BSES Limited

FINAL REPORT – SRDC PROJECT BSS208

IMPROVING PLANTING SYSTEMS FOR SUGARCANE

by

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SD04009

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SUMMARY

This project has researched the major factors affecting the establishment of a sugarcane crop. Adoption of a systems approach has resulted in an improved planting system that matches the requirements of the growing of seed cane, production of high-quality billets and meters and places the billets at rates to ensure optimum crop yields.

It was initially realised that the supply of high-quality seed billets was critical to ensure an improvement in the planting system of sugarcane. Developing recommendations for growers to produce the high-quality, disease-free seed sugarcane suitable for planting billets was an essential requirement. Many cane treatments and additives were trialled, but many effective treatments were found not to be cost effective. However, many tasks were identified that growers can undertake to ensure sound and erect planting cane. The machine cutting of plants has previously been a major deficiency as mechanised harvesters were not developed to cut high quality, low damage billets. This project has quantified the requirements of a seed billet-cutting harvester and machine modifications were field tested. Sound recommendations for growing planting cane and cutting this cane to produce sound billets have been developed and extended to the industry. The development of recommendations for high-quality seed billets is a major success of this project.

The project has successfully undertaken the first detailed review of the requirements and current operational performance of current billet planters. An improved billet-metering system, the first truly precision metering of billets, was developed as a replacement from the crude mass-flow metering systems of various form used by the sugarcane industry. Planter characteristics, such as billet drop height, have been addressed, as has matching the billet meter to minimum-soil-disturbance planter components.

One critical operational requirement that this precision billet-metering system had to fulfil was to be compatible with the planting characteristics of the double-disc groundtool developed by BSES. This goal was achieved, and a prototype billet planter produced that incorporated the double-disc opener and the precision billet-metering system. This system allows planting rates to be halved compared to the rates of current billet planters, but the use of high-quality seed billets is an essential requirement of this new system. The developed metering system is a radical departure from the elevating slat-type meters current used on all billet planters and commercialisation of this planting system must be carefully planned.

When proposed, a significant outcome of this project was to investigate and develop technologies to protect planting billets by coatings that would prevent the ingress of rotting diseases and slow desiccation of the billet. Much knowledge has been acquired and future studies are suggested, but current technology is not considered suitable for commercial usage.

Adoption of all the technologies developed within this project will take time, but industry awareness of the need for change is high. The adoption process is well advanced, although adoption varies between canegrowing regions. Due to the current state of the sugarcane industry, adoption will occur in a series of steps, but this is considered appropriate, as growers can learn as they adopt new components of the system. Certain

components of the system must be adopted prior to others. For example, the production of high-quality planting billets is an essential requirement, but is applicable to all growers irrespective of what type of planter they use.

This project clearly illustrates the value of a multi-discipline team adopting a systems approach to a major sugarcane industry problem.

1.0 BACKGROUND

Mechanisation of sugarcane planting has evolved from the Don-type drop planter, which required erect, pre-stripped cane, to the wholestalk ‘trash’ planter, and now to the current billet planters. Each transition has seen substitution of manually performed operations by machine operations. With each transition there has been an increase in planting rate in an attempt to compensate for the greater machinery input and increased damage to the ‘seed’. Planting rates have increased by 50-100% with the change to billet planting. Despite this significant increase in planting rate, there has been no increase in crop yield when compared to wholestalk planting.

Billet planters offer the advantages of high planting work rates and reduced labour requirements. Unfortunately, other features that are considered by some to be advantages have been shown to lower the field performance of billet planters. Lodged and poor quality cane can be easily cut to produce low quality billets, which may then result in unsatisfactory crop establishment. Some growers believe it is not important to specifically grow cane for plants under a billet-planting system. Often the harvester used to cut cane for the mill is also used to cut billets for planting. Many harvester operators do not appreciate the higher quality requirements of billets for planting. The cumulative effect of these deficiencies has been a reduction in the reliability of establishment with billet-planted crops when compared to wholestalk plantings.

The widespread adoption of billet planters in some districts has caused difficulties for the distribution of Approved Seed to growers. These problems are increasing as more hectares are planted using billet planters. Problems include the difficulty of transporting billets over long distances, limited storage life of billets, and the risk of spreading disease into Approved Seed plots through the use of harvesters. Approved Seed is an important component of the integrated disease management for a number of diseases.

Pineapple disease caused by the fungus *Ceratocystis paradoxa* is commonly associated with failures in billet planted cane. The disease can be controlled by fungicides if good quality billets are used, but treatment is ineffective on damaged or single node billets. Nutrition of the cane used for planting and some chemical and physical treatments applied after cutting the planting material can improve germination. These treatments are poorly defined and hence are not extensively used in Australia. In many crops there has been an interest in polymer coating of seeds to protect the seed and to increase the efficiency of applied chemicals. Initial research with polymer coatings of sugarcane setts has shown some improvement in germination under stressful environments.

This project addresses some of the negative results of increased mechanisation of sugarcane planting. An improved planting system will increases the efficiency and the reliability of sugarcane establishment. A 10% improvement in the efficiency of planting operations could save the industry $10m per annum apart from increases in yield from improved crop establishment. This saving is an underestimate, as cane saved from the planting operation would have additional growing time and hence greater yield before being harvested.

2.0 OBJECTIVES

This project aimed to improve the current system for billet planting of sugarcane by:

- developing recommendations for growers to produce high quality cane suitable for planting;
- developing methods for cutting and handling high quality (minimum damage) billets;
- developing methods of protecting the billets from rotting diseases and desiccation by protective coatings and investigate treatments to stimulate rapid germination;
- developing prototype equipment for the precision planting of high quality billets;
- in conjunction with other research projects, quantifying the optimum distribution/spacing of high-quality billets over various environments; and
- assessing planting options such as high quality coated billets as an alternative for the distribution of Approved Seed.

The objectives were met completely, as summarised below, and are discussed in more detail in the following sections of this report.

Objective 1 - Develop recommendations for growers to produce high quality cane suitable for planting.

Preventing lodging was identified as a key to producing high-quality billets. Methods were developed to control the vertical growth of cane and, therefore, reduce the risk of lodging, by applying inhibitors of the plant hormone, gibberellin. Two chemicals were tested and both were effective at controlling vertical growth. One chemical was too expensive at current prices, but the second chemical, which is also being considered as a ripener of sugarcane, should be tested further.

Addition of nitrogen and phosphorus to cane to be used for planting can improve germination in some situations. Phosphorus is important in soils low in available supplies of this nutrient. Nitrogen is generally beneficial when applied 6-8 weeks before planting.

Objective 2 - Develop methods for cutting and handling high quality (minimum damage) billets.

The supply of high-quality planting seed is an essential prerequisite for any planting operation. Sugarcane cropping differs greatly from most agricultural crops in that the crop is propagated vegetatively and planting material is normally produced by the grower. The advent of mechanised harvesters was followed by the evolution of the billet planter. However, most sugarcane harvesters have been developed to cut sugarcane that is delivered to the sugar mill. Billets from commercial harvesters often have sound billet levels of 30% or less.

We developed recommendations for modifying commercial sugarcane harvesters to supply planting billets with sound billet percentages approaching those from wholestalk hand planters. Information used was supplied from this project and other SRDC-funded projects undertaken by the BSES engineering group. With wide dissemination of these recommendations, adoption has been very high. Feedback from owners of modified machines report high levels of satisfaction.

Objective 3 - Develop methods of protecting the billets from rotting diseases and desiccation by protective coatings and investigate treatments to stimulate rapid germination.

The concepts of protective billet coatings to minimise the effects of rotting diseases and desiccation and methods of stimulating rapid plant germination were innovative and indicate considerable foresight towards improving the reliability of planting sugarcane. We undertook detailed testing of these concepts, but the approaches investigated failed to adequately protect billets from pineapple disease and slowed germination as the shoot pushed through the protective coating.

Hot-water treatment for short periods gave excellent stimulation of germination, but this treatment does not appear to be practical for commercial planting. Hot-water treatment is recommended for research and rapid propagation of new varieties where maximum and uniform germination is required.

A range of other chemical and biological products was tested to determine there efficacy in stimulating germination, but only the fungicide that contains mercury gave any stimulation.

Objective 4 - Develop prototype equipment for the precision planting of high quality billets.

We reviewed current billet planting technology and defined the specifications for precision billet-planting machinery. A precision billet-metering system that is compatible with a reduced planting rate of high-quality billets and the minimum-soil-disturbance technology associated with the double-disc planter opener was developed and tested under commercial conditions. This precision planter MUST be supplied with high-quality, high-viability billets. A perceived limitation is the reduced planting speed of this machine, but we and many innovative growers believe this is an acceptable compromise between planting rate and superior billet placement under condition where current planters are unable to operate.

Objective 5 - In conjunction with other research projects, quantifying the optimum distribution/spacing of high-quality billets over various environments.

A planting rate must always incorporate a level of over-planting as insurance to allow for factors such as non-viable eyes, insect damage, poor sett-soil contact, etc. A series of trials was conducted under dry planting conditions that support a desired establishment rate of 3-4 evenly spaced primary shoots to the row metre. The trials showed that establishment rates of 75-80% can be achieved if high-quality billets are planted through a well-set-up planter. Even allowing for a minimum establishment rate as low as 50%, planting rates of 4-6 eyes to the row metre are acceptable. Planting at this rate is equivalent to planting less that half the rate that current commercial billet planters do. This reduced planting rate has been used to establish several trials for the Sugar Yield Decline Joint Venture. Minimum tillage, double-disc planters modified to meter billets at these planting rates have confirmed the suitability of these rates/billet distribution. Uniform billet spacing is an essential prerequisite of a precision-planting system.

Objective 6 - Assess planting options such as high quality coated billets as an alternative for the distribution of Approved Seed.

Planting options, such as high-quality, coated billets, as an alternative form of Approved Seed for grower propagation, were not viable due to negative results in Objective 3. The use of high-quality billets as a source of Approved Seed has been addressed in this project, and commercial applications of these practices are currently in use. The high planting rates of current billet planters are an impediment to the use of this machine for planting Approved Seed.

3.0 PRODUCING HIGH QUALITY CANE SUITABLE FOR PLANTING

This section addresses objectives 1 and 5.

3.1 Introduction

Sugarcane is planted as vegetative cuttings (seed cane) taken from the stalks of the plant. Buds and root primordia are found at each node of the sugarcane stalk. Billet planting takes the vegetative cuttings or billets that are cut by a chopper harvester and plants them. Hence, the quality of the billets produced by the chopper harvester can have a large influence on the success of establishment of the sugarcane plants when planted with this system (Robotham and Chappell 2002). The two vital characteristics of quality billets destined for planting are that they should have at least two nodes or buds per billet and that they should be free of damage such as splits and cuts to the rind of the billet.

Chopper harvesters are designed to cut sugarcane that is to be sent to a sugar mill and the billets are 150-300 mm (Robotham and Poulsen 1996). Although the length of billets produced by the harvester can be adjusted, longer billets (> 300 mm) are incompatible with the current billet planters. In some cultivars, the distance between nodes can be 200-300 mm. This means that billets cut from these cultivars have only one node at best. The presence of two or more nodes helps to protect cuttings from soil-borne fungi that cause rots of the cuttings (Girard and Rott 2000). Producing sugarcane with shorter distance between nodes will increase the probability of having a greater number of billets with more than one node.

Recent improvements to chopper harvesters used to cut billets have greatly reduced the number of damaged billets (Robotham and Chappell 2002). These improvements include rubber coating the feed rollers and synchronising the speed of the feed rollers. However, even with these improvements, cane that is lodged can suffer a high proportion of damaged billets as the twisting of the lodged stalks as they are feed into the harvester can cause damage. Cane growers have used many methods to attempt to prevent sugarcane that is being grown for seed cane from lodging. These treatments have included delayed planting or ratooning, reducing fertiliser application, reducing irrigation and defoliating the crop by mowing or application of paraquat herbicide (Hussey 2000). These treatments are often affected by subsequent environmental conditions. If rainfall events occur, with-holding irrigation water is obviously ineffective. Some highly vigorous cultivars have a tendency to lodge irrespective of the application of these treatments. These cultivars cannot be easily planted with the wholestalk planting system and suffer poor establishment if the lodged cane is planted with the billet-planting system. This can lead to reduced adoption of these varieties even though they may have higher productivity. Treatments that could improve the chances of achieving erect stands of sugarcane grown for seed cane would increase the probability of obtaining successful establishment.

Gibberellin is a plant hormone involved in cell elongation (Sachs 1965). Chemicals that inhibit gibberellin biosynthesis have been used to control the growth of turf and fruit trees. paclobutrazol and flurprimidol have both been used commercially to suppress grass growth in parks and other public grasslands (Watschke *et al*. 1992). Paclobutrazol (Cultar®, Syngenta) is registered in Australia for use on fruit trees to restrict vegetative growth and improve fruit size. A chemical that became available in Australia towards the end of the project, triexapact-ethyl (MODDUS®), is being tested as a cane ripener. These chemicals may restrict vertical growth of sugarcane reducing the risk of lodging and reducing the internode length.

In this section of the report, we detail experiments conducted to determine whether ideal planting material can be produced by controlling the growth of the cane by physical trimming, by addition of nitrogen and phosphorus, by gibberellin inhibiters, or by planting density.

3.2 Nitrogen, phosporus and trimming

3.2.1 Trial 1

Trial 1 tested the effect of an application of N, P and N+P 8 weeks before planting on germination.

Methods
Treatments were:
1. Untreated control;
2. Nitram 38 kg/ha N;
3. Triphos 40 kg/ha P;
4. Nitram+ Triphos 38N+40P kg/ha;
5. DAP 38N+40P kg/ha;
6. DAP 19N+20P kg/ha.

Treatments were applied 8 weeks before cutting for planting to a block of Q120 at Tully. Soil samples were taken before planting for nutrient analysis. Cane was cut from each of the plots, the number of buds on each stalk was counted, and the cane was then planted through a wholestalk planter. The cane was planted in a randomised complete-block design of all treatment combinations with two replicates. The number of shoots in each plot was counted at 2-3 day intervals after planting. Cane yield and CCS were measured 12 months after planting.

Results

Application of nitrogen significantly improved germination (Figure 1), but application of P had no effect. Phosphorus levels in the control soil in this experiment were high 154.8 mg/kg and the nitrate and ammonium-N levels were low (1.0 and 5.3 mg/kg, respectively).

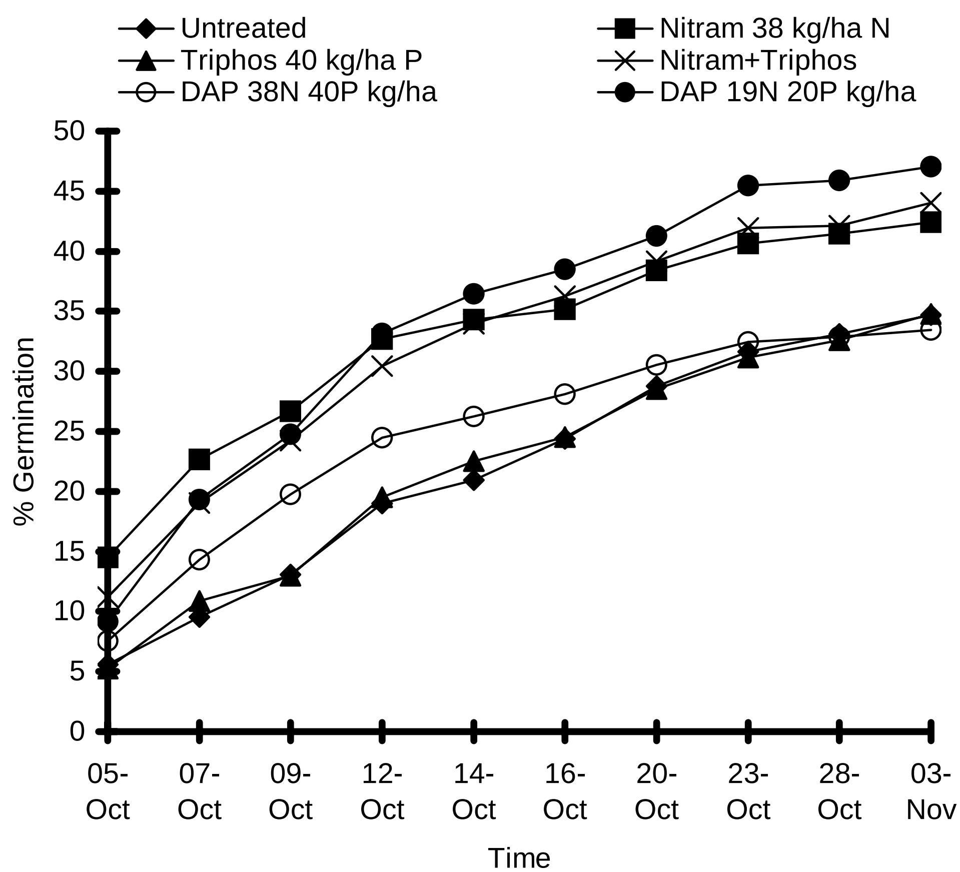

Figure 1 **Effect of nitrogen and phosphorus fertilisers applied 8 weeks before cutting for plants**

This trial was severely affected by flooding and the subsequent yields were too low for meaningful interpretation. However, there were no significant differences in yield or CCS among any of the treatments (Table 1).

Table 1 Harvest results for Trial 1 testing the effect nitrogen and phosphorus fertilisers applied 8 weeks before cutting for plants

Treatment	CCS	Cane yield (t/ha)	Sugar yield (t/ha)
1. Untreated	13.64	28.47	3.88
2. Nitram-38kg N	13.65	31.04	4.24
3. Triphos-40kg P	13.59	24.58	3.34
4. Nitram+Triphos - 38N+40P	13.79	32.85	4.53
5. DAP - 38N+40P	13.90	25.07	3.49
6. DAP - 19N+20P	14.13	29.65	4.19

3.2.2 Trial 2

Trial 2 tested the combined effects of trimming and of nitrogen (N) or phosphorus (P) application on subsequent germination.

Methods
The treatments were:
Factor 1:
1. Untreated control;
2. Nitram 38 kg/ha N;
3. Triphos 40 kg/ha P;
4. Nitram 38 kg/ha N + Triphos 40 kg/ha P.

Factor 2:
1. No trimming;
2. Trimmed.

The block to supply the planting material was planted with Q120 in August 1997. The treatments in the source planting material were arranged in a randomised complete-block design of all combinations of the two factors with two replicates. The trimming treatments involved cutting the cane above the growing point between the second and third dewlaps from the top of the stalk. The cane was trimmed on 23 January and 10 March 1998. The fertiliser treatments were applied 6 weeks before cutting-planting on 3 July 1998. Soil samples were taken before planting for nutrient analysis.

The cane was cut from the treated plots on 25 August 1998, the number of buds on each stalk was counted, and the cane then planted through a wholestalk planter. The cane was planted in a randomised complete-block design of all treatment combinations with four replicates. Each source plot provided planting material for two replicates. The number of subsequent shoots in each plot was counted at 2-3 day intervals. Cane yield and CCS were measured 12 months after planting.

Results
In the untrimmed cane, the fertiliser treatments gave no significant increase in the proportion of buds germinating, but in the trimmed cane, N, P and N+P all gave a large and overall significant response (Figure 2). The control soil used in this experiment was

relatively low in P (57 mg/kg) and has a high P-fixing ability. The nitrate-N in the soil was 3.8 mg/kg and the ammonium-N was 13.2 mg/kg.

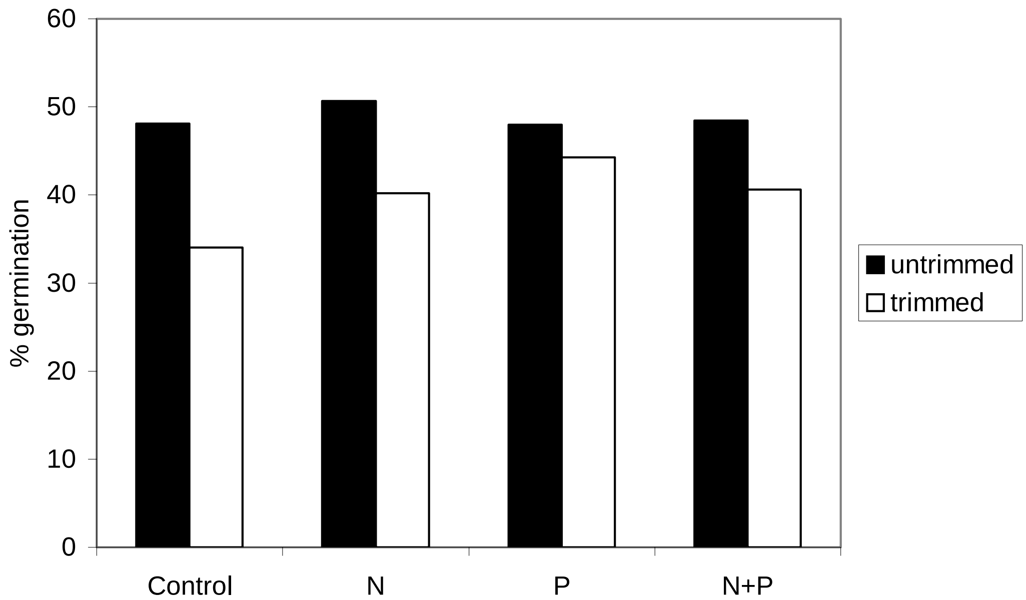

Figure 2 Effect of trimming and application of nitrogen (N) and phosphorus (P) on subsequent germination in Trial 2

The yields of the cane planted from the treated cane were low and there were no significant differences between treatments (Table 2), despite the differences in germination.

Table 2 Harvest results for Trial 2 testing the effect of trimming and fertiliser on subsequent germination

Fertiliser	**Trimming**	**CCS**	**Cane yield (t/ha)**	**Sugar yield (t/ha)**
Untreated -Control	Trimmed	17.09	47.72	8.15
Untreated -Control	Untrimmed	16.87	60.14	10.14
Nitram 38 kg/ha N	Trimmed	17.07	54.14	9.24
Nitram 38 kg/ha N	Untrimmed	16.77	60.95	10.22
Triphos 40 kg/ha P	Trimmed	16.86	58.50	9.86
Triphos 40 kg/ha P	Untrimmed	17.21	57.74	9.94
Nitram 38 kg/ha N + Triphos 40 kg/ha P	Trimmed	16.84	55.49	9.34
Nitram 38 kg/ha N + Triphos 40 kg/ha P	Untrimmed	17.10	56.90	9.73

3.2.3 Trial 3

Trial 3 tested the effect of trimming on subsequent germination of six cultivars.

Methods

Two plots, each 3 rows by 5 m long, were either trimmed or untrimmed in strips of first-ratoon Q117, Q120, Q124, Q127, Q152 and Q158 at BSES Tully. The trimming treatments involved cutting the cane above the growing point between the second and third dewlaps from the top of the stalk. The cane was trimmed on 23 January and again on 3 March 1998.

The cane was cut from the treated plots on 25 August 1998, the number of buds on each stalk was counted, and the cane planted through a wholestalk planter. The cane was planted in a randomised complete-block design of all treatment combinations with two replicates. The number of shoots in each plot was counted at 2-3 day intervals.

Results

The trimming treatment was successful in preventing lodging and shortening nodes in the six cultivars (Figure 3); the average node length was reduced by 30% in Q117, Q120, Q152, and Q158, but only by 14% in Q124 and 10% in Q127. Node length was particularly short in the middle of the stalk where nodes were forming at the time the treatments were applied. Trimming significantly reduced germination in Q158 and Q117, but not affected in the other cultivars (Figure 4). The reduced germination may have been an artifact of the increased number of nodes per billet in the trimmed cane, with apical dominance restricting the number of buds germinating on the treated billets.

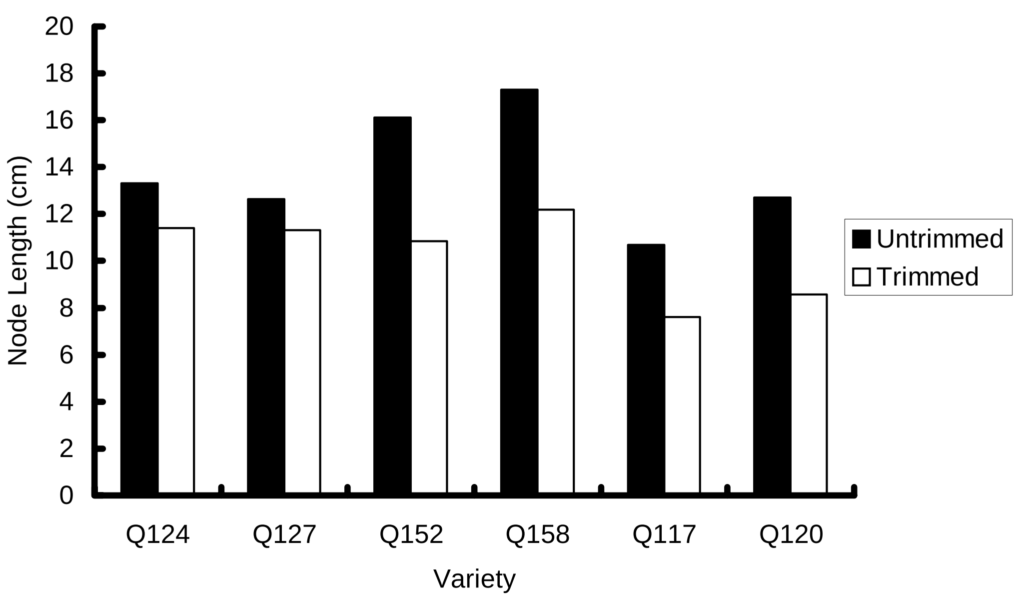

Figure 3 Effect of trimming on resultant node length in Trial 3

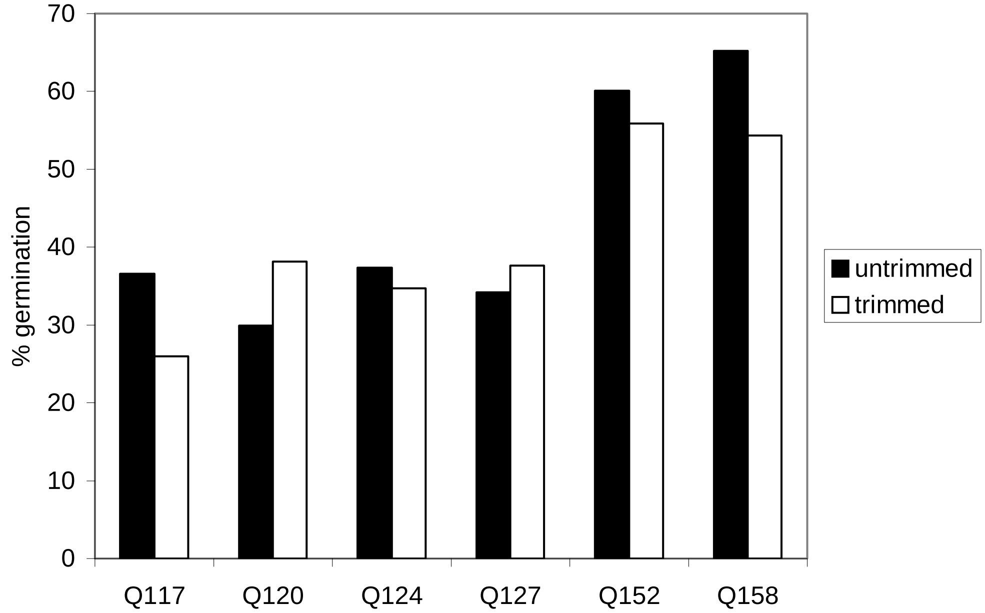

Figure 4 Effect of trimming on resultant germination in Trial 3

3.2.4 Discussion

Although trimming reduced internode length and would probably reduce the risk of lodging, it was deleterious to germination in most cultivars tested. The reduced internode length was not even along the stalk, with some very short internodes and some normal-length internodes. This treatment, therefore, would not provide billets for planting with uniformly shorter internodes. Trimming cannot be recommended as a treatment for producing better quality planting material and research in this area was discontinued after the initial trials.

Application of nitrogen and phosphorus to planting material 6-8 weeks before planting was beneficial in some cases. Phosphorus appeared to be beneficial in soils with lower levels of this nutrient and nitrogen was beneficial in some cases. These results support the findings of other research (Yates 1964; Ingram 1986; Croft 1998) and growers should be encouraged to add these nutrients to plant sources to improve germination.

3.3 Gibberellin inhibiters

The aim of these experiments was to determine whether gibberellin inhibiters were capable of reducing vertical growth of cane and thus reducing internode length without deleterious effects on germination of the treated cane.

Paclobutrazol (Cultar®, Syngenta) was registered in Australia for use in horticulture and, later, triexapact-ethyl (MODDUS®) became available. Both chemicals inhibit gibberellin, the plant hormone responsible for cell extension.

3.3.1 Cultar®

Two experiments were established to test the effects of Cultar® (paclobutrazol).

3.3.1.1 Experiment 1

Experiment 1 aimed to identify the rates of paclobutrazol that were effective in controlling the growth of sugarcane and whether there was any phytotoxicity from the chemical.

Methods
Paclobutrazol (Cultar®, 250g/L Syngenta) was mixed with 5 L of water and applied with a watering can to the soil at the base of a young ratoon crop of Q158 at BSES Tully on 5 October 2000. The crop had a light trash blanket and the chemical was applied onto the trash blanket. The rates tested were 0, 0.25, 0.5, 1.0. 2.0, 4.0, 6.0, 8.0 and 10.0 kg ai/ha. The plot size was one row by 5 m with a two-row gap between adjacent treated rows and a 2 m gap between plots down the row. There were three replicates of each treatment arranged in a randomised complete-block design.

Ten stalks were marked in each plot and the height of the stalks from ground level to the top visible dewlap was measured weekly. The number of stalks was determined 1 and 2 months after treatment. Notes were made on the effect of the treatments on leaf colour and structure.

In May 2001, 8-10 stalks were taken from each plot and the length of the internode sections were measured and the number of buds counted. These stalks were then planted through a mechanical planter. This experiment was planted in a randomised complete-block design with plots of two rows by 10 m long. The number of shoots was counted weekly and the percentage of germinated buds calculated.

Data were analysed by analysis of variance. The relationship between the different characters measured and the rate of paclobutrazol were analysed by linear regression.

Results
Growth rates of the treated plots were lower under the four highest rates (4-10 kg/ha) during the third week after application and remained significantly lower until week 16 (Figure 5). An application of the herbicide, paraquat, between weeks 3 and 4 had a dramatic effect on growth during week 4 in all treatments, but the plants quickly recovered from this treatment. The paraquat was applied as a routine weed-control measure.

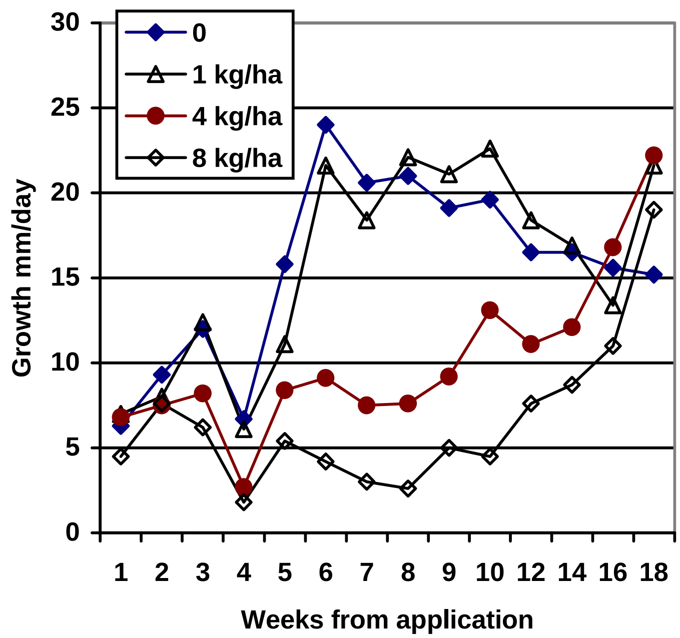

Figure 5 **Growth rate of cane treated with paclobutrazol in Experiment 1 (growth following application of 6 and 10 kg/ha was similar to that at 4 and 8 kg/ha, and at <4 kg/ha was similar to that at 0 and 1 kg/ha)**

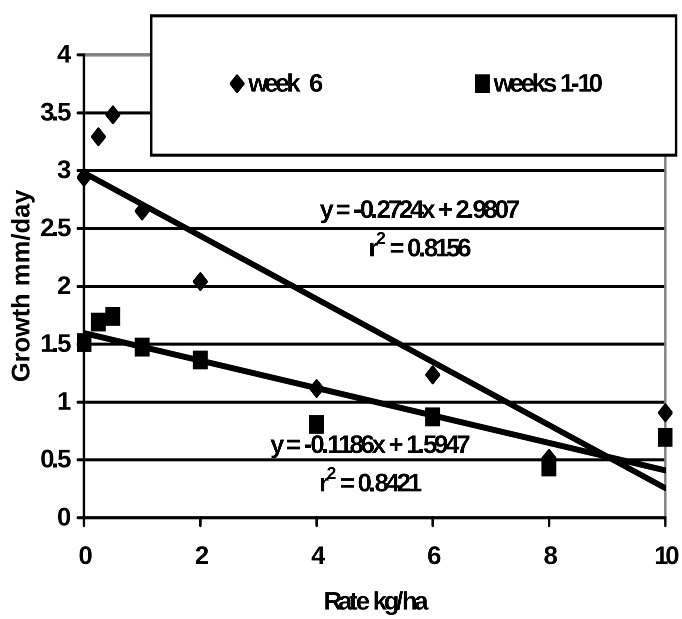

Figure 6 **Relationships between the mean growth rate per day averaged over the first 10 weeks of the experiment and during week 6, and rate of paclobutrazol in Experiment 1**

The relationships between the mean growth rate per day averaged over the first 10 weeks of the experiment and during week 6, and rate of paclobutrazol are shown in Figure 6. There was a highly significant relationship between growth and rate of the chemical for both these time periods. At the end of 11 weeks, the highest four rates had reduced growth by 36-58% compared with the untreated control.

At 9 weeks after the treatments were applied, the number of stalks per meter of row showed a significant positive relationship with rate of paclobutrazol (Figure 7). The higher rates of paclobutrazol had 20% more shoots than the control.

