TRIALS COMPARING SEMI-MECHANISED AND CHOPPER HARVESTING METHODS OVER THREE SEASONS IN SWAZILAND

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Abstract

The South African Sugar Association Experiment Station, Agricultural Engineering Department conducted a series of semi-mechanised versus fully mechanised harvesting trials on a large commercial estate in Swaziland over the 1998/1999, 2000/2001 and 2001/2002 seasons. During the trials machinery performance was measured, differences in the quality of cane delivered to the factory were determined, and associated infield cane losses were measured.

The results of all three trials showed that infield cane losses were statistically significantly lower where the cane was cut manually and loaded mechanically, compared with cane harvested by chopper harvester. The three trials showed that the quality of cane delivered to the factory by the chopper harvester treatments was not statistically significantly different to that delivered by the manually harvested and mechanically loaded treatments. Mechanical loader and chopper harvester performance varied considerably depending on the type of machine, cane yield, and crop and field conditions.

Keywords: manual harvesting, mechanical harvesting, cane quality, cane losses

Introduction

As mechanisation is being used increasingly in the Southern African sugarcane industries, there is a need to determine machinery performance indices and the effect that mechanisation has on cane yield, cane quality, infield losses and mill performance. An attempt was made to measure unaccountable losses when using chopper harvesters as well as the effect that various treatments had on ratoon regrowth.

The Agricultural Engineering Department at the South African Sugar Association Experiment Station (SASEX) last conducted trials over 20 years ago to assess mechanical loading, combine harvesting performance and cane losses (de Beer and Boevey, 1977a; de Beer and Boevey, 1977b; de Beer and Boevey, 1979; de Beer, 1980). A new series of trials was designed to generate information on machinery performance at current levels of management and production. The sub objective of these trials was to measure cane quality which impacts on the recently introduced relative value (RV) payment system, as well as green cane harvesting because of mounting pressure not to burn cane prior to harvest.

Methods and Materials

Three separate harvesting trials were conducted over three successive seasons on the Royal Swaziland Sugar Corporation (RSSC) estate located at Simunye. The trials were designed to determine differences in cane yield and quality as well as losses from various types of loaders and chopper harvesters.

To be relevant, the tests had to be conducted under infield harvesting conditions, with as little disruption to the normal harvesting schedule as possible. It must be noted that in the case of the chopper harvested treatments the plots consisted of full and part row lengths, whereas the manually cut and mechanically loaded plots did not always cover the entire row length. This was a change from the conventional plot technique, as the plots did not consist of a predefined area of the same size and shape for all treatments. This option made the trials easier to control, less disruptive and requiring fewer resources, and therefore less expensive.

Trial 1

This trial was situated in Field 502 and harvested over the period 30 August to 4 September 1998. The following three treatments were replicated seven times:

Control	Hand cut, Tamhe push-pile loader (mounted on a Bell 1754 two wheel drive tractor) loading into bins
Treatment 1	Hand cut, J&L continuous loader loading into bins
Treatment 2	Case Austoft 7000 harvester cutting burnt cane and delivering the billeted cane into bins.

The average area per plot was 0,4 ha with mean yields of approximately 45 tons cane. The field was sprinkler irrigated using an overhead dragline system. The variety was NCo376 in its third ratoon, with pre-harvest yield estimates of 95 t/ha. The cane rows were ridged up and the row spacing was 1,5 m.

Trial 2

This trial was situated in Field 1010 and harvested over the period 9 to 13 October 2000. The following five treatments were replicated eight times:

Control A	Hand cut, Cameco SP 2254 push-pile loader loading into bins
Control B	Hand cut, Cameco SP 2254 push-pile loader loading into Landtrains
Treatment 1	Case Austoft 7000 harvester cutting burnt cane and delivering the billeted cane into high-lift trailers
Treatment 2	Case Austoft 7000 harvester cutting green cane and delivering the billeted cane into bins
Treatment 3	Case Austoft 7000 harvester cutting in burnt cane and delivering the billeted cane into bins.

The average area per plot was 0,48 ha with mean yields of approximately 39 tons cane. The field was irrigated by surface drip. The cane variety NCo376 was in its fourth ratoon with pre-harvest yield estimates of 80 t/ha. The row spacing was 1,5 m.

Trial 3

This trial was situated in Field 1218 and harvested over the period 8 to 13 July 2001. The following three treatments were replicated 12 times:

Control	Hand cut, Cameco SP 2254 push-pile loader loading into bins
Treatment 1	Cameco CHW 2500 harvester (Case Austoft not available) cutting burnt cane and delivering the billeted cane into high-lift trailers
Treatment 2	Cameco harvester cutting green cane and delivering the billeted cane into bins.

