effects on force, energy, damage and losses were measured. The data obtained and reported add substantially to the state of knowledge on the cutting of cane.

Only the oblique angle did not show significant effects on the measured variables, and so the hypothesis that slicing would improve cutting was not proven. Furthermore, a correlation between the ratio V_t/V_n and cutting forces was sought, but the correlation did not show a satisfactory coefficient.

It appears that the micro-scale interaction between the edge and the cane is more important in determining the parameters and quality of the cut. For the large serration (15mm pitch), the micro-geometry of the cutting edge was of the same scale as the cane itself, and the cut parameters depended more on the relative alignment of the teeth and the cane at the instant of contact.

The small serration (3 mm of pitch) appears to offer the best cut. It is surmised that with serrated edges the points initiate the cut first, and the edges inside the serration continue the cut in the material that is lodged between the teeth. With small serrations fewer fibres are involved in cut at the same time, reducing damage, force and energy.

The oblique angle shows some effect on damage when working with a smooth edge at 600 rpm. It was possible to note that an excess of slicing or an excess of impact causes more damage. With serrations, the oblique angle has no consistent effect on damage, and therefore the hypothesis that a greater degree of edge slicing will reduce cutting damage has not been proven. It has been concluded that this is so because the full range of slicing or impact occurs inside the teeth of the serrations.



It appears that working at 600 rpm rather than at 450 rpm shows the best results. When speed increases, it is suggested that the individual fibres of the cane do not have enough time to re-arrange in the presence of an external force and the rupture occurs with less displacement of the fibres, reducing damage, losses, forces and energies.

Further tests were carried out to consider the effects of knockdown, and to define the effects of blade edge angle on the cut.

These laboratory tests did not show significant differences between backward and forward blades, but in the presence of knockdown the forward blade shows some advantage, causing less damage. The range of bevel or blade edge angle investigated did not show any difference, and a sharpened standard blade can reduce the cutting forces by 17 % and damage by 15 %.

The laboratory tests were used to plan a series of field tests to measure the performance of serrated and slicing blades in the field. The field tests started with backward serrated blades, and at the same time the Mossman Mill contractors undertook independent field trials based upon these ideas using standard blades set at a forward angle.

The backward serrated blade cuts well while the serration is new, but once the serration starts to wear, the blade starts pushing the cane away, forcing to operator to lower the basecutter. On the other hand, the standard forward angled blade feeds the cane better than the conventional basecutter, and makes it possible to work a little above the ground. There were no problems with trash blocking the forward blade, as had been feared.

With the standard blade when it is set to cut high, the blade slides along the cane , causing problems with feeding, forcing the operator to lower the basecutter. With serrations it is possible to work a little high, because the teeth of serration engage with the cane causing less damage to the stool and reducing the wear of the blade. The forward angled blade helps to feed the cane into the feed train, and in association with serration



appears to be the best configuration. Forward blades feed cane better than standard blades, and can pick up lodged cane that would otherwise be missed.

With serrations, the forward angled blades appear to protect the serration, which works longer than on the backward blade, and after the serration wears, the serrated forward angled blade works as a standard forward angled blade, which is better than the conventional basecutter.

With a little modification, it is possible to change the conventional basecutter to a forward angled basecutter. The maximum possible forward angle is 23 degrees, so that the blade will not hit the guide of the blade on the other disk. The serration pitch recommended is about 5 mm (it can work longer than 3 mm), and a laser following a serrated path can cut this edge on a blade tilted at an angle to the laser beam.

The poor seasons in the last two years have curtailed the planned field trials. The seasons have finished early, and there has been an understandable reluctance on the part of contractors to complicate their operations by undertaking field experiments.

For a lodged crop, dished basecutters appears to be the best, and have been accepted in the work carried out at Mossman. However, for a standing crop hilled up, the dished basecutter did not work properly, adding a lot of dirt to the cane supplied, leading to the trials being abandoned by the contractor.

A contractor in Mossman proposed a forward angled blade and disk configuration featuring blades longer than conventional, intended to give longer intervals between blade replacements.



7 Assessment of Likely Impact

The major findings of the project are:

- forward facing blades appear to improve cutting and feeding, and because they can be set higher without compromising pick up, they will reduce the dirt in cane
- forward facing blades cause less damage in the presence of knockdown
- serrated edges improve cutting, reducing forces, energy and damage

All of these findings are of value to the industry.