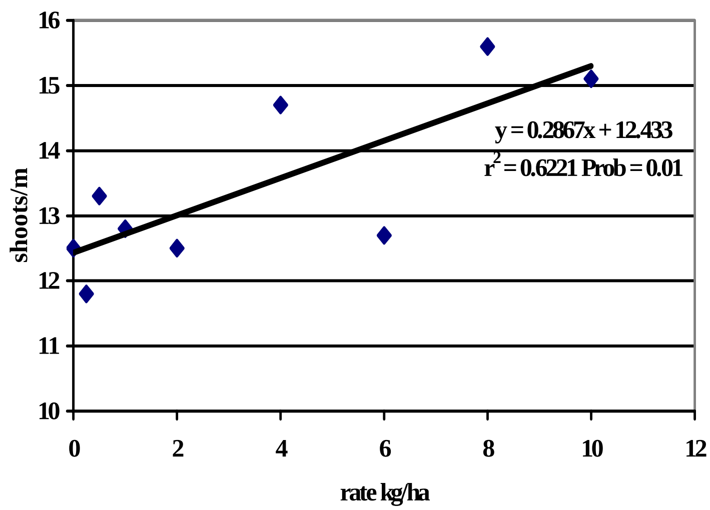

Figure 7 Effect of paclobutrazol on subsequent shoot population 9 weeks after treatment in Experiment 1

In May, 7 months after application of the paclobutrazol, there was a highly significant negative relationship between internode length and rate of paclobutrazol for average of internodes 1-10 (r^2 = 0.69). Paclobutrazol rates of 6, 8 and 10 kg/ha restricted the internode length of nodes 1 to 5, but only 10 kg/ha restricted the internode length of internodes 6-9 (Figure 8).

The plants treated at the four higher rates of paclobutrazol showed darker green leaves than those in the untreated control plots and showed a distinct bunching of the top leaves. New leaves were being produced, but there was limited stalk extension.

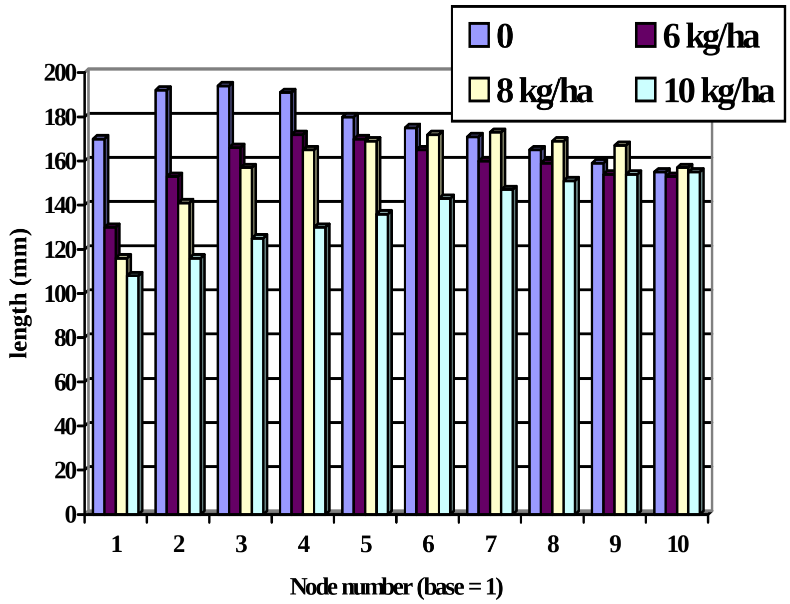

Figure 8 **Effect of paclobutrazol on internode lengths 7 months after treatment in Experiment 1**

Germination of sugarcane stalks taken from the paclobutrazol-treated plots, 7 months after treatment, showed a significant positive relationship with percent germination of buds at 3 weeks after planting (Figure 9), but at 8 weeks after planting there was no difference between treatments (data not shown).

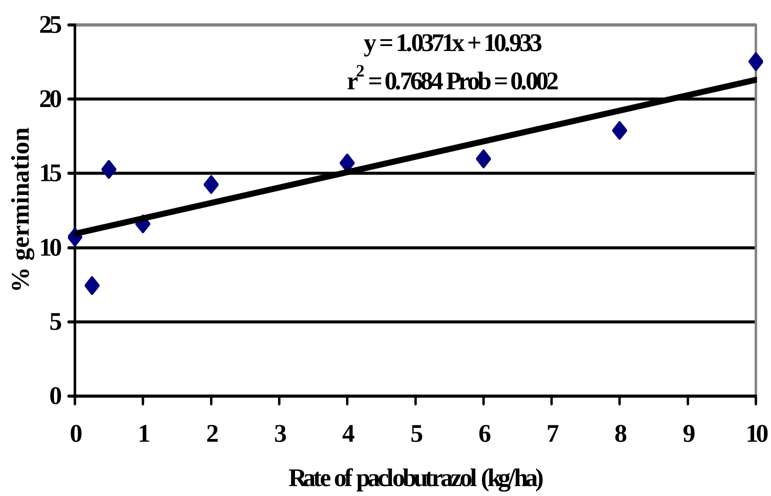

Figure 9 **Effect of paclobutrazol on germination at 3 weeks after planting in Experiment 1**

3.3.1.2 Experiment 2

Experiment 2 aimed to identify the rates of paclobutrazol applied at different times that were effective in controlling the growth of sugarcane and whether there was any phytotoxicity from the chemical.

Methods
In this experiment, four rates of paclobutrazol, 0, 1.25, 2.5 and 3.75 kg ai/ha, were applied to a plant crop of cultivar Q181^A in Tully during late 2000 and early 2001. The treatments were applied on four different schedules: December only; January only; December and February; and January and March. The paclobutrazol was mixed with 5 L of water and applied with a watering can to the soil at the base of the plants. The plot size was three rows by 5 m with a one-row gap between adjacent treated rows and a 1 m gap between plots down the row. There were three replicates of each treatment arranged in a randomised complete-block design.

Stalk heights from ground level to the top visible dewlap were measured on five stalks from each plot weekly until April 2001. Sugar content, fiber and stalk percent moisture were measured in June 2001 on a sample of six stalks per plot. The measurements were made on fibrated cane using by infra-red reflectance (NIR) using the procedures of Berding and Brotherton (1999).

In May and August 2001, 8-10 stalks were taken from each plot and the length of the internode sections were measured and the number of buds counted. These stalks were then planted through a mechanical planter. The germination experiments were planted in a randomized complete-block design with plots of two rows by 10m. The number of shoots was counted weekly and the percentage of germinated buds calculated.

The characters measured in the treated plant source and in the germination experiment were analysed by analysis with two factors: rate of paclobutrazol and time schedule for application.

Results
The low rate of paclobutrazol (1.25 kg/ha) reduced the growth of the Q181^A by an average of 26% for 4 weeks when applied in December, but only reduced growth by an average of 10% for 3 weeks when applied in January (Figure 10). Reapplying the chemical to the plots that were treated in December reduced the growth by an average of 22% for a further 4 weeks. Reapplying the chemical in March to plots treated in January had no further effect on the growth of the cane.

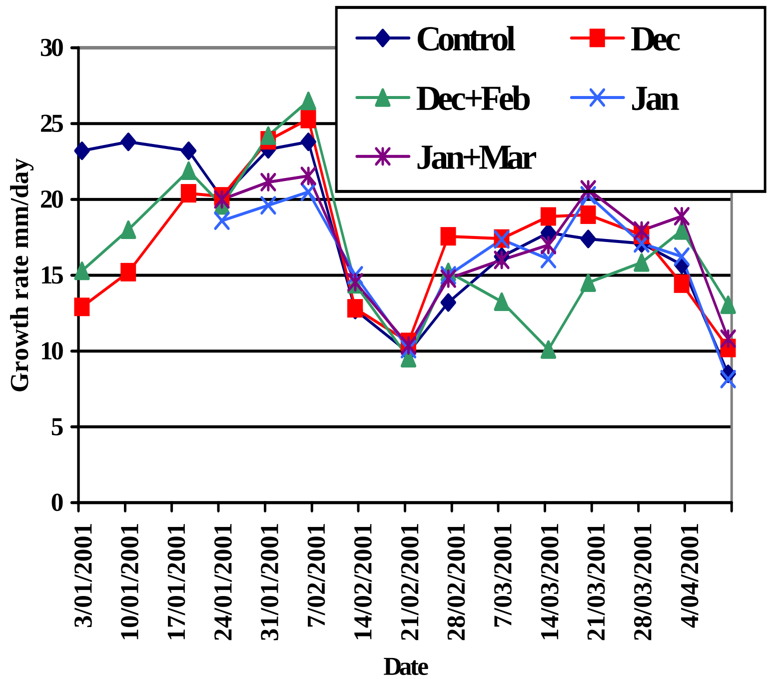

Figure 10 **Growth rate of cane following application of 1.25 kg/ha of paclobutrazol at four treatment schedules in Experiment 2**

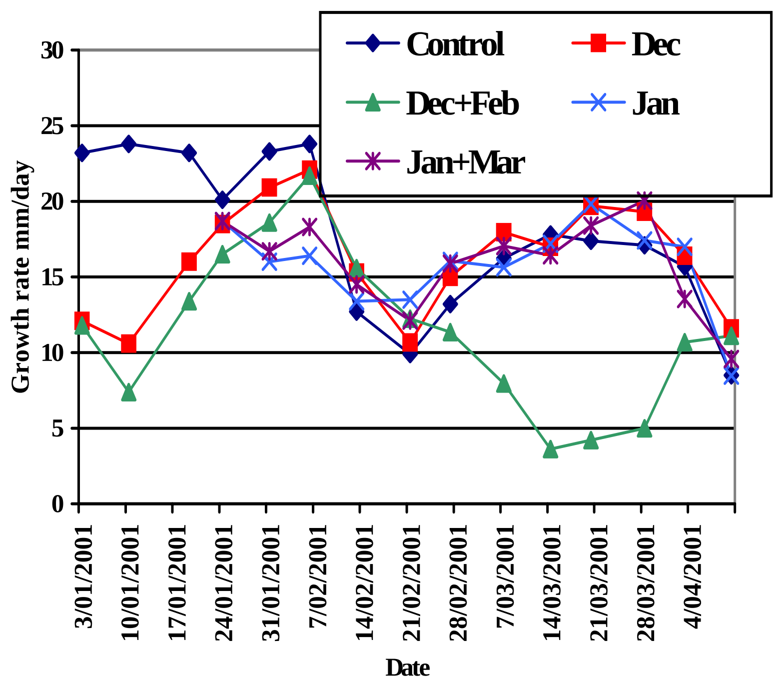

Figure 11 **Growth rate of cane following application of 2.5 kg/ha of paclobutrazol at four treatment schedules in Experiment 2**

Paclobutrazol at 2.5 kg/ha reduced growth by an average of 31% for 7 weeks when applied in December, but only reduced growth by 22% for 2 weeks when applied in January (Figure 11). Reapplying the chemical at this rate to plots treated in December reduced the growth by an average of 56% for a further 6 weeks. Reapplying the chemical in March to plots treated in January had no further effect on growth of the cane.

The highest rate of paclobutrazol (3.75 kg/ha) reduced growth by an average of 66% for 7 weeks when applied in December, but only reduced growth by 26% for 5 weeks when applied in January (Figure 12). Reapplying the chemical at this rate to plots treated in December reduced the growth by an average of 70% for a further 7 weeks. Reapplying the chemical in March to plots treated in January reduced growth by 25% for a further 5 weeks.

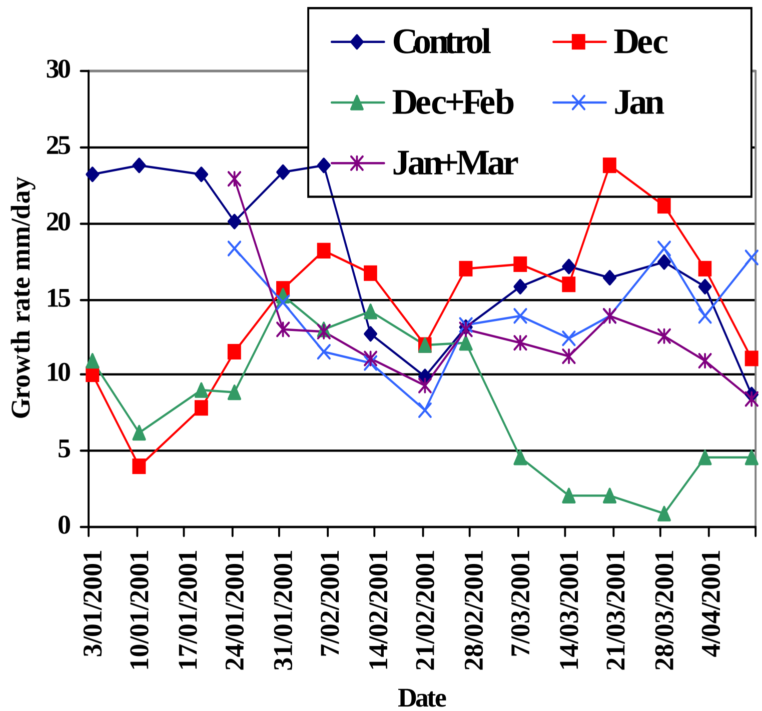

Figure 12 **Growth rate of cane following application of 3.75 kg/ha of paclobutrazol at four treatment schedules in Experiment 2**

Paclobutrazol had a small but highly significant effect on percent moisture in stalks and percent fibre (Table 3), but did not significantly affect CCS (data not presented).

Table 3 **Effect of paclobutrazol on percent moisture and percent fibre in Experiment 2**

Rate (kg/ha)	% moisture*	% fibre*
0	69.7 a	12.0 a
1.25	70.2 b	11.8 a
2.5	70.1 ab	11.7 ab
3.75	70.5 b	11.4 b

*Numbers within a column followed by the same letter are not significantly different at P = 0.05

Cane in plots treated at the higher rates of paclobutrazol showed bunching of the top leaves and a generally darker green leaf colour. Cane in some control plots and plots treated with the lower rates had partially lodged at the end of the experiment. Cane in plots treated with the higher rates did not lodge.

There was a highly significant interaction between the rate of paclobutrazol and application schedule for average internode length 8 months after commencement of the experiment. The distribution of internode lengths along the stalks (Figures 13-16) had a similar pattern to the growth rate over time for the same treatments (Figures 10-12). The internode length for the highest rate of paclobutrazol (3.75 kg/ha) ranged from 60 to 120 mm and for the 2.5 kg/ha rate from 80 to 136 mm.

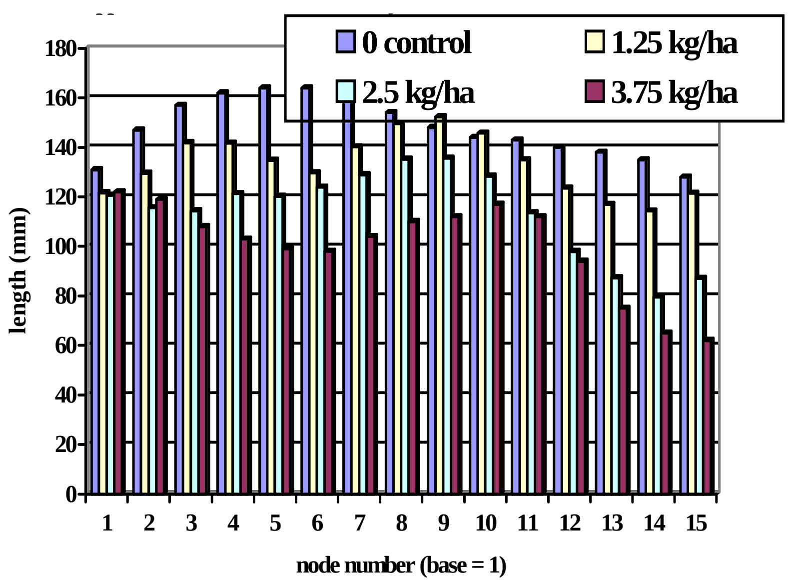

Figure 13 **Internode length 8 months after application of paclobutrazol in December and February in Experiment 2**

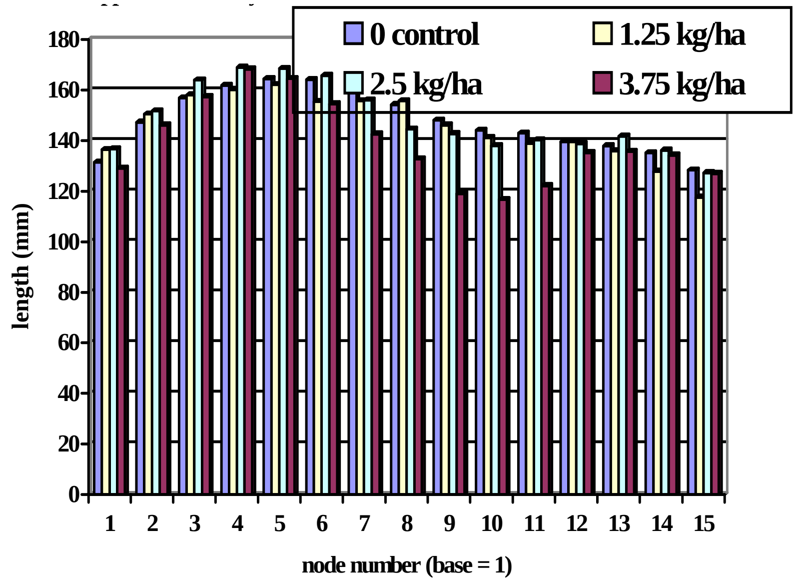

Figure 14 **Internode length 8 months after application of paclobutrazol in January in Experiment 2**

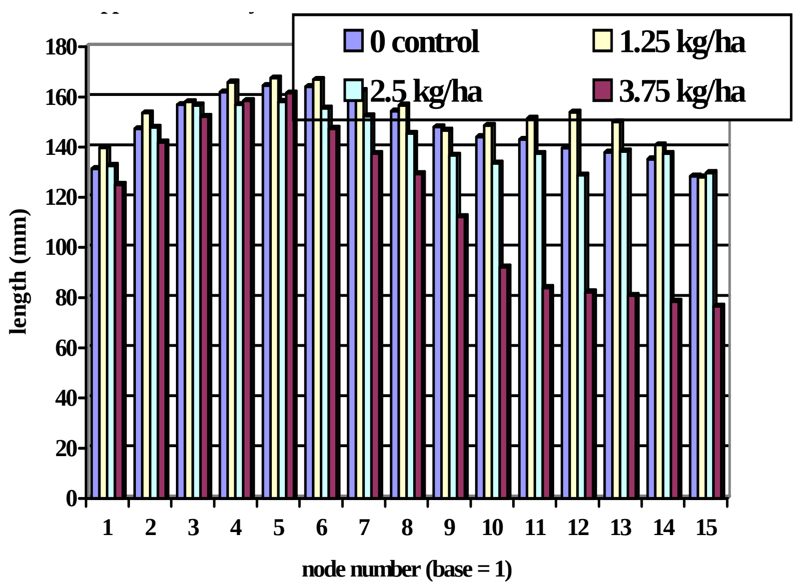

Figure 15 **Internode length 8 months after application of paclobutrazol in January and March in Experiment 2**

Paclobutrazol significantly improved the germination 21 days after planting in May (Table 4), but the germination at the end of the experiment did not significantly differ among treatments. There was no significant difference between germination of any treatments when the cane was planted in August.

Table 4 Effect of paclobutrazol on germination at 21 and 54 days after planting in Experiment 2

Rate (kg/ha)	% germination								Mean	
	21 d				54 d					
	Application schedule*				Application schedule*					
	D	D+F	J	J+M	D	D+F	J	J+M	21 d	54 d
0	18.8	15.1	17.9	21.9	65.8	62.5	58.0	64.2	18.4	62.6
1.25	18.9	26.6	14.5	23.8	57.5	68.6	54.8	68.9	20.9	62.5
2.5	24.9	25.0	22.1	27.0	72.3	71.1	63.9	69.2	24.7	69.1
3.75	17.9	21.4	23.7	32.8	55.6	64.4	64.0	70.3	23.9	63.6
Mean	20.1	22.0	19.5	26.4	62.8	66.6	60.2	62.8		

*D = paclobutrazol applied in December only; D+F = paclobutrazol applied in December and February; J = paclobutrazol applied in January only; J+M = paclobutrazol applied in January and March.

3.3.1.3 Discussion

The aim of this research was to limit the internode length of sugarcane to make it more suitable for planting through billet planters. Paclobutrazol effectively controlled internode length of two cultivars with no phytotoxicity or negative effect on subsequent germination of the treated cane. Paclobutrazol-treated cane of both cultivars germinated significantly faster when planted in autumn.

The effect of paclobutrazol on sugarcane was similar to that reported for vertical growth restriction in other grasses (Watschke *et al*. 1992). Other treatments used to restrict the growth of sugarcane tend to give a dramatic effect on growth for a short period. These treatments can give a number of extremely short internodes, but when growth resumes the new internodes are of near normal length, for example an application of paraquat herbicide to experiment 1 caused a sharp reduction in growth for 1-2 weeks but did not affect growth after this relatively short period. Paclobutrazol gave a general restriction of internode length for 6-7 weeks after application. The internode lengths obtained from two applications of 2.5 kg active/ha paclobutrazol to Q181^{A} were 80-136 mm, which is ideal for billet planting.

Repeat treatments at the higher rates in Experiment 2 appeared to give a more severe effect, suggesting there was some carryover of the chemical in the soil or the plant from the earlier treatments. Repeat treatments were reapplied at the same rate as the first treatment. In future experiments reduced rates for repeat treatments should be investigated. The results suggest that a treatment of 2-4 kg active/ha followed by a repeat treatment of between 1-2 kg active/ha may be suitable.

Treatments applied earlier in the season consistently gave the greatest responses. Late applications in March only restricted growth at the highest rate in experiment 2. Treatments that were started in January allowed the plants to produce a number of relatively long internodes before the treatments commenced. This is undesirable, because, ideally, the internode length should be as uniform as possible to allow the machines to be designed to cut uniform length cuttings.

Plots treated with paclobutrazol were less susceptible to lodging, but this needs to be confirmed with larger plots.

Paclobutrazol gave a small but significant increase in stalk percent moisture in stalks. Increased stalk moisture content has been linked to improved germination of sugarcane in a number of studies (Chen *et al*. 1986; Ingram 1986). Early germination of cane taken from both experiments was improved when it was planted in the autumn, but at the final germination counts there was no difference between treatments. Rapid germination is highly desirable because the quicker the sugarcane germinates and establishes the less susceptible it is to the risk of adverse weather conditions or attack by pathogens.

In Experiment 1, the effects of similar rates of the chemical were less and took longer to develop than in Experiment 2. This was possibly due to the presence of organic matter. In another experiment, the chemical was applied to a ratoon crop of Q138 with a heavy trash blanket (leaf litter) and there was no response to the chemical at rates of 3.75 kg/ha (data not included). When the trash was removed from this site and the chemical was reapplied, there was significant restriction in growth. If paclobutrazol is applied to ratoon crops with trash blankets, the trash should be removed or the chemical should be applied below the trash blanket.

These experiments demonstrated the principal that paclobutrazol can be used to control sugarcane growth; it can restrict internode length with no apparent effect on germination of the cuttings taken from treated stalks and it is relatively easy to apply. However, at the effective rates the chemical is not viable for commercial application at current prices. The estimate of cost for treatment is \$500-1000/ha depending on supplier and quantity purchased.

3.3.2 MODDUS®

One experiment was established to test the efficacy of MODDUS® (triexapact-ethyl).

Methods

The treatments were applied to a plant crop of cultivar NCo310 at BSES Woodford. The cane was planted in September 2002 and the treatments were applied on the 2 April 2003. Treatment was later than planned because of extended periods of rain in February and March. A hand boom spray powered by compressed air was used to apply the treatments. Plots were four rows by 5 m long and there were three replicates of each treatment arranged in a randomised complete-block design. Treatments were:

1. Untreated control;
2. 25 g/ha triexapact-ethyl (100 mL/ha MODDUS® 250g ai/L);
3. 50 g/ha triexapact-ethyl (200 mL/ha MODDUS® 250g ai/L);
4. 100 g/ha triexapact-ethyl (400 mL/ha MODDUS® 250g ai/L);
5. 200 g/ha triexapact-ethyl (800 mL/ha MODDUS® 250g ai/L);
6. 400 g/ha triexapact-ethyl (1600 mL/ha MODDUS® 250g ai/L);
7. 800 g/ha triexapact-ethyl (3200 mL/ha MODDUS® 250g ai/L).

The height to the top visible dewlap of 10 stalks in each plot was measured at 0, 14 and 21 days after treatment. Two stalks were cut from each plot 11 and 16 weeks after the treatments were applied and were planted in potting mixture and placed in a glasshouse. The number of germinating shoots was counted at 2-3 day intervals. The height of the germinating shoots to the top visible dewlap was measured when germination was complete.

Results

There was a significant linear relationship between growth rate of the treated cane and rate of MODDUS (Prob. < 0.05, Figure 16) 2 weeks after application of the chemical. Growth rate was restricted by 70% by 800 mL/ha MODDUS. It was not possible to determine the duration of activity of the chemical because a severe storm caused lodging in the field and this made accurate growth measurements impossible.

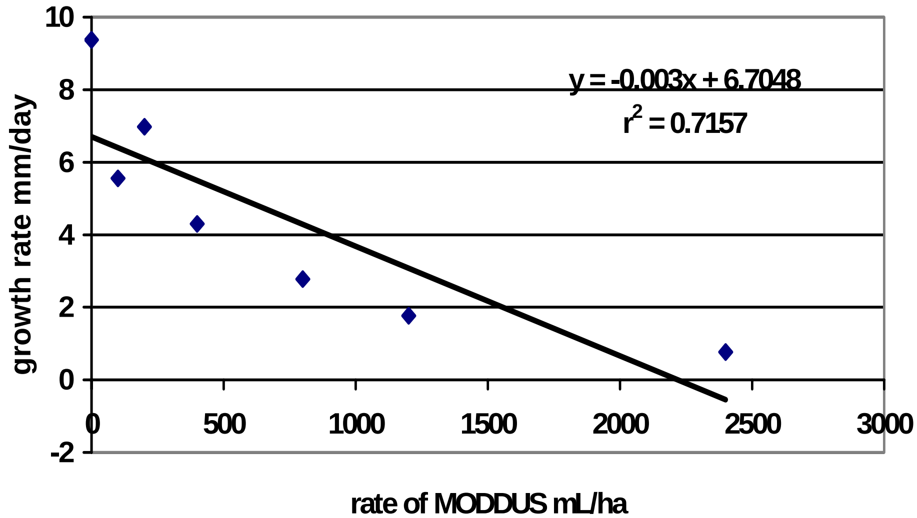

Figure 16 Effect of MODDUS on growth rate of cane 2 weeks after application

Germination of the cane taken from the treated plots was not significantly different from the untreated control in either the 11 or 16 weeks germination tests. However the germinating shoots in the plots treated with the higher rates of MODDUS had significantly reduced vertical growth in both germination tests (Figure 17). The stunted cane in the germination test showed no other symptoms of phytotoxicity and the shoots resumed normal growth after 6-8 weeks.

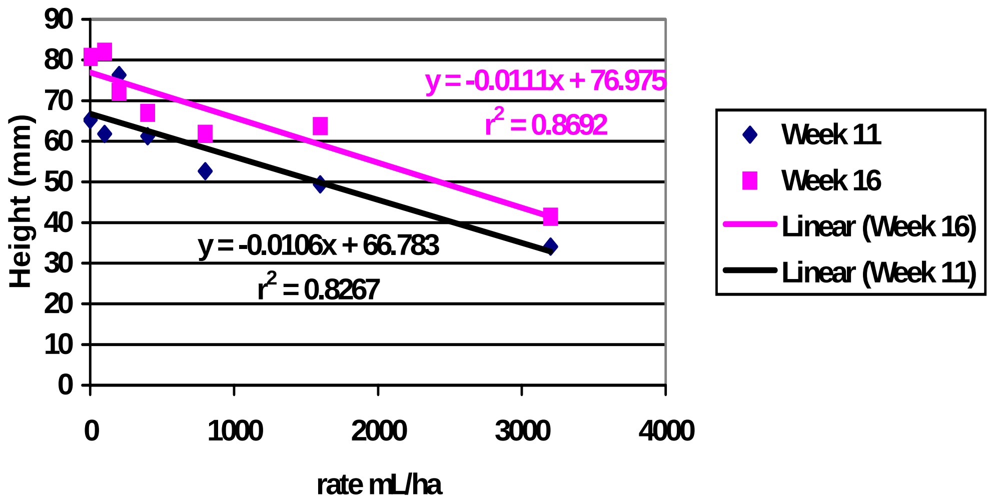

Figure 17 **Effect of MODDUS on growth rate of subsequent cane plants cut 11 and 16 weeks after application**

Discussion

MODDUS restricted the growth of sugarcane stalks at rates of 100 mL/ha and above. Unfortunately, the duration of the growth restriction could not be measured in this experiment because of lodging in the field.

MODDUS did not affect germination of the treated cane. The chemical was still active in the plant 11 and 16 week after treatment and the vertical growth of the subsequent germinating shoots was restricted for 6-8 weeks after germination compared to the untreated control.

MODDUS should be tested further as a method of controlling growth of sugarcane planting material and the testing should be conducted in northern Queensland where lodging of planting material is a greater problem. The chemical should be applied in December or January and we suggest that, based on this initial experiment, rates in the 200-800 mL ai/ha range should be tested. Growth of the germinating shoots should be monitored to determine if the restricted vertical growth of the germinating shoots is likely to be a factor limiting the use of the chemical.

3.4 Planting spacing/density

A critical design input prior to developing prototype equipment for precision planting of high-quality billets was to define the required planting rate. This component of the project was confirmed by a series of field trials at Bundaberg and Ingham. We do not claim this to be the definitive testing of planting rate, but was sufficient to enable Objective 4 to be undertaken.

3.4.1 Machinery used

All trials were planted using the BSES precision planter developed in the SRDC-funded project BSS154 ‘Improving sett/soil contact to enhance sugarcane establishment’. This planter (Figure 18) was ideal for this project, as the simple billet metering mechanism can accurately and repeatably reproduce desired billet spacings. The metering mechanism consists of a magazine of billet tubes capable of holding 25 billets (only double-eye billets used in these trials). The billet tubes are made of 50 mm polyethylene plumbing tube, each about 350 mm long. When planting a trial, the magazine slides sideways (perpendicular to the direction of travel) and the lower portion of the billet tube is exposed, enabling the billet to fall into the planting furrow. The magazine is pulled sideways by a nylon cord attached to the hub on the planter depth-wheel. The hub with four protruding bolts of the adjustable drive ‘spider’ can be seen clearly in Figure 18. Hence, the planting rate of the billets is directly proportional to the forward distance travelled by the planter. Trial plot length is varied by increasing or decreasing the circumference scribed by the bolts. Each plot has the same number (25) of billet planted, but plot length was varied to produce different planting rates. For example, the 4 eye/metre treatment would contain 25 double eye billets or 50 eyes and would be 12.5 m long. Plot length and, hence, planting rate is highly repeatable. Because the number of eyes per plot was accurately known, only counting of the primary shoots was required to determine germination and/or establishment rates. Excavation of the plots was not normally required, but was occasionally undertaken in cases of low establishment percentages. Treatments were replicated three or four times depending on the area available to the trial.

Figure 18 Magazine planter used for all plant spacing trials

The frame and most components of magazine planter were assembled using the agricultural 'clamp and wedge' system or quick release pins. The planter could be quickly assembled or disassembled and easily fitted into the back of a utility vehicle. A pneumatic presswheel with a mass-loading system was used to firm the soil around the planted setts.

All trials used high quality, hand-cut double (two) eye billets. Billets were soaked in fungicide after cutting and stored in clean buckets prior to planting.

3.4.2 First trial series

Methods

Trial 1 was planted at the Lawson site to the south of Bundaberg and it was an observation trial to test the planting methodology and to ensure the trial treatments included planting rates that would produces crop yields equivalent or superior to current grower practices. The trial was planted on 25 January 1999 into a wet, loam soil. Cultivar Q141 was used.

Treatments included hand-cut or 'perfect' billets, sound billets from a harvester, and damaged billets also from a harvester. The sound and damaged billets were obtained by hand selection from a machine-cut billet sample. All hand-cut billets had two eyes, but the machine cut billets varied according to the chopper set-up of the harvester. Average numbers of eyes planted were: 'perfect' billets 7.1 eyes per metre; sound billets 9.4 eyes per metre; and damaged billets 6.1 eyes per metre. Mutilated billet were not included, as these billets were determined to be useless as planting material. Billet selection criteria were based on a modified version of the ISSCT Mechanical Harvester Testing Protocol (Appendix 6 and Section 4 of this report). The same cultivar was planted in the remainder of the field using a Bonel (Populan type) planter and billets were cut by an Austoft 7000 harvester. Three lengths of commercial cane row were excavated to determine planting rate of the billet planter, which averaged 15.4 eyes per metre of row. As all this trial was within commercial cane fields, all cane was planted to match the grower's row spacing of 1.5 m.

Trial 2 compared minimum planting rate (4 eyes per metre), trial planting rate (6 eyes to the row metre with hand-cut billets, sound billets and damaged billets), and conventional billet-planted cane (field estimated planting rate 14.5 eyes per row metre). The trial was planted on 22 February 1999 in ideal conditions on red volcanic soil at Windermere, using cultivar Q155. The along-the-row spatial variability of the billet planter is very large compared to the accurate placement of the BSES precision planter. A HBM planter was used for the commercial planting surrounding the trial and billets were cut by an unmodified Austoft 7000 harvester. Sections of each treatment, 8 m long were cut and weighted, including the trash but minus top. Bulk samples from the billet-planted treatment was machine cut with an Austoft 7000 harvester and weighed using the BSES weigh truck. Two machine harvested sections were 80 and 120 m long. Crop growing conditions were very good.

Results

Trial 1 was our observation trial to ensure methodology was correct, but useful data were still obtained. Establishment rates for all treatments were excellent, due to the moist conditions at planting and good soil temperatures. Average rates were 75% for hand-cut billets, 66% for sound billets, 67% for damaged billets and 28% for the machine cut, billet-planted treatment. This result shows how damaged billets under ideal conditions may give acceptable establishment rates, but the damaged billets will establish poorly under less-favoured conditions. Establishment from the hand-cut billets exceeded the establishment of the other treatments. While not statistically different, the yields of all precision-planted treatments exceeded the commercial billet-planted yield: 128 tonnes/ha for hand-cut billets, 132.9 tonnes/ha for sound billets, 133.3 tonnes/ha for damaged billets and 120.4 tonnes/ha for the commercial billet planted cane.

Trial 2 highlighted the ability of a uniformly planted crop that is grown under good field conditions to compensate for reduced crop establishment (Figure 19). Establishment rates for this trial were 74% for perfect billets, 68% for sound billets and 53% for damaged billets, respectively.

The bulk machine-harvested samples yielded 176 and 183 t/ha, respectively and compared favourably to the hand-cut yields from this treatment. The machine-harvested, bulk sample was an additional sample and was only undertaken because the weigh truck was available in the area. The order of trial yield data (Figure 19) is consistent with the crop establishment at about 40 days. It is important to note that this trial was an autumn-planted crop (approximate age at harvest was 15 months) and the cultivar Q155 is one capable of forming a large plant stool. The estimated planting rate at 4 eyes per metre is about 1.5 t/ha, while the commercial billet-planted crop was planted at an estimated 6 t/ha.

