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Harvester performance testing
Literature review
Loss measurement in sugarcane harvesting

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CONTENTS

Page No.

SUMMARY

In the process of development of a performance testing protocol for sugarcane harvesters, the need for an independent review of the literature pertaining to sugarcane loss measurement became apparent. This review was commissioned by SRDC to concentrate on the methodology of testing. The loss process is shown to be complex and the subject is one where the statistical aid to engineering investigation is so affected by this complexity that great care needs to be taken in trial procedures and analysis to ensure the validity of results. From the examination of recent detailed data, backed up by the historical information, suggestions for future development are included.

The obvious facts from the literature are that:

(a) the classical approach of taking measurements, in the field, of inputs and outputs of the desired clean cane is subject to the effect of variability such that the resources required for the establishment of adequate significance of differences makes the procedure almost impractical;
(b) such testing in a test facility of machine processes can produce adequate results;
(c) the direct method of collecting cane 'lost' does not cater for juice and minute fragment loss. This 'invisible' loss is shown to be a major consideration and its variability between treatments may invalidate comparisons using direct collection methods.

A less obvious matter is the apparent reduction in the sucrose content of the desired clean cane as it passes through the harvest process.

The latter consideration suggests that the measurement of the sucrose weight loss (a dry weight measure) would be of more value than the cane weight loss. Some recent trials have provided information on the sucrose weight of the input and output, and the results indicate that control of variability is superior to that obtained in the clean cane weight analysis.

Future development approaches suggested are:

(a) developing test facility techniques for machine process evaluation. Aim to establish the closure error;
(b) examining the sucrose loss measurement.

1.0 BACKGROUND

The process of harvesting sugarcane to produce a product free of extraneous matter (EM) has always been accompanied by the loss of millable cane. This loss increased considerably with the change from whole-stalk to mechanical billet harvesting and even more with the move into green cane harvesting with the increased demand for removal of extraneous matter. As the industry increased its awareness of the problem, some reduction has occurred. However, the predominating economic demand has been for increased machine throughput, and this has, to some extent, outbalanced the effectiveness of measures to minimise cane loss in harvesting.

Production efficiency entails keeping control of cane loss whilst still producing a clean product at the required throughput. Initially it is necessary to measure the absolute value of the pertinent parameters and then to compare the effects of changes in procedures or equipment. For this, effective measurement of cane loss as well as of cane cleanliness is necessary. Measurement of production efficiency during the harvesting process in the field is a most difficult task because of the practical operational problems and the variability of the crop. Some routine measures have been taken to estimate and control the amount of extraneous matter in the cane supply, but the measurement of loss of cane and of sucrose, even on an experimental basis, has been a major problem. To some extent, this has retarded cane harvester development world-wide.

2.0 OBJECTIVES

The aim of this report is:

(a) to provide a concise summary of the information available on measurement of sugarcane loss and of sucrose loss;

(b) to interpret the information to provide a technical basis for development of the measurement methods making the most efficient use of resources.

3.0 MEASUREMENT METHODS AVAILABLE

Because of the variability encountered in this measurement, it is desirable that important parameters, eg field conditions, machine design and special alterations, be reported to aid comprehension of the reported results.

The many aspects in measurement of cane loss are commented on by Mason, *et al.,* (1980). Some method variations have since arisen but the various classes of methods that have been used to measure cane (and components) loss can be reduced to:

Direct measurement	The material lost per unit area is physically collected and weighed: 'Blue tarp' method. Pick-up or scrap recovery method.
Indirect measurement	The yield per unit area before and that after harvest is determined. The loss is the difference between feed and product calculated from weights and analysis of these yields: Material balance method (on cane). Pol and ccs balance method.
Inferential measurement	This uses a parameter, eg acoustic, which can be calibrated against known loss; cane loss monitors.

Pol is an estimate of sucrose content and ccs is an estimate of recoverable sucrose (commercial cane sugar).

3.1 Direct measurement

Direct measurement is theoretically preferable because only the one error, that of the weight measurement, is involved. The values are reliable to the extent that they are minimum values. However, in practice, the sorting of material from extraneous matter and collection is labour intensive and, as pointed out by de Beer *et* al., (1992), the shattering of cane to juice and minute particles plus dehydration leads to possible severe underestimation. Whilst precision can be evaluated, there is no check on the accuracy unless a material balance with closure error calculation is involved.

The 'blue tarp' method was developed to reduce the labour resources required by concentrating on the primary cleaning fan discharge. It involves placing tarpaulins beside the cane row to be harvested so that material thrown from the harvester extractor/s is directed onto the tarpaulin as the machine passes. The sugarcane fragments are then sorted from this mass and weighed. A modification of this method was used mainly in the extension exercise reported by Linedale (1997) in order to estimate the total cane loss occurring. From comparison of 'blue tarp' loss with material balance loss in the field, a factor of two was adopted to be applied to the 'blue tarp' loss to approximate the material balance loss. At a later stage, an experiment (Ridge, pers. com., 2001) was carried out to refine this factor. Norris and James (2001) summarised this experiment (Appendix 3), which showed that the factor was a non-linear function of the fan speed.

Pick-up or scrap recovery is the physical collection of cane fragments from nominated areas of the harvest area following passage of the harvester. Rozeff (1982; 1995) reports the derivation and use of a factor to apply to pick-up weights varying from 1.3 to 1.5.

3.2 Indirect measurement

Indirect measurement has the disadvantage that the loss measurement is a difference that has contributions from at least two error sources and, in practice, from several.

The clean cane material balance method is:

(a) sample the field crop in the designated block to obtain gross harvestable t/ha (stalk plus extraneous matter);
(b) analyse samples of the field crop to determine the clean cane (stalk only) content. Available yield of clean stalk = (gross yield) x (clean stalk content);
(c) weigh the harvested cane from the designated block to obtain harvested yield;
(d) analyse samples of the harvested cane to determine the clean stalk content. Harvested yield of clean cane = (harvested yield) x (clean cane content)
(e) cane loss t/ha = (available clean cane) – (harvested cane) t/ha;
(f) cane loss % available clean cane = (cane loss t/ha)/(available clean cane t/ha) x100.

The material balance may be closed in the controlled environment of test facility operation, if all outputs could be measured. This step would enable the accuracy of the loss measurement to be checked. In practice, there is always a closure error so that statistics are used to provide an estimate. It is of importance to determine whether the closure error is random or includes a bias. In the field, the balance cannot be easily closed, so that, in general, accuracy can only be inferred from comparisons with test facility results.

While losses in the harvest operation have generally been presented as cane loss, it may be argued that the loss of pol (a sucrose approximation) content is important, or that the loss of ccs (recoverable commercial sugar) content is important since these are the intended products of the present industry. These results also respond to stalk degradation and deterioration that are omitted in clean cane loss.