The average area per plot was 0,34 ha with mean yields of approximately 47 tons cane. The field was irrigated with sub-surface drip. The cane variety was NCo376 in its first ratoon with pre-harvest yield estimates of 145 t/ha. The cane was planted in tramlines 0,4 m apart at a row width of 1,8 m. The cane was chemically ripened and this resulted in a good burn.

All treatments were assigned to plots within each replication using randomised blocks (Cochran and Cox, 1957). In all cases the hand cut cane was burnt prior to harvesting and then cane from four rows was placed into a single windrow for push-piling.

The data was analysed using the One-Way ANOVA (Cochran & Cox, 1957) to determine statistically significant differences between the treatments for the quality and yield characteristics, as well as for infield losses and ratoon crop evaluation.

Treatment plot area measurements
The row spacing was measured several times at random sites along the width of the field using a measuring tape. The total length of each plot was measured using a mechanical measuring wheel, with randomly selected plots checked using a 50 m tape measure.

The net plot area for the control plots (manual cut, mechanically loaded) was determined from the total length of windrowed cane multiplied by four and then by the row spacing. In the mechanically harvested plots the net plot area was calculated by multiplying the number of harvested rows or partial rows by the row length and average row spacing.

Cane mass measurements and mill cane quality sampling
The plot areas were relatively large as cane was transported to the mill in approximately 50 ton payload vehicles, which arrived at an estimated average rate of one every 10 minutes. The weighbridge and mill sampling system was geared to handle a single truckload or 50 ton batch. The plot size was based on existing parameters, as treatments were designed to test the efficiency of the commercial operations.

Each consignment of five bins (one plot) was loaded onto the road transport vehicles on the various transloading zones. Careful monitoring ensured that cane from the various treatments was correctly consigned and that only cane from the same plot was loaded onto the road transport vehicle. On arrival at the mill the loaded transport vehicles were weighed, the cane tipped onto the mill carrier and sampled by the mill's cane testing department. The analysis performed by the cane testing department included Brix %, pol % and moisture from which purity %, fibre %, non-pol % were calculated. Ash % analyses were carried out on a few consignments in Trial 3. On departure from the mill the vehicles and five empty bins were again weighed to obtain the net cane mass delivered per load (harvested plot area).

On average, the burn to delivery delay was less than 20 hours and the cane was usually crushed and analysed between three to seven hours after arriving at the mill. However, some consignments had burn-to-crush delays of 42 hours. The excessive delays were due to transport problems and mill breakdowns.

Infield cane losses
Each plot was harvested and/or loaded as in the current commercial practice. The loading operation was performed with the infield transport travelling over a previously loaded windrow or harvested row. In the case of the mechanically loaded treatments it was important to achieve this so that the ground loss sampling area spanned both the area where the windrow lay and the area between the windrows. In the case of the chopper harvester treatments, five or more cane rows were harvested until five bin trailers were filled.

After mechanical loading or harvesting was completed, the RSSC harvesting crew gleaned each plot. The Swaziland Sugar Association Technical Services (SSATS) and RSSC Agronomy staff then carried out cane loss sampling. The method of measuring cane left after mechanical loading or harvesting was to randomly select sample areas within the treatment plot and peg out a 6 m^2 sampling area using four pegs joined together by a length of rope. Cane left behind, including whole or damaged stalks and stalk pieces, whole or damaged billets, topscane (millable cane tops) and stubble, were carefully gleaned and then weighed using a 5 kg spring balance.

It must be noted that although no attempt was made in any of the trials to analyse the quality and length of cane billets produced by the J&L loader or either of the chopper, billets trampled either by the harvester or continuous loader themselves or by following transport were, however, multiplied by a factor of 1,5 (de Beer *et al*, 1985) to obtain realistic cane losses.

Machinery performance
Machinery performance was measured in all three trials using the time and motion study method (Murray and Meyer, 1982) and an analogue stopwatch.

Ratoon regrowth evaluation
The RSSC Agronomy Department collected stalk population measurements over a seven month period after applying the treatments in Trial 1. SSATS Agronomy Department measured stalk population and stalk heights for the various treatments in Trial 3.

Results and Discussion

Direct comparison between the three trials for machine performance, cane losses or quality of cane delivered to the mill, could not be made due to varying field and crop conditions. However, useful trends and performance indicators were obtained.

Cane quantity and quality delivered to the mill by various harvesting systems

Trial 1
The quantity and quality of cane delivered to the mill by the various treatments are given in Table 1.