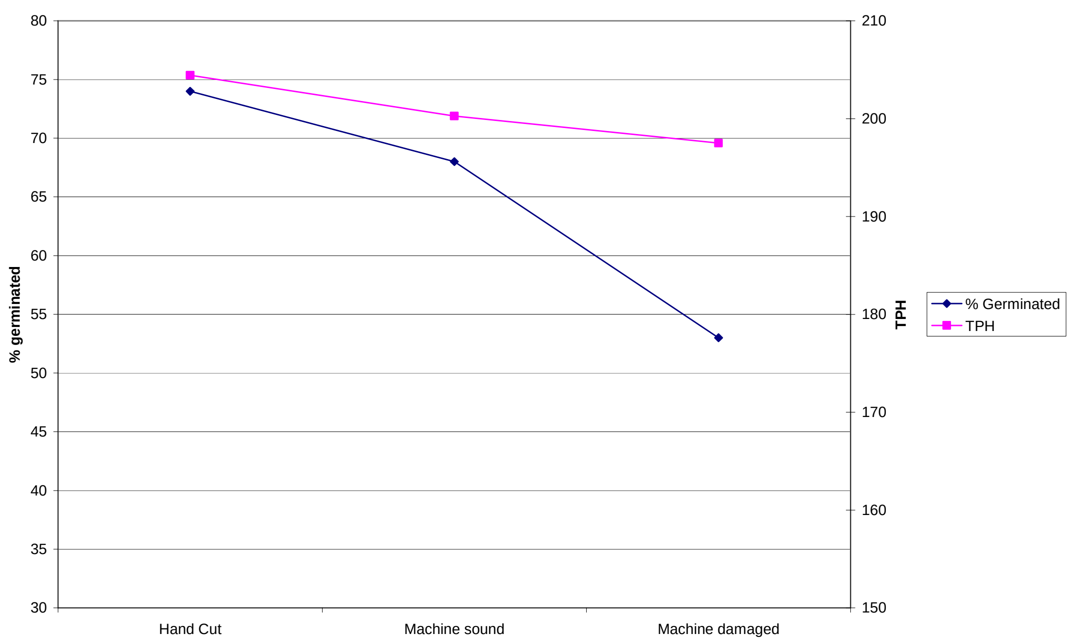

Figure 19 Germination/establishment and cane yield averaged over planting rates in Trial 2

While Figure 19 shows reduced cane yield with lower plant establishment, cane yield when measured as tonnes of cane per established eye or primary shoot showed the ability of the sugarcane plant to 'compensate' for the reduced shoot numbers by producing either a greater number of millable stalks or stalks of a greater weight or a combination of both. Cane yields per established eye or primary shoots were 7.1 kg for perfect billets, 9.5 kg for sound billets and 13.4 kg for damage billets, respectively. The reduction in establishment with sound and damaged machine-cut billets was, however, greater than the relative increase in yield per established eye and total crop yield reduced from perfect billets to sound billets to damaged billets.

Overall, results from trial 2 showed:

- Cane planted at 4 eyes per metre yielded 248 t/ha, which was significantly greater (at 5% level) than all other plantings.
- Within the 6 eyes planted per metre treatments, treatments using the sound billets and high-quality hand-cut billets yielded the highest, although these differences were not statistically significant.
- High crop yields were achieved, but that from the billet-planted treatment (183 t/ha) was lower than those from the other treatments (perfect billet 215.2 t/ha; sound billet 210.8 t/ha; damaged billet 207.9 t/ha), although this result was not statistically significant.

3.4.3 Second trial series

Five additional planting rate/precision billet spacing trials were undertaken (three in the Bundaberg region and two in the Ingham region).

Methods

All five planting rate/high quality billet spacing trials were planted under very dry soil moisture conditions. The Bundaberg and Ingham areas were without useful rainfall for more than 4 months prior to planting and soil moisture levels were insufficient for crop establishment. At all Bundaberg sites, some form of irrigation was required to ensure establishment of the trials, for example supplementary irrigation using a tanker was used at the Grange site and without this additional input, plant populations would have been unacceptable for the trial. Unfortunately, irrigation was not available at the Ingham site. The experimental planter was taken by vehicle to Ingham to plant two billet planting rate trials on the property owned by Robert, Alan and Jack Aquilini. Alicia Cordingly (Tully) and Kylie Webster (Ingham) assisted in the planting and undertook monitoring of this trial.

All trials are described by the name of the site owner or, in the case of the Bundaberg Sugar Ltd site (Grange), the farm name. Trials in order of planting date were:

- James – Bundaberg, 22 August 2000
- Lawson- Bundaberg, 24 August 2000
- Grange - Bundaberg, 25 August 2000
- Aquilini Trial 1 – Ingham, 5 September 2000
- Aquilini Trial 2 - Ingham, 6 September 2000.

All sites shared the same experimental treatments of:

- 2 eyes per row metre;
- 4 eyes per row metre;
- 6 eyes per row metre;
- 12 eyes per row metre (Aquilini Trial 1 and Trial 2 only).

The plant spacing of 2 viable eyes per metre row was included to determine the spacing at which yield reduction due to insufficient planting rate would occur. As all treatments had the same number of billets planted, this corresponded to plot lengths of 26 m, 13 m and 8 m, respectively. The 12 eyes per metre of row treatment was achieved by double planting the row and hence this treatment had a plot length of 8 metres. All treatments were replicated four times at each site. At all sites, four replicates of the grower's billet-planted cane was selected, crop growth monitored during the season, and these areas harvested as part of the trial. As the billet-planted treatments were planted by a range of commercial planting machines, the actual planting rate varied from site to site: 30 eyes per metre at James, 12 eyes per metre at Lawsons, 13.7 eyes per metre at Grange, and 22 eyes per metre in both the Aquilini trials. As all trial sites were within a commercial cane field, the trials were subjected to similar growing conditions as the commercial cane.

Results

The experimental planter did not have the ability to plant to the same depth as commercial billet planters. At both Ingham sites and the James site, the trial plantings were into very dry soil. The billet planter formed a deeper furrow and, hence, was able to access additional soil moisture at depth to achieve acceptable plant establishment. The Aquilini trials were planted deeper than normal in an effort to ensure the planted setts were in contact the moist soil. However, our experimental planter was not sufficiently robust and heavy to plant to a similar depth as the billet planter. The combination of limited soil moisture at the sett and excessive depth of soil cover, caused by deeper planting, resulted in severely reduced crop emergence in both Aquilini Trial 1 and Aquilini Trial 2.

The results from the James trial (Figure 20) clearly show the effect of shallower planting of the experimental planter and the very dry conditions during the plant establishment and crop growth periods. This site had the highest commercial billet planting rate at 30 eyes per metre of row, but had an establishment rate of only 47%. This establishment rate is considered unacceptably low as the crop was spray irrigated immediately after planting. The 2, 4 and 6 planted eyes per metre all had reduced establishment (about 50%) due to the dry conditions. The lack of follow-up rain or irrigation produced sub-standard crop yield and this was the only trial where the billet planted crop out yielded the precision-planted treatments.

Crop establishment at the Lawson site was good for the 2, 4 and 6 eyes per metre treatments at 75%, 80% and 80%, respectively. The billet-planted cane was planted at a significantly higher rate (12 eyes per metre), but had a much lower establishment (37%) and the lowest crop yield (107 t of cane per hectare). The highest cane yields were the 4 and 6 eyes per metre treatments at about 140 t of cane per hectare (see Figure 21). When compared on a yield per planted eye or yield per established eye, all precision-planted rates were superior to the grower billet-planted treatment.

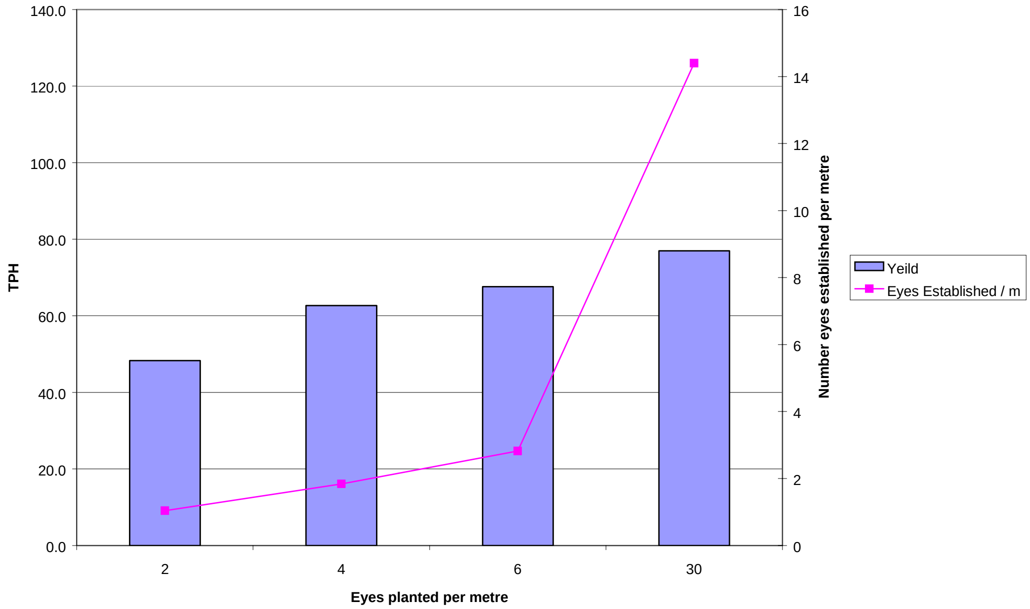

Figure 20 Planting rate, establishment rate and crop yield for the James trial

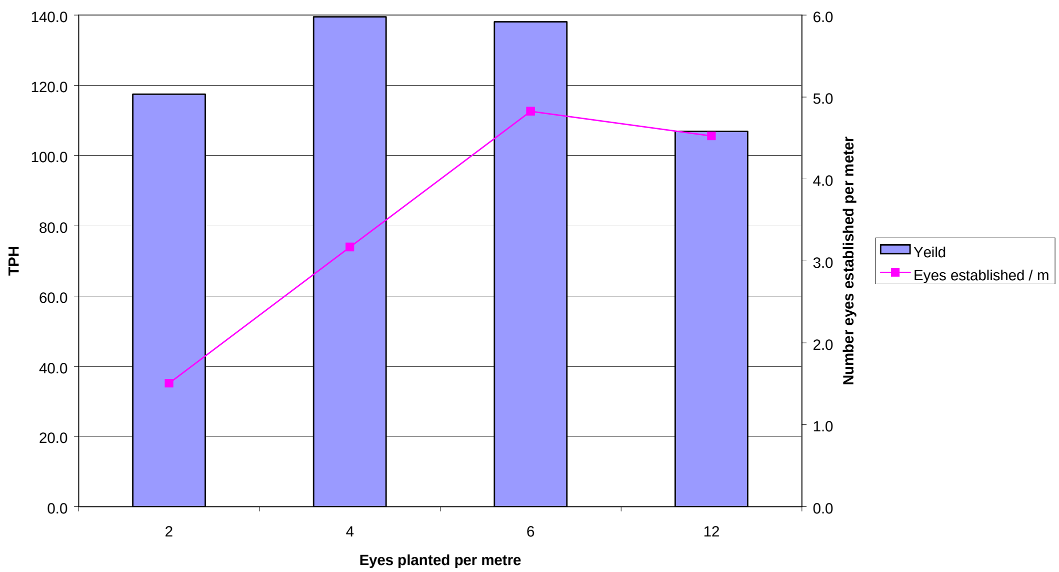

Figure 21 Planting rate, establishment rate and crop yield for the Lawson trial

The Grange trial resulted in similar plant establishments and yield trends to the Lawson trial, although all establishment rates were lower (Figure 22). The red soil at this site required three supplementary irrigations, using a vehicle-mounted tank, to ensure an acceptable level of establishment. The billet-planting rate (grower treatment) was similar to the Lawson rate, although the establishment rate for the billet planted cane was lower at 38%. The Grange trial had the highest crop yields for the 4 and 6 planted eyes per metre of row. The 2 eyes per metre and the commercial billet planted treatments had similar yields of about 115 tonnes per hectare. The placement of the trial relative to the grower's commercial cane is shown in Figure 23.

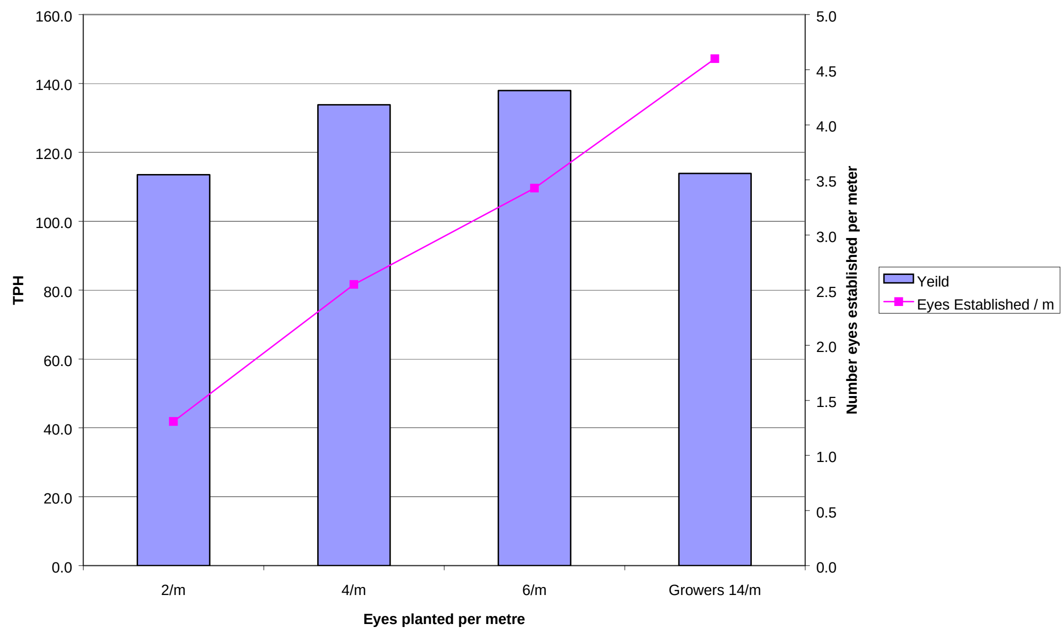

Figure 22 Planting rate, establishment rate and crop yield for the Grange trial

Figure 23 Grange trial showing uniform spaced primary shoots

The Aquilini trials were monitored and harvested, but again the crop establishment was so poor that the yield results from these two trials were dismissed.

Of the five trials undertaken only the Lawson and Grange yield results were considered acceptable. This result highlights how dependent field trials are on external factors such as weather and, hence, the necessity for establishing five trials to ensure that some useful data was obtained within the specified time frame.

3.4.4 Discussion

This component of the project was initially intended to be undertaken in association with another project that did not receive funding. We undertook the field trials after many observations and stalk counts of commercial sugarcane crops. Most high-yielding crops in the southern canegrowing regions produce 100,000-140,000 millable stalks per hectare. This equates to 15-20 stalks per metre of row at 1.5 m row spacings. Establishing 3-4 uniformly spaced primary shoots and allowing for 3-4 secondary shoots developing to maturity on each stool will produce the required number of millable stalks.

Based on the results of this project and supporting results from trials conducted by the Sugar Yield Decline Joint Venture (SYDJV) at Gordonvale, Ingham, Mackay and Bundaberg, a desired minimum plant establishment of 3-4 uniformly spaced shoots per metre of row has been recommended to the industry. All double-disc planters manufactured for BSES and growers have had the planting rate reduced to produce this outcome. To achieve this field establishment, planting rates of 4-6 eyes per metre are recommended. This information has been disseminated to growers at field days, growers shed meetings and media articles. Demonstration and extension of this information to growers and machinery manufacturers must continue.

4.0 METHODS FOR CUTTING AND HANDLING HIGH QUALITY (MINIMUM DAMAGE) BILLETS

This section addresses Objective 2. This objective was seen as the most critical achievement of this project. If a method of mechanically producing high quality planting billets could not be developed, the project was to be concluded or project objectives significantly redefined.

4.1 Test methodology

The examination of interactions between the harvester, billet quality and planter performance commenced during the 1999 autumn planting in the Bundaberg region. Our previous work had focused primarily on the quality of billets produced from the harvester. Early in this project, we realised that the entire planting system, growing plant cane, cutting, handling, metering and placing in the soil, must be studied if reliable crop establishment is to be achieved.

We developed a protocol for quantifying the quality of planting billets, whether produced by hand cutting, wholestalk planter or mechanical cane harvester. This protocol specifies how the sample is collected, the sample volume and the methodology used to assess billet quality. We used the ISSCT Mechanical Harvester Testing Protocol (ISSCT 2000; Appendix 6) as a guide to determine the methodologies used in this project. However, these criteria were developed primarily for cane supplied to a sugar mill and, after trialling, we determined them to be too crude for planting billet assessment. The definition, by the ISSCT protocol, of a sound billet as '*Those sections of stalk longer than 100 mm with no splits (other than growth cracks) longer than 80 mm in length through one end. Small rind cracks, less than 40 mm long are not regarded as splits. No section of rind more than 400 mm^2 removed exposing the pith, no squashed ends with frequent rind cracks.*' was not appropriate for planting billets as this level of splits and rind damage may have significant effects on bud establishment. Previous billet observations had shown that commercial feedtrain rollers could produce square-shaped rind indentations that were less than 20 mm by 20 mm, yet significantly reduced the integrity of the billet. Our billet-quality assessment criteria used a modified version of the ISSCT protocol with the definitions of damage and mutilated billets remaining much the same, but the definition for sound billets being higher or more strict. We defined a sound planting billet as '*Those sections of stalk longer than 100 mm with no splits (other than growth cracks) that could exude juice when squeezed by hand. Growth cracks are not regarded as splits. No section of rind removal is allowed and frequently squashed ends not permitted.* While this definition may appear excessively severe, it is based in the quality of billet produced by a wholestalk planter using sound cane stalks. As can be seen in the billet-quality data presented later, most billets from a wholestalk planter are within these 'sound billet' category specifications.

We determined the billet quality produced by wholestalk planters, conventional cane harvesters and modified harvesters by taking a billet sample of at least three plastic rubbish bins in volume from either the planter hopper or the bulk cane field bin. The source of the billets was noted to determine if a reduction in billet quality could be quantified due to the transport and handling process. Care was taken to ensure all billets within the sample area were collected and a biased sample of long billets was not collected. Each bin of billets was selected from a different region of the hopper/bin and the billet samples were then sorted into length and damage categories and weighed. The sorting, weighing and recording process is time-consuming taking 1-2 hours. The quantification of billet quality is still somewhat subjective, hence all billet sorting was undertaken by Win Chappell and/or Brian Robotham to ensure consistency of assessment.

4.2 Machinery

4.2.1 Wholestalk planter

We quantified the quality of billets from several commercial wholestalk planters. We consider the wholestalk planter as the 'industry best' planter, as it can produce the highest quality billet cut, the least billet rind damage and the best along-the-row billet spacing. Commercial use of this machine is decreasing in popularity due to the high labour requirement and low work-rate, but it is still widely used by many growers for planting commercial sugarcane and used by most growers for planting clean seed material and new varieties obtained from Cane Productivity Services. We used the wholestalk planter was used as the industry standard against which all billet quality and spatial distribution of planters for the sugar industry were compared.

Figures 24 and 25 show the billet quality and length produced by two similar types of wholestalk planters cutting two sugarcane cultivars. Planter 1 has a target billet length of 300-350 mm, while planter 2 has a target billet length of 350-400 mm. This variation in billet length is a function of mechanical design (diameter) of the feed rollers; the wholestalk planter has a rotary-chop billeting system that uses two equal-sized drums. The drums have two blades per drum to cut the billets and rubber feed tubes (rubber hose) to ensure uniform flow of cane through the planter. The two cutting blades are spaced 180° apart and the drums are timed to ensure the blades intersect producing a high-quality cut of the billet.

Figures 24 and 25 show that billet length is very uniform and target length equals half the pitch circle diameter (PCD) of the drum and rubber feed tubes. Billet length cannot exceed the target billet length and the small number of shorter billets is the result of initial and final billets from the stalk. Billet length cannot be varied without changing the diameter of the drum, which is a major task, and it is a function of planter design not cane quality or how the planter is fed. Planter 1 has slightly small drums and cuts a 300-350 mm length billets compared to planter 2 with large diameter drums cutting 350-400 mm billets. It is important to note the percentage of billets within the target range is similar for both planters (planter 1 = 92%; planter 2 = 84%). The variation in billet quality (% sound, damaged and mutilated billets) is a function of cane cultivar, cane quality and machine set-up (knife sharpness and feed roller condition). Within the accuracy of the billet-quality criteria, these two results illustrate the narrow range of billet quality and length results to be expected with this type of planter.

Based on current knowledge, the 'ideal' future planter for the sugar industry must have the billet quality and spacing features of the wholestalk planter.

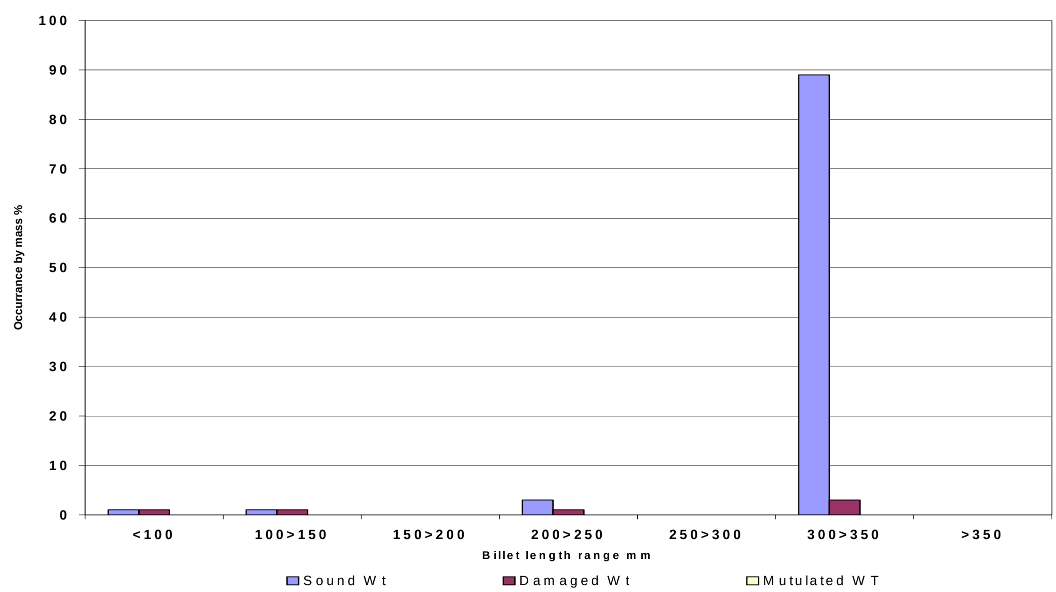

Figure 24 Billet quality and length of planted billets from wholestalk planter 1 planting Q124

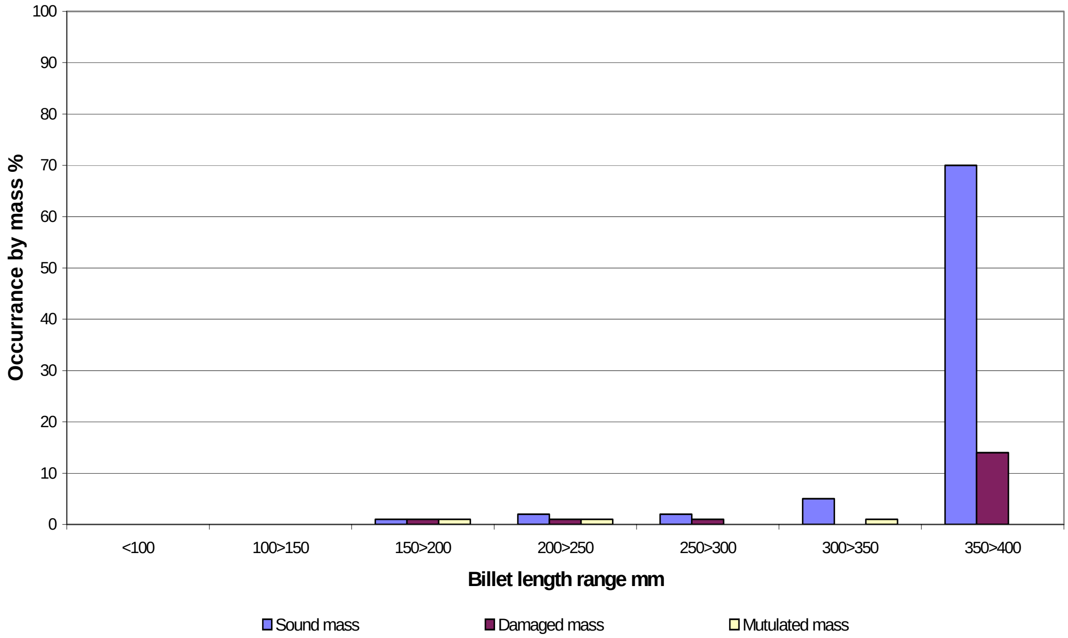

Figure 25 Billet quality and length of planted billets from wholestalk planter 2 planting Q141

4.2.2 Harvester-cut billets

The current commercial sugarcane harvester was designed to cut cane for supply to the mill at high pour rates (tonnes of cane per hour). Our discussions indicate that many growers, harvesting representatives and harvester designers believe that billet quality is not an important criterion for milling billets. The industry may penalise harvesting contractors supplying excessively long billets or high trash levels, but billet quality per se is not rated as an important criterion. Because of this desire to maximise feed through the harvester with little consideration of billet quality, several important harvester design features that influence billet quality have been compromised seriously.

The billet length and quality analysis for a standard commercial harvester cutting in erect cane is shown in Figure 26; this machine was used to cut billets for planting. The total percentage of sound billets is approximately 60% and billet length varies over a large range. The chopper system of this machine was set to cut ‘short’ (200-250 mm length range) billets. The most notable feature is the wide variation in billet length (7% in 150-200 mm, 40% in 200-250 mm, 35% in 250-300mm and 15% in 300-350 mm). The total percentage damaged and mutilated was also very high at 38%, by weight, of the total sample. Samples from different machines and with other cane cultivars commonly produced damaged and mutilated percentages as high as 70%.

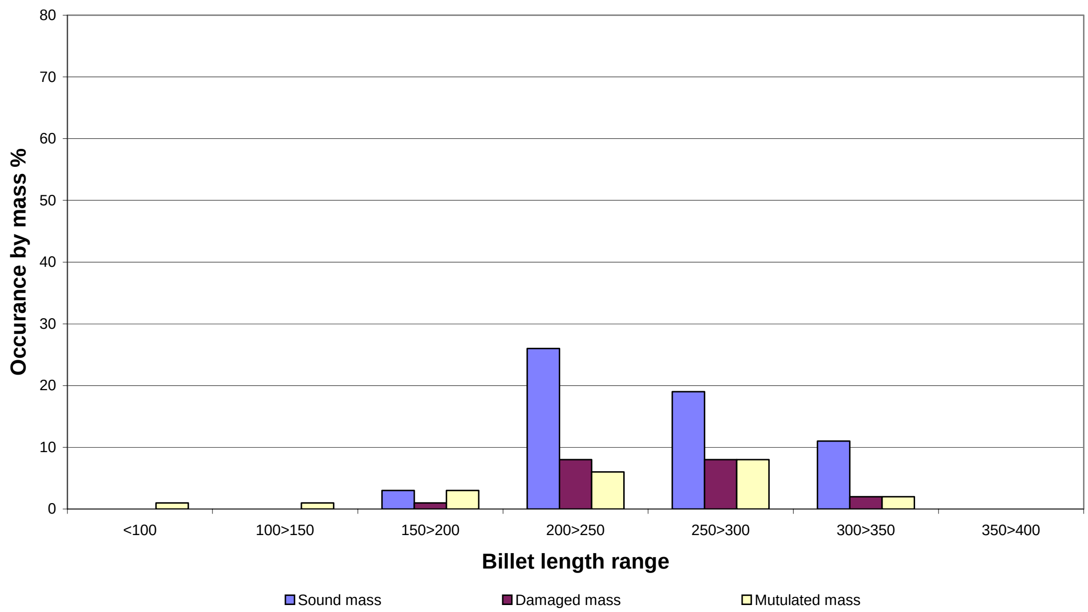

Figure 26 Billet quality and length of planting billets from a typical unmodified cane harvester operating in an erect and medium yielding crop

Comparing these results with those from the wholestalk planter clearly illustrates why many planted sugarcane billets often establish poorly in the field. An examination of the harvester specifications revealed the reason for the wide variation of billet length. Most harvesters initially had all feedtrain speeds match until an industry trial in the mid 1980s. This unreplicated trial showed that when harvesting burnt cane at low pour rates, operating several feedtrain rollers at different rotational speeds resulted in SRDC-funded project BSS188 'Improving the performance of chopper systems in harvesters. Unfortunately, most cane is now harvested green and instantaneous pour rates may exceed 200 t/h but the feedtrain roller speeds remain unmatched. Cane is fed erratically through the harvest feedtrain system and, hence, the erratically fed choppers cause the wide variation of billet lengths seen in Figure 26 Project BSS188 clearly quantified the negative effects of this practice on billet length, billet quality and suggested excessive harvester power consumption due to this mismatch.

These figures and the detailed visual billet examination enabled some of the damage sources to be identified. We suggest that variable billet length is caused solely by the mismatched feedtrain speeds, but billet damage is due to a combination of mismatched feedtrain speeds and aggressive steel rollers. Detailed examination of billets indicated significant damage that could be identified from the feedtrain/roller system. Indentations from the serrated roller slats caused significant rind damage on billets. Speed mismatch of feed-rollers results in eye damage and the wide variation in billet length.

The billet assessments also showed that sharp, thin basecutter blades are preferred to thick blades, but the basecutter only accounts for one cut per stick of cane. For a cane stalk of say 2 m in length, the basecutter will account for one cut, the topper one cut and the chopper will produce six cuts. Thus, if the quality of the billet cut is not satisfactory, chopper performance should be critically reviewed before basecutter performance. The type of cut produced by the basecutter is significantly different to that of the chopper and hence easily identifiable.

This assessment process was repeated using billets obtained from commercial and grower-modified machines. From these tests, we identified potential sources of billet damage within the mechanical harvester and transport system. However, other factors that also influence billet quality include crop cultivar, crop maturity, crop stature (erect or lodged), harvester type, harvester pour rate and operator technique. Analyses of billet samples from numerous harvesters have indicated the magnitude of interactions between many of these factors. It was therefore considered impractical to quantify all sources of billet damage. An achievable goal was to priorities the critical sources of billet damage, thus defining the limitations of current machines. Sources of damage in the harvesting and transport system were rated as:

- gathering or pick-up (Very Low with erect crops to High with badly lodged crops);
- basecutter (Medium);
- feedtrain/roller (High);
- chopper/thrower (Medium to High);
- elevator boot and elevating (Low); and
- transportation (Nil to Low).

Due to variations in results from machine to machine and crop to crop, we could not quantify accurately the various sources of billet damage in the harvest and transport system. In both this project and in BSS188, we were unable to identify increased billet damage from the unloading, transport and planter filling operations. Hence, these components were given low priority with respect to damage analysis.

4.2.3 Harvester modifications

To determine the efficacy of harvesters used to cut billets for planting, we took about 50 billet samples from a number of harvesters. These machines ranged from standard commercial machines to machines with various modifications. All standard machines displayed similar length and quality characteristics, but several machines showed significant improved billet length distributions. Figure 27 is an example of 'modified' harvester that was used primarily for cutting planting billets. Although billet damage levels were still excessive at greater than 50%, the billet length distribution was very narrow with about 70% of billets being 250-300 mm long. A detailed examination of this machine revealed that the previous owner had replaced several of the hydraulic motors in the feed train rollers to ensure rollers speeds were more closely matched.

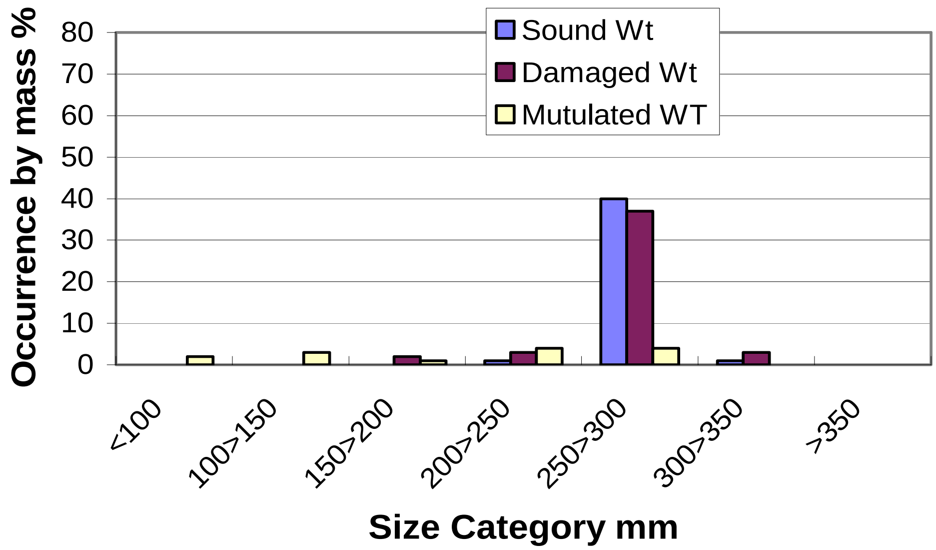

Figure 27 **Billet quality and length for planting billets from a grower-modified cane harvester**

After performing this large number of billet quality assessments, we found that we could quite accurately quantify the harvester without a physical examination of the machine. All unmodified or 'standard' harvesters produced a reasonably consistent variation in billet lengths. With limited experience, this 'billet-length signature' from an unmodified harvester with mismatched feedtrain rollers speeds could be identified easily. It is important to note that billet length uniformity/variability was influenced by roller speed variation, whereas billet quality was a function of roller type, roller aggression and harvester feeding system. Clearly, these areas of the harvester must be critically addressed if mechanical harvesters are to produce high-quality planting billets.

4.2.4 Rubber-coated feedtrain rollers and feedtrain optimisation

We field tested an innovative harvester modification, funded through an SRDC Innovator's Grant. The modification consisted of replacing all steel rollers in the harvester feedtrain with rubber-coated feed rollers.

As the roller system was identified as a high source of billet damage, rubber coating of harvester feed rollers is likely to minimise rind damage. The coating used on the rollers is a 95% natural rubber from Malaysia. Because of the manufacturing process, this product has very high wet-abrasion strength. This relatively soft, but tough, rubber ensures good wet grip and, hence, positive feed of the cane. The rollers were coated using a bonding process that must be performed at the supplier's factory. Only limited roller preparation was required prior to coating. Rollers must have all hard-faced ripple strips removed and then ground to a smooth finish with a hand-grinder. The direction of rotation must be specified on the rollers, as this determines how the joining splice is made to maximise coating life. The initial rollers had longitudinal grooves to assist feeding of the cane, but, as the rubber coating has sufficient 'softness' to ensure positive feed, the grooves were unnecessary and are no longer specified. The commercial steel rollers for harvesting cane for milling and the rubber-coated rollers for cutting planting billets are shown in Figure 28.