The pol and ccs loss method is:

(a) sample the field crop in the designated block to obtain gross t/ha (stalk plus EM);
(b) analyse samples of the field crop to determine the gross components (pol and ccs) in cane.
Available yield of components = (gross yield) x (components content);
(c) weigh the harvested cane from the designated block to obtain harvested yield;
(d) analyse samples of the harvested cane to determine the components content. Harvested yield of clean cane = (harvested yield) x (components content);
(e) components loss t/ha = (available components) – (harvested components) t/ha;
(f) components loss % available clean cane = (components loss t/ha)/(available components t/ha) x100.

A major practical difference from cane loss is that the EM analysis of the cane samples is not necessary, and the component analyses required are routinely available at the process section of the factory.

3.3 Inferential measurement

For inferential measurement, a calibration reference is required which must be as precise and accurate as possible. It is probable that this would be supplied through use of a test facility. This method will not be investigated further in this review.

4.0 LITERATURE REVIEW

The following section is an attempt to derive some commonality in the loss sources identified in the literature and the quantifications quoted therein. Many of the papers have corresponding ISSCT references or internal reports which are not cited unless providing new information on cane loss measurement.

Cane loss has generally been expressed as weight of clean stalk per hectare, or as a percentage of the clean cane available per hectare. This is a practical measure developed as an easily visualised concept for use in extension. It differs from the scientific measure which is dry matter. Dry matter is expressed in pol and ccs yields and this concept is developed in this review. In the literature, available cane may be clean field stalk or mill delivered weight and this is often not indicated in the expression. For rough estimation, crops can be assumed to yield 100 t/ha, when the figures are comparable. Cane loss is very variable because of the many influential factors (Appendix 2) and consequently the values determined in experimental trials can only refer to the circumstances of those trials.

In this review, the statistical significance of results is reported at a probability of 0.05 and is termed 5% level.

4.1 Topper loss

Topper cane loss is a result of the variability in height of the growing point of the cane stalks, so that there is a compromise between top material included and cane lost.

Fuelling (1981) reported that erect Q90 showed a standard deviation (SD) of the preferred topping point of approximately 300 mm. When topping 'low' in pre-harvest tests of cane topping, the collection of tops showed a cane loss averaging 4.2% of cane. In the more normal trials, the mean cane loss calculated was 0.5 t/ha and possibly not significantly different from zero.

Hurney and Ridge, (1984) in similar trials found mean loss in burnt cane of 0.89% and 1.75% depending on the method of calculation.

Fernandez (1992) comments on the use of a simulation of the topping operation and found that in typical Cuban crops topping 10-20% above the mean height of the stalk produced a loss of less that 1.0%.

4.2 Gathering and pick-up loss

This loss is due to failure to pick up stalks lodged or knocked down and part stalks formed during the gathering process and dropped. In practice, the material left in the field includes material dropped from all harvesting processes and it is difficult to dissect out the material lost in a specific process from the total material gathered. Thus, in much of the literature the distinction is blurred.

Fuelling *et al.,* (1978) attempted to do this distinction by recording ground loss of pieces above 500 mm in length, and quote a value of up to 3 t/ha in the northern area.

Mason *et al.,* (1978) reported that in replicated trials, total cane picked up after harvest weighed 2.0 – 10 t/ha. This included extractor material.

The doubt on the process source of the material picked up needs to be considered in the following.

4.3 Basecutter and feed-train losses

The gathering and billet producing processes are sources of cane damage. As cane is damaged, cut, etc, juice and often fibrous materials are expelled. This is a source of cane loss that was disregarded for some years. The extent of cane damage itself was a source of concern from the deterioration aspect rather that for the loss aspect. Norris *et al.,* (1998) investigated the feeding of lodged green cane and illustrated the factors contributing to the damage. Developments from this and results are reported by Norris *et al.,* (2000 a and b). The three operating variables of significant influence on loss were pour rate, feed-train roller speeds and cultivar.

Mason *et al.* (1978) report that in an extensive test program in the field, percentages of damaged and mutilated billets from 17 to 33% were recorded with 50% where the chopper blades were blunt.

In the South Johnstone area, in burnt cane, Frost and Stevenson (1980) stated that surveys revealed that sound billets had risen from 30.2% in November 1978 to 58.4% for the whole of 1979. This beneficial rise was contributed to by an intensive extension process.

Norris *et al.,* (1998 a and b) reported on comparative performances of a MF405 and an Austoft 7000 and gave the billet damage results from replicated tests (replication details not given). Sound billets in the product ranged 28.8–62.7% and, at the other extreme, mutilated billets ranged 15.7–38.3%. The MF405 used a blower cleaning device so that ejected material did not pass through the fan. At one trial site, material ejected by this device was collected on a 'blue tarp'. The analysis of this material showed that 33% of the material recovered was mutilated billets. This material had not been through a fan and was feed process damage.

Ueno and Izumi (1993) commented that in their study in green cane, only 4.2–34.9% of the billets produced were undamaged.

Hockings *et al.,* (2000) in investigating chopper operation in the Bundaberg test facility recorded billet damage in the range 22.0–55.0%.

Basecutter performance evaluation was reported by Henkel *et al.* (1979) in which basecutter height was varied in replicated trials. Ground cane losses reported, measured by gathering and weighing of stalk, stubble and butt cane, varied from an average of 0.31 t/ha with the basecutter 50 mm below ground level to 9.52 t/ha with the basecutter 50 mm above ground level. Examination of the data provided indicated high significance ($p = 0.006$) of the results.

The basecutter produces a spray of juice and fine particles, only part of which may be incorporated into the stream heading up the feed-train. The feed-train also attempts to dislodge dirt, and cane particles may also be lost. The chopper and feed-train can create damage due to feeding problems, and the chopper action produces more juice and particles that may be lost. Thus, not only is solid material lost, but also the damaged material remaining will have lost juice with a potential loss of ccs%.

Kroes (1997) related the knockdown and basecutter damage to the loss of cane particles in the extractor. The components of green harvested cane were compared with and without extractors operating. While the experiment design is not given, these component values compared well with predictions from theory. The particle loss recorded was 8.65 kg from a harvested cane sample of approximately 150 kg.

In the paper by Davis and Norris (2001), basecutter losses of 9.7 t/ha (lodged cane) and 3.0 t/ha (erect cane), feed-train losses of 7.0 and 5.3 t/ha, respectively, and ground losses of 3.0 and 4.1 t/ha, respectively, are reported. These measurements were taken by physical collection in the field and it is stated that these averaged results were from extremely variable data. A significant decrease in ccs of stalk material was reported and this will be commented on in the total loss section of this review.

Linedale *et al*., (1993), recording the results of an extensive survey, found variety dependency in pick-up losses. The loss from Q141 was estimated at 73% of the total loss compared with 45% for CP51-21.

Bundaberg Sugar (2001) produced data from a survey of 66 harvests on material, excluding extractor material, gathered after harvest. The amounts averaged 1.0 t/ha from the average yield of 89 t/ha. Loss tended to increase with crop size. Replication was not listed.