8 Project Technology

These developments were discussed in May 2001 with one of the manufacturers of basecutter blades (Pratco), and Pratco undertook to manufacture and promote dished disks with forward blades, disks with long angled blades, and serrated edges based on their hard-faced standard blades. Again, these innovations were being launched and promoted in a poor season, so that while angled and dished disks have been sold, the longer blade option has not been taken up. Pratco also attempted to commercialise serrated edges by modifying their production technique for laying hard facing, but this was not successful. The alternative is to just allow the hard faced blades to wear naturally, which will produce an adequately serrated edge.

Pratco remain optimistic that these innovations will start to move in the next year (2002), which will provide a successful outcome to the project. Forward angled basecutter blades, with or without serrated edges, represent an improvement on standard basecutter blades and can be fitted to all harvesters.



9 Recommendations

The innovations that are the outcomes of this project are now in the hands of the industry and a manufacturer, but it is uncertain whether they will be developed and trialled with sufficient enthusiasm to ensure that they are properly evaluated, now that the project team has dispersed. This uncertainty is compounded by the uncertain economic and production situation of the sugar industry, which will constrain any attempts to develop and prove a new technology over the next few years.

This uncertainty is also increased by the fact that a fair evaluation of innovations such as these requires reliable methods for measuring stalk damage and loss, stool damage, and dirt in cane, remembering that cultural practices and basecutter disk geometry also have to be properly aligned. While dished disks were successful in Mossman, in Murwillumbah they were not compatible with the hilling practices, and the trials had to be abandoned before the forward blades could be assessed. Attempts to carry out trials within commercial operations are always dependent on goodwill, and a stage is reached where the operation has to be given precedence over the trials.

Serrated edges have been shown in the laboratory to cut better, and field experience in Mossman showed that they were capable of picking up sprawled cane even when operating above the surface. The question has now become one of how to manufacture them commercially, which must be possible, given that grain header knives are serrated in much the same way, and are manufactured and sold in large numbers.

The task of a research team is to demonstrate that an idea will work, and to obtain laboratory and field data that show that it does. The team can take the idea part of the way to being marketable, but is not generally funded to create a complete and marketable outcome. It is not always possible for the research team, or the research funders, to identify the most suitable organisation for manufacturing the relevant outcomes.



Companies with an existing presence in the market, with the capacity to manufacture the outcomes, (such as the blades and disks defined in this research), do not necessarily have the resources to evaluate research reports or to undertake, sponsor and evaluate further field trials. In the case of the serrated blades defined by this project, it is now necessary to locate alternative manufacturers because the company that can manufacture smooth edged blades cannot produce serrated edges.

There is also a problem in funding further development of an outcome. A manufacturer prefers to have a reasonable potential market so as to be able to manufacture in bulk, and potential users want the items available at a price comparable with that of the items that they are replacing. One cannot move without the other, and this is particularly so when money is in short supply.

All of these factors make it difficult to capture outcomes when they consist of actual hardware, rather than (for instance) recommended changes in field operations or modifications to harvester settings.

Given the generic difficulties associated with capturing the benefits of engineering related research projects within the cane industry the research team would like to take this opportunity of encouraging SRDC to review possible options for improving this situation.

The Cotton Research and Development Corporation supported a "Field Mechanisation Officer" position during the 1990's to speed the adoption of existing guidance and precision agriculture related technologies within their industry. We would encourage SRDC to review the nature and quantity of un-realised machine related technology existing within the industry and determine if such a program could be of value.

We have also had experience with the use of a number of Federal Government funded programs under the Innovation in Agriculture banner that can be used to support adoption of existing technology.



The industry currently faces a major crisis in achieving world's best practice in terms of harvester and transport performance. Innovative approaches will be required to ensure that projects such as this deliver the real benefits that are possible.

10 Publications

Da Cunha Mello, R, Harris H D (2000) *Angled and serrated blades reduce damage, force and energy for a harvester basecutter* Conference of Australian Society of Sugarcane Technologists, Mackay, May, 212-218

Da Cunha Mello, R, Harris H D (2000) *Cane damage and mass losses for conventional and serrated basecutter blades* Conference of Australian Society of Sugarcane Technologists, Bundaberg, May 2-5, 84-91

Harris H D, da Cunha Mello, R (1999) *Kinematics and blade shapes and edges for alternative basecutter configurations*, Conference of Australian Society of Sugarcane Technologists, Townsville, April, 185-190.