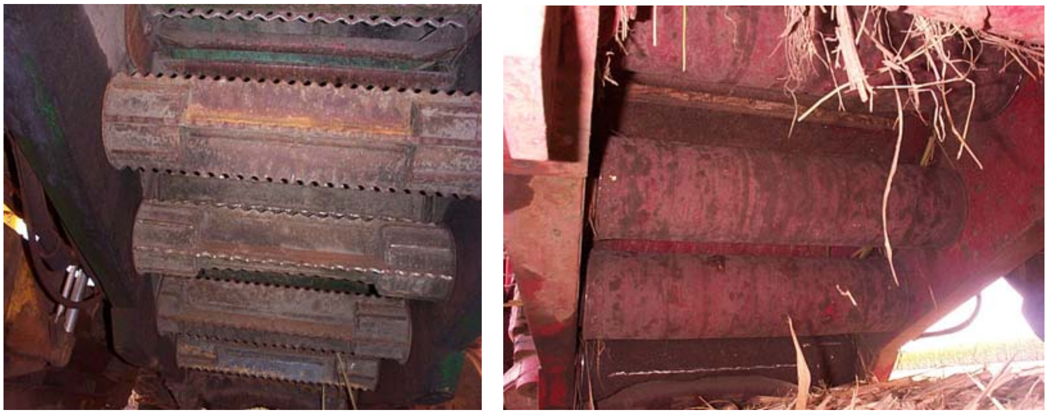

Figure 28 Feedtrain rollers: (left) commercial steel rollers; (right) modified rubber-coated rollers

Life expectancy of the rubber-coated will vary depending on soil type and the presence of obstructions, but, with care, throughputs in excess of 80 000 t of cane can be expected. Some sticks and stones were present in some areas harvested and limited abrasion damage occurred to the rubber coating on the lower feed rollers.

Roller speeds MUST be matched to ensure that all rollers have the same surface rotational speeds. Fitting rubber rollers with positive grip to feed the cane but with mismatched roller speeds will result in rollers 'slipping' against the flow of cane. As the rubber is softer than the commercial steel rollers, grooves are quickly worn in the rubber coating (Figure 29). Matching roller speeds prevents rubber wear and reduces the power required to convey the cane through the machine. The process requires adjusting roller speeds by speeding up the few slower rollers, rather than slowing down the faster rollers. This is best achieved by rekitting the smaller chopper motors so both are the same, eg 30 cubic inches, and rekitting the bottom roller motors to the same sized cartridge as the upper roller motors. The chopper motor size change will marginally slow the choppers, but this is not a major issue when cutting billets for plants. Unfortunately, the feedtrain optimisation process cannot be prescriptive, as variation in the hydraulic systems between harvester models is significant. Harvesters must be examined and modified on a machine-by-machine basis.

Figure 29 Grooves in a rubber-coated roller caused speed mismatch

A harvester with optimised (or matched) feedtrain rollers and rubber-coated rollers was field tested. The machine produced a high percentage of high quality, sound billets due to rubber-coated rollers, and a very uniform billet length due to the optimised roller speeds. More than 80% of billets were sound and 88% of billets were 250-300 mm long (Figure 30).

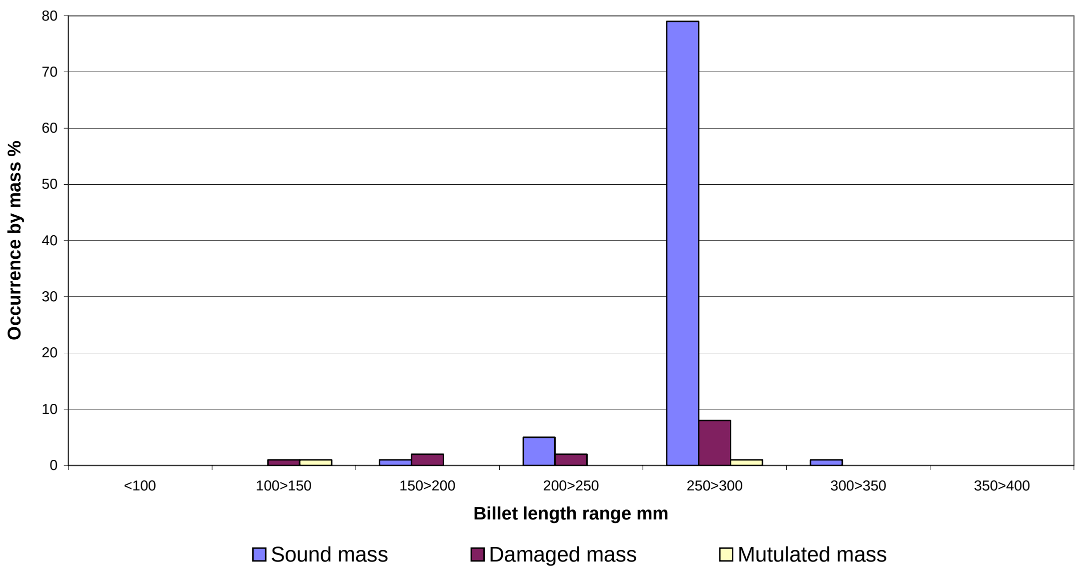

Figure 30 Billet quality and length of planting billets from harvester with rubber-coated feed-rollers and uniform feed-roller speed

Several harvesters modified with rubber-coated rollers are being used for both plant cutting and commercial harvesting. While this is not the preferred option, many growers/planting contractors cannot afford to have a harvester solely for cutting planting material. For smaller operators this is an acceptable option.

4.3 Crop characteristics

Machine modifications are only part of the solution, as factors such as crop cultivar and crop presentation, erect or lodged, have a significant effect on billet quality. Figure 31 shows the same modified harvester as used to cut billets in Figure 30, but harvesting a less erect and different cultivar of sugarcane. The total percentage of billets in the 250-300 mm length range remained similar (87% in Figure 30 and 78% in Figure 31), but the percentage damaged billets increased from 8% to 20%. Clearly, growing the crop as a plant material source is an important criterion. Growers must be aware that if a crop is allowed to lodge or lodges due to weather conditions, billet quality from that cane will be significantly lowered.

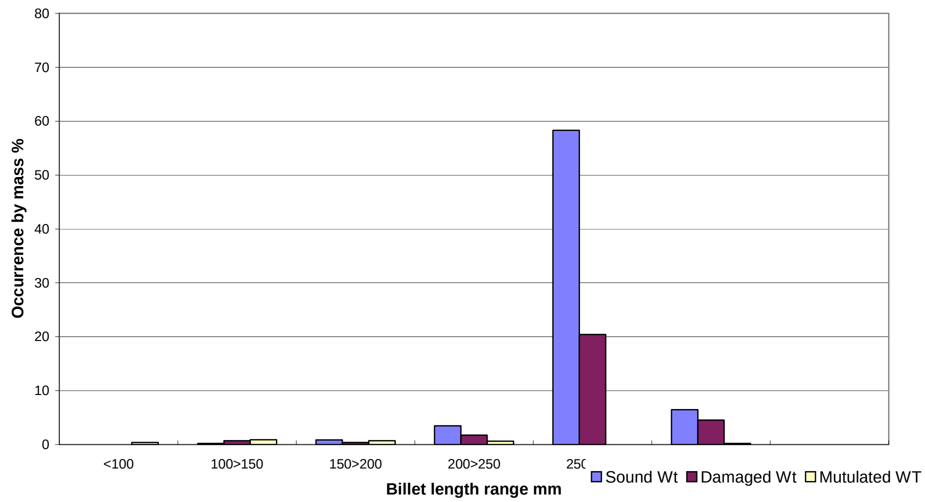

Figure 31 Billet quality and length from a modified harvester cutting lodged sugarcane

4.4 Testing the system

In 1999-2000, the Bundaberg CPPB decided to supply to growers propagation material of new cane cultivars as billeted cane as well as wholestalk cane. After discussions with us, they undertook all cutting with a harvester fitted with rubber-coated feed rollers and with feed roller speeds optimised to BSES specifications. The cane cut by this machine was erect and carefully grown for planting material. This was an ideal test to determine the quality of billets that could be produced under controlled conditions. Both quality and length uniformity were very high with in excess of 80% of billet classed as sound and about 90% of billets 250-300 mm long (Figure 32).

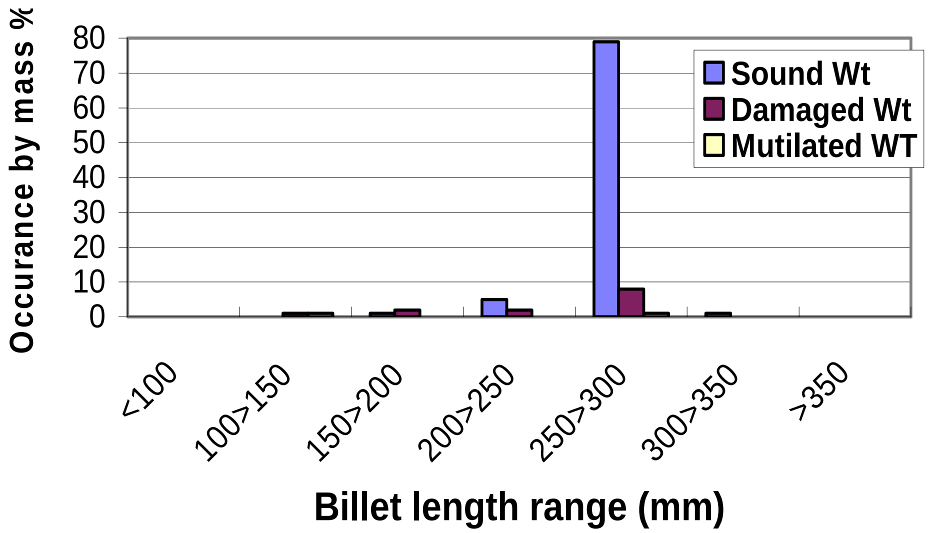

Figure 32 **Billet quality and length from a modified 'plant cutting' harvester cutting Q150**

4.5 Implementing the system

The system is now proven and several publications (see section on Publications) have been produced to encourage adoption. Presentations to grower groups have also been undertaken.

A written presentation on how to improve billet planting was prepared for NSW Information Meetings (Harwood, Broadwater and Condong on 20-21 March 2000) and an accompanying visual presentation was given at all meetings. A series of five shed meetings was conducted at Ingham, Tully (2), Innisfail and Meringa. These meeting were dedicated to improvements to billet planting. Attendance ranged from satisfactory to standing room only at the Meringa meeting. Based on the information presented at these meetings, it is estimated that 25-50 harvesters have been modified to BSES specifications. Contact with owners of these machines and growers with cane planted from the machines have indicated satisfaction with the resulting billet quality. This positive feedback has been a very pleasing component of this project.

This result and responses from owners of modified harvesters clearly indicates that:

- sound research was undertaken to determine methods of cutting high-quality planting billets;
- growers are now aware of billet quality issues with planting billets;
- this information has been successfully disseminated to growers and harvesting contractors;
- the expectation/demand by growers that only high-quality planting billet be used for planting have been created.

A requirement of this project was to publish and release recommendations for cutting high quality billets using modified commercial harvesters. Initially, internally published

Information Sheet titled ‘Update – Rubber-Coated Rollers’ was produced in August 1999. This was followed by a similar publication titled ‘Rubber-Coated rollers – Second update’ in January 2001. Both information sheets (see Appendices) proved to be very popular and the document templates were emailed to most BSES extension officers (Queensland and New South Wales) so they could produce their own sheets as required.

The brochure detailing recommendations for the production of high-quality planting billets was produced (Appendix 1). This brochure titled ‘Getting better planting billets by modifying your harvester’, describes why modifications are required to current harvesters, modifications required and the desired sequence of undertaking these modifications. The brochure was reviewed by BSES engineering and extension staff. A second publication Appendix 2), titled ‘Guide to sugarcane planting’, was produced detailing the field and plant requirements of planting billet production.

5.0 PROTECTING BILLETS FROM ROTTING DISEASES AND DESICCATION BY PROTECTIVE COATINGS AND STIMULATING RAPID GERMINATION

This section addresses Objective 3.

5.1 Introduction

Planting sugarcane is the most expensive operation on a sugarcane farm. Germination failures can severely affect the economic performance of a farm with high costs of replanting, loss of production from a shorter growing season for the replanted crop or low production and premature plough-out of crops with partial germination failures. The most common preventable cause of germination failure is pineapple disease (Girard and Rott 2000), caused by the fungus, *Ceratocystis paradoxa* (Dade) Moreau. The disease is favoured by poor-quality planting material, especially with splits or pipes, and adverse environment factors, such as low temperature, excess soil water or dry soil. Anything that reduces the rate of germination will favour the disease.

Pineapple disease is partially controlled by the use of fungicides that are applied to billets by sprays or dips. The fungicides are generally effective, but cannot control the fungus if there is damage to the billets or the billets have natural pipes in the centre. Pipes are formed in some cultivars as a response to certain environmental conditions, such as rapid growth after an extended dry period. Pineapple disease has been associated with failure of billet planting when the harvester has damaged billets.

Mercurial fungicides have been used for many years to control pineapple disease and they have an additional advantage in that they stimulate more rapid germination (Steindl 1970). Stimulation of germination gives an added advantage to the germinating billet above the direct control of the fungus. Unfortunately, the mercury in the fungicides presents operator and environmental concerns. Approximately 60% of fields in Australia are planted using the mercurial fungicide Shirtan®.

The aim of this section of the project was to investigate alternative methods to stimulate germination and protect setts from pineapple disease. We tested combinations of hot-water treatments, hot-water sprays, fungicides, coatings and surface abrasion to determine their efficacy in increasing germination.

5.2 General methods

To identify treatments that were worthy of further testing, small-scale glasshouse tests were conducted. The treatments were applied to one-eye setts and the setts were then planted in vermiculite in shallow trays. The trays were placed in the glasshouse and kept moist. The number of developing shoots was counted at 1-3-day intervals.

Our experience with the glasshouse experiments has been that they give a reasonable indication of a treatments effect, but the results can be misleading because of the small number of buds tested and the variation in germination between buds collected from different stalks and from different parts of the stalk. For these reasons, treatments that showed promise in the glasshouse were further tested in small-plot field trials.

In these trials, the treatments were applied to one- or two-eye setts and the setts were planted into the field by hand and covered with soil. The number of developing shoots was counted at 2-3-day intervals.

To test for pineapple disease control, the treated setts were sprayed with a spore suspension of *C. paradoxa* after they were placed in the ground but before they were covered with soil. The *C. paradoxa* was grown for 2-3 weeks on potato-dextrose agar and the spores were harvested by scraping the surface of the agar with a scalpel and washing the spores into a container. Control plots were sprayed with water.

5.3 Hot-water dips and long sprays

5.3.1 Glasshouse trial

One-eye setts of Q120 were dipped in water at temperatures from 24-60°C for 5 or 10 minutes and planted in a glasshouse. There were two replicates of 10 buds for each treatment.

Temperatures of 52-58°C gave significant stimulation of germination when treated for 5 min (Figure 33). Temperatures of 50-58°C stimulated germination with a 10-minute dip (Figure 34).

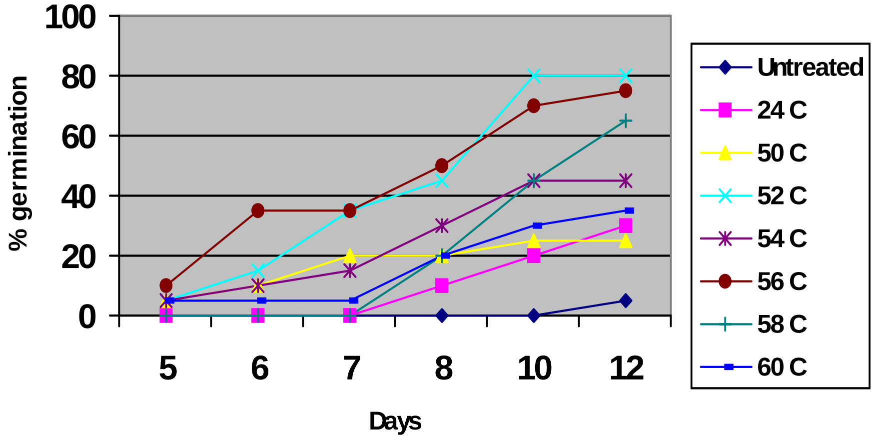

Figure 33 **Germination of cane dipped in water of different temperatures for 5 minutes**

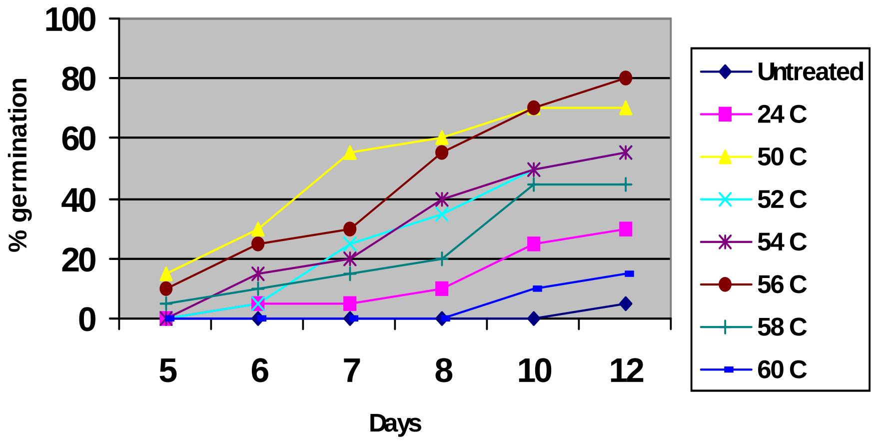

Figure 34 **Germination of cane dipped in water of different temperatures for 10 minutes**

5.3.2 Field trials

Two trials were conducted to determine whether hot-water treatment improved the field control of pineapple disease.

Trial 1 was planted in the field at Tully with the following treatments:

1. Control – no treatment
2. Control + pineapple disease (PD)
3. 52^{o}C 10 min
4. 52^{o}C 10 min + PD
5. 52^{o}C 10 min + propiconazole 50 μg/L (Cane Sett Treatment®, CST) + PD

Trial 2 was planted in the field at Woodford with the following treatments:

1. Control – no treatment
2. Control + pineapple disease (PD)
3. 52°C 10 min + propiconazole 50 μg/L (Cane Sett Treatment®, CST)
4. 52°C 10 min + propiconazole 50 μg/L + PD
5. 56°C 15 min spray + propiconazole 50 μg/L
6. 56°C 15 min spray + propiconazole 50 μg/L + PD
7. 586°C 15 min spray + propiconazole 50 μg/L
8. 58°C 15 min spray + propiconazole 50 μg/L + PD
9. 60°C 15 min spray + propiconazole 50 μg/L
10. 60°C 15 min spray + propiconazole 50 μg/L + PD

Trial 1 was planted with Q120 and had four replicates in a randomised complete-block design. Trial 2 was planted with Q124 and had five replicates in a randomised complete-block design of factors.

In Trial 1, short hot-water treatment (52°C for 10 min) significantly improved the speed of germination, total germination and pineapple disease control (Figure 35). The germination in Trial 2 was variable due to waterlogging in some plots and no differences between treatments were significant. We present the results because they show some trends that can be compared with Trial 1. In Trial 2, there was an improvement in early germination from hot water dip (52°C for 10 min) alone, but the effect did not result in more shoots at the end of the experiment (Figure 36).

A hot-water dip combined with fungicide improved the control of pineapple disease compared to fungicide alone. Hot-water sprays alone did not improve germination (Figure 37), but hot-water spray plus fungicide was better than fungicide alone at controlling pineapple disease (Figure 38).

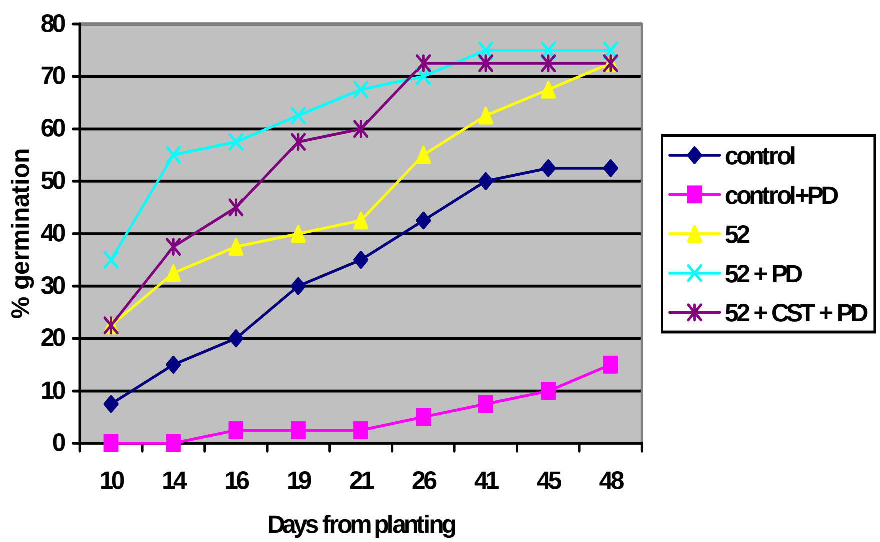

Figure 35 **Effect of hot-water dip on germination and pineapple disease control in Trial 1**

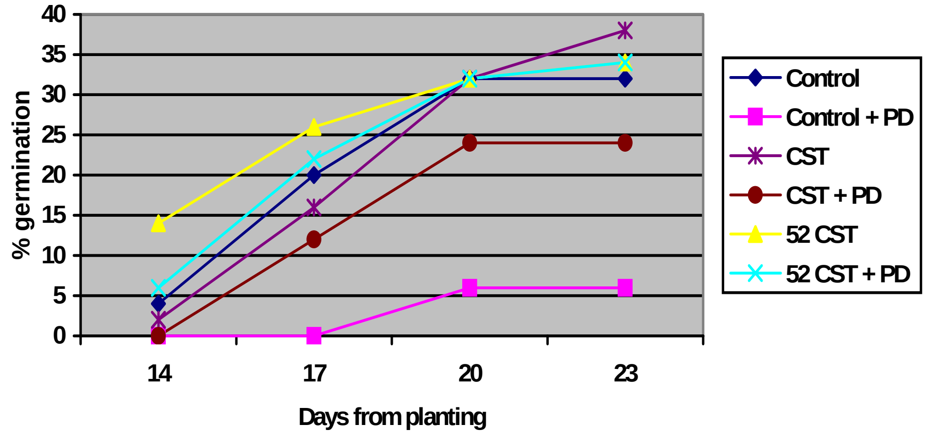

Figure 36 **Effect of hot-water dip on germination and pineapple disease control in Trial 2**

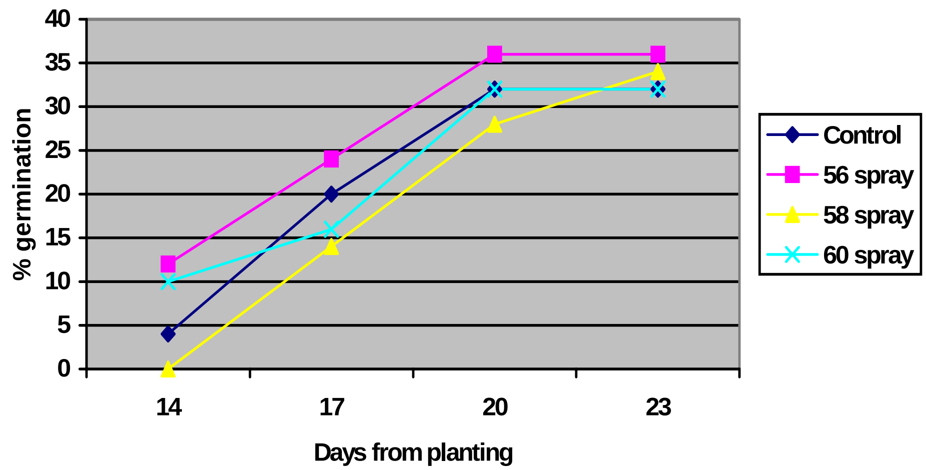

Figure 37 **Effect of long hot-water sprays on germination in Trial 2**

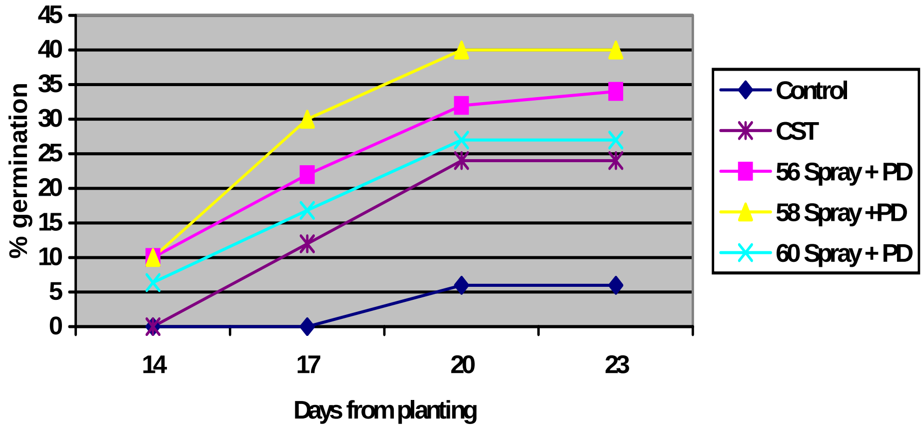

Figure 38 **Effect of long hot-water sprays on pineapple disease control in Trial 2 (spray treatments were also treated with CST)**

5.4 Short hot-water sprays

A glasshouse experiment was conducted to determine whether it was possible to use short high-temperature sprays of water to give the same response as the hot-water dip. The treatments tested were:

1. Control – untreated
2. 52°C for 10 min dip
3. 60°C spray 30 s
4. 60°C spray 60 s
5. 65°C spray 30 s
6. 65°C spray 60 s
7. 70°C spray 30 s
8. 70°C spray 60 s
9. 75°C spray 30 s
10. 75°C spray 60 s

There were two replicates of each treatment in a randomised complete-block design and each replicate consisted of 20 one-eye setts of Q124.

There was a significant negative correlation between increasing temperature of hot-water sprays and germination for the 30 s spray and an obvious, but non-significant, effect for the 60 s spray (Figure 39). Only the 75°C sprays were worse than the control and the 60 and 65°C sprays at both 30 and 60 s were equal or better than the 52°C dip for 10 minutes. The 60 and 65°C sprays were considered worthy of further testing.

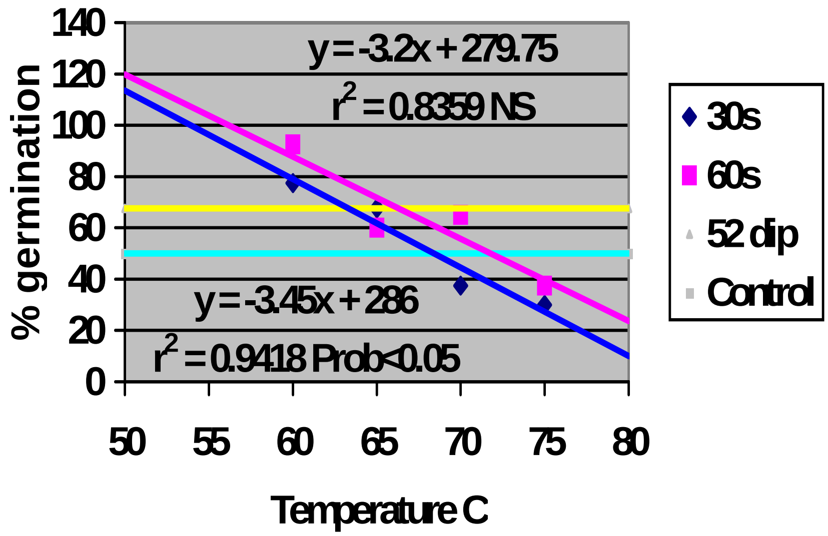

Figure 39 **Effect of hot-water sprays on germination**

5.4.1 Field trials

The hot-water sprays that showed promise in the glasshouse trial were tested under field conditions with and without pineapple disease.

In Trial 1, the fungicide propiconazole (Cane Sett Treatment®) was applied to all hot-water dip and spray treatments. There were five replicates with 20 one-eye setts of Q120 planted in each replicate in a randomised complete-block design. The trial was planted in the field at Tully in September 1999. The treatments were:

1. Control – no treatment
2. 52°C 10 min dip
3. 60°C spray 30 s
4. 60°C spray 60 s
5. 65°C spray 10 min
6. Control + pineapple disease (PD)
7. 52°C 10 min dip + PD
8. 60°C spray 30 s + PD
9. 60°C spray 60 s + PD
10. 65°C spray 10 min + PD

In Trial 2, the fungicide flusilazole (Cane Strike®, CS) was applied to all hot-water dip and spray treatments. There were five replicates with 20 one-eye setts of Q124 planted in each replicate in a randomised complete-block design. The trial was planted in the field at Woodford in August 1999. The treatments were:

1. Control – no treatment
2. 52°C 10 min dip
3. 60°C spray 60 s
4. 65°C spray 10 min
5. Control + pineapple disease (PD)

6. 52°C 10 min dip + PD
7. 60°C spray 60 s + PD
8. 65°C spray 10 min + PD

In Trial 1, the 52°C 10 min dip and 65°C spray of 10 min both gave a significant stimulation of germination (Figure 40) but neither of the short sprays at 60°C stimulated germination. All hot water dip and spray treatments significantly improved germination compared to the CST alone in the presence of pineapple disease (Figure 41).

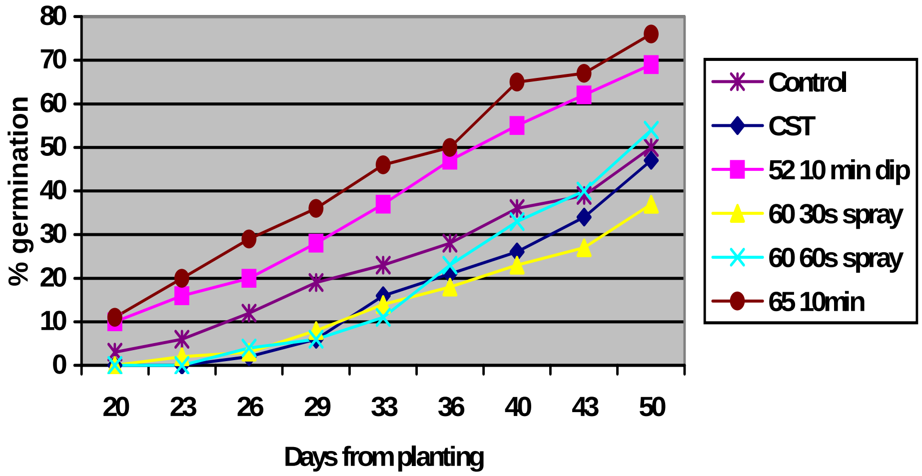

Figure 40 Effect of hot-water sprays on germination in Trial 1 (spray treatments also treated with CST

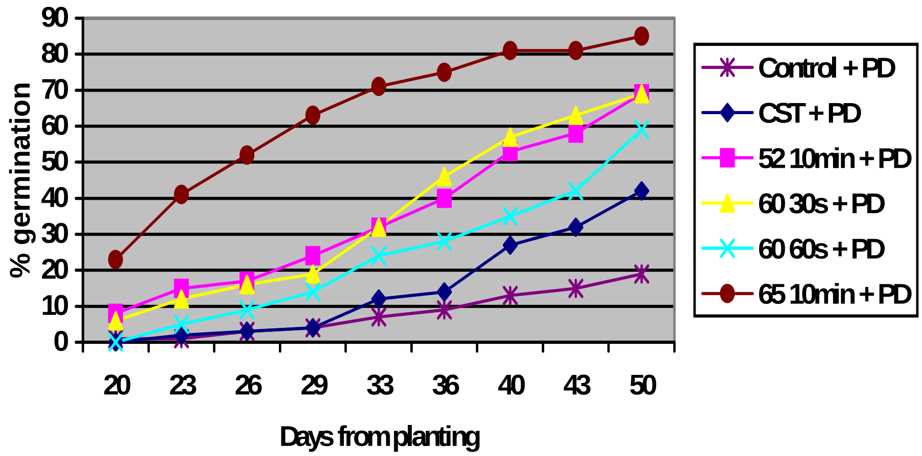

Figure 41 Effect of hot-water sprays on germination and pineapple disease control in Trial 1 (hot-water dips and sprays also treated with CST)

In Trial 2, the 52°C 10 min dip and 65°C 10 min spray significantly stimulated early germination, but there were no significant differences at the end of the trial (Figure 42). In the presence of pineapple disease, the 52°C 10 min dip and 65°C 10 min spray again significantly stimulated early germination but the final germination was not significantly better than the Cane Strike® alone (Figure 43).

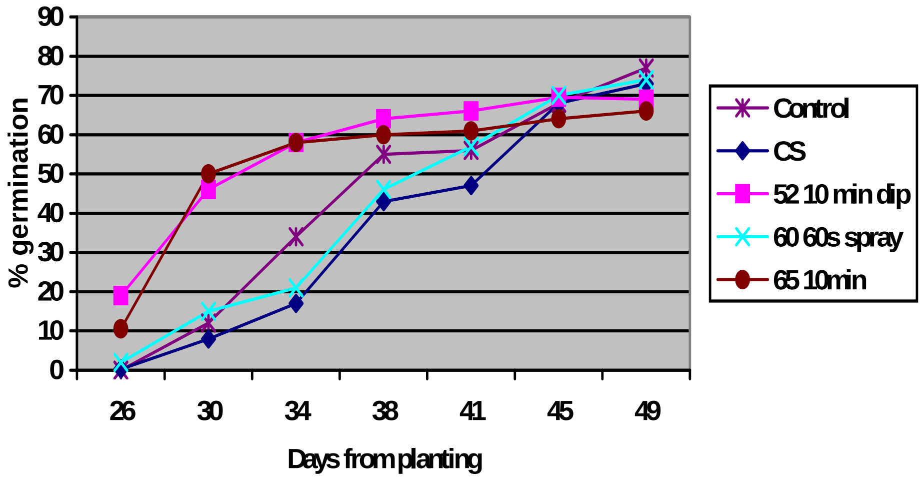

Figure 42 **Effect of hot-water sprays on germination in Trial 2 (spray treatments also treated with CS)**

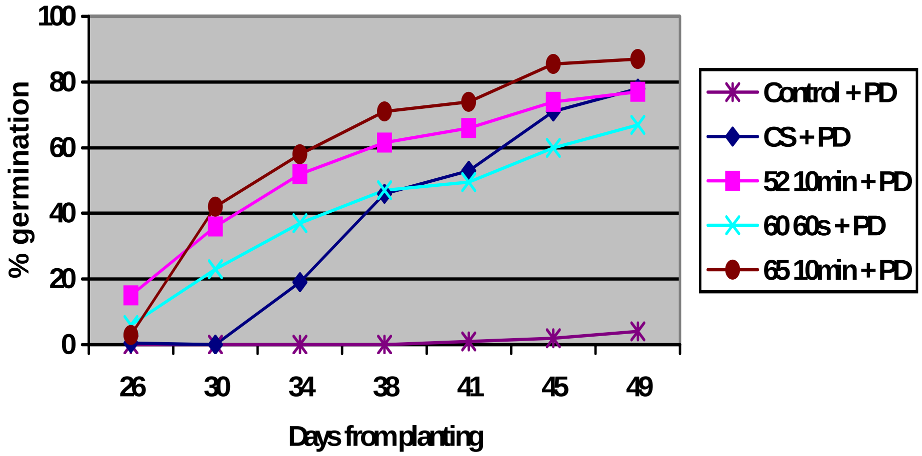

Figure 43 **Effect of hot-water sprays on germination and pineapple disease control in Trial 2 (hot-water dips and sprays also treated with CS)**

5.5 Polymer coatings

Two trials tested the germination of one-eye setts coated in polymer film (Vitafilm® vegetable wrap). Setts were coated by initially heat-sealing in the wrap and then heat-shrinking the wrap to give a tight fit.