4.4 Chopper loss

Moller (1975) reported on a trial where topped clean stalks were artificially stood to simulate rows of cane and harvested using a primary extractor fan only. He reported a ground loss of 4.9% with a standard deviation of 2.4% from two varieties. In a following memorandum, he reported a Massey Ferguson laboratory test where a harvester chopper was used to cut nominal 300 mm billets. The chopper produced small billets and fragments of cane amounting to 3.38% of the feed and there was an unexplained loss of 0.46% of the original weight.

Fuelling (1981) gives results of 'no cleaning' harvest of known weights of cane where weights of the product enabled a chopper loss to be calculated. Note that this presumably included basecutter and feed-train loss. Although the tests were done in duplicate, the cane loss results for MF 305, 12%, and VT6000, 2%, are quoted as variable.

Norris *et al.,* (2000 a and b) provided plots indicating the dependence of damage and loss on operational parameters. The loss mean was 3.4% across all chopper systems tested in optimal set-up.

Recent work (James, 2001) has unpublished data comparing ccs % cane for short and long billet lengths. This work shows that over replicated harvests, the ccs obtained cutting short billets averaged up to 1.36 units lower than that obtained cutting long billets. The short billets had a lower juice Brix and lower juice purity than the long billets. The differences were statistically highly significant. This is an interesting result and the cause deserves further investigation. This loss compounds with the weight loss determined by direct measurement

Hockings *et al.,*(2000) reported on chopper system tests in the test facility. Cane loss was assessed by the mass balance between feed cane weight and that of billets plus large billet pieces. The significance of the mean results is not given, but chopper losses range 1.0–3.0 % (derived from charts).

4.5 Extractor fan loss

In the removal of extraneous matter, billets and cane particles can be entrained in the air stream, (Clayton and Churchill, 1972; Clayton *et al*., 1985). Much of the particle mass formed previously in the gathering, basecutting, feeding and chopping, but held in the cane stream, may be lost. The extraneous matter will be coated with juice spray and this may also be lost in the cleaning. In suction fans, the material extracted passes through the fan and may be shredded so that later identification is impossible. Blower fans allow a measure of identification of particles since these do not pass through the rotating blades.

Moller (1975), in the clean stalk experiment described previously, reported that the recovered extractor loss plus unexplained loss, the latter apparently from a material balance, was 5.9% with SD of 1.3%.

Fuelling *et al.,* (1978), in the dissection of cane left in the field, considered the fraction less than 500 mm long as lost in the cutting, conveying and cleaning systems. Over a range of harvesters and areas, they record values up to 3.1 t/ha for burnt cane and up to 2.5 t/ha for green cane.

Fuelling (1981) used the material balance method to estimate cane loss. The extractors reduced the cane yield by an average of 3.7 t/ha.

Hurney and Ridge, (1984) using the material balance showed a mean loss of 4.04–4.90%.

Ridge and Pearce (1996) report numerous cane loss results used during the testing of extractor systems. Both test facility and field tests are reported, but the detail of the test design is not made clear. The values range up to 22.3% cane loss.

Bundaberg Sugar (2001) found in its survey of 66 harvests that extractor losses determined from pick-up were 0.45 – 13.16 t/ha (mean 2.45t/ha). Replication was not listed.

4.6 'Invisible' loss (material balance closure error)

This is made up of the juice and unidentifiable fine juice-holding particles in the material discarded by the harvester as opposed to the particles able to be identified.

Neves and Perticarrari (1998) reported on work done in a Copersucar test facility in Brazil where the closure of the material balance was termed the invisible loss. For the basecutter this was 0.79%. Operating on SP80-1842 cane with trash, invisible loss for the rollers, choppers cleaning and elevator was 2.38% with the fan speed of 1,350 rpm, and 1.38% at 1,000 rpm. The total harvest invisible loss was 2.17 - 3.17%. The results were lower for the other variety tested and for clean cane feed. There were 10 to 12 replications for each variety and speed, which provided a standard error of the mean of 0.16. Unfortunately, and probably due to resource shortage in the Bundaberg test facility, closure errors appear not to be recorded except in the experiment to estimate the 'blue tarp' factor.

4.7 Total loss

Fuelling *et al.,* (1978), in combining the results of the two fractions collected, record total cane losses of 1.1–3.7 t/ha for burnt cane and 1.7–8.5 t/ha for green cane.

Mason *et al.,* (1978) reported that cane left in the field varied up to 13.2 t/ha, but that the average was 2.3% for burnt cane and 3.0% for green cane. Confidence limits are provided for each variety and machine. It was noted that these values are underestimates of the real situation.

Fuelling (1981) measured the variation of yield in the field and on that basis used nine and 12 replications in cane loss trials on burnt cane. Cane loss was calculated by the material balance method, using the 'no cleaning' results as the yield basis. The loss is given using various combinations of the cleaning devices, topper, primary and secondary extractors and the levels of significance indicated. Over all tests, an average cane loss of 4.1 t/ha and a sugar loss of 1.0 t/ha are shown.

Rozeff (1982) reported that from a very extensive survey in the Rio Grande valley of sugarcane scrap left on the ground after harvest for the year 1979 – 1980 the loss was 9.31% of the net cane. It was stated that the values had been adjusted by an experimentally determined factor of 1.5 normally (1.3 used because of lighter cane) to compensate for crushing and desiccation. Trials conducted during the 1993-94 harvest comparing green and burnt harvest using similar technique are reported by Rozeff (1995). The compensation factor was 1.5 giving a scrap loss average of 20.3% for green and 8.0% for burnt cane.

In Sudan, Burleigh *et al.* (1982) compared the loss in manual harvest with that in mechanical harvesting in a series of replicated field trials. The cane loss was 8.8 % and 22.4%, respectively, of available cane and 8.7% and 25.5%, respectively, of the pol available. These results were significant at the 1% level. A number of overseas papers giving losses of cane during mechanical harvest are cited in this and similar papers, but have not been referenced in this review because the available information appears to be an adequate sample.

Hurney and Ridge, (1984) used the material balance method and used 7-14 replicates per treatment. The basis for calculation of cane loss was the 'no cleaning' yield. In burnt cane, the overall mean cane loss was 5.79 t/ha. Some trials of green cane harvesting gave quite variable results and insufficient results were obtained for any conclusions to be drawn, although a loss of 7.6% on one machine was significant. It was noted that the blower fan speed of the Claas machine had a definite effect on the cane loss; in one case a reduction in fan speed changed the cane loss from 11% to 4%. It was noted that the method using the 'no cleaning' run underestimates the total loss because ground loss and a proportion of basecutter and feed-train loss are not included.

Ridge *et al.,* (1984) emphasised the importance of replication and concluded that the use of a test facility in a controlled environment would allow more accurate determinations to be made.

Because harvester performance results obtained to date were not of sufficient quality to enable fine tuning of the equipment and techniques, a test facility was developed at BSES Bundaberg. Ridge and Dick (1987) reported early results from this development. The system had no normal basecutter operation so that losses were derived from the feed-train, chopper and extractor operations only. The results are presented with the appropriate least significant difference (lsd) of 5%. In the first series, cane loss % ranged 4.2 - 18% with lsd (5%) approx 2%. These results included a chopper loss determined at 3.0% although no confidence limits are indicated. In the second series, a chopper loss reduction from 2.3 to 1.4% could be verified with lsd (5%) of 0.3%. Precision in measuring was found to be superior to those achieved in field tests. Cane loss values for significant (5%) differences in the test facility were 1.9 – 2.3% using 4-5 replicates. In field tests with 6 – 14 replicates, these values were 2.7 – 13.0%.

Further test facility results are provided by Ridge and Dick (1988 a and b; 1989) where the influence of variety on cane loss and the use a portable facility to extend the scope of this work was reported. Typically, four replicates for each treatment were used and provided lsd (5%) of 3.0% for cane loss. Varieties produced cane losses in the range 4.9-18.1% so that reasonable grading was provided.

Ridge (1990) summarised previous work and reported on testing of modifications to enable satisfactory green cane harvesting using the same methods.

The development of a cane monitor was reported by Dick *et al.* (1991) and Dick and Grevis-James (1992) where, initially, test facility trials using material balance showed up to 13% cane loss and chopper loss of 1.9%. In later field trials, clean cane material balance was used to standardise the monitor readings. Replication was used, but the statistics are not provided. Yield losses reported range up to 21.1% in untopped green cane.

The results of a survey of cane loss in green cane harvesting in the Mulgrave area are reported by Shaw and Brotherton (1992). The 'blue tarp' method was used after an elementary calibration was performed during the cane monitor calibrations of Dick and Grevis–James. The results gave some credence to the use of a factor of 2.5 to apply to the tarp cane weights to align them with the material balance results. With these provisos, the average cane loss over the survey period was estimated at 8.2 t/ha. The pooled standard deviation of replicate results about their respective means was 0.84 t/ha. It was noted that the purity of juice in the expelled fragmented material was typical of cane stalk, rather than of tops.

A coordinated extension approach to harvesting is reported by Linedale *et al*., (1993). As an extension tool for cane loss measurement, direct measurement, either physical collection or the 'blue tarp' method, was used with application of a factor of 2.0 to the weight of cane collected. Replication was used to the extent of available resources and thus was not consistent. Extractor losses averages were 0.6 – 2.0 t/ha in burnt cane, 4.3 – 8.1 t/ha in green cane. In trials where the extractor speeds were varied, the cane loss increased progressively from approximately 1.0 t/ha at low speeds to 3.0 to 12.3 t/ha at the highest speeds. Values for precision are not presented possibly because the data were to be used only in awareness demonstration of the problems. In the summation of the campaign (Linedale, 1997), the range of cane loss measured in 1995 was 0.9–5.6%.

The measurement of material left in the cane plots in Okinawa is reported by Ueno and Izumi (1993). They report extractor losses of 2.8 – 15.2 t/ha and uncut cane and dropped material 0 – 8.5 t/ha.

In 1999, Sao Martinho Mill in Brazil conducted a survey of cane loss in its harvesting operations using direct collection (Sao Martinho, 1999). Over 169 harvests by billet machines, the cane loss results ranged 2.93 – 4.02 t/ha, averaging 3.63 t/ha.

Zillman and Harris (2001) described the development of the Jetstream cleaning system. To assess the value of modifications and for comparisons between machines, a 'blue tarp' test was used without application of any factor. Considering all tests, the mean loss percentages recorded for different units were 0.70 ± 0.16, 0.73 ± 0.26, 0.98 ± 0.36 and 5.4 ± 1.5, the confidence levels being for 95% certainty.

Davis and Norris (2001) reported on the investigation into the impact of harvesting on the difference of ccs between field and mill. Trials were conducted in both the field and in the test facility. A considerable drop in ccs % stalk (significant at 5% level) was found between field stalk and the billets in the elevator boot. The disturbing feature is that this ccs loss occurred before chopping into billets. The ejected cane collected on the tarpaulin had an even lower ccs (also significant at 5% level).

Whiteing *et al.* (2001) reports on a series of field trials carried out in 1997 - 2001 to define the performance of later model machines with the aim of establishing optimum modes of performance. Material balance was used to measure total loss and 'blue tarp' method to establish the extractor loss. Data were provided by BSES (2001) on trials in this series. Three and four replicates per treatment were used. Total cane loss (treatment mean) recorded was 0.29 – 31.66 t/ha (mean 9.57 t/ha) and extractor loss 0.36 – 8.19 t/ha (mean 2.60 t/ha). The material balance differences between treatment means were significant at the 5% level in only two trials. Extractor loss differences by the 'blue tarp' method were significant (5% level) in six cases.

5.0 MAGNITUDE OF CANE LOSS

An accurate absolute magnitude of loss is necessary for economic evaluation of harvesting. An accurate magnitude, while not absolute, is necessary for economic comparison of treatments (modifications of equipment or procedures). Technical comparisons may not need this accuracy provided statistical significance is achieved. The following is an outline of the absolute magnitude of loss from the various harvester processes and the total loss.

Table 1 provides a summary of the literature sources of values of loss used to provide the following estimates of reasonably normal values. The loss values are expressed as either t/ha or percentage of original cane. In Appendix 2 of this review, typical harvesting scenarios are presented based on these estimates.

The *direct collection method* indicates a minimum value for each measurement since the highly disintegrated material and juice dispersed and evaporated are unlikely to have been collected. Total cane loss recorded (excluding adjusted 'tarp' losses) from replicated trials varies, 1.1–8.5 t/ha in Australia and 2.8-15.2% overseas.

The 'blue tarp' method (no factor) shows extractor losses approximately 0 - 8 t/ha.

Indirect measurement by material balance shows total loss 4.1–21.1% in replicated trials in Australia with 22.4% in replicated trials in the Sudan. Australian work indicates the total is the sum of contributions from topper loss 1.75%, ground loss 0.31–9.5 t/ha, basecutter loss 3.0 - 9.7 t/ha, feed-train 4.1–7.0 t/ha, chopper loss 1.0–4.0% and extractor loss to 6%, although some of these results are said to be from very variable data. Added to this is invisible loss 2.17 – 3.17% measured in Brazil in well replicated trials. This invisible value is due to contributions from basecutter to 0.79%, feed-train to 1.38% and chopper to 2.38%.

Cane damage results varied 17–62.7% and this was typical of both Australia and overseas. The result of this is seen in the figures given by Burleigh *et al.* (1982) where the pol loss was 3.1% above the cane loss and in the ccs in clean cane losses reported in Australia.

The above summary illustrates the variability of cane loss depending on the circumstances, and the possibility of extremely significant loss. However, loss in weight of pol and ccs is shown to be an even more important item, strongly influenced by cane damage.