In Trial 1, one-eye setts of Q120 were used and were planted in a glasshouse. There were two replicates of 10 buds for each treatment. The treatments were:

1. Control – no treatment
2. Control + pineapple disease (PD)
3. Propiconazole 50 μg/L (Cane Sett Treatment®, CST)
4. CST + PD
5. 52^{o}C 10 min + CST
6. 52^{o}C 10 min + CST + PD
7. Poly wrap (PW)
8. PW + PD
9. PW + CST + PD
10. PW + 52^{o}C + PD
11. PW + 52^{o}C + CST + PD

In Trial 2, the one-eyed setts of Q120 were planted into the field at Tully with four replicates in a randomised complete-block design. The treatments were:

1. Control – no treatment
2. Control + PD
3. 52^{o}C 10 min
4. 52^{o}C 10 min + PD
5. PW
6. PW + PD
7. PW + 52^{o}C 10 min
8. PW + 52^{o}C 10 min + PD

In Trial 1, the poly wrap was significantly worse than the control (Figure 44) and did not improve control of pineapple disease when used alone or in combination with fungicide (Figure 45). The hot-water dip significantly improved the germination and pineapple disease control of the poly wrap treatments (Figure 45). The poly wrap delayed germination.

In Trial 2, the poly wrap did not effect germination (Figure 46) and did not improve the control of pineapple disease when combined with fungicide (Figure 47).

Because the poly wrap was deleterious to germination and did not improve pineapple disease control, trials were discontinued with this type of product.

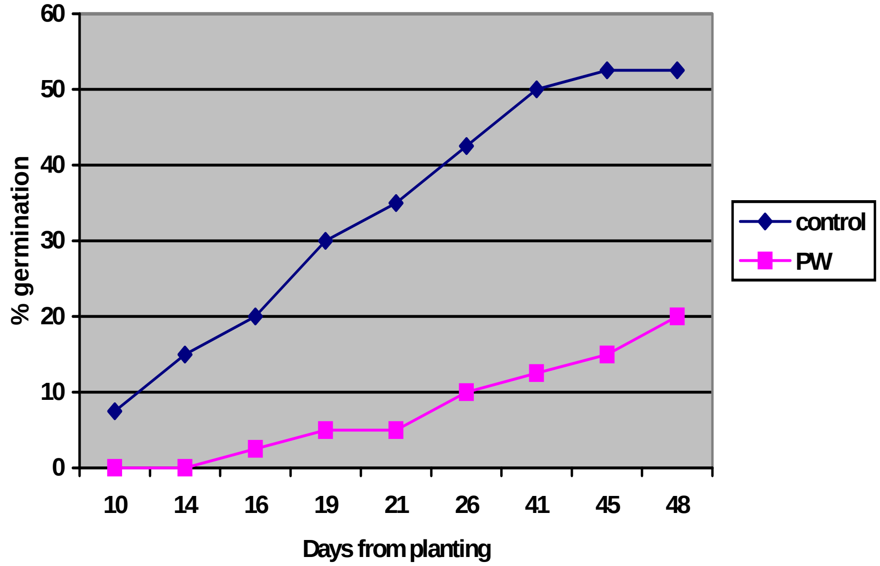

Figure 44 Effect of poly wrap on germination in Trial 1

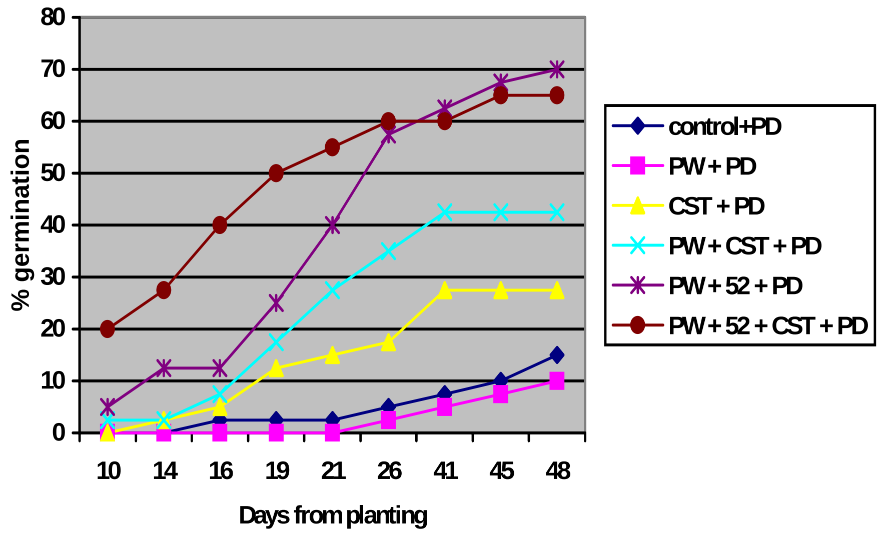

Figure 45 Effect of poly wrap on germination and pineapple disease control in Trial 1

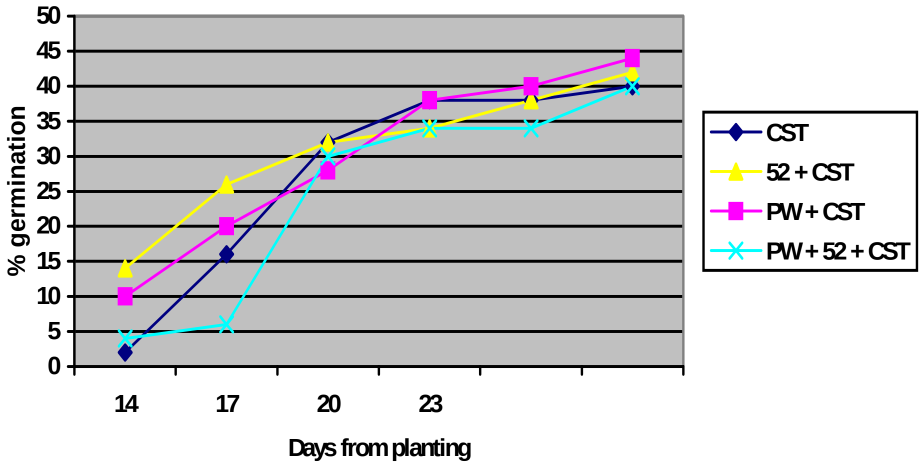

Figure 46 Effect of poly wrap on germination in Trial 2

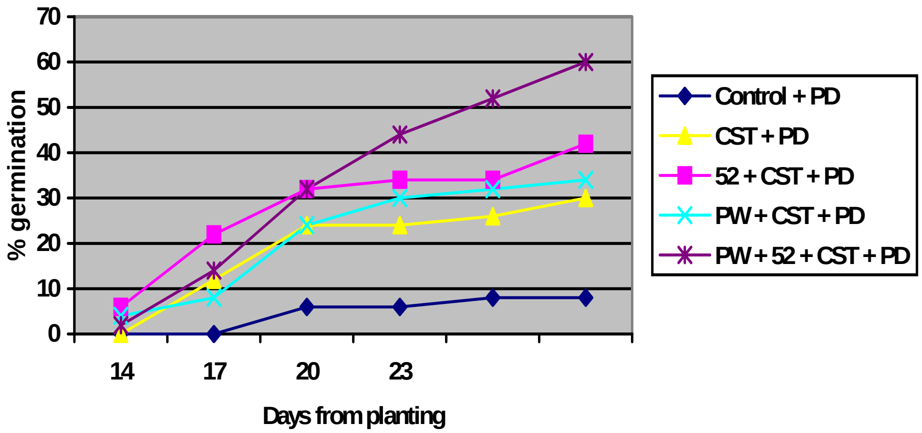

Figure 47 Effect of poly wrap on germination and pineapple disease control in Trial 2

5.6 Film coatings

Discussions with Prof. Jeff Hoy, Louisiana State University, who is conducting research on billet planting, suggested that anti-transpirants that coat the billets with a protective film can improve germination. The anti-transpirant Envy® is registered in Australia. A spray adjuvant, Bond®, has been promoted to improve pineapple disease control when added to the fungicide spray. These two chemicals were tested for their effect on germination with and without pineapple disease in two trials.

In Trial 1, the setts were dipped in Cane Sett Treatment®, allowed to dry, and then dipped in Envy® (10% solution). The Bond® (1 % solution) was mixed with the Cane Sett Treatment ®.

In Trial 2, the setts were dipped in Cane Strike® or Shirtan®, allowed to dry and then dipped in Envy® (10% solution). The Bond® (1 % solution) was mixed with the Cane Strike® or Shirtan®.

Trial 1 was planted at Tully with Q120 and had four replicates in a randomised complete-block design. Trial 2 was planted at Woodford with Q124 and had five replicates in a randomised complete-block design.

In trial 1, neither Envy® nor Bond® had a significant effect on germination in the absence (Figure 48) or presence of pineapple disease (Figure 49).

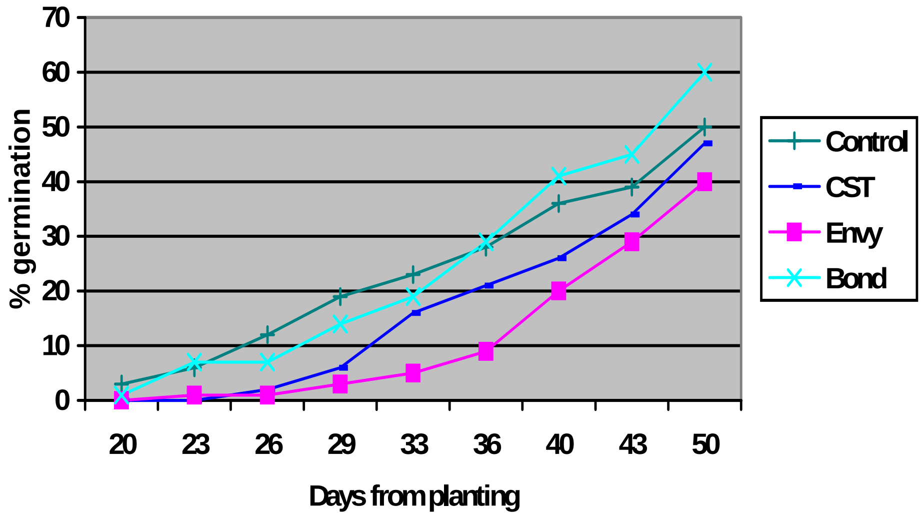

Figure 48 **Effect of film coatings on germination in Trial 1 (also treated with CST)**

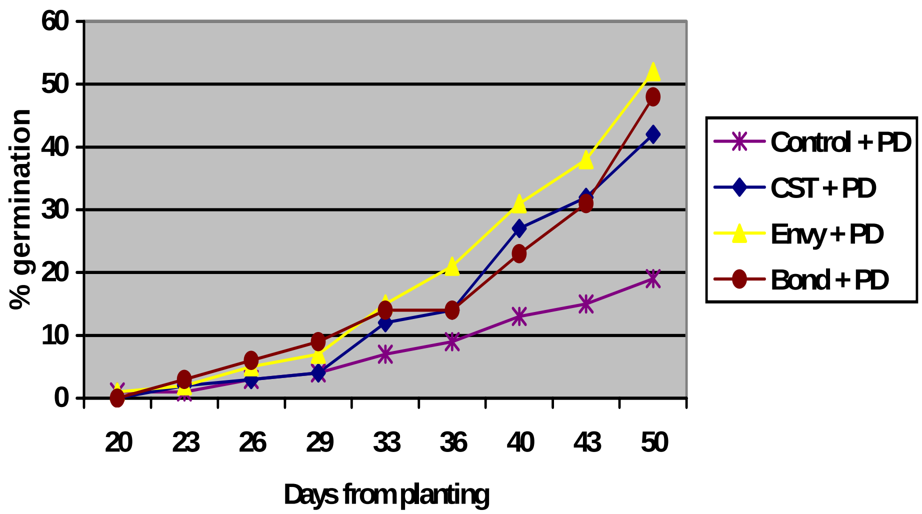

Figure 49 **Effect of film coatings on germination and pineapple disease control in Trial 1 (also treated with CST)**

In contrast to Trial 1, the stimulation of early germination by Shirtan® in Trial 2 was significant when applied alone and in combination with Bond® in comparison to Cane Strike® alone or in combination with Bond® (Figure 50). Only the Shirtan® plus Bond® was significantly better at the end of the trial compared to the untreated control. The stimulation of early germination was also significant when Shirtan® was combined with Envy (Figure 51). The Bond® and the Envy® alone did not improve germination.

The Cane Strike® and Shirtan® gave excellent control of pineapple disease but the Bond® (Figure 52) and the Envy® (Figure 53) did not add to the control obtained with the fungicides alone.

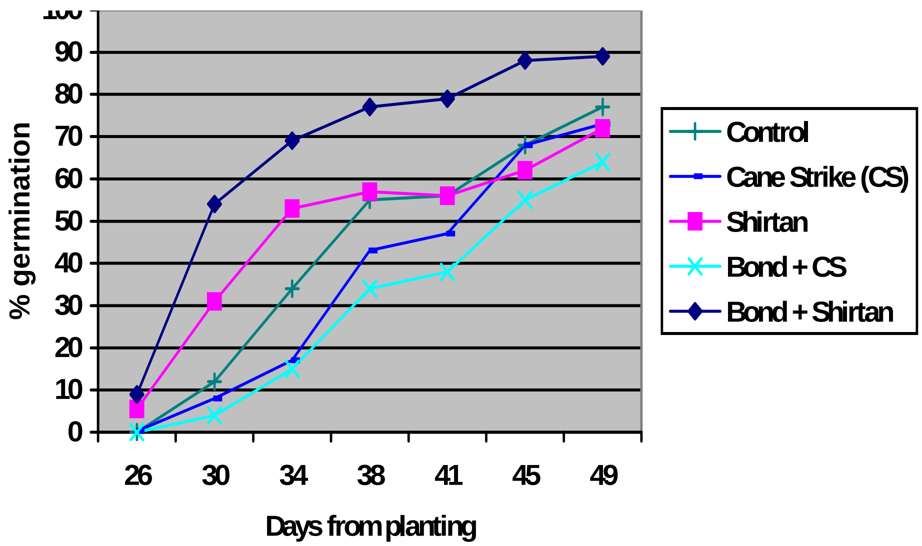

Figure 50 Effect of Bond and fungicides on germination in Trial 2

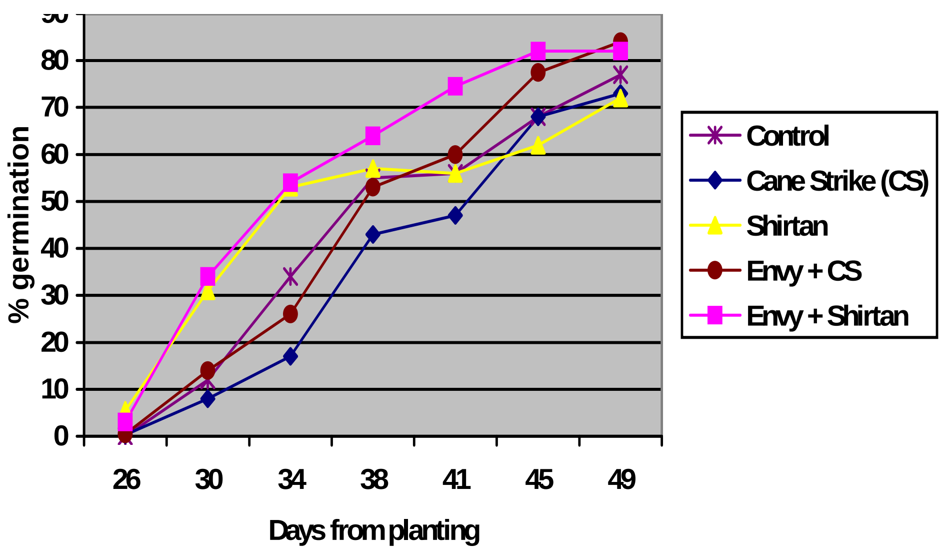

Figure 51 Effect of Envy and fungicides on germination in Trial 2

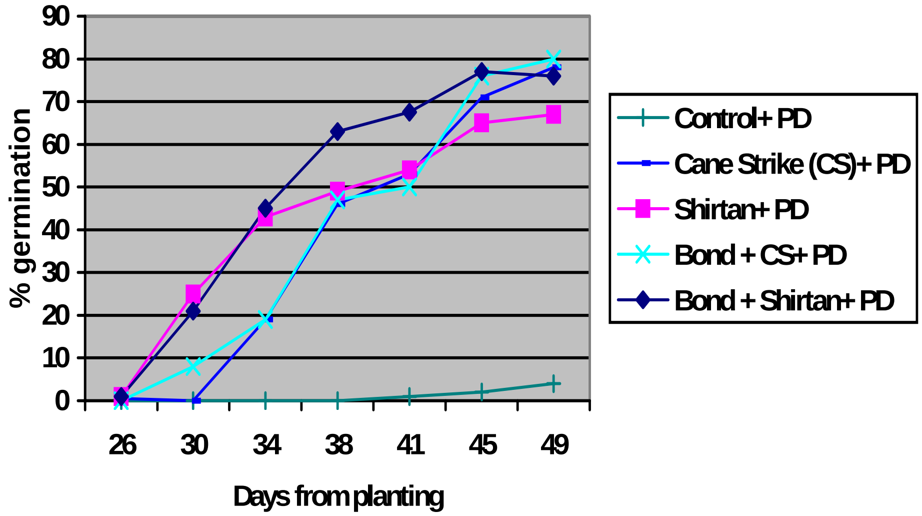

Figure 52 **Effect of Bond and fungicides on germination and pineapple disease control in Trial 2**

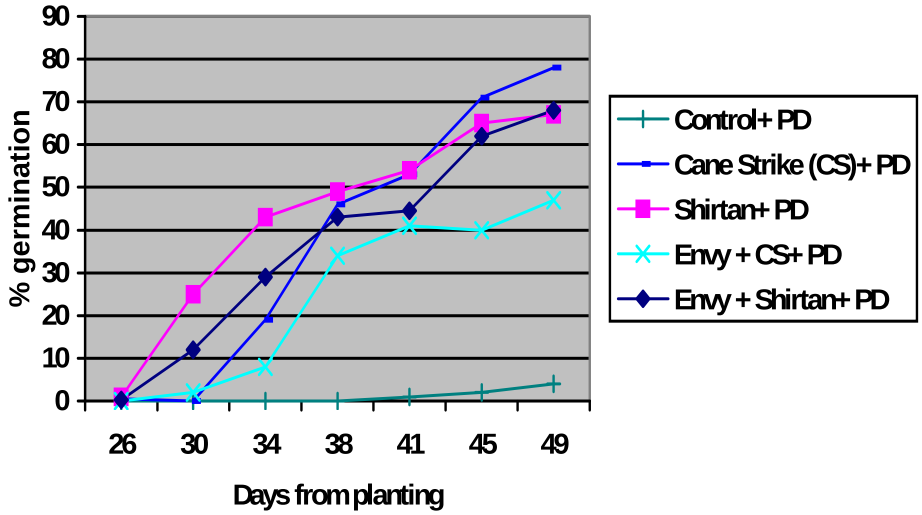

Figure 53 **Effect of Envy and fungicides on germination and pineapple disease control in Trial 2**

5.7 Fungicides

Methoxymercuric chloride (Shirtan®) is used in 60% of fields planted in Queensland. Heavy metals have been reported to stimulate germination in other plants. Recently, mancozeb (Dithane®), a fungicide that contains the metals manganese and zinc has been reported to control the organisms associated with yield decline (Magarey and Bull 2003).

In trial 1, we compared a band application of two rates of mancozeb sprayed over the setts to Cane Sett Treatment® and Shirtan®. The trial was planted at Tully with Q120 and had four replicates in a randomised complete-block design.

In trial 2, Shirtan® was compared to Cane Strike®, two rates of mancozeb sprayed over the setts and a combination treatment of Cane Strike® and copper oxychloride (Cu oxy). The trial was planted at Woodford with Q124 and had five replicates in a randomised complete-block design.

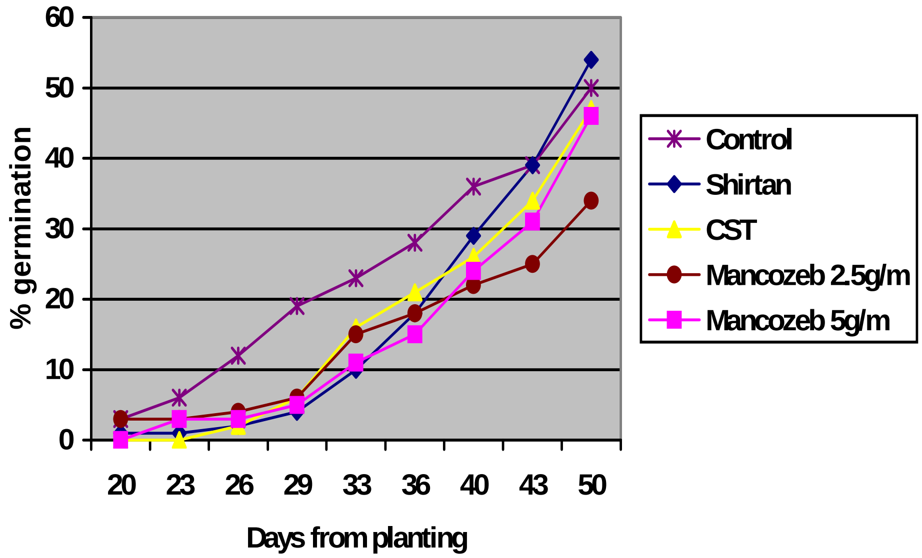

Figure 54 Effect of fungicides on germination in Trial 1

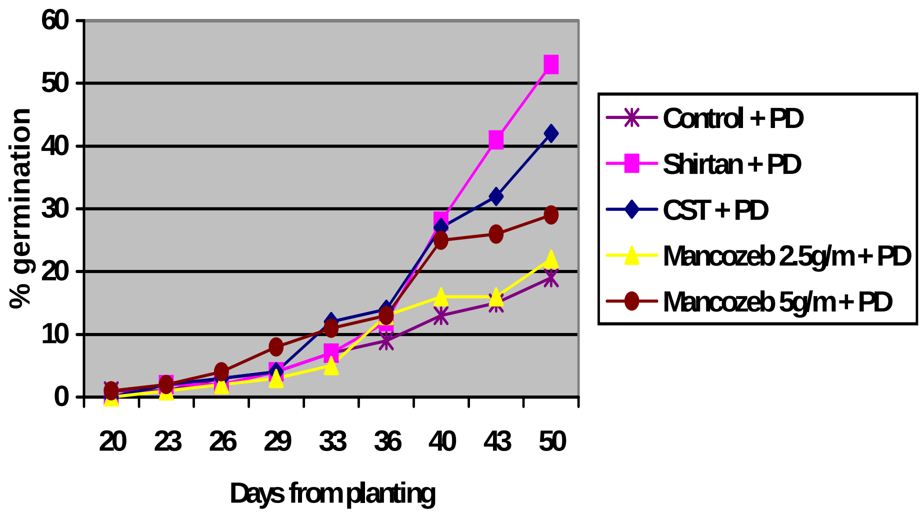

Figure 55 Effect of fungicides on germination and pineapple disease control in Trial 1

In trial 1, none of the fungicides including Shirtan® improved or stimulated germination in the absence of pineapple disease (Figure 54). Shirtan® gave the best control of pineapple disease followed by Cane Sett Treatment®, but there was no evidence of stimulation of early germination (Figure 55). Mancozeb at both 2.5 and 5 g/m of row were not significantly better than the untreated control although the mancozeb 5 g/m of row was close to significant.

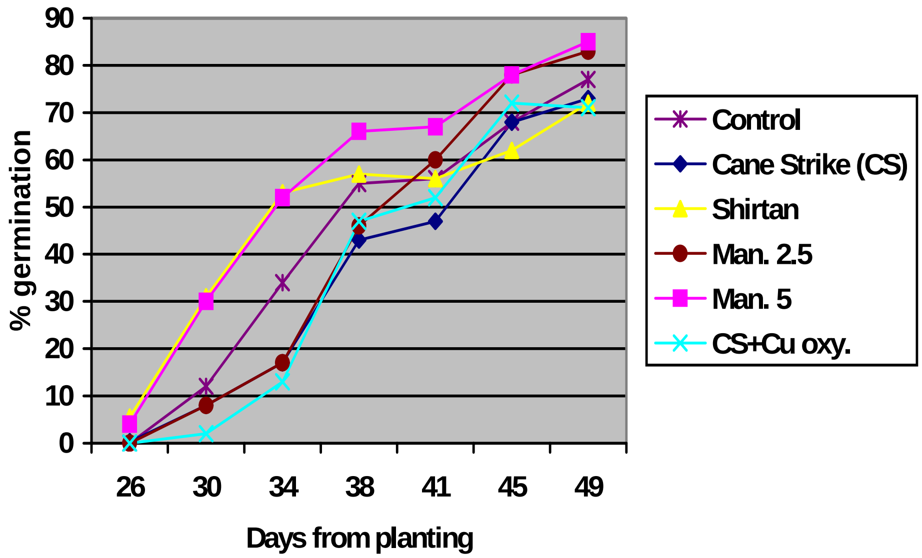

Figure 56 Effect of fungicides on germination in Trial 2

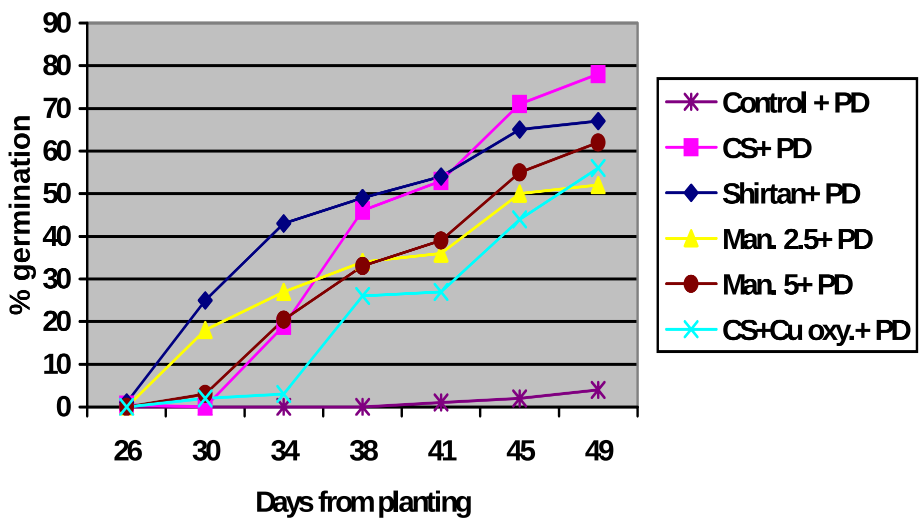

Figure 57 Effect of fungicides on germination and pineapple disease control in Trial 2

In trial 2, Shirtan® and mancozeb 5 g/m row significantly stimulated early germination compared to Cane Strike® but not the untreated control (Figure 56). Copper oxychloride did not stimulate germination. All of the fungicides gave excellent control of pineapple disease and there was no significant difference between the fungicides (Figure 57).

5.8 Summary of temperature, fungicide and wrapping treatments

Hot-water treatment as either a dip or a spray consistently stimulated germination, but these treatments are unlikely to be practical for commercial use. They may be important in research where rapid and reliable germination is required. Attempts were made to find a short hot-water spray treatment that could be adapted to commercial situations, but this was not successful.

Poly wrapping of setts was detrimental to germination and this approach was abandoned. Anti-transpirants that form a film over leaves were investigated but they did not add to the control compared to fungicides alone. The spray adjuvant, Bond®, which has been promoted by some chemical dealers, did not improve the control of pineapple disease compared to fungicide alone.

The fungicides Shirtan®, Cane Sett Treatment® and Cane Strike® consistently controlled pineapple disease. Shirtan® stimulated early germination in the Woodford trial, but not the Tully trial. The higher soil temperatures in Tully may have masked the response. Mancozeb at 5g/m of row controlled pineapple disease and stimulated early growth at Woodford. It also gave some control of the disease at Tully. This treatment should be tested further because it may also give benefits in partial control of yield decline.

Although none of the treatments tested so far appears to be both practical and able to improve germination, compared to the currently available fungicides, this area should continue to receive attention because it is unlikely that the mercury fungicides will not be available indefinitely.

5.9 The effect of mild abrasion on eye germination/establishment

While undertaking the billet spacing trials, early germination and establishment were often observed in the machine-cut billets compared to the hand-cut, ‘perfect’ billets. As great care was taken with the handling of the hand-cut billets, this response appeared to conflict with our initial hypothesis that minimum or no billet damage would give maximum billet germination and viability.

Based on these field observations, a single replicated field trial was undertaken in an attempt to quantify if surface abrasion or agitation of the billet during machine harvesting could be the cause of the improved early germination and establishment. High-quality hand-cut billets were produced from seed-quality Q124 sugarcane. Half the billets were treated to simulate harvesting treatment, comprising 2 minutes agitation in a commercial concrete mixer. The billets were treated in small batches of about 12 billets to ensure that the billets moved freely in the mixer bowl and did not form a static clump.

The mild surface abrasion of the planted billets appeared to stimulate the billet in someway and the initial rate of germination of the treated billets was greater. Although the final germinations for both treatments are similar, the abrasion treatment produced a higher initial rate of shoot germination (Figure 58). The earlier established plants produce larger plants, had better root development and, hence, were better able to survive unfavourable field conditions. This field effect warranted additional testing and the controlled environment of a glasshouse were considered the ideal trial site.

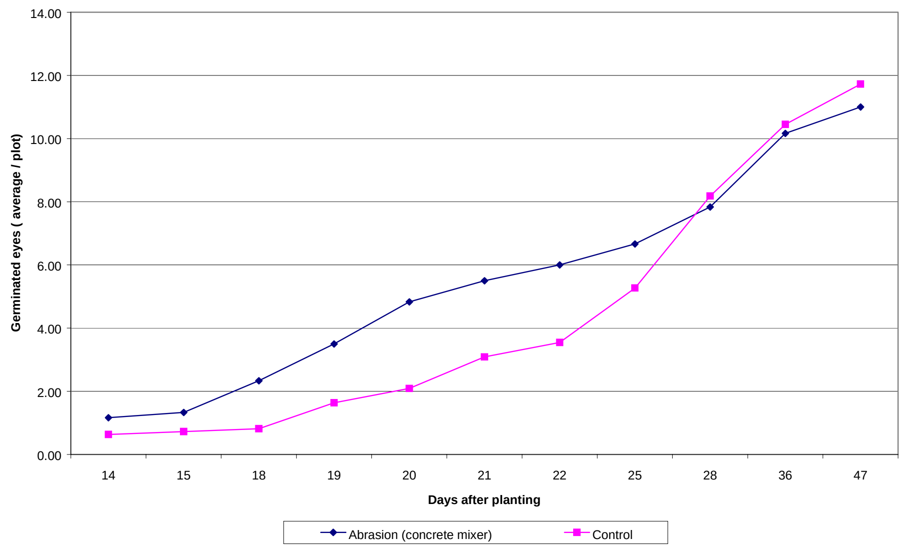

Figure 58 Effect of mild abrasion of sugarcane germination/establishment under field conditions

A series of three glasshouse trials to further quantify the effect of abrasion as a stimulant for germination was undertaken. The trials examined how a simulated abrasion treatment (2 minutes in a concrete mixer) affects:

- high-quality hand-cut billets;
- billets from a wholestick planter;
- billets from a commercial sugarcane harvester.

Trials were undertaken using cane cultivars Q151 (planted 11 November 2000), Q155 (planted 21 February 2001) and Q151 (planted 6 April 2001). Fresh billets were collected from a commercial harvester and at that time a number of cane stalks were collected from the same field. A portion of the wholestalk cane was then feed through a wholestalk planter and the billets collected. These billets are referred to as wholestalk billets. The remaining cane was hand cut to produce high-quality cuts.

The three billet samples were then subjected to the following treatments:

- surface abrasion by agitation in a concrete mixer for 2 minutes;
- wiped with acetone to remove surface wax;
- untreated (control).

The acetone treatment was suggested by a BSES agronomist as germination responses from this treatment (wax removal and/or alcohol stimulation) had previously been reported. This was not considered a commercial billet treatment option, but was included as an addition treatment for comparison of the abrasion treatment. In the last trial (April 2001), the concrete-mixer abrasion treatment was replaced with an aggressive brushing using a stiff bristle, nylon brush. All trials were conducted in soil-filled trays and four replicates planted. A glasshouse at BSES Bundaberg was used for all trials. A similar procedure was used for all trials and, hence, details of the November are only given. After the appropriate treatments were undertaken, billets were placed in the trays, covered with a uniform depth of soil and placed in the glasshouse. Trials were regularly observed and shoot counts commenced after the first shoots appeared. This was usually after about 9 days and shoot counts conducted daily. The trials were continued for about 40 days or until increases in primary shoot numbers ceased.

The harvester-cut untreated billets in the February 2001 trial (Figure 59) showed a similar effect to that observed in the field. The billets produced by the harvester showed a greater rate of germination and establishment when compared to the wholestalk and hand-cut treatments. As was expected, the wholestalk and hand-cut treatments had similar establishment rates. Final establishment rates were 91% for harvester-cut billets, 80% for hand-cut billets and 75% for wholestalk billets. The average establishment for all billet types was 82%.