Table 1 Cane loss references dissected by loss source

			Loss Source											
Reference (abbreviated)	Year	Method	Topping	Ground	Base cutter	Feed train	Chopper	Extractor fan	Total	Sugar	Damage	Invis ble	Not pub.
Berding *et al.*	2002									#			
BSES	2001	Both							#				#
Bundaberg Sugar	2001	Coll.*							#				#
Burleigh	1982	M.B.**							#	#			
Clayton J	1972							#					
Clayton *et al.*	1985							#					
Davis & Norris	2001	Both		#	#	#	#	#		#			#
de Beer *et al.*	1983	Coll.										#	
Dick & Grevis-James	1992	M.B.							#				
Fernandez	1992		#										
Frost & Stevenson	1980										#		
Fuelling	1981	M.B.	#			#		#	#				
Fuelling *et al.*	1978	Coll.		#					#				
Henkel	1979	Coll.		#									
Hockings *et al.*	2000	M.B.					#				#		
Hurney *et al.*	1984	M.B.	#						#				
Ivin & Doyle	1989									#			
James	2001									#			#
Kroes	1997			#	#								
Linedale *et al.*	1993	C"tarp"f***							#				
Linedale	1997	C"tarp"f							#				
Mason *et al.*	1978	Coll.							#		#		
Moller R.B.	1975	M.B.					#	#				#	#
Neves & Perticarrari	1998	M.B.			#	#	#					#	#
Norris *et al.*	1998	Coll.			#	#	#	#					

			Loss Source										
Reference (abbreviated)	Year	Method	Topping	Ground	Base cutter	Feed train	Chopper	Extractor fan	Total	Sugar	Damage	Invis ble	Not pub.
Norris et al.	2000	Both					#						
Ridge	1990	M.B.							#				
Ridge et al.	1984	M.B.							#				
Ridge pers. com.	2001	Both							#				#
Ridge & Pearce	1996	M.B.						#					
Ridge & Dick	1987	M.B.					#		#				
Ridge & Dick	1988	M.B.						#	#				
Ridge & Dick	1989	M.B.					#		#				
Rozeff	1982	Coll.							#				
Rozeff	1985	Coll.							#				
Sao Martinho	1999	Coll.							#				#
Shaw & Brotherton	1992	C"tarp"f							#				
Ueno & Izumi	1993	Coll.		#				#					
Whiteing	2001	Mat.Bal.****							#				
Zillman & Harris	2001	C"tarp"f						#					

* collection; ** mass balance; ***c'trap'f – collection by tarpaulin; **** material balance

6.0 DISCUSSION

6.1 The loss process

The pattern of cane and ccs loss is complex and, because of the large damage figures shown, the process as it appears from the literature is described. This is to provide a basis from which to assess measurements.

The harvester gathering process can cause stalk damage, which includes fracture, particularly in lodged heavy crops. In damage of cane stalk, particles of juice bearing material and juice itself are expelled from the stalk. In basecutting and in the feed-train, where the cane is shaken to remove dirt, and subjected to pressure, more damage occurs. Some of the particles, including part stalks in the gathering process, escape from the stream and become 'ground' loss. Juice may fall to the ground and become loss or it may coat billets and trash. Then, in the chopper, not only are juice and particles expelled, but offcuts at the end of stalks are formed.

In the extractor, any material under billet size has a greater probability of being expelled with extraneous matter. Thus, loss from the extractor is not only from entrained billets and tops where mutilation occurs, but also includes contributions from the damage that occurred earlier in the process. This, of course, also applies to a secondary extractor. Juice coated on ejected material is also lost.

Thus, field results of ground, basecutter, etc, loss have to be interpreted when compared with the more isolated process values available from test facilities. The addition of component losses to attempt to estimate total loss is not generally reliable.

In the same way, in harvest, both the cane stalk weight and the ccs content of that stalk decrease. Thus, the cane loss is theoretically an underestimate of the stalk ccs weight loss, which is the crucial figure.

From this viewpoint, the problem is both multifaceted and of major proportions. Berding *et al.,* (2002) reported that in series of trials over two seasons in green cane, the ccs of the green cane supplied to the mill was virtually unchanged from that of the gross available material in the field. This was in spite of the obvious removal of extraneous matter during harvest. In effect, as much sound cane was discarded as was extraneous matter

Precision of measurement (see below) is fundamental to evaluation of the resources required. However, evaluation of the results on precision alone is insufficient since treatment results may suffer from different bias from the absolute value. In practice, the 'invisible' loss is the bias. For extractor fans, in Appendix 3, it is shown that the 'invisible loss' at 1,000 rpm of 1.3% (9.6–6.4 kg) increased to 6.7% (24 – 8 kg) at 1,450 rpm, while the actual 'blue tarp' loss increased from 2.7% to 3.3%. Thus, in a comparison, the actual difference between treatments was almost masked by the bias introduced by 'invisible' loss change.

6.2 Precision

Precision is defined here as the variability of the sample results within treatments about the mean. It is expressed here as the standard error (SE) within treatments.

The importance in the design of trials is shown in the following exercise.

The range of cane loss involved in most investigations is 0–15% of available cane (say, 8% as the middle of the range). For various numbers of replicates, the SE of treatment cane loss mean needed to achieve significance at 5% for:
(a) a difference from zero cane loss;
(b) a difference of 2% from a similar treatment mean;
is shown in the table below. The difference of 2% is considered quite adequate for treatment comparisons. This table provides a basis for evaluating the information in the following summary.

Replicates	**SE of treatment mean required**	
	(a) diff. from zero	(b) diff. of 2% from mean
15	14.4	2.6
10	11.2	2.0
5	6.4	1.1

6.2.1 Direct measurement

The precision of the measurement can be estimated where the results from replicates of treatments are recorded. Zillman and Harris (2001) report confidence limits (at 5% level) of 0.16 – 1.5% for cane losses in the range 0.70 – 5.4% for the 'blue tarp' method. The confidence limits (at 95% level) correspond to standard error values 0.08 – 0.75 t/ha (SE = (lsd / $t_{0.05}$) x $\sqrt{(n-1)}$) and are in % units of the available gross harvested crop. In that work, replication within treatments was not utilised and the confidence limits were calculated from aggregations of data.

An extensive set of results provided by BSES in 2002 is summarised in Table 2. The average standard errors within treatments of the loss values, and the mean loss value derived from analyses of variance, are:

	SE cane loss	**Mean**
'blue tarp' t/ha	0.71	3.3
'blue tarp' with factor applied t/ha	1.43	5.2

The factor used was a non-linear function of the extractor fan speed. Any use of the statistics must consider this.

In the 'normal conditions' trials reported by Mason *et al.,* (1980) the range of trial mean pick-up loss as a percentage of the total of harvested clean cane plus pick-up, was for green and burnt cane, respectively, 0.9–5.4% and 1.4–6.4%. Whilst cognisant of the possible skew in such results, a very approximate test measurement standard error of 1.7% is inferred, ((range / 6) x n^0.5).

6.2.2 Indirect measurement

Table 2, derived from green cane data given in BSES (2001) shows typical average sample standard errors of the loss values within treatments and also the mean loss values for clean cane, pol and ccs.

Component	SE loss t/ha	SE % field	Mean loss t/ha	COV %
Clean cane	7.55	6.99	8.52	88.6
Pol	0.60	2.90	2.72	22.1
ccs	0.60	3.03	2.38	25.2

The coefficient of variation (COV), which expresses the standard error as a percentage of the mean, is much less for pol or ccs losses than for clean cane.

The least significant differences (lsd) between treatment means reported by Fuelling (1981) and by Hurney and Ridge, (1984), mainly in burnt cane, indicate that for the cane loss between treatments the standard error was approximately 6 t/ha, (SE=(lsd)/$t_{0.05}$) x √(n/2)) where n = number of replicates. Both these trial series used clean cane material balance methods. This value is slightly under the value shown in the table above, perhaps reflecting the effect of green harvest. Fuelling (1981) showed 0.7 t/ha SE for ccs loss, calculated by a similar procedure.

The loss is the difference between two yield values. Each treatment yield was subtracted from the mean of the trial field yield values. For comparison, from green cane data of BSES (2001), the standard errors and means of these yields are given below:

	SE t/ha	Mean t/ha
Field cane yield t/ha	8.02	131.0
Net yield clean cane t/ha	5.91	110.3
Pol yield t/ha	0.88	16.2
ccs yield t/ha	0.77	15.1

In experiments run in the test facility at Bundaberg BSES, as reported by Ridge and Dick (1987), the cane material balance method was used. The lsd (5%) values quoted ranged 1.9 – 2.3%. The number of replicates per treatment was 4 – 5 so that the standard error of cane loss values was under 2.0. In the use of the portable rig in other districts, using four replicates, an lsd of 3% was reported (Ridge and Dick, 1988 a and b), indicating a standard error slightly above 2.0%.

It is apparent that for identifying the difference in results from harvester hardware or techniques, the precision shown for direct methods and by the test facility is adequate with a reasonable replicate number. That shown for field trials using cane material balance imposes limits on comparisons due to the number of replications required. The pol and ccs field methods show promise because the precision indicated approaches that required for the 2% loss difference used in the table at the commencement of this section.

TABLE 2 Means and probability from analysis of variance of BSES Trials 1997-2001

Trial	**Tre**	**Rep**	**tarp raw t/ha**			**tarp adj'd**					
			mean	**SE**	**prob.**	**mean**	**SE**	**prob.**			
			t/ha	**t/ha**		**t/ha**	**t/ha**				
T7 18/8/97	3	3	2.08	1.10	0.251	3.72	1.56	0.046			
T8 20/8	3	3	3.32	0.69	0.800	6.63	1.37	0.800			
T9 22/8/97	4	3	2.75	0.77	0.073	5.86	1.42	0.003			
T10 28/8/97	3	4	1.86	0.63	0.536	3.73	1.26	0.536			
T11	3	3	1.22	0.58	0.322	2.57	1.21	0.322			
T12	4	3	1.77	0.41	0.083	3.48	0.59	0.001			
T13	1	3	7.95	0.49	0.000						
T14	3	3	6.57	1.05	0.020	13.46	2.34	0.007			
T16	3	3	1.53	0.61	0.017	3.20	1.42	0.009			
T17	3	4	2.56	0.67	0.005	5.30	1.49	0.002			
Vasta18/8/99	3	4	1.78	0.51	0.000	3.88	1.10	0.000			
GS&FS12/8/99	3	3	5.93		0.001		1.33				
Ext 11/9/01	3	3									
			highly significant		blue	signif.	red		signif. @	.05 - .15	green
all	mean		3.28	0.71		5.18	1.43				
T12 T17	mean		4.08	0.68		6.36					
Trial			**M.B. cane loss t/ha**			**pol. loss t/ha**			**ccs loss t/ha**		
			mean	SE	prob.	mean	SE	prob.	mean	SE	prob.
				t/ha			t/ha			t/ha	
T7 18/8/97	3	3	5.83	5.05	0.290						
T8 20/8	3	3									
T9 22/8/97	4	3	11.48	2.67	0.000						
T10 28/8/97	3	4	16.55	5.76	0.962						
T11	3	3	7.59	2.73	0.352						
T12	4	3	2.71	4.99	0.856	3.44	0.63	0.717	3.36	0.62	0.637
T13	1	3	11.83	9.18	0.041	3.24	0.47	0.000	2.89	0.41	0.000
T14	3	3	16.38	11.97	0.565	2.14	0.36	0.016	1.64	0.35	0.026
T16	3	3	3.02	10.82	0.491	2.25	0.88	0.230	1.85	0.84	0.278
T17	3	4	10.90	6.04	0.122	2.53	0.54	0.025	2.17	0.51	0.027
Vasta18/8/99	3	4	4.04	8.78	0.481						
GS&FS12/8/99	3	3	3.44	8.36	0.249						
Ext 11/9/01	3	3									
all	mean		8.52	7.55							
T12 - T17	mean		8.97	9.01		2.72	0.60		2.38	0.60	
Trial			cane loss %			pol loss %			CCS loss %		
			mean	SE	prob.	mean	SE	prob.	mean	SE	prob.
			%	%		%	%		%	%	
T7 18/8/97	Data unavailable										
T8 20/8	Data unavailable										
T9 22/8/97	Data unavailable										
T10 28/8/97	Data unavailable										
T11	Data unavailable										
T12	4	3	2.43	4.48	0.856	15.56	2.82	0.717	16.21	2.99	0.637
T13	1	3	8.19	6.36	0.041	14.45	2.10	0.000	13.98	1.98	0.000
T14	3	3	12.46	9.06	0.391	12.23	2.05	0.016	10.67	2.27	0.026
T16	3	3	2.54	9.08	0.491	10.79	4.24	0.230	9.77	4.46	0.278
T17	3	4	7.93	4.39	0.122	12.71	2.73	0.025	12.03	2.83	0.027
Vasta18/8/99	Data unavailable										
GS&FS12/8/99	Data unavailable										
Ext 11/9/01	Data unavailable										
T12 T17	mean		6.71	6.99		13.15	2.90		12.53	3.03	

6.3 Accuracy

Accuracy is defined as the bias of the estimate mean from the real value. Thus a measurement may have high precision but the mean may have a significant bias as compared to the true value.

In the interpretation of results, care has to be taken that the scope of the measurement is clearly understood. For instance, the unadjusted 'blue tarp' loss is normally a measurement of the material ejected from the primary extractor. Comparison with a 'total' loss ignores the factors that vary the gathering loss.