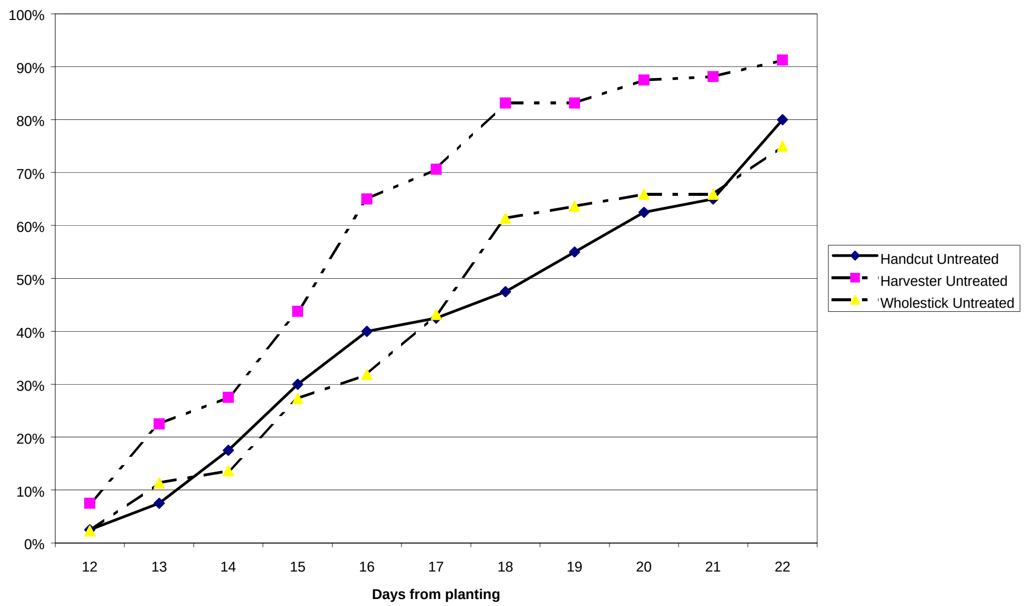

Figure 59 Establishment of control treatments with different billet sources

Figure 59 does not show the complete story, as time of emergence is not given appropriate weighting. This means a plant that emerged on day 21 is given the same ranking as a plant that emerged on day 12 or day 13. Early emerged plants will have greater root and stalk development. An alternate presentation of data as plant-days on the horizontal axis would display both the time since emergence and the number of plants emerged. However the results, summarised in Figures 60 and 61, showed no establishment response from either of the three billet types to the abrasion or the acetone treatments. Although only the data from the February 2001 trial are shown, similar results were obtained from the all trials.

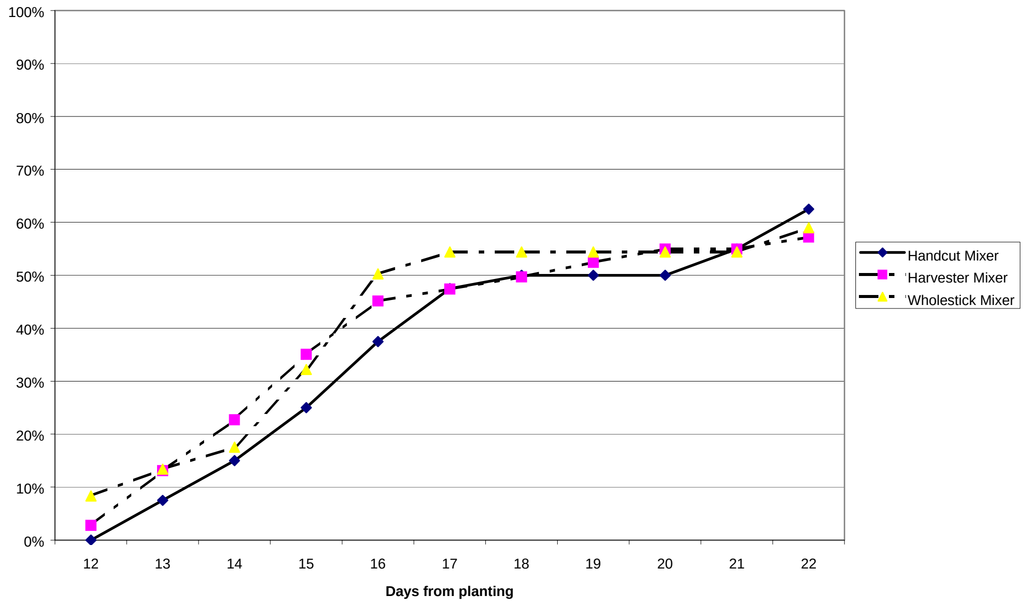

Figure 60 Establishment response to abrasion treatment (concrete mixer)

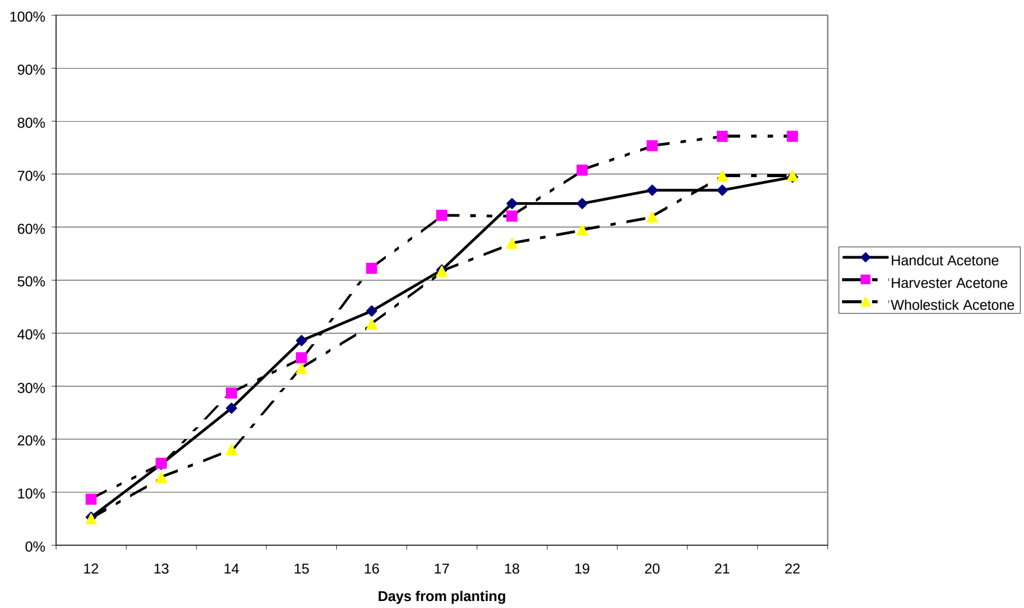

Figure 61 Establishment response to acetone treatment

Suggested reasons for a lack of establishment response to the abrasion and other treatments are:

1. billet abrasion is not the causal agent or the sole causal agent;
2. the amount of abrasion induced by the concrete mixer was too mild to induce the desired effect. If the amount of abrasion used in the was excessive, a reduction in emergence should have been evident; or
3. incorrect or inappropriate trial methodology.

While we do not have sufficient evidence to prove which of the above three options is correct, we favour option 1 of billet abrasion not being a sole causal agent. The trial methodology for the abrasion/billet trials is quite simple and it is proposed to conduct additional field trials duplicating the glasshouse trials.

6.0 PROTOTYPE EQUIPMENT FOR THE PRECISION PLANTING OF HIGH-QUALITY BILLETS

This section addresses objective 4.

6.1 Review of alternative equipment

A literature review was prepared by Barry Croft (Croft 2000) and has been published as BSES report (see Publications arising from this project). The discussions with ‘parties in the materials handling industry’ were not undertaken, as the billet-coating component of this project was abandoned.

6.2 Planter specifications

Exhaustive discussions with various parties within the sugar industry and other agricultural sections initially identified two billet linearization mechanisms for research interest.

6.2.1 Defining the criteria

Design and development of improved billet metering system commenced with a patent search conducted on methods of singulating rod-like objects. Commercial equipment is available to align very uniform items, such as screws for automated assembly of many consumer items such as whitegoods. A patent search was conducted at the Australian Patents Office in Brisbane, with help from their staff. Using their facilities both Australian and world-wide patent searches could be undertaken, but the patents from individual countries could not be searched. While this searching methodology did revealed many mechanisms or concepts of interest, none was directly applicable to the metering of seeds, billets or similar items. This patent review was considered a necessary step in the design process as utilisation of a developed concept would be a desired outcome.

A meeting to determine design criteria was held at BSES Bundaberg on 19 August 1999. This meeting was attended by representatives of sugarcane growers, sugarcane machinery manufacturer (P&H Rural Pty Ltd, now known as Unibar Engineering Pty Ltd) and SRDC. Based on the outcome of this meeting and other findings, the concepts for initial study were reduced to a minimum number (maximum of three or four) and bench testing undertaken. Based on the results of the bench testing, the concept or concepts with the best potential to satisfy the design criteria would be further developed. At this meeting the following criteria were decided as desirable for an improved billet planter that will supply billets at a uniform rate, with acceptable levels of 'misses' or 'multiples':

- All planting setts are double eyed, of highest quality and free of trash within limits of a best practice 'modified' harvester.
- Sett length be in the 250-350 mm range.
- Billet singulation be high. The metering system should be biased against billet misses or gaps. The occurrence of double or multiple billets should be limited.
- Planter will use the double-disc opener, hence have minimum soil disturbance, accurate sett placement and ideal sett/soil contact.
- Billet metering accuracy will not be compromised by a large uncontrolled 'drop' to ground.
- Planter will use presswheels with appropriate soil firming pressures.

Assuming perfect billet singulation and the abovementioned billet length ranges, then:

- If the spacing between planted setts is 50 mm, there are 2.5-3.3 setts per row metre with 5.0-6.6 eyes per metre;
- If the spacing between planted setts is 100 mm, there are 2.2-2.8 setts per row metre with 4.4-5.6 eyes per metre.

We want to establish 3-4 primary shoots/stools per metre of row. Planting rate factor of safety (to allow for unviable eyes, mortality due insects, deficiencies with billet placement, etc) varies from 2.2 to 1.1.

Unfortunately, the current billet planter has evolved to enable quite high operating groundspeeds. At high groundspeeds, billet metering and soil placement are severely compromised. Hence, an allowable planting speed of 5 km/h (1.38 m/s) and a field efficiency of 70% were assumed. This would produce a daily workrate of 6.0 ha per 8-hour day.

Alternate establishment rates will influence planting rate, such that:

- 3 stools/m and 80 % establishment (3.75 eyes/m 1.8 setts/m 2.5 setts/s)
- 3 stools/m and 70 % establishment (4.3 eyes/m 2.15 setts/m 3.0 setts/s)
- 3 stools/m and 60 % establishment (5 eyes/m 2.5 setts/m 3.5 setts/s)

BSES trials of commercially planted cane using current billet planters produced rates of 9-10 setts/m or about 15 eyes/m. This equates to a planting rate of about 15 t/ha, which is four times our proposed planting rate. At a planting groundspeed of 8 km/h, current billet planters must meter about 20 setts/second and these setts will be conveyed with no spatial accuracy.

Planting Rate at 1.5 m rows: assume a billet/sett weigh 200-250 g
2.8 setts/m = 4.2 t/ha
2.2 setts/m = 3.3 t/ha

Planting Rate at 1.85 m rows: assume a billet/sett weigh 200-250 g
2.8 setts/m = 10 t/ha
2.2 setts/m = 8.1 t/ha.

6.3 Testing the concepts

Two systems of billet linearization were chosen for construction and bench testing.

Rotary singulation. Several growers were aware of a billet-alignment system developed by a CSR engineer in the early 1980s. The device was intended to achieve higher packing densities of commercially cut sugarcane in rail bins. Unfortunately, very little detailed information could be obtained. Allegedly, a full-sized version of the system had been trialled and, according to the growers, had successfully aligned billets to achieve the desired densities. Why this development was not used commercially could not be determined. Evidence of this or other appropriate developments was not found during the patent search.

Based on the verbal description given by the growers, a prototype rig was manufactured. The system comprised two counter-rotating discs with surface-mounted agitated bars. The discs were approximately 600 mm in diameter and driven by two hydraulic motors, connected in the series. Four radial agitator bars of 25 mm by 25 mm angle iron were attached to the disc surface. Various parameters such as speed of rotation and billet feed rate were altered to determine efficacy of singulation, sensitivity to physical dimension of the billet and potential for damage to the billet during the singulation operation.

Rotations of 30-120 rpm were trialled with the unit and no linearisation of the billets could be measured. Possible reasons for the failure of this device to linearise billets are:

- Diameter of rotating discs was too small;
- Angle between discs was too great or too small;
- Agitation of the disc (type of agitator bars used) was either too aggressive or not sufficiently aggressive. Should the system require additional agitation to achieve linerisation, billet and eye damage would be expected to be significant.

An attempt to contact the developing engineer was unsuccessful so additional testing of this prototype was abandoned.

Singulation using vibration. This used an inclined slope with applied vibration to align billets prior to metering. Once aligned, billets could be metered easily using a slat conveyor or rotary-type metering system. This work was based on limited trials conducted during cane-cleaning research undertaken by a commercial firm. After the trials were abandoned, parts of the vibrating chute were acquired by BSES for further testing. The optimum mode of vibration, in terms of magnitude, frequency and direction (X, Y or Z planes), required for billet linearisation has not been determined. Vibration is used to align screws, fasteners and other items that vary dimensionally between length and width. These items can broadly be classed as similar to billets, as they are long, yet uniform in cross-section.

Video footage of the billet pick-up (or lack of billet pick-up) by the current elevating slat conveyor systems clearly shows that random alignment of the billets was often the reason billets were not selected by the passing slat of the conveyor. The use of uniform length billets should enhance the performance of a vibrating mechanism to align the billets.

The vibration based system to align the billets showed the most potential and a Brisbane based vibration consultancy firm was engaged to assist with the initial design. Vipac Engineers & Scientists Ltd was recommended after discussions with engineering staff from the University of Queensland. Our commission to Vipac was: *to provide expertise in the area of vibration to facilitate BSES to investigate the use of vibration for billet orientation.*

After initial discussions and task clarification, a full-day workshop was held a BSES Indooroopilly. The workshop was attended by two project research staff and two engineers from Vipac. Research conducted by Norris (pers. comm.) with grain seed indicated the areas of critical design to be examined. While engineers from Vipac were determining optimum vibration frequencies and amplitudes, basic concepts to be used with a vibrating billet aligner were tested.

6.3.1 Billet alignment

A batch-type billet aligner has been trailed and although performance is acceptable, a continuous process is preferred to a batch process. Two hypotheses critical to the operation of billet alignment were tested experimentally.

Hypothesis 1: *Is billet orientation and placement a critical variable for billet metering?*

Packing/metering techniques with grain seed and commercial products appear to support this hypothesis, but testing was required for further development in sugarcane. A CNH Austoft billet planter with a slatted, rubber belt and a hydraulic drive was used in the tests. The planter was operated with the billet pick-up section of the hopper either full of billets or with minimum fill (near empty but with full coverage of billets); Robotham and Poulsen (1996) have documented the corresponding increase in billet metering feed rate when the depth or 'head' of billets on the metering conveyor is increased. They recommended that the depth of billets remain constant or a near to constant as possible to ensure uniform metering of billets. These two tests examined the feeding of randomly orientated billets to an elevating slat feeding system. A video camera recorded the number of billets on each slat. The video tape was later replayed a slow speed and billet data (number of billets per metering slat) obtained.

Figures 62 and 63 show that, while 3 billets per slat is the most frequent occurring metering rate, increasing the depth of billets greatly increases the frequency of 4, 5 and 6 billet per conveyor slat. Output of the mass flow elevating slat billet meter has a linear relationship to the depth of billets covering the elevating conveyor. However, can billet alignment/linerisation further improve billet metering uniformity?

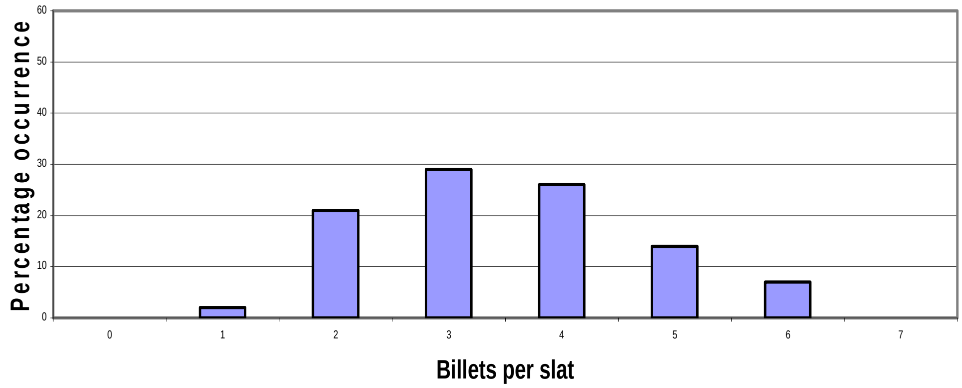

Figure 62 Distribution of billets per slat with feed hopper full

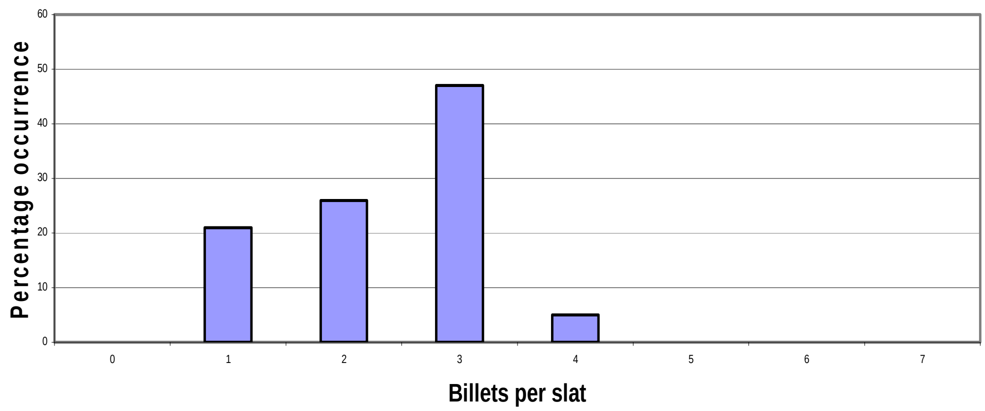

Figure 63 Distribution of billets per slat with minimum fill in feed hopper

The rubber belt metering conveyor had two rows of slats attached, with the slat position offset by half the slat spacing (Figure 64). A wooden magazine box was constructed to enable linear feeding of one row of slats. Aligned billets were hand packed into the magazine and the planter elevator operated under simulated planting conditions. The number of billets per slat was again recorded using a video camera. As little attempt was made to optimise the test-rig feed system from the magazine to the belt slats, billet pick up and segregation was not optimised, but was satisfactory for trialling purposes. The number of slats either without a billet or with two or greater billets would be reduced by improving the design of this region.

Figure 64 Rubber belt elevating conveyor showing two rows of offset slats and number of billets conveyed per slat

The improvement in billet metering is shown clearly in Figure 65; 50 % of slats had only 1 billet when the magazine was used compared to 3% and 22% in Figures 62 and 63, respectively.

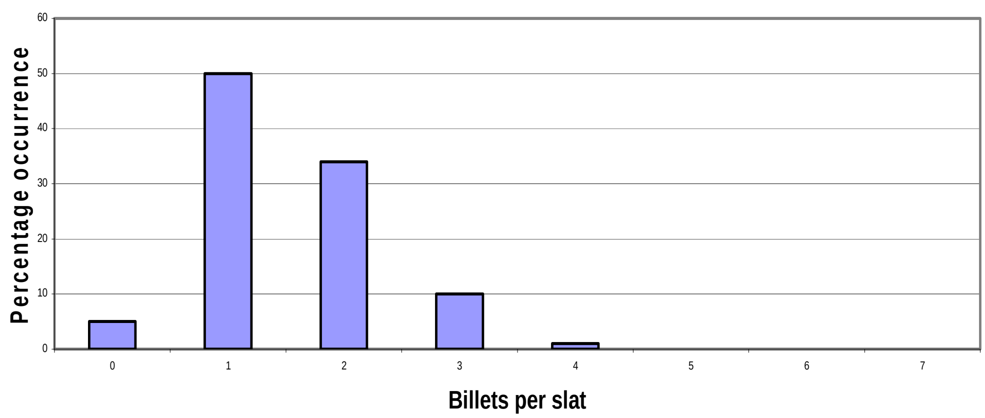

Figure 65 Distribution of billets per slat with the linear-feed magazine

Hypothesis 2: *Billet spacing accuracy is greatly reduced by a large uncontrolled billet drop.*

The same CNH Austoft slatted belt billet planter with a hydraulic drive was used in these tests. Uniform length billets were handfed onto the conveyor slats while the billet planter was in operation. One billet was placed on each slat of the moving conveyor. This was equivalent to perfect operation of the billet metering system, but, for our convenience, only one half of the conveyor was used. This metering rate in billets per minute or billet per metre of row travelled is significantly less than an actual planting rate. This does not affect the trial, as the aim was to quantify the reduction of billet metering accuracy with the current design of billet planter. The area of interest was the uncontrolled drop from the top of the metering conveyor to the soil surface. The billet planter travelled with the planter boards just skimming the ground and billets were placed on the ground simulating the billet planting. The trials were undertaken until 66 billets had been metered and the trial then repeated. The distance from start of trial to the centre of each billet was measured. A target planting spacing was calculated from the total distance travelled and the number of billets metered.

Figure 66 clearly shows that when perfect billet metering is imposed, the deficiencies of the current billet delivery component of the planter are highlighted.

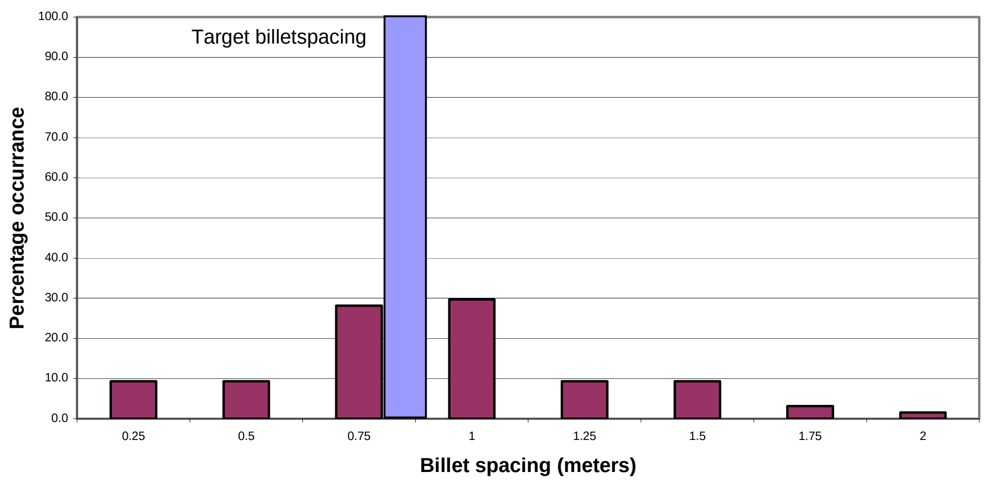

Figure 66 Effect of billet-delivery system on billet spacing

This is consistent with the test results from seed metering systems used in the grain industry. Most commercial billet planters ‘lift’ billets to 1.5-2 m above ground level during the billet metering process. From this height, the billet has an uncontrolled drop or fall to the planting furrow. In our test, the billets, when placed onto the conveying belt, were uniformly metered to give a theoretical target spacing of 0.78 m. The uncontrolled drop to the planting furrow greatly reduced spacing accuracy. The billet spacings measured had deteriorated from the theoretical target to a minimum spacing of 0.25 m and a maximum spacing greater than 2.0 m.

An improved billet meter must be matched to a billet delivery system to minimise the distance of uncontrolled billet drop. While there are many variations, three basic types of billet planter have been identified; elevating slat, external drum (Figure 67) and internal drum (Figure 68). The external and internal drum meter types have poor billet release point and large uncontrolled drop distances to the ground. Based on these results, a preferred billet planter would use an elevating slat system to both meter the billets and lower the metered billets to the delivery point, thus minimising the uncontrolled drop distance (see Figure 69).

Figure 67 External drum meter

Figure 68 Internal drum meter

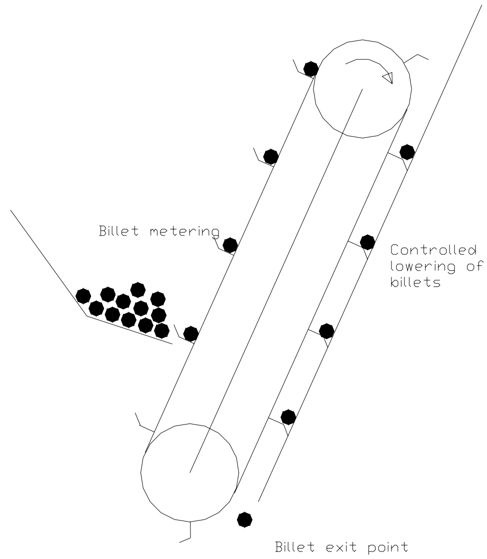

Figure 69 Proposed system of controlled lowering of billets with minimum uncontrolled drop distance

An alternative system would be to position the billet metering system as low as possible on the planter frame such that the distance from the billet release point to the soil is minimised. Uncontrolled drop distances of less than one metre would be considered acceptable.

6.3.2 Vibrating billet alignment and metering

Vipac engineers produced their recommendations of the frequency and amplitude of vibration to best align billets and a test rig was designed and constructed (Figures 70-71). The vibration excitation mechanism consists of a mass eccentric to a rotating shaft. The shaft was belt driven by an electric motor. Rubber isolation mounts enable the vibrating plate to be near resonance when operating. A vibration speed or frequency of the plate was about 12 Hz and the eccentric mass produced about 1.3 g of linear vibration.

Figure 70 Eccentric mass

Figure 71 Prototype vibrating billet-alignment system

After initial testing showed very slow billet movement, the eccentric mass was increased to produce a linear vibration of about 2.5 g. Billet alignment has been shown to improve as the residence time of the billets to the vibration was increased. However, increasing the residence time of the billet reduced the billet metering rate. Billet metering rate had to reduce to improve the alignment of billets. Acceptable levels of billet alignment occurred at billet metering rates of about 1.6 billets/second (100 billets/minute), which is equivalent to planting speed of less than 2.5 km/h. This metering rate is insufficient for a commercial billet planter, but metering rate could potentially be increased by:

- Using a larger hopper to increase the time that the billets are subjected to vibration;
- Increasing the linear vibration and/or including pre-conditioning by adding a low-frequency, high-amplitude vibration to the system;
- Using two or more billet alignment systems per row, thus halving or further reducing the required rate of alignment to suit a given billet metering rate (this option is the least preferred).

Operation of the prototype vibrating alignment system was observed critically during testing. There may have been some potential in inclining the vibrating plate to ensure that one end of all billets is aligned, but this appeared to be another task that would further reduce the rate of billet alignment. Due to the long residence time required to achieve full alignment of the billets, additional trialling of this mechanism was terminated.

6.3.3 Rotating disc meter

Interactions with a commercial food company led us to examine an aligning concept used by a major producer of food additives. The unit was used to align bottles prior to the filling process on an assembly line. A visit was made to the company plant at Brisbane to examine the working machine. The initial appeal of the concept was its simplicity and minimum number of moving parts. Speed of alignment was considered a potential problem but the idea had sufficient promise that construction of a prototype was justified.

The design was scale up to suit cane billets and a static test rig constructed. The diameter of the rotating disc was increased to 1200 mm and the recessed well made 85 mm wide (Figure 72). The disc was made from construction plywood and the inner and outer discs screwed together. A flange to suit a hydraulic motor was fitted to the middle of the disc on the underside. Three nylon trolley wheels, 50 mm in diameter, were attached to the machine frame with the wheel running close to the outer edge of the rotating disc (Figure 73).

Figure 72 A billet lying in the recessed well

Figure 73 Roller supporting the disc

A single rubber-bladed agitator was fitted with provision to fit an additional unit if required. The agitator was used to remove multiple billets from the line of billets and mounted just before the metering belts (Figure 74). The agitator rotated such that multiple billets were removed from the line of billets in the recessed well and thrown into the centre of the disc. The agitator was driven by a low speed, high torque 12 V motor.

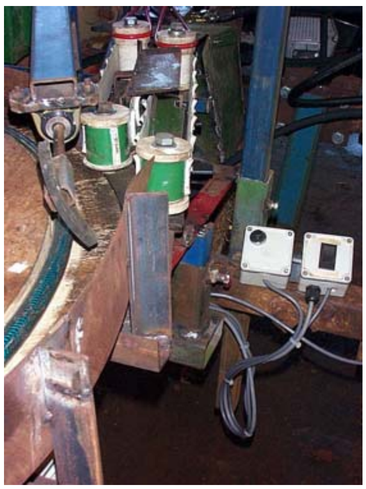

Figure 74 Ribbed metering belts showing modified flipper and control box for billet feed onto the disc

Initial testing was promising but the initial recessed well distance was too great, resulting in excessive number of multiple billets metered. The width of the recessed well was reduced to 65 mm. This resulted in a billet storage capacity on the rotating disc of about 8-10 billets (assuming a 350 mm billet length).

The following issues were considered important by the research team:

- Improving feeding into the metering belts by using ribbed belting;

- Alter the metering belt assembly such that the inner belt is fixed and the outer belt is movable. The prototype unit had the inner belt movable and outer belt fixed;
- Refining the cane flippers system to ensure effective removal of multiple billets prior to billets entering the metering belts.

Bench testing and modification of the meter design was undertaken and trials tested the suitability of each modification. On several occasions, a modification that took several days to complete would be found to be detrimental to the performance of the meter. Most design work involved refining the design of the billet entry into the metering belts. The belt roller had to minimise the pick-up of multiple billets yet still ensure a smooth flow of billets onto the metering belts. Testing of the static test rig was undertaken at metering rates of about 250 billets per minute, which equates to a planting speed of 5 km/h. It is believed that due to the reduced billet planting rate of this concept, gains would also be made in planting field efficiency thus further improving the hourly or daily planting rate.

Billet metering rates that exceeded 200-250 billets per minute showed a decline in even feeding into the meter and, in extreme cases, blockage of the meter. This is consistent with the performance of grain seed precision planter metering units where operation about a certain limit will result in a massive reduction in metering efficiency. A high level of operator education would be required to ensure acceptance of this type of planter.

6.4 Building an experimental billet planter

A surplus single row billet planter was purchased from Bundaberg Sugar Limited at minimal price and the frame was stripped of unnecessary components. Items retained included the frame, wheels and billet hopper thus version is considered. The double-disc opener design to suit the disc meter was drawn and the unit constructed. The experimental planter was a single-row unit, as this would allow optimisation of the metering system before a dual-row or similar planter was built.

Initial field testing was conducted under non-planting conditions with the billets surface placed into a shallow slot made by the double-disc opener. This methodology had the advantages of easily assessment of billet spacing, testing under extremes of dry and wet soil conditions, and billets could be recycled for additional tests. The majority of early testing of the disc metering system used high-quality hand cut billets, as harvesters were unable to enter the field for much of the testing period. These billets were 250-350 mm long. The availability of surplus billets from a harvesting test program improved our understanding of the relationship between billet length and the required geometry for the lower well area on the spinning disc. These surplus billets were cut by a machine set-up for supplying the mill and the average length was about 175 mm. Testing the current metering system with ‘short’ 175 mm billets increased the incidence of multiple billets metered to around the 30% level.

We had to wait until significant field planting were undertaken to further fine-tuning of the design to minimise the occurrence of multiple billets. If either the well gap is increased or billet length is reduced such that two billets can lay side-by-side, significantly reducing the ability of the flipper to prevent metering of double billets. This finding further supports the decision made early in this project that only harvesters with optimised feedtrain and rubber-coated feed rollers will be suitable to supply planting billets to this type of planter. The reduced planting rate can improve planting field efficiency but unless uniform length seed of the highest quality is available, a sub-optimum plant stand will result.

Major alterations were performed on the metering belt configuration (Figure 75). The inner belt assembly is now fixed with the outer belt assembly being movable. This is the reverse of the bench test rig. This change has improved the flow of billets onto the metering belts. The flipper unit was also improved and was hydraulically powered. Field testing quickly determined that a second billet flipper was required and an additional unit fitted. Provision for the second flipper unit was already been allowed for in the design.

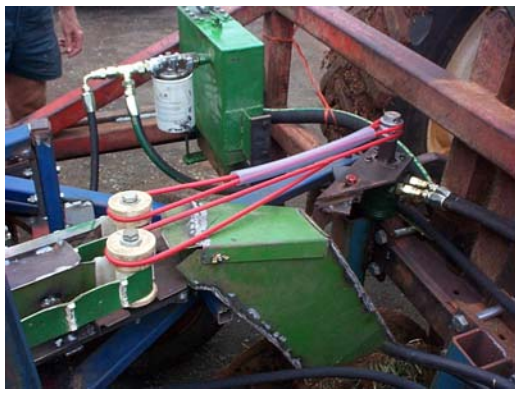

Figure 75 Single-motor belt-drive system

The billet trajectory into the discharge chute and to the double discs had potential to cause the occasional blockage due to billets contacting the two drive belts used in the initial design. The use of two hydraulic motors in a direct drive configuration to drive the metering belts, as envisaged in the final design, has prevented this problem (Figure 76).

Figure 76 Dual-motor direct-drive system

6.5 Field testing the billet planter

The experimental planter was initially field tested at the Southern Research Station at Bundaberg. As previously mentioned, this testing involved operating the planter with the double-disc opener just penetrating into the soil. The double discs must turn during the planting operation to ensure a uniform flow of the billets through the opener. This method also ensured that billets were held by the soil trench and hence did not move from their initial drop point. A sample of billet placement from this planter is shown in Figure 77.

Figure 77 Billets placed in a shallow slot during testing of experimental planter

The test billets had an average length of about 300 mm. After a test, the position to the centre of each billet was recorded relative to a datum point. This data was analysed and billet spacing distributions presented as a histogram in Figure 78. Although additional adjustment and fine-tuning was to be made of the meter, this spacing distribution was considered very acceptable. The target spacing was in the 350-400 mm range. Billet spacings greater than twice this distance were recorded as gaps while closer billet spacings are classed as multiple placements. Multiple billet placements are undesirable but spacing gaps are considered unacceptable. This result showed that:

- the most frequently occurring billet spacing was the target spacing;
- 19% of billet were within the target spacing;
- 92% of all billets were within one billet length (300 mm) of the target spacing.

These are the measures of spacing uniformity commonly used to assess the performance of metering units used for cereal grain seeds.

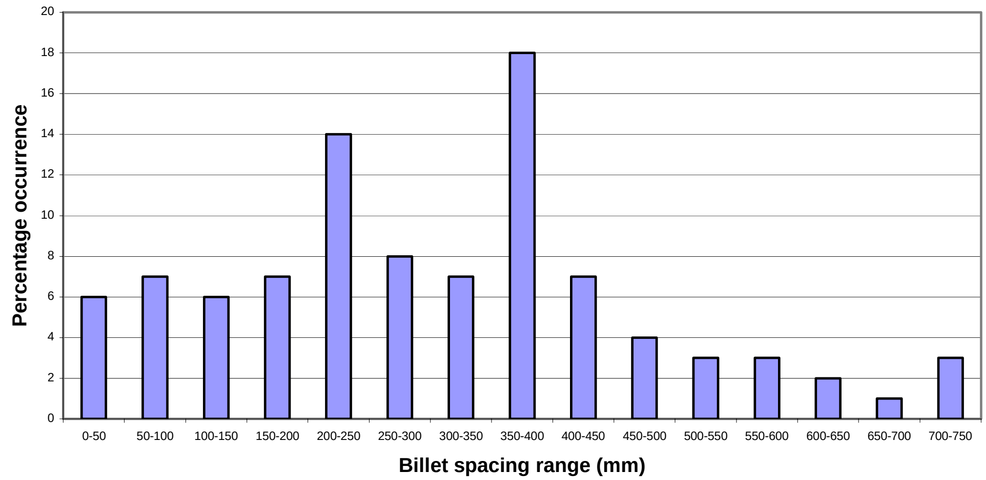

Figure 78 Field billet spacing using disc and belt metering system

6.6 Features of the disc and belt metering concept

It is important to highlight several innovative and desirable features of this metering system. The spinning disc is used to align and undertake initial singulation of the billets. The disc imparts a centrifugal force on the billets, thus forcing them to the outer circumference of the disc.