6.3.1 Direct measurement

In the direct measurement methods, it is obvious that the result, if dissection of cane from extraneous matter is carefully done, is an accurate representation of the *minimum value* of the cane loss. The papers by Rozeff (1982; 1995), Burleigh *et al.* (1982), Bundaberg Sugar (2001), Sao Martinho (1999) and Ueno and Izumi (1993) provide a range of values for this minimum loss – although Rozeff does have a compensation factor for sample crushing and desiccation. In a comparison of machines, Zillman and Harris (2001) give values provided by the 'blue tarp' method. Those provided by Shaw and Brotherton (1992) and Linedale (1993) by the 'blue tarp' method have an adjustment factor applied and cannot be regarded as minimum values.

No estimation of 'invisible' loss or of sugar loss is available from these methods. The comparison of mean loss values with other methods indicates that the underestimation because of this may be major in many cases. This is indicated in Figure 1 that is taken from trial results which had significance (at 5% level) reported by BSES (2001). The presentation against fan speed is merely to separate the groups for easy identification, as the trials had no relevance to each other. It is shown that for different extractor fan speeds, the ratio between the results from direct and indirect methods alters considerably. The direct result is shown decreasing at the higher speeds. Since this is contrary to deduction on engineering principles in general it places doubt on the use of the direct method for comparisons. If the aim of the project is limited to treatments where engineering theory does not have this contrary view, the direct method may be useful. For absolute loss measurements, because of this underestimation, the likelihood of 'invisible' losses seriously affecting results must be considered in any project.

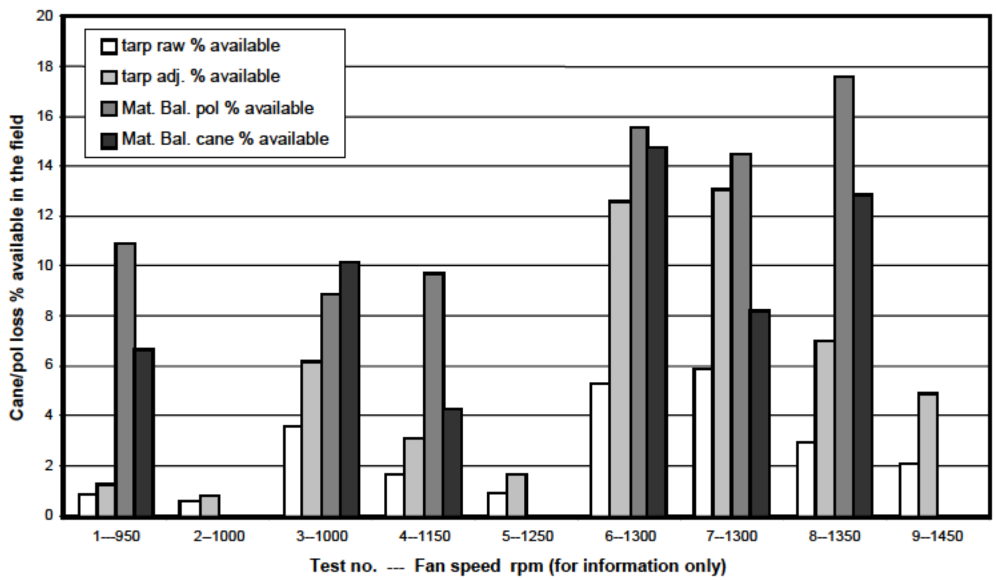
6.3.2 Indirect measurement

In the indirect measurement methods, in theory, an accurate estimate of the total loss can be obtained. This is because a measurement of the input and of the final output is taken and the difference should encompass all possible sources of loss. It is necessary that a satisfactory level of significance of treatment differences be obtained in the results. It is vitally important that an unbiased and precise measure of the available cane in the field is obtained since this is the value against which treatment values are assessed. In practice, a 'no cleaning' treatment is used as the source of the field values. This introduces bias by ignoring the ground loss and much of the basecutter loss.

With respect to pol and ccs loss, the content of bins of uncleaned green cane are of low density, as low as half that of cleaned cane. Mill feeding equipment is not tuned to accept this so there is uncertainty whether the milling of the low density green rakes gives unbiased pol and ccs results.

The only method of determining accuracy is by a combination of the physical collection of loss material and the material balance to determine the difference which is the closure error or 'invisible' loss.

Figure 1 Comparison of treatment loss measurements From BSES 1997- 2001 trials



6.4 Summary

The following table is presented, not as a definitive comparison, but as a basis to foster further development of methods.

Loss meas. method	Precision (SE) % of available	Accuracy	Practical difficulty
Pick-up	1.7	Good for minimum value	Large labour requirement
Blue tarp	0.7	Good for minimum value	Moderate labour requirement
Mat.balances			
Clean cane– test facility	2.0	Good overall	Large resource requirement
Clean cane– field	6.0	Dependent on field measurement	Major resource requirement
Pol–field	2.9	Dependent on field measurement	Moderate resource requirement
ccs– field	3.0	Dependent on field measurement	Moderate resource requirement

The direct methods provide a precise and an accurate *minimum* value of cane loss. In treatment comparisons, the change in 'invisible' losses between treatments has to be evaluated before the results can be substantiated as estimates of real differences.

The indirect (cane material balance) methods can produce an adequate standard error in a controlled-environment test facility. With a weighed and analysed input, the method is also accurate. However, in the test facility, the closure error should be determined as an expression of the accuracy. The full action of the harvester cannot be reproduced in the test facility. The gathering and full basecutter operation require field operation.

In field testing, the precision of the uncleaned field yield becomes a major issue for both precision and accuracy. Because of this and the level of precision of the cleaned rakes, the practicability of the cane material balance method, particularly in green cane, has to be carefully considered.

The pol and ccs material balance methods have the practical advantage that EM analysis is not required and all the weight and analysis data except fibre content can be provided by the normal routine methods of the mill. The disadvantage is that EM does have sugar content. The extent of this content is shown by Ivin and Doyle (1989) and Berding *et al.,* (2002). In the investigation reported by Crook *et al.,* (1999), the mean analyses of EM components taken from unreported data were:

	Pol %	**Fibre %**	**ccs**
Tops	1.48	14.18	-0.55
Trash	2.16	38.48	0.53

The pol was rarely above 2.0% and ccs above 1.5%.

Thus, the uncleaned cane and the harvested cane will have more pol than in the field clean cane while ccs will be relatively unaltered. Investigation (Brotherton, 2002), using a model of the harvesting process derived from the Crook *et al.,* (1999) data, indicates that only in extreme abnormal conditions would the pol and ccs method not be expected to give meaningful results.

7.0 RECOMMENDATIONS

Progress in cane harvester development depends on the reliability of performance testing, including cane and sucrose loss measurement, not only in test facilities, but also in the field.

Where absolute cane loss values are required, indirect test methods are recommended. The clean cane method involves a major allocation of resources, but it is possible to estimate the accuracy. In this method, the other parameter in harvester performance, extraneous matter, is also measured.

For testing of machine process modifications, test facility operation should be considered where possible.

The large ccs % clean cane loss reported during harvest and also during short billet production should be examined, since this would give priority to measurement of the loss of sucrose mass. With the practical advantages of pol and ccs loss methods, these warrant close examination. Towards this, the possible bias in pol and ccs results due to milling of very trashy crops needs to be clarified.