Billets are then aligned tangential to outer circumference of the spinning disc. Multiple billets are removed prior to metering by the rotating flipper. Additional field testing showed improved singulation by operating the disc at a slightly greater rotational speed without any increase in billet damage. The rotational speed of the disc used for the field trials was 40 rpm.

The innovative hydraulic drive system ensures precise regulation of metering rate with varying ground speed of the planter. This ground sensing and hydraulic interface is shown in Figure 79. The hydraulic drive system is critical to the compatibility of the disc and belt metering system. It is important to note that this metering system meters on a length of cane basis and also at a preset ratio (based on distance travelled by the planter to the desired billet planting rate). An alternative description is that this metering system does not meter individual billets but supplies a continuous length or supply of sugarcane billets based on a preset planting rate. This is significantly different concept to current billet planters that unsuccessfully attempt to meter individual billets. This disc and belt metering system is, to a certain degree, independent of individual billet length.

Figure 79 Hydraulic ground-drive system controlling billet metering rate showing jockey wheel and hydraulic metering valve

6.7 Production of a prototype planter

Components of the experimental planter were modified to produce a prototype planter; only minor modifications were required.

Rotational speed of the spinning disc was further optimised with the critical requirements being:

- a speed to produce sufficient centrifugal speed to ensure billets are quickly moved to the outer edge of the disc; and
- the tip speed of the outer edge of the disc must exceed the billet metering rate in metres of billets per minute.

Automation of the sugarcane billet feed from the bulk hopper onto the spinning disc was investigated using an optical sensor interfaced to the hydraulic solenoid. The sensor was positioned opposite the metering belts and would detect if billets were present in the recessed well at that point. If billet were not present, the sensor would activate the hydraulic motor on the bulk cane elevator. Further testing of this concept is required to optimise the duration of this billet feeding cycle. We propose that a variable-duration option be made available to suit different cane diameters and flow characteristics.

6.8 Testing the prototype planter

6.8.1 Test of prototype

Bundaberg Sugar made a significant area of land available to plant a large-scale trial on the Fairymead Mill Plantation - adjacent to a previous large no-tillage trial planted 12 months previous using the BSES single row double-disc planter. Planting material was provided by Bundaberg Sugar staff and cut using their modified harvester with rubber coated feed rollers. We used well-grown Q138. Half the site was planted by the BSES planter and the other half planted by a modified Moller planter owned by Bundaberg Sugar.

The first bin of billets had high levels of damage, but we suspected that this was caused by breaking into the block or a similar fault. However, the billet quality of subsequent billet bins did not improve. Metering blockages occurred due to the excess rind protruding from the cut ends of the billets.

Planting rate was slow due to the frequent blockages caused by the poor quality billets (Figures 80-81). Prior to planting half the field, planting was interrupted while we hand cut a fully planter hopper of billets. Planting of these high quality billets was trouble-free and was quickly undertaken. The hand-cut billets planted two row of the field and a further two rows were planted using the single row double-disc, wholestalk planter. Billet quality and poor planting technique resulted in the half of the field planted by the modified Bundaberg Sugar planter being abandoned and later ploughed in.

Figure 80 Damaged billets on disc

Figure 81 Example of split billet (Q138)

The poor quality of the Q138 billets was further investigated and the performance of the modified harvester monitored. After cutting the Q138, the harvester was used to cut planting billets from a field of Q151. The quality of these billets was high as would be expected from this machine. Clearly the problem was in the brittleness of the previously cut Q138 cane. This problem was discussed with several growers and examples of similar experiences related.

Comments from senior Bundaberg Sugar staff have indicated approval of the planting technique and an expectation of an acceptable crop yield. The success of a previous zerotillage commercial planting has prompted Bundaberg Sugar to modify two planters for use in their autumn planting program.

6.8.2 Further field tests

Background

All precision metering mechanisms have maximum operating speeds and beyond these speeds performance will deteriorate. As a finite amount of time is required for seed billets to align, be selected for metering and be metered, it is a reasonable hypothesis that the less dimensionally uniform the seed billet, the longer the time required to align and meter the seed billet. If we compare the dimensions of a near spherical soybean seed, about 5 mm in diameter, to those of a sugarcane billet at 250-300 mm long and 20-50 mm diameter, clearly the soybean seed can be metered by an open-cell-type plate meter (eg Covington double-inclined plate planter) independent of dimensional orientation. A sugarcane billet, on the other hand, must be oriented in longitudinal pattern or side-by-side if a basic metering process is to be undertaken. Previous work undertaken as part of this project attempted to use vibration to align the billets prior to metering. The vibration based research was abandoned when the alignment times were found to greatly exceed the billet metering rate.

We now asked 'Is the maximum allowable planting rate of the developed billet metering system suitable for the Australian sugarcane growers?'.

The testing program was aimed to determine the acceptable maximum metering rate, translate that to field planting speeds, and examine options that may increase the maximum planting rate. To understand the range of metering speeds in billets metered per second, the following assumptions were made:

Billet length	300 mm
Billet spacing	0 and 50 mm

Table 5 shows the minimum acceptable billet metering rates and, in reality, the planting rate would be set closer to the 0 mm gap between billets to allow for non-viable eyes, billet metering errors, etc. The table highlights the actual metering rates required in terms of billets/second. The double-disc wholestalk planter we used had been modified to plant with about a 50 mm spacing between sets but the billet planter will aim for end-to-end billet placement. At 6 km/h, the meter must be processing about 5.5 billets/second or 340 billets/minute. To do this with a high level of accuracy is a considerable task especially when the product is cylindrical, of variable diameter and not uniform.

Table 5 Comparison of planting speed, billet spacing and planting rate

Ground speed km/h (m/s)	Billet metering rate (billets/second)		Metering belt speed m/sec	
	0 mm gap	50 mm gap	0 mm gap	50 mm gap
2 (0.6)	1.9	1.6	0.57	0.48
4 (1.1)	3.7	3.2	1.11	0.96
6 (1.7)	5.6	4.8	1.68	1.44
8 (2.2)	7.4	6.3	2.22	1.89
10 (2.8)	9.3	7.9	2.78	2.37

Methodology

Simulated field plantings were undertaken using uniform length billets that were surfaced planted to ensure no billet displacement after planting. The position of the centre of the billet relative to adjacent billets was recorded and the billets recycled for subsequent tests. About 40 field tests were undertaken, but many tests were to understand the feed requirements of billets onto the spinning disc. Individual billets were reused for only 2-3 days then discarded and replaced with fresh billets. During the tests, the operation of the disc and metering belts were video recorded and this vision later examined in slow motion to determine any operational problems.

Planter ground speeds tested were 2.2, 2.9, 3.6, 4.5, 5.2, 5.6 and 6.9 km/h. These speeds corresponded to the ground speeds obtained by operating the test tractor in different gear ratios and 1300 engine revolutions per minute. Speeds greater than 7 km/h were not possible due to the output of the PTO driven hydraulic pump that supplied oil to the motors on the metering belts.

Results

Each groundspeed test was repeated a minimum of two times and the results compared to ensure similar performance. Tests were repeated until consistent results were obtained. In all 16 data sets were recorded. As the desired billet placement was billets end-to-end without a gap, then the distance between billet centres of adjoining billets would be 300 mm. The number of billets between plus and minus one billet spacing and plus and minus half a billet spacing were calculated to quantify the billet metering performance. This examines the number of billets present in the 0-600mm and the 150-450 mm spacing ranges.

Table 6 gives some general results. Interpretation of these is somewhat subjective, as there are no definitive guidelines as to how to analyse or define acceptable billet spacing. The first observation is the deterioration in meter performance as ground speed is increased. This is consistent with the performance of all agricultural seed metering systems ranging from simple systems that rely on gravity to feed seeds into cells or more complex pneumatic–assisted plate meters. The metering performance of all these systems rapidly decline once the point of maximum metering accuracy has been reached.

Table 6 Averaged trial results showing billet spacing occurrence within two distance ranges

Ground speed km/h	Billets/sec	Occurrence within 0-600 mm range (%)	Occurrence within 150-450 mm range (%)
2.2	2.0	94.0	64.0
2.9	2.7	96.5	68.0
3.6	3.3	96.5	73.0
4.5	4.2	92.5	63.5
5.2	4.8	90.0	57.5
5.6	5.2	85.5	51.5
6.9	6.4	84.0	50.0

Because of the analysis used, all billet occurrences outside the 0-600 mm range must be comprise gaps (spacing greater than 600 mm). For example at 2.2 km/h, 6% of the recorded billet spacings were gaps in the 600 mm or greater range. At 6.9 km/h, this percentage had risen to 16%. Examination of Figures 82-84 shows that as speed or billet metering rate increases, the percentage of billets at the optimum spacing (300 mm) decreases. Billets in the 300-350 mm spacing range varied from about 17% at 2.9 km/h, 13% at 5.2 km/h, to 7.5% at 6.9 km/h. The metering system functions best at low metering rates and deteriorates as metering rate increases. Based on these results, the maximum speed of the current billet meter is about 6 km/h or 5.5 billets/second. Operation at ground speeds less than this figure is recommended. This is a critical for successful operation of the planter. Modifications to increase this rate have not been successful.

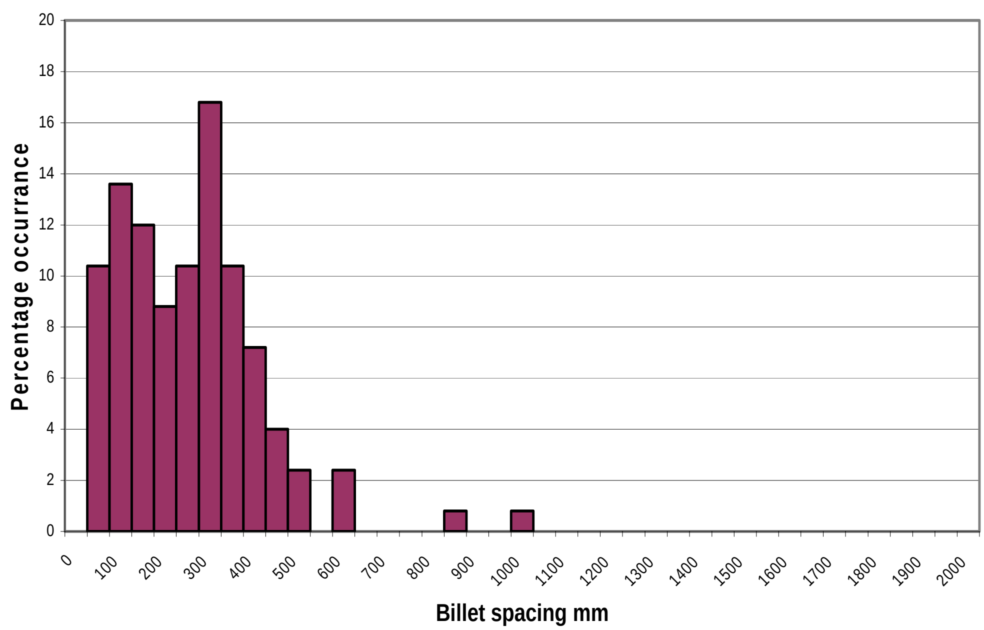

Figure 82 Spacing histogram for 2.9 km/h ground speed

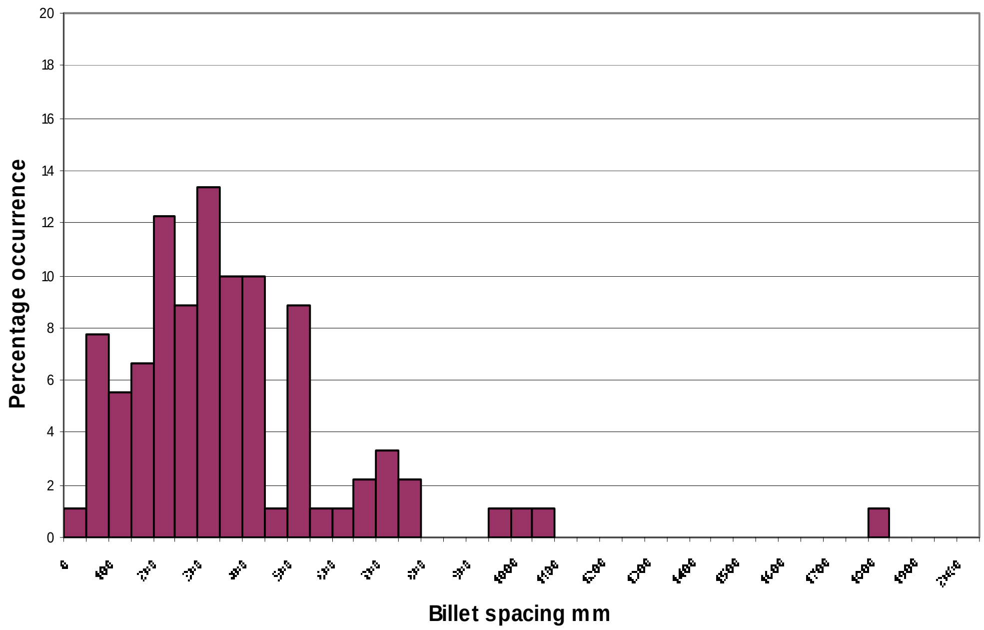

Figure 83 Spacing histogram for 5.2 km/h ground speed

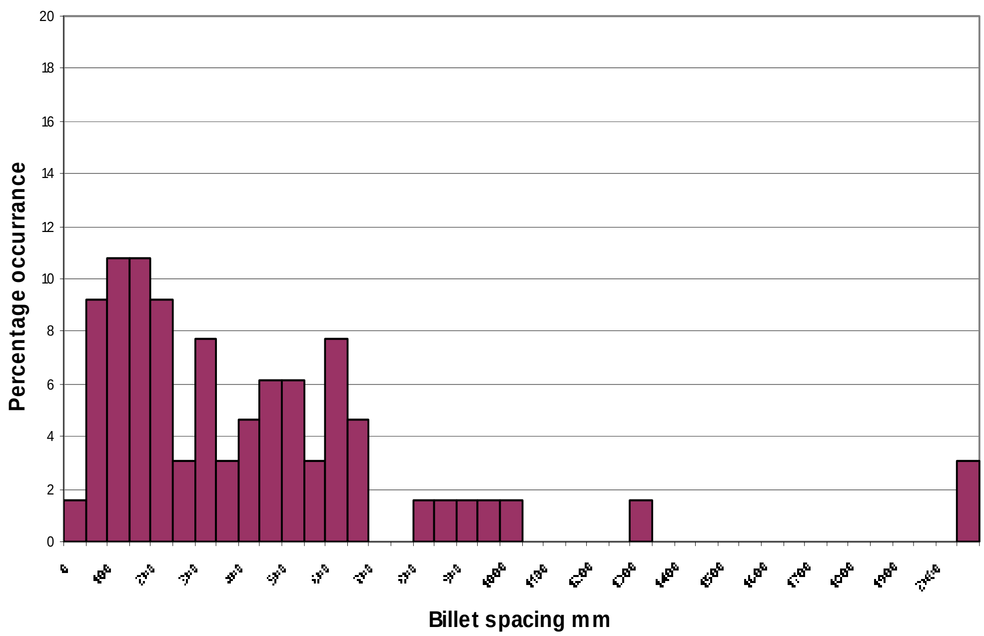

Figure 84 Billet spacing histogram for 6.9 km/h ground speed

6.8.3 Trial planted using double-disc billet planter

A 1 ha, minimum-tillage trial block at the QDPI Research Station, Bundaberg was available for planting using the prototype billet planter. The block had been mounded, cleared of large stones, and weeds controlled with herbicide. The block was planted on 18 March 2004 using sugarcane cultivar Q138. This planting date was later than desired, but a suitable harvester to cut the plants was not available until this time. The cane selected by QDPI staff was considered too large to produce high-quality planting material, but was used as no other cane was available. A billet quality assessment revealed that only 29% of the billets were sound, but the planting was undertaken primarily to test the planter.

Strips of row, about 10 m long, were randomly selected and shoot counts undertaken. A total of five strip samples were measured. Shoot distribution showed acceptable spacing uniformity along the crop row (Figure 85). This result represents shoot populations 28 days after planting. A small number of shoots have emerged after this date. Figure 85 shows the crop growth at 36 days after planting.

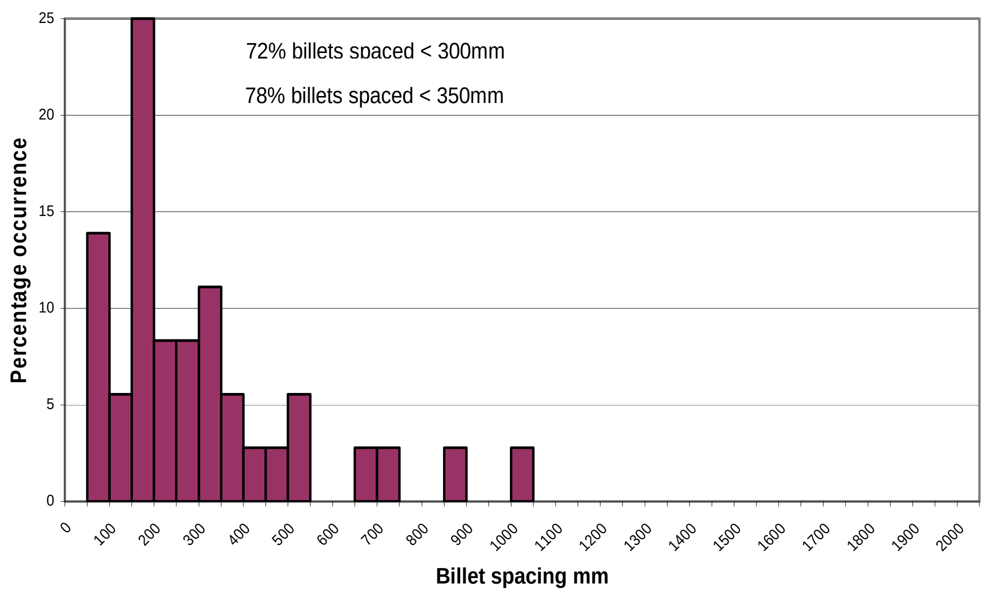

Figure 85 Shoot spacing at QDPI trial site

This result is considered very good considering the quality of the seed used. The planting, however, showed several minor deficiencies in the planter design. During early morning planting with moist billets, moisture and soil built up on the spinning disc, and billets were not positively conveyed to the metering belts; planting stopped until the disc dried. We intend testing a textured plastic surface on the disc. Several areas of trash adherence were identified and modifications undertake to prevent this reoccurring.

It is important to note in Figure 86 the large area of undisturbed traffic zone in the field, and the minimum soil disturbance due to the 15° angle of the double-disc planter unit. This is a commercial crop and will be harvested in the 2004-2005 harvest season.

Figure 86 Sugarcane emerging at QDPI no-tillage billet-planted trial

6.8.4 Commercial planters

We also monitored the progress of two billet planters that are utilising the high quality, uniform length billets from modified harvesters (rubber-coated rollers and constant speed feed train). Both planters were new machines and were purchased based on recommendations from this project. Both machines have had additional modification and adjustments prior to planting. Both operators have reported reduce planting rates, due to improved metering of the more uniform 'seed' and hence superior along the row sett placement. Whilst this was a significant improvement, we do not believe the performance of these machines satisfy the performance criteria of this project.

6.9 Discusssion

The performance of current commercial planting machines has improved as a result of this project and the subsequent dissemination of results. However, the precision billet planter developed as part of this project is not a stand-alone machine. Acceptable planting performance by the double disc billet planter requires:

- erect sugarcane grown specifically as planting material;
- billets cut by a harvester specifically modified for plant cutting; and
- operation within a defined speed range and to specified operating parameters.

We spent a significant amount of time informing growers that this project is offering a billet-planting system of which all components must be adopted if a successful outcome is to be achieved. This requires a significant change in the mind-set of many growers, but we believe the goal is being achieved. An example of this changing of industry perception of planting is a comment by a senior Bundaberg Sugar Ltd agriculture manager that a problem with the precision billet planter is that it requires high-quality planting billets to perform successfully. We believe this comment highlights a positive feature of this planter and the planting system proposed.

Clearly, the industry will take time to adopt this level of change, but the process has commenced and momentum is increasing. The improvement of billet planting will be an evolutionary change rather than a revolutionary change. Operation of the precision billet planter without the use of high-quality, high-viability billets will, in most cases, lead to unacceptable plant establishment and, hence, reduced crop yields. This project has researched and recommends an improved planting system comprising several critical components that must be adopted in full or the system not adopted.

Regions such as Sarina now have more than 10% of their area under minimum tillage, 1.8-1.9 m wide dual-row sugarcane. Much of this cane is now planted using billet planters incorporating many of the criteria from this project. While many of these plantings have compromised the system slightly, the critical components are being adopted. Several of the commercial planting are using double-disc planting groundtools with an included angle of 30-40°. This has resulted in excessive soil disturbance, causing planting speeds to reduced to a maximum of 5 km/h. We accept this as an acceptable compromise for the initial adoption/evolution phase, but will ensure that growers understand the desired goals of the system.

It is very important to highlight the fact that this project has undertaken first development and use of a precision billet planter in the Australian sugar industry and many in the industry still believe that the current system with its excessive planting rates and poor crop establishment is acceptable and more concerning, that this result cannot be improved. Change will take time but progress is very encouraging. The current financial state of the sugarcane industry has not assisted in the adoption of this technology by machinery manufacturers. The adoption of break-crops, such as soybeans, maize, etc, has forced many growers to refocus on how much ‘seed’ they plant and the percentage of that seed establishing to become an economically viable crop.

7.0 HIGH-QUALITY COATED BILLETS FOR THE DISTRIBUTION OF APPROVED SEED

This section addresses objective 6.

This project has researched the concept of high-quality, sealed cane billets that could be an appropriate means of distributing Approved Seed. Benefits of this system have not been proven and the use of protective coatings and sealed billets has been discussed in Section 4.

Treatments that successfully improved plant germination and/or establishment, such as short-hot-water immersion, have been rejected as not practical under the current cropping system. At this stage, general guidelines for the distribution of high quality, sealed approved seed are not appropriate. As growers accept the precision billet metering concept, requirement for this guideline will be reviewed. The advent of concepts such as SmartSett® may alter how future distribution of approved seed is undertaken. We are watching the adoption of billets as a method of receiving Approved Seed and have worked closely with groups such as Bundaberg CPPBs. The use of a harvester with rubber-coated rollers and optimised feedtrain at a local CPPB mother plot produced the highest quality machine cut billet recorded by the BSES Bundaberg researchers. When billeted seed cane was supplied, BSES recommendations developed as part of this project were followed. The use of the gibberellin inhibiters may have a place in managing approved seed plots for restricting lodging and for producing high quality billets. Further research is required on the use of MODDUS® for this purpose.

8.0 OUTPUTS

This project has produced publications detailing how to produce sugarcane suitable for planting material (Appendix 2) and the requirements of a harvester to ensure high-quality billets are cut from this sugarcane (Appendix 1). These publications define an improved planting system, but we have tried not to be prescriptive in these publications but explain the principles of the proposed system.

Attempts to produce high-quality planting material have confirmed earlier reports that adding nitrogen and phosphorus to cane 6-8 weeks before it is cut for planting can improve germination. This treatment has been included in the guidelines for best practice planting techniques.

The chemicals that inhibit gibberellin can be used to restrict cane growth and reduce the risk of lodging. Cultar® improved early germination of the cane, as well as restricting the growth. Unfortunately, the cost of Cultar® is presently excessive and it cannot be considered for commercial application. If the price comes down it would be a useful chemical for use by growers to obtain high quality planting material. MODDUS® is likely to be registered as a ripener in cane and the cost of the treatment for restricting growth of planting material should be reasonable. MODDUS® did not improve germination in glasshouse trials, but it did stunt the growth of the shoots at the higher rates tested. Further testing of this chemical is required. The effect of the chemical on ratoon shoots after its use as a ripener should be monitored.

Attempts to develop practical methods to stimulate germination and protect setts with polymer coatings have failed. Hot-water dips and sprays can stimulate germination and improve pineapple disease control, but are not practical for commercial application. Hot water should be used to stimulate germination in research projects where a highly reliable and uniform germination is required. The hot-water treatments may useful in propagation of new varieties, where rapid build-up of stocks is required. All of the polymer coating and polymer films tested did not improve germination or pineapple disease control. Mancozeb was used to treat the soil around the planted sett and in one trial it stimulated germination and controlled pineapple disease. Mancozeb can also control the organisms associated with yield decline. Mancozeb should be tested further and its effect on control of yield decline as well as pineapple disease should be assessed.

The precision billet planter developed during this project is the first attempt by the sugarcane industry to minimise planting rates and still achieve high crop yields. The technology and the principles involved have been well documented to ensure experiences during development can be shared with others. This planter can place billet at spatial accuracies not possible by current planting machines. We believe that this technology will assist to ensure the future viability of sugarcane production in Australia.

The most significant technology-transfer has been a large no-tillage planting of about 50 ha undertaken by Bundaberg Sugar Limited. Sugarcane was direct drilled into the sprayed-out stool of the previous crop using the precision planter. This has enabled sub-surface trickle tape to be used for an additional crop, thus accruing significant savings to the company. This planting has been used as a component of several grower tours to show the potential on minimum and no-tillage practices. An additional field planting using the precision billet planter has been undertaken at the same site.

There are also several very strong improved planting/controlled traffic discussion groups at various cane growing regions within Queensland. Groups at Sarina and Mackay have been addressed as part of this project. Some of these groups may only comprise of small numbers of growers but they are very actively involved in changing their cane planting system.

9.0 OUTCOMES

Industry awareness of the limitations of the current billet planting system is now at a very high level. The real cost of planting and the benefits of a well-established sugarcane crop are better understood than prior to the commencement of this project. The results of many media articles, grower meeting presentations and conference presentations can be seen in the widespread adoption of harvester modifications on machines cutting billets for plantings. Most growers are aware of this work, and the positive testimonials from those who have undertaken the modifications have assisted greatly in the widespread adoption. The supply of high-quality planting billets to the planter is one of the important and essential outcomes for sugarcane planting.

Modifying the harvester is an essential component of the system and growers are now undertaking sugarcane plantings aimed at seed cane production.

Although the precision billet planter is not yet commercially available, its development has highlighted the excessive planting rates of many commercial billet planters. The double disc planting groundtools also have a requirement of reduced planting rate and a high level of spatial distribution along the crop row. Already we are seeing modifications of current planters to reduce planting rates. While these attempts will have only limited success, the industry is being positioned to accept the new precision billet planter.

The current reduced returns from sugarcane are a useful catalyst to ensure that adoption of an improved sugarcane planting system will continue.

10.0 RECOMMENDATIONS FOR FURTHER WORK

- Conduct further field demonstrations of the improved billet planter to grower and machinery manufacturers. Trial plantings are planned for the Isis mill region and all three mill areas in New South Wales in the spring of 2004.
- Assist the commercialisation of the spinning-disk billet metering system through design input as the concept is taken to a production prototype version. Areas where engineering assistance may be required include automated supply of billets to the alignment table and ensuring the belt pick-up system is commercially robust.
- Monitor the adoption of precision planting technology and ensure that a matched system of cane production, production of high-quality billets, and precision metering and billet placement is delivered to growers.
- Continue extending the benefits of improved planting systems to the Australian sugarcane industry. Groups targeted will include growers, planting contractors and machinery manufacturers.
- Further test MODDUS® for reducing the risk of lodging to produce high-quality planting material.
- Monitor the price of Cultar® or chemicals with the same active ingredient and, if there is significant reduction in price, renew development of this product for producing high-quality planting material.
- Further test mancozeb for pineapple disease and yield decline control when applied over the sett at planting.

11.0 PUBLICATIONS AND INFORMATION DISSEMINATION

BSES Limited Publication 'Get better planting billets by modifying your harvester' (Appendix 1)

BSES Limited Publication 'Guidelines for sugarcane planting' (Appendix 2).

BSES Publication 'Update on rubber-coated rollers' (Appendix 3).

BSES Publication 'Rubber-coated rollers – second update' (Appendix 4).

BSES Publication 'How to assess billet quality for planting'(Appendix 5).

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Displays of the rubber coated roller and billet quality issues at the Agro-Trend Field Day, Bundaberg (1999, 2000 and 2001)

Grower and harvester owner meetings were held at Mossman, Meringa, Bundaberg, Childers, Nambour, Rocky Point and the three mill areas of New South Wales.

Field demonstrations of improved double-disc planters have been held in most sugarcane regions with the most recent being during the Southern Regional Bus Tour held on 25 May 2004.

12.0 ACKNOWLEDGEMENTS

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APPENDIX 1 – Brochure on getting better planting billets

The Results

Operators of modified machines have made comments like:

"Very visible improvement in uniformity of billet length and billet quality";
"Enhanced evenness of feed";
"Lower extraneous matter and dirt levels".

Growers and planting contractors who have made these modifications have seen that the higher quality billets have improved crop establishment they can then cut back on planting rates. Several planting contractors have increased the area they plant due to positive customer feedback and claim the changes to be "money well spent".

This work has been funded by BSES Limited and Sugar Research and Development Corporation (SRDC). BSES engineers are continuing their industry-funded research to raise billet quality, improve harvester feeding, and minimise sugar losses. For more information contact engineering staff at BSES Limited, Bundaberg on 07 4132 5200.

BSES
Sugarcane for the future

GET BETTER PLANTING BILLETS BY MODIFYING YOUR HARVESTER

Planting is an expensive operation and using anything other than the highest quality planting billets can reduce plant establishment lowering future crop yields. Sharp basecutter and chopper blades, erect cane and moderate pour rates help produce high-quality planting billets.

However, you can get much better planting billets from your current harvester by making several modifications.

Optimisation of Harvester Feedtrain and Chopper
You may have read that BSES Limited highly recommends optimising the harvester feedtrain roller-speed and roller-to-chopper ratio to improve the efficiency of ordinary harvesters.

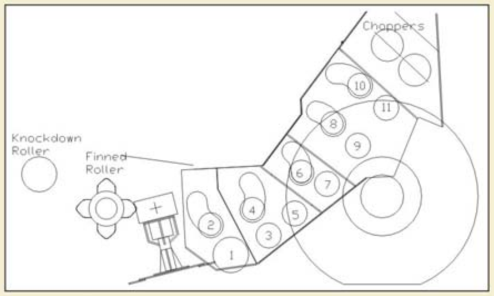
This modification is **ESSENTIAL** for harvesters that cut planting billets. It is also highly recommended for harvesters cutting commercial sugarcane. BSES can match the tip speeds of all feedtrain rollers to give an 'even flow' of cane to the choppers and ensure that the rotational-speed ratio between the rollers and chopper is correct.

Uniform length, high quality billets cut by a modified harvester

Why do it?
Optimising feedtrain rollers and roller-to-chopper ratio means that harvesters will produce billets of uniform length with high quality end cuts.

Many harvesters have been manufactured with feedtrain rollers working at differing tip speeds. This can improve dirt rejection at *low pour rates in burnt cane*. To allow cutting of different billet lengths, manufacturers fitted a variable speed control to the upper group of feedtrain rollers. Billet length is varied by quite 'savage' and undesirable alteration of the relative speeds of the feed and cutting system. Rind damage increases and the quality of the billet cut decrease as these speeds are mismatched.

How BSES does it?
We first measure the current speeds of all rollers and choppers and record component specifications on your harvester (see diagram below). This can be a difficult task as access to some rollers is limited.



Cross-section of harvester showing basecutter, feedtrain rollers and choppers.

We then use that information to compare possible modification options and select the most suitable combination. We do charge you for this service, as we use specialised aids and our considerable experience.

Our recommendations will depend on the model and configuration of the harvester. Hydraulic systems can vary between different model harvesters, so minor changes to the hydraulic plumbing may be needed. Varying hydraulic motor sizes and hydraulic components may also be required.

Machines set up as dedicated plant cutters can be optimised so that their two-bladed 12-inch chopper systems will cut high quality, planting billets 250-300 mm long.

Harvesters that have had their feedtrain optimised can cut both planting billets and commercial sugarcane. However cutting a longer, uniform length billet may reduce the amount of cane that will fit into a bin. Manufacturers are now using BSES research and incorporating matched feedtrain systems on newer model harvesters.

Rubber-Coated Feed Rollers

Optimisation will give uniform-length billets, but aggressive, square-edged rollers will badly damage the sugarcane rind as billets are pulled through the harvester. This will destroy eyes and make billets more susceptible to drying out and to invasion by pineapple disease; germination will be poor.

Rubber coating of the feed rollers will minimise this damage. A 95% natural rubber that is highly resistant to wet-abrasion is used. It is soft, so there is positive grip of the sugarcane under wet conditions, but it is very tough. The coating is attached to the feed roller using an industrial glue. Most growers rubber coat the top 9 or 10 feed rollers, but the buttlifter (roller number 1 on the diagram) is usually not coated.

If you use rubber-coated rollers but don't optimise the feedtrain speeds, you will get rapid wear of the rubber coating. This is because of the speed differences between rollers and the flow of cane. You should both optimise the feedtrain and use rubber coated rollers to get the optimum setup for cutting planting material.

If you decide not to rubber coat the feed rollers, then make sure that all rollers are well worn and free from square edges or areas of hard-facing weld. This will help reduce rind damage from the feed rollers, but will not be as good as coating the rollers.

Rubber coated rollers fitted to the top roller group of an optimised harvester.

Knockdown angle

Many commercial harvesters push the cane over to large angle before it is cut by the basecutters. This aggressive bending of the cane can sometimes split or snap the cane stalk. As erect cane is recommended for producing planting billets, the knockdown roller and the finned roller (see harvester diagram) may be removed or raised to minimise cane damage during harvesting.

APPENDIX 2 – Brochure on guide for sugarcane planting

8

Things to do

Plan your planting well in advance and ensure you:

- Start with cane grown for planting
- Produce high quality, sound billets
- Treat billets carefully and use the appropriate fungicides and insecticides
- Place the billets into a good seedbed, cover with the correct amount of soil and firm the soil with a presswheel

Follow the recommendations in this publication and you have done all you can to ensure a good sugarcane crop.

This work was conducted by Brian Robotham and Barry Croft. Funding was from BSES Limited and the Sugar Research and Development Corporation (SRDC). BSES engineers are continuing their industry-funded research to raise billet quality, improve crop establishment and minimise sugar losses. For more information contact engineering staff at BSES Limited, Bundaberg on 07 4132 5200 or your local extension officer.

BSES Sugarcane for the future

BSES Sugarcane for the future

GUIDE FOR SUGARCANE PLANTING

Planting is the most expensive operation in the sugarcane production system; it costs you about $320 per hectare (depending on region). You waste that money if you get poor crop establishment. To get the best crop establishment, you must use the highest quality planting billets and place them into soil conditions that promote germination and establishment. There is no magic formula for a good plant strike, but correctly doing a set of basic actions will tip the odds of success well in your favour.

What can I do?

Remember good planting is the essential first step to a good crop. A poorly planted crop will never match the yield of a well planted crop. So when planting always:

- Start with good seed cane and product high quality planting billets;
- Treat them with care and the appropriate fungicide and insecticide sprays;
- Put billets into a good seedbed, cover with correct amount of soil and firm the soil after planting.

Plan your planting, follow the recommendations in this publication and you have done all you can to ensure a good sugarcane crop.

What type of material should I plant?

Grow sugarcane specifically for planting material. You must deliberately produce sugarcane that is suitable for plants rather than for maximum production.

If you start with unsuitable or diseased planting material, you will have little chance of getting a good strike. Make sure that all planting material is confirmed as disease-free prior to use. Planning is essential to ensure high quality cane is available at planting time.
High quality planting material is produced by:

- Growing cane in a disease-free and well-drained environment;
- Growing cane in a weed-free and sugarcane volunteer-free environment;
- Avoiding lodging by planting or ratooning later in the season, withholding fertiliser and/or water, or planting on less fertile soil;
- Satisfying the plant's nutritional requirements but aiming to produce a moderate yielding crop - application of nitrogen 1-2 months before cutting plants may improve germination;
- Satisfying the crop's water requirements to produce billets with 2-3 internodes per billet (internode spacings of about 200 mm);
- Growing cane under uniform soil conditions to ensure a uniform crop of even maturity;
- Obtaining the original material from an approved seed source and increasing it to commercial quantities in on-farm nursery plots. As a rule of thumb, rely on a 20 to 1 multiplication per year when using a whole stalk planter (1 kg will produce 400 kg in 2 years). This amount will be about halved if a billet planter is used.

If you are unsure of the disease status of your sugarcane plants, contact a BSES extension officer or a Productivity Officer for RSD testing prior to planting.

The 'ideal' billet for a mechanised billet planter is:

- 250-300 mm long;
- minimum of 2 nodes per billet with sound eyes;
- both ends cleanly cut (no squashing of ends);
- minimum damage to rind from the harvester rollers;
- free from piping (hollow centres);
- actively growing;
- free of pests and disease;
- contains little trash.

Erect cane is essential for plant material. Most growers know that lodged, bent cane is unsuitable for whole stalk planters. However, BSES research shows that this cane also produces billets of poor quality, even when cut with best-practice, modified, plant-cutting harvesters. Sometimes lodged cane, that is unsuitable for planting by whole stalk methods, is machine cut for planting billets. These billets can germinate poorly.

Crop lodging is managed by crop husbandry. Nutrients, in particular nitrogen, must be limited and rates applied will depend on previous field history. Do not use more than 100 kg N/ha. Planting after large, well-grown legume crops may result in excessive N levels. Crop growth can also be controlled by restricting irrigation, late ratooning or planting, and planting

You can, however, make changes to billet planters to improve performance. Maintaining a uniform 'head' or depth of cane over the elevating conveyor will improve uniformity of billet metering. Planting rate increases with excessive depth of billets or 'cover' of the elevating system and reduces as depth of billets is reduced. Planting clean billets free from trash will assist in even flow of billets within the planter hopper and assist in maintaining an even head of cane billets. Excessive planting speeds should avoided, with 8 to 10 km/hr being the limit for most planter types.

The uncontrolled drop of billets from the top of the elevating slats of billet planters makes the gap and clump distribution of this meter worse. Some early billet planters have used the elevator slats to lower billets to maintain billet spacing integrity.

How do I ensure planting hygiene?

Ratoon stunting disease (RSD) and leaf scald are caused by bacteria that can be spread by cutting implements and contact with the cut ends of billets. These diseases cause severe losses, and you should make sure that they are not brought onto your farms by contaminated planting equipment or in diseased planting material. The bacteria are highly contagious, and a contaminated harvester or wholestalk planter cutting billets can spread them very efficiently. Planting machinery should be disinfected before changing plant sources, varieties or farms.

Machinery can also carry weed seeds between farms or districts and good hygiene will prevent the spread of weeds.

An implement can be disinfected by:

- Removing all soil and plant material using high-pressure water and detergent.
- Spraying cutting surfaces and parts that contact cut surfaces with a registered product containing 0.1% benzalkonium chloride. The disinfectant should be left in contact with the implement for 5 minutes before further use. The disinfectant is degraded by exposure to sun, soil and organic matter.
- Disinfecting the basecutter, chopper box, extractor fans, the whole feedchain, boot and elevator slats of harvesters when cutting cane for planting billets.
- Disinfecting planters and haulouts.
- Flushing the recirculating fungicide spray-system with disinfectant, as they can carry RSD bacteria and spread disease.
- Regularly removing soil, cane billets and trash from the machines and cleaning all machinery before leaving a site. Billets should never be carried over from one job to the next. Planting billets should always be freshly cut. It is cheaper to discard day-old billets rather than to use these as planting material and then suffer a suboptiminal crop establishment.

the leg shaft to minimise rind damage. Irrespective of the type of basecutter used, keep the harvesting pour rate even and moderate. Harvester pour rates of 55 to 75 tonnes/hour are recommended. During operation, various machine components should be regularly maintained to ensure that high-quality billet are produced.

Basecutter blades require regular maintenance:

- Keep blades extended to the maximum length possible;
- Use thin blades as these produce the best quality cut;
- Replace blades when the cutting edge becomes dull and rounded.

Chopper blades should be sharpened regularly and replaced if damaged or when worn excessively. As a guide, blades should be resharpened after cutting each 20 tonnes of billets, but more often in abrasive soils or where rocks are present. Portable, battery-powered grinders and impact wrenches make these jobs easy.

What about handling and transport?

BSES research shows that most normal billet handling systems are not detrimental to billet quality, but excessive handling of billets should be avoided. Maintain and operate all handling and planting machinery to ensure that billets remain in good condition. Check billets regularly during planting and identify and rectify any changes in billet quality. Always empty and clean haulouts and planters of all billets when changing varieties and farms

SOIL CONDITIONS FOR PLANTING

What soil tilth is needed?

Because soils vary greatly, there is no recipe for land preparation. If you use a conventional planter, whole stalk or billet, you must obtain a suitable soil tilth before planting. You know your soils better than we do, but remember that most soils require only limited tillage to produce a satisfactory seedbed for sugarcane. Excessive tillage using aggressive implements, such as a rotary hoe, will lower organic matter, producing a poorly structured soil that will reduce crop establishment. Poorer soils will degrade quicker than better soils. The move by growers to new or modified planting machinery will result in the industry moving away from over-worked, finely powdered seedbeds.

The idea that a well-tilled, fine soil is essential for sugarcane germination and establishment is incorrect if improved planting machinery is used. Many growers have significantly reduced the number of times they till fields and are seeing the benefits of minimum- and no-tillage planting. Good soil structure and moisture conservation associated with minimum tillage provide ideal conditions for germination. With improved planting equipment such as double-disk planters and modified planters with narrow planting chutes, you won't need as much, if any, tillage for seedbed preparation. Be aware of the needs of your planting equipment and use only enough land preparation to prepare a suitable seedbed.

Is soil temperature important?

Soil temperature is a critical variable for sugarcane germination and emergence. Time to sprout differs between varieties, but relies on accumulating temperature-day units. Establishing cane using fewer days at higher soil temperature will reduce loss through disease and insect damage. Cane should not be planted:

- when soil temperatures at the sett are below 18°C;
- immediately before or after heavy rainfall when soil temperatures may rapidly decrease, particularly in late autumn or early spring.

You should regularly measure the temperature of your soil before planting and during crop establishment. This will allow you to determine causes if crop establishment is poor. Remember that plant rows running from north to south may have soil temperatures in the sett zone up to 10°C higher than rows running east to west. If planting early, plant into your well-drained and trash-free blocks first, but check soil temperature before starting.

PLANTING THE CROP

How much soil cover?

Sugarcane plants can emerge from a range of soil depths, but, as the cover of soil over the sett increases, plant emergence is slowed and fewer plants will emerge and establish. The best soil cover will depend on soil type, time of year and local conditions, but usually 40-65 mm is acceptable. Disk-type soil coverers are best on conventional planters, as these coverers are easily adjusted and suit a wider range of soil types than fixed tines. Stop regularly during planting and dig in the furrow to check the amount of soil covering the sett. This is particularly important if soil type changes.

Is soil firming required?

Effective presswheels are essential components of both whole stalk and billet planters. However, many presswheels are not effective (see *BSES Bulletin* No 59, July 1997). Those with high soil-firming pressures significantly improve both the rate and the percentage of crop establishment. Rollers are not recommended as they generally have lower pressing forces and will firm excessive area. Tractors must NOT be used to press the soil after planting as the planted billets can be damaged.

Using an effective presswheel on the planter ensures:

- only soil covering the sett is pressed (why press other parts of the field and make it easier for weeds to germinate?);
- an extra field operation for soil firming is not required, as the furrow is opened, sett placed, furrow closed and soil firmed, all in one machine pass; and
- depth of soil cover on the sett is more uniform.

How should fungicide be applied?

Fungicides will protect billets against soil-borne diseases, particularly pineapple disease. However, they are only effective at protecting sound billets with two or more nodes and no pipes. You have a choice of fungicides that are registered for use on sugarcane, but use all as in the label instructions. Mercury-based fungicides also stimulate germination, but the future availability of this product is limited.

Most planters use a billet-dip system, a spray system, or a combination of both. There is no advantage of one system over the others, although systems that recirculate the fungicide solution are prone to soil contamination and many have been modified by owners, making comparisons difficult.

Fungicide application systems can be tested by adding a marker dye to the tank. After application, cut ends of the billets MUST be completely covered by the fungicide solution. Make sure that you clean fungicide-dip tanks regularly, as they can become polluted with soil and weed seeds. In many areas, dip tanks are becoming less popular as billet planting is adopted. Spray systems must use low pressure (maximum 70 kPa *10 psi*) and large orifice nozzles to produce large droplets that give effective billet cover and minimal spray drift.

Is insecticide needed at planting?

In some areas an insecticide may be required to control wireworms and other pests that attack the germinating buds. Insecticides used to control these pests should only be used as specified on the label instructions. They are usually sprayed from a gravity-fed tank directly over the billet as it is placed in the furrow.

How do I apply fertiliser at planting?

Planting fertiliser is usually placed beside the billets during planting, usually on the sides of the furrow. Take care to prevent contact between the fertiliser and the billet, as the fertiliser can burn the young shoots. Minimum- and no-tillage plantings often require fertiliser and setts to be placed in the same soil slot. In these cases, use reduced rates of low salt index fertilisers (DAP and sulphate of potash type fertilisers) to minimise toxicity to the emerging plants. Additional fertiliser can be applied after the crop has established using a disk coulter rig. Allowable fertiliser rates will depend on fertiliser type, soil type and planter opener so discuss reduced tillage fertiliser options with your BSES extension officer.

What about the billet metering system?

Metering system of a billet planter should supply high quality seed billets at a uniform rate, with acceptable levels (very low) of 'misses' or 'multiples' within the planted row.

Whole stalk or whole stick planters, when supplied with high quality cane, are the most uniform and precise planters available. The use of a ground-wheel drive system and positive feeding of the sugarcane stalk ensures uniform plant spacing over a range of ground speeds. The high labour requirements of wholestalk planters mean they are becoming less popular. These machines should be used to plant all nursery plots to maximise the area planted by a given quantity of seed cane.

All current billet planters use mass-flow billet-metering systems that typically have poor singulation of billets and need high planting rates. At lower planting rates, they commonly deliver clumps of billets and then gaps with no billets this leads to poor plant spacings. Planting rates of billet planters are often at least double than for whole stalk planters to reduce the number of gaps along the planted row.

on less fertile soil types. Growth may be controlled or limited by strategic applications of non-systemic herbicides and/or the early season slashing of the seed plants to ensure that the plants are ready at the appropriate time.

Research into suitable growth inhibitors to economically control internode spacings or products to stimulate germination of eyes on the cane sett is continuing.

Where should I propagate plants?

Growing cane for plants does not require the same inputs as a commercial crop. The best soils on the farm should not be used to propagate plants, but don't use the worst ones either. Soils should be well drained and ideally have little or no slope. The site should be readily accessible by machinery and be weed free.

Limited natural rainfall and readily available irrigation is ideal, as you can 'control' plant growth.

Plant for propagation only in clean (free from volunteer sugarcane plants), fallowed blocks. **Never** plant into plough-out replant blocks.

Pests, such as weevil borers, bud-moth borers and wart-eye mites, should be avoided if possible. Cane should be inspected for these pests and, if they are heavily infested, use plants from somewhere else.

MACHINERY ISSUES

What harvester should I use?

Sugarcane must be harvested with the appropriate machinery to produce the highest quality planting billets. Billet-planting systems require a modified harvester to supply billets, as commercial machinery is often too aggressive and will cause excessively high levels of billet damage. Our field tests have shown that a combination of **erect, high-quality cane and the use of machinery specifically modified for the production of planting billets** can produce planting billets of equivalent quality to those from a whole stalk planter. It is vitally important that the harvester operator is very aware of all the factors that contribute to the production of quality planting billets and takes due care when operating the harvester.

The harvester to cut planting billets should be modified with:

- feedtrain rollers speed optimised to BSES specifications (ratio of roller speed to chopper speed is critical to ensure clean cut of the billet);
- rubber-coated feed rollers to minimise rind damage;
- reduced cane knockdown angle to prevent splitting of the cane stalk.

(See the publications *Get Better Planting Billets by Modifying Your Harvester* and *The Harvesting Best Practice Manual for Chopper-Extractor Harvesters* available from BSES Limited offices)

An underslung basecutter box is best for cutting plants, but these are not commonly used in the industry. When using the leg-type basecutter box, remove all feed paddles or aids from

APPENDIX 3 – Update on rubber-coated rollers

INFORMATION SHEET

UPDATE – RUBBER-COATED ROLLERS

Rubber-coated harvester feed rollers help produce high quality billets for planting. A modified harvester owned by Gary and Sandra Walk of Bundaberg was described on pages 3 and 4, BSES Bulletin No. 66 April 1999. Since then several other planting contractors have undertaken the same modifications on their harvesters. This sheet includes additional details on the roller coating process and usage of modified harvesters.

The coating used on the rollers is a 95% natural rubber from Malaysia. Because of the manufacturing process, this product has very high wet-abrasion strength. This relatively soft, but tough, rubber ensures good wet grip and hence positive feed of the cane. The rollers were coated by:

Linatex Australia Pty Ltd
108 Grindle Road
ROCKLEA QLD 4006
Telephone: 07 33639200

This is a new product for this company. The initial rollers had longitudinal grooves to assist feeding of the cane. The Walk's paid about $850 to have the first roller coated, but prices have reduced to $340 each for batches of 8. The rubber coating exhibits sufficient 'softness' to ensure positive feed and the grooves appear to be unnecessary. Rollers currently used are without grooves and are coated for $250 each (for batches of 8).

Life expectance of the coating is not yet fully known at this stage, but to date the Walk's harvester has cut about 40 000 tonnes of cane and the roller coating is showing only minimal wear. Some sticks and stones were present in the areas harvested and limited abrasion damage has occurred to the rubber coating on the lower feed rollers.

Only limited roller preparation was required prior to coating. Rollers had all bars removed and were ground to a smooth finish with a hand-held grinder. The direction of rotation must be specified on the rollers as this determines how the joining splice is made to maximise coating life.

Roller speeds MUST be altered to ensure all rollers have the same surface rotational speeds. This is a task for a 'good hydraulics expert' (*Ensure you can find one, beware of the rogues*). Adjust roller speeds by speeding up the few slower rollers, rather than slowing down the faster rollers. This is best achieved by re-kitting the smaller chopper motors so both are the same, eg 30 cu ins and re-kitting the bottom roller motors to the same sized cartridge as the upper roller motors. The chopper motor size change will marginally slow the choppers, but this is not a major issue when cutting billets for plants.

A harvester with rubber-coated rollers will be used for limited commercial cutting during this harvest. This will ensure a significant amount of cane will be harvested by this machine and give an accelerated wear test of the roller coating.

Additional Comments:
Check that the chopper is cutting cleanly. Sharp and thin chopper blades will produce the best cuts. Depending on the chopping system, some billet damage may be produced by the thrower bars. This results in billets with surface splits in the middle of the billet. Damage may vary from fine cracks to major indentations. Removal of the thrower bars or a similar modification may increase the percentage of high quality billets. Research has shown that when cutting brittle canes, the differential chopper system may cause less billet damage than a conventional chopper system. Lodged cane produces poor quality billets and badly lodged cane will produce very poor quality billets. This means poor plant strikes.

APPENDIX 4 – Rubber-coated rollers – second update

BSES Advancing Sugar **INFORMATION SHEET**

RUBBER-COATED ROLLERS - SECOND UPDATE

To produce high quality billets for planting requires rubber-coated harvester feedrollers and a modified feedtrain. The rubber coating on the feedrollers ensures minimum damage as the cane is conveyed through the machine. A uniform speed feedtrain ensures uniform length billets are produced. The first harvester, modified by Gary and Sandra Walk of Bundaberg, was described on pages 3 and 4, BSES Bulletin No. 66 April 1999. There has been significant adoption of these harvester modifications in the last 3 years. This sheet includes additional details on the roller treatment process and usage of modified harvesters.

Rubber Coating Rollers

The coating used on the rollers is a 95% natural rubber from Malaysia. Because of the manufacturing process, this product is highly resistant to wet-abrasion. The relatively soft, but tough, rubber ensures good wet grip and hence positive feed of the cane through the harvester. The rollers are lagged by:

Tastex Linings	or	Linatex Aust Pty Ltd
10/60 Coulson St		PO Box 7292
WACOL QLD 4076		GARBUTT QLD 48145
Telephone: 07 3271 6303		Telephone: 07 4753 3900
Fax: 07 3271 6305		Fax: 07 47533905
Email tastex@bigpond.com		Email linetex@ultra.net.au

Both companies are experienced in the lagging process and use a similar lagging material. Other manufacturers are offering coatings but with a lower quality material. Most contractors have opted for the more durable and expensive material quoting the removal and refitting of rollers into the harvester as a time consuming operation that they only want to do once. Tastex Linings have quoted $230 per roller – 20 mm coating (to be held unit Jan 2002). Linatex are currently charging about $280 per roller - 25 mm thick coating.

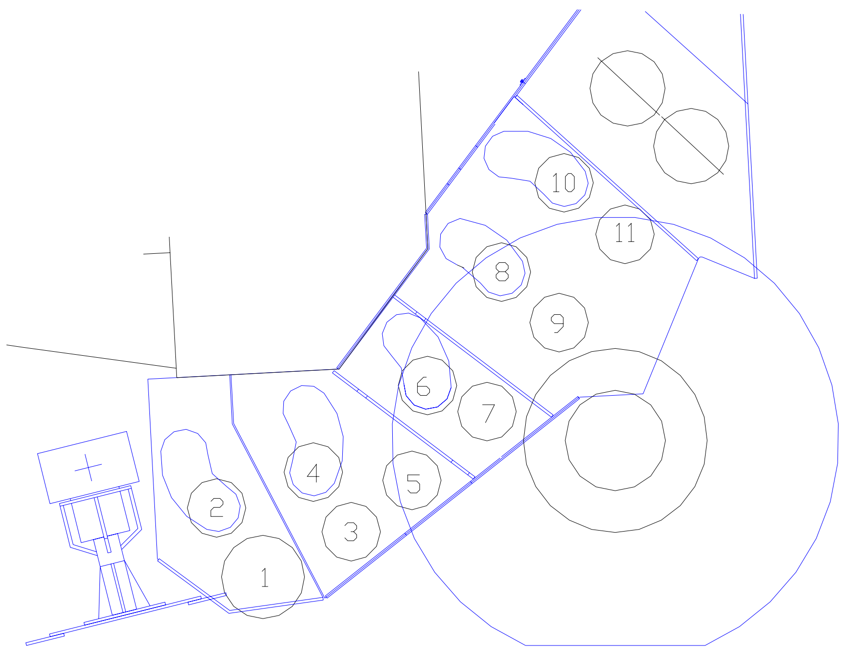
Roller Preparation

Only limited roller preparation is required prior to coating. All 'sharks teeth' bars must be removed and the roller ground to a smooth finish using a hand-held grinder. Depending on age and condition of rollers, new rollers may sometimes be the cheaper option. The direction of roller rotation must be specified as this determines how the joining splice is made to maximise coating life.

Feedtrain Roller Speed Modification

Roller speeds MUST be altered to ensure all feedtrain rollers have similar surface or tip rotational speeds. The rubber coating minimises billet damage while the constant speed feedtrain ensures uniform length billets and further reduces billet damage. Current commercial cane harvesters are NOT supplied with feedtrain rollers of similar surface or tip rotational speeds.

Due to hydraulic system variations between different makes and models of harvesters, it is not possible to give a concise description of how to achieve a uniform feedtrain speed. This is a task for a 'good hydraulics expert' (*Ensure you find one!*). Adjust roller speeds by speeding up the few slower rollers, rather than slowing down the faster rollers. This is best achieved by re-kitting the smaller chopper motors so both are the same, eg 30 cu ins and re-kitting the bottom roller motors (1 to 5) to the same sized cartridge as the upper roller motors (6 to 11). The chopper motor size change will marginally slow the choppers, but this is not a major issue when cutting billets for plants.



When adjusting roller speeds, work down the feedtrain from the chopper motors and aim to have:

- The ratio of cane roller tip speed/chopper tip speed of 0.6 – 0.7
- All rollers, 1 to 11, must have similar tip speeds (if the buttlift roller, number 1 on above diagram, is of a larger diameter its speed must be proportionally reduced to ensure correct tip speed).

Key points

- One chopper motor may have to be changed to match the size of the largest motor. (These two motors are sometimes used to divide the hydraulic oil flow.)

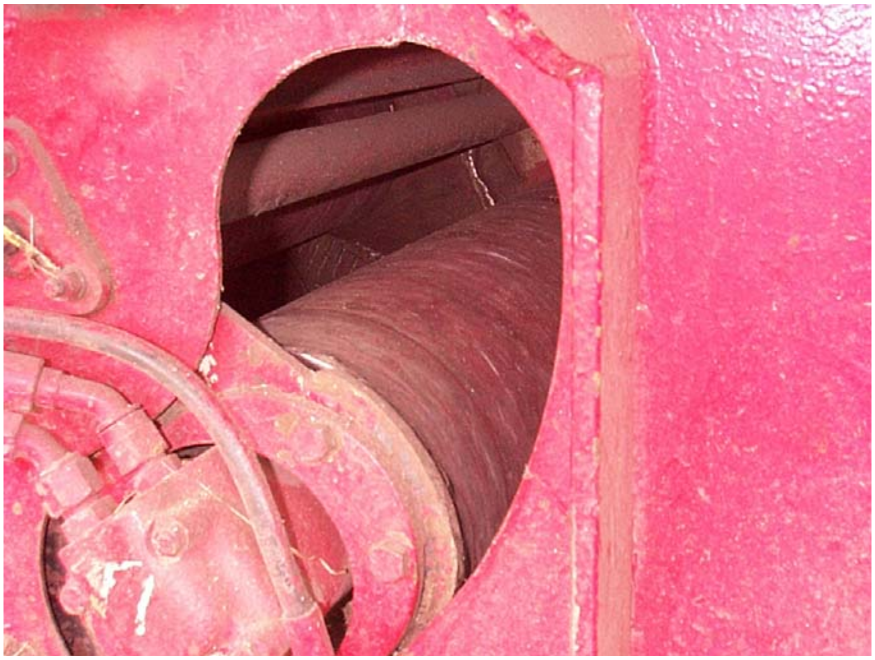
- Increase the speed of the lower rollers to match the speeds of the upper motor group (note the effect of the larger buttlifter diameter).

***Additional Comments*:**

Check that the chopper blades are cutting cleanly. Sharp and thinner basecutter and chopper blades will produce the best cuts. Depending on the chopping system, some billet damage may be produced by the thrower bars. This is evident by billets with surface splits in the middle of the billet. Damage may vary from fine cracks to major indentations. Removal of the thrower bars or a similar modification may increase the percentage of high quality billets. Research has shown that when cutting brittle canes, the differential chopper system may cause less billet damage than a conventional chopper system. Lodged cane produces poor quality billets and badly lodged cane will produce very poor quality billets. This means poor plant strikes.

One harvester fitted with rubber-coated rollers was used for commercial cutting of cane during the 2000 harvest. After cutting about 30,000 tones of cane, this operator claimed improved feeding of cane and better cleaning that resulted in lower EM readings. Coating wear has been minimal. The coated rollers have been tested under a wide range of wet and muddy conditions with positive cane feed and minimal mud build up. Life expectance of the coating is not yet fully known, but to date the Walk modified harvester has cut about 80 000 tonnes of cane and the roller coating is showing acceptable wear. Some sticks and stones were present in the areas harvested and limited abrasion damage has occurred to the rubber coating on the lower feed rollers. Wear of the roller coating indicate that rubber coated rollers may be a future option for commercial cane harvesters.

Underside view of rubber coated rollers on Austoft 7000



Floating Top Roller (rubber coated) Austoft 7000

APPENDIX 5 – How to assess billet quality for planting

INFORMATION SHEET

How to assess billet quality for planting

It is NOT POSSIBLE to look at a bin of billets and estimate the billet quality – a manual billet assessment MUST be done.

To assess the quality of your planting billets, collect about 1-3 rubbish bins in volume – take all billets not just the good ones. Billet quality is based:

- Variation in billet length
- The number of sound, damaged, and mutilated billets.

Billet length distribution: - sort the billets into categories of 0-100 mm, 100-150 mm, 150-200 mm, 200-250 mm, 250-300 mm, 300-350 mm, 350-400 mm and longer than 400 mm lengths. Weigh each category and then graph or table the results as percentages by weight of the total sample weight.

Then sort each length category into sound, damaged, or mutilated billets. Express the proportions of each category as a percentage (by weight) of the total sample.

Identifying a billet as sound, damaged or mutilated is made easy by using the following guidelines.

Sound Billets are:

- longer than 100 mm with no splits (other than growth cracks). Small rind cracks, less than 40 mm long are not regarded as splits.
- with no section of rind more than 200 mm^2 removed exposing the pith
- with no squashed ends with frequent rind cracks.

Damaged Billets have:

- splits larger than 40 mm in the rind and totalling more than 80 mm per billet or with sections of rind between 200 and 1000 mm^2 removed, exposing the pith.
- no squashed ends with frequent rind cracks.
- all billets less than 100 mm in length.

Mutilated Billets are:

- those, which have been broken, squashed and damaged so that there are numerous rind cracks and a portion of the cane is reduced to a pulpy condition
- billets with more than 1000 mm^2 of rind removed are also classified as mutilated.

Percentage of sound billets of good length is simply the percentage, by weight, of sound billets in all categories greater than 250 mm in length. A figure of 75% or greater for sound billets is quite acceptable.

APPENDIX 6 - Test procedures preferred by ISSCT for mechanical sugarcane harvesters or harvesting systems

INTRODUCTION

To thoroughly evaluate the performance of a harvester or harvesting system requires extraordinary expenditure of resources. Users of harvesting equipment would normally not require such a comprehensive test, especially if they wish to compare a proposed harvesting system with an existing one. Comparative tests where, for example, the user wants to establish the difference in cane quality and quantity for various systems, can be conducted fairly easily.

Research organizations and manufacturers of harvesting machinery on the other hand, would want to evaluate machines in much more detail in an attempt to quantify even small differences between machines or to establish the effect of different settings on a particular machine's performance. For this the test procedures need to be far more elaborate and precise and in some instances, bench testing will be required.

One of the main hurdles in testing a single machine is to establish a standard against which to measure performance and in this case it will have to be the crop as it is presented to the machine. If the potential yield and extraneous matter levels of the cane in the field are known exactly, this can be compared with the product delivered by the machine. Unfortunately it is almost impossible to estimate sugarcane yield sufficiently accurately for this purpose. It is therefore recommended that users of machines should not test a single machine in isolation but should rather conduct comparative testing.

The following test procedures can be used to compare various sugarcane harvesting systems, e.g. hand cutting and loading vs whole stalk mechanical cutting and loading vs chopper harvesting. The purpose of the test and the data required must be carefully considered to ensure that no unnecessary work is done.

Test procedures cover both infield and mill analyses. In many instances more reliable data can be gained for valid conclusions by concentrating all efforts and manpower on infield testing and analyses rather than by diluting the effort to include sampling for mill analyses. On the other hand, if dependable and accurate mill analyses are possible, the infield effort can be considerably reduced.

Wet fields will result in an appreciable amount of soil being included. Unless an acceptable method of determining the soil content is available, tests should only be done under dry field conditions.

Notwithstanding the following recommendations, all published test reports **must provide adequate descriptions** of the actual test procedures used.

COMPREHENSIVE PROCEDURE

Pre-harvest data

1. **Plot size**

   The individual experimental unit on which a treatment is tested will be referred to as a plot. Plots should be chosen to suit field characteristics, e.g. irrigation blocks and harvesting system (size must be adequate to ensure operation of harvester at production rates), but each must yield at least 10 tons. If sampling at the mill is required, the plot size should be big enough for two samples to be taken from the cane of each plot.

2. **Number of replications**

At least ten replications should be conducted per treatment and all relevant data should be recorded for each separate replication.

3. **Design**

For similarity, plots should be paired or grouped if there are more than two treatments. Allocation of treatments to plots within each pair or group should be done randomly (i.e. a statistical randomized design).

4. **Field conditions**

Field conditions for the total trial area should be as uniform as possible, especially with regard to cane yield, height and degree of lodging. The following factors must be noted:

4.1 Yield estimate and yield uniformity (see Annexure A)
4.2 Crop variety; brittleness
4.3 Stalk length and diameter at ground level. Uniformity of stalk height and diameter
4.4 Trash habit (loose or tight)
4.5 Crop state, i.e. plant or ratoon number
4.6 Age of crop
4.7 Green or burnt and burn quality
4.8 Degree of lodging (see Annexure A) and direction of lodging
4.9 Amount of suckering, dead cane, tops, leaves and other extraneous matter (see Annexure A).
4.10 Row spacing, surface profile of the row and row length
4.11 Soil type and moisture condition
4.12 Presence of stones and obstructions
4.13 Width of headlands for turning
4.14 Sketch map of trial area indicating treatment plots and other physical characteristics.

Conducting the test

Cane loses weight and starts deteriorating immediately after it is cut. Operations should therefore be timed to minimize these effects. All plots in a replication should be burnt at the same time if they are to be burned. The same number of plots from each treatment should be harvested per day and the cane should be weighed as soon as possible and not later than 24 hours after cutting.
The speed of operation and setting of components such as toppers, base cutters and extractor fans should be determined by the operator to suit prevailing field conditions and to give acceptable production rates. A constant speed must be maintained. Only experienced operators should be used. Average pour rate or cutting speed must be measured and output per operating hour must be noted. Fuel consumption expressed in litres per ton cane harvested must be measured.

Harvesting data

1. **Cane sample**

For whole stalk cane (cut manually or mechanically) at least ten random samples, each approximately 20 kg, are taken from each plot before the cane is stacked, bundled or loaded. If cane is cut green and subsequently burnt in the windrow, sampling should occur after burning. Samples are taken by removing stalks from all levels of the windrow to ensure that cane from all the rows included in that windrow is represented. The samples of stalks are weighed as they come from the windrow. All tops, trash and other extraneous matter adhering to the stalks are then removed and the clean stalks are weighed again. This gives a measure of the extraneous matter content which is expressed as a percentage of the total sample. If required, the extraneous matter removed from the stalks is sorted into its components which are weighed separately and again expressed as a percentage of the total sample.

Samples from chopper harvested cane are taken directly from the machine. A portable chute (see Annexure B) is hung on the back of the haul-out bin. Samples are taken by signaling the haul-out driver to move forward momentarily so that the harvester discharges directly into the chute. The chute has a door on one side and it remains closed until a sample is required. It is then opened and closed after the sample is collected. This prevents extraneous matter from the secondary extractor entering the sample when a sample is not being taken. At least five random samples, each of approximately 25 kg are taken in this way from each plot. During the sampling procedures, all harvester fans are kept at normal operating levels. It may be more practicable to capture larger samples directly in a trailer, truck or container. Samples of 150 to 300 kg will result in smaller coefficients of variation. Each sample must be analysed immediately for millable cane and extraneous matter and, if required, fractions of millable cane, tops, trash, soil, etc. must be weighed and expressed as percentages of the total sample.

2. **Net cane delivered**

The net quantity of cane delivered at the mill is found by subtracting the estimated amount of extraneous matter, determined by means of the cane sample (from 1), from the gross mass of cane of each plot as measured on the weighbridge, then adding the net weight of all samples taken from that plot. It is essential that the cane from each plot be weighed and recorded separately. Results can then be assessed with the aid of statistical analysis.

3. **Gleaning**

If gleaning is a normal post-harvest practice, this should be done on the trial area and the cane gleaned from each plot must be weighed separately. This information must be shown as a separate item in the trial results.

4. **Cane left in the field**

After all harvesting operations are completed on any plot, the amount of millable cane left behind should be determined. This is done by marking out three random sample sub-plots per plot and proceeding as described in Annexure C.

5. **Billet sampling**

Five samples, each of approximately 20 kg, are taken for each treatment from the cane delivered by the chopper harvester's elevator.

6. **Billet length**

The billet samples are sorted into size categories of 0-100, 100-150, 150-200, 200-250, 250-300, 300-350, 350-400 and longer than 400 mm and the quantity in each category is weighed. Mean billet length can be calculated by assuming the following mean lengths for each category: 50, 125, 175, 225, 275, 375 and an estimate of length for the 400 mm category. The calculation is then carried out as follows:

$$\text{Mean billet length} = \frac{50W_1 + 125W_2 + 175W_3 \text{ etc}}{\text{Total weight of sample}}$$

where W_1 = weight of billets 0-100 mm

where W_2 = weight of billets 100-150 mm

where W_3 = weight of billets 150-200 mm

Standards for acceptable mean billet length vary with weather conditions and the delay between cutting and crushing, from 300 mm in hot, wet conditions to 200 mm in cool, dry conditions.

7. **Billet quality**

The above samples are sorted into sound, damaged and mutilated billets according to the definitions given in Annexure D. The proportions of each category are expressed as a percentage by weight of the total sample.

The suggested method of rating billet quality is to calculate the **percentage of sound billets of acceptable length**. For this classification, sound billets need to be weighed in their respective size categories. The percentage of sound billets of more than 250 mm in length is a commonly used classification. A percentage of 70 can achieved but this is highly dependent on crop conditions and will be less where cane is lodged.

Sound billets:

- those sections of stalk longer than 100 mm with no splits (other than growth cracks) longer than 80 mm in length through one end. Small rind cracks, less than 40 mm long are not regarded as splits. No section of rind more than 400 mm^2 removed exposing the pith, no squashed ends with frequent rind cracks.

Damaged billets:

- those with splits larger than 40 mm in the rind and totaling more than 80 mm per billet or with sections of rind between 400 and 2000 mm^2 removed, exposing the pith. No squashed ends with frequent rind cracks. All billets less than 100 mm in length.

Mutilated billets:

- those which have been broken, squashed and damaged so that there are numerous rind cracks and a portion of the cane is reduced to a pulpy condition. Billets with more than 2000 mm^2 of rind removed are also classified as mutilated.