Direct methods including the 'blue tarp' may be considered for simple comparisons where engineering considerations demonstrate that the modifications tested will not affect the 'invisible' loss. For absolute loss measurement, direct methods are one part of the process combining with indirect measurement in closing the material balance.

In the reporting of trials, it is desirable that important parameters, eg trial design, field conditions, machine design and special alterations, be reported to aid comprehension of the reported results.

Regarding statistical terms, I regard the standard error within treatments as fundamental. However, for visualisation, the confidence limits and least significant difference between means can be more meaningful and therefore more useful in practice.

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APPENDIX 1

Typical harvest scenarios

By choosing figures from the references, a typical scenario for harvest with reasonable cleaning is envisaged to demonstrate the typical relative size of losses in the various processes and whether the process losses can be added. Loss is expressed as *cane loss % available cane* in the field. The first column is the loss in the named process. The second column is the portion which is a loss at that process and not carried with the cane stream to a later process. It is then able to be added to give the total loss of total loss.

Burnt cane harvest:

Process incurring loss	%	**Additive loss %**
Topping	0.5	0.5
Gathering	0.5	0.5
Basecutting	2.5	1.5
Associated ccs % stalk loss	3.0	2.5
Feed-train and choppers	2.5	0.5
Extractor fans	2.5	2.5
Total		**8.0**

Green cane harvest:

Process incurring loss	%	**Additive loss %**
Topping	0.25	0.25
Gathering	2.5	2.5
Basecutting	3.0	1.5
Associated ccs % stalk loss	3.0	2.5
Feed-train and choppers	3.0	0.5
Extractor fans	4.5	4.5
Total		**11.75**

'Invisible' losses are not added because the associated ccs % stalk is a component of this.

APPENDIX 2

Sundry information

The following items have application when considering harvest trials and are included for information. Publications referred to are listed in References (section 8.0).

Variation within the field

Crook (1999) in field sampling took six samples of approximately 50 kg by hand cutting the cane complete with EM. For the sound cane, the actual ccs showed a pooled SD over the survey of 1.03% ccs. The corresponding pol % cane showed a result of 0.93 unit.

Kingston and Hyde (1995) found the ccs content of 23-25 tonne rakes of cane had a range of 1.1-2.1 %.

The South Johnstone Cane and Sugar Quality Committee (1980) in extensive sampling of the burnt cane supply in the field using 10-25 kg samples derived a sample SD of 3.30%.

Fuelling (1981) reported the bin weights of twelve consecutive rows of equal length of cane in three sites. Converted to cane yield, the mean and standard deviation values were respectively, 97.7, 5.09; 95.9, 3.99, and 90.5, 7.10 t/ha. On this basis, nine and 12 replications were used in the test series.

Berding (pers. comm.) stated that where dual row cultivation was used a relation between adjacent row yields has been found. Random selection of rows needs to take this into account.

Variation between rakes within harvest treatments

The following undoubtedly is similar to the work that provided the basis for the comments by Ridge and Dick (1987) on the number of replicates required for statistically significant results.

Assuming trials are randomised, there are three cases of interest. The variation within treatments between:

1. samples of field cane including extraneous matter. Samples taken are rakes cut with no cleaning in action;
2. samples of cane with the respective treatment applied. These are the weights of cane rakes as delivered to the mill;
3. samples of cane as delivered with weight adjusted by the EM content to estimate the clean cane delivered.

A further case is the variation of the weight of ccs (or of pol) in the rakes delivered to the mill.

To obtain these estimates, from trials conducted by BSES in 1997-2000, the variances between samples (rakes) within treatments were pooled. The trials used two, three and four replicates of each treatment, providing results for up to 31 treatments for cases 2 and 3 above. From the same data source, only five treatment results from five trials were available for case 1. Because of the disparity in numbers of treatments, the information is presented in two forms, first, based on all the available data and second, based on the five trials that used replicates of the 'no cleaning' treatment. The results are presented as yield (t/ha).

All available data						
Yield t/ha		**Number of treatments**	**Pooled variance**	**Pooled std deviation**	**Mean**	**Coeff of variation**
'no cleaning'	Biomass less roots.	5	64.23	8.02	130.99	6.12
'no clean' ccs	ccs in above	5	1.41	1.19	18.72	6.34
Gross rake	Rakes as delivered	31	43.69	6.61	118.40	5.58
Gross rake ccs	ccs in above	31	0.63	0.80	15.10	5.27
Net rake	Rakes less EM content	28	12.63	3.55	111.34	3.19

Trials T12,T13, T14,T16&T17 data						
Yield t/ha		**Number of treatments**	**Pooled variance**	**Pooled std deviation**	**Mean**	**Coeff of variation**
'no cleaning'	Biomass less roots.	5	64.32	8.02	130.99	6.12
'no clean' ccs	ccs in above	5	1.41	1.19	18.72	6.34
Gross rake	Rakes as delivered	13	23.76	4.87	126.98	3.84
Gross ccs	ccs in above.	13	0.45	0.67	16.79	4.01
Net rake	Rakes less EM content	13	27.20	5.22	118.21	4.41

The variation in ccs yield for field cane delivered to the mill is much higher than that shown for the net yield. This is of great concern since the field cane rakes provide the estimate of the block potential yield of clean cane or of ccs and errors here introduce bias which affects the accuracy of cane loss measurement.

APPENDIX 3

Extract from Power Point presentation

Norris, C and James, M (2001). The measurement of in-field cane loss: historical perspective.

- With the move to green cane harvesting, and extractor-based cleaning systems, there was a significant need for an extension tool to demonstrate cane loss and approximate its magnitude.
- It was therefore decided to attempt again to correlate cane loss to 'scrap' that could be found in extractor efflux.
- **A stationary machine (Toft 7000 prototype) was set up and trials undertaken:**
- The harvester was fed with ~300 kg bundles of unstripped cane of one variety.
- The pour rate was approximately 60 t/hr.
- The resulting mass of cane and cane fragments, both at the elevator and on a tarpaulin laid out next to the primary extractor, was weighed.
- This was repeated three times at each of two fan speeds (1,450 RPM and 1,000 RPM).
- Tarp factor development (Ridge, pers. com, 2001): 1,450 rpm fan speed.
- 300 kg of green cane with 20% EM = 240 kg of clean cane.
- With cane loss of 10%, net cane recovered in bin = 216 kg, loss = 24 kg.
- Cane recovered from the tarp = 8 kg, Adjustment factor = 3.
- 1,000 rpm, with a cane loss of say 4%, net cane would be = 230.4 kg, loss 9.6 kg.
- Cane recovered on tarp = 6.4 kg, Adjustment factor = 1.5.
- Three replicates were run at each extractor speed.
- You can see from the above that cane collected from the tarp is not much different in the two cases.
- *but the actual cane loss is 2.5 times higher in the first case.*