Table 1. Cane quantity and quality analysis - Trial 1.

Treatment	Tons /ha	T suc /ha	Pol %	Purity %	Fibre %	Moist %	Brix % DM
Control	103,40	15,07	14,60	86,17	12,89	70,17	56,80
Treatment 1	105,60	15,77	14,94	85,45	12,26	70,25	58,87
Treatment 2	99,20	14,16	14,27	85,53	12,29	71,04	57,61
CV %	4,7	5,2	2,3	1,7	6,6	0,7	3,8
LSD (0,05)	5,94	0,95	0,39	1,67	0,96	0,58	2,54
p-value	0,08	0,01	0,01	0,60	0,31	0,01	0,24

Cane delivered
The average tons cane per hectare delivered by the Austoft harvester (Table 1, 99,2 t/ha), the Tamhe (103,4 t/ha) and the J&L loader (105,6 t/ha) varied (-5,1%, LSD 5,94), but was not statistically different at the 5% level of significance. This may be attributed (partly) to the relatively fewer replications in this trial.

Sucrose yield
The mean sucrose yield using the Austoft harvester was significantly lower than the yields from the Tamhe push-pile loader and the J&L continuous loader at the 5% level of significance. In fact, the sucrose yields from the Tamhe push-pile loader and the J&L continuous loader were 10,3 and 6% higher, respectively, than that of the Austoft harvester.

Cane composition and quality
There was evidence of statistically significant differences among the treatments for pol % cane and for moisture % cane. The difference in pol % cane between the J&L loader and Austoft harvester was large (0,67 with LSD (0,05) = 0,39). The lower pol% cane for the Austoft harvester may be explained by the statistically significant higher moisture % cane (i.e. lower dry matter). Differences in Brix % DM

between the treatments were not found to be statistically significant at the 5% level. This is difficult to interpret since higher moisture usually implies less extraneous matter, which should result in improved Brix % DM and sucrose content, but this was not evident.

Trial 2
The quantity and quality of cane delivered to the mill by the various treatments are given in Table 2.

Cane delivered
Although the difference between the average tons cane per hectare delivered to the mill by the chopper harvester plots and the hand cut, mechanical load plots in burnt cane was statistically significant at the 10% level, the average cane tonnage delivered per hectare for the different treatments varied widely (from 76,6 to 86,3 t/ha). The wide range of yields from individual plots (65 to 110 t/ha, with a CV% of 8,1%) is difficult to explain, except that the variety of soil forms may have played a role.

Table 2. Cane quantity and quality analysis - Trial 2.

Treatment	Tons /ha	T suc /ha	Pol %	Purity %	Fibre %	Moist %	Brix % DM
Control A	76,60	10,10	13,21	84,70	14,90	69,40	51,10
Control B	79,30	10,71	13,52	85,70	14,40	69,80	52,30
Treatment 1	79,70	10,21	12,84	84,40	14,80	70,00	50,80
Treatment 2	81,80	10,17	12,43	81,60	16,70	68,10	47,80
Treatment 3	86,30	11,04	12,81	84,40	14,60	70,20	50,20
CV %	8,1	9,1	4,8	3,0	8,7	1,6	5,4
LSD (0,05)	6,67	1,04	0,63	2,62	1,34	1,16	2,80
p-value	0,07	0,29	0,02	0,05	0,01	0,01	0,04

Sucrose yield
There were no statistically significant differences between the mean sucrose yields across the five treatments.

Cane composition and quality
The pol % cane for the hand cut, mechanically loaded cane was significantly higher at the 5% level. The higher cane tonnage for the chopper harvested cane was counterbalanced by the lower pol %, which may have resulted from more tops since the lower pol % has arisen via all three components, moisture, brix % DM and purity, as would be expected with less mature stalk. As would be expected, fibre % was significantly higher for green cane than burnt cane, and Brix % DM lower.

Trial 3
In this trial pre-harvest cane quality samples for all treatments were taken and sent to the Mhlume Cane Testing Service for analysis. The results showed that there were no statistically significant differences across the 36 plots for any indices, indicating that the field was suitable for the trial.

The quantity and quality of cane delivered to the mill by the various treatments are given in Table 3.

Cane delivered
Pre-treatment cane yield estimates were carried out in the control plots (manual cut, mechanical load) to establish the cane yield benchmark against which all treatments would be measured. The 48 pre-harvest yield estimate plots consisted of 3 m section of a windrow, or a total harvest area of 21,6 m^2 each. The pre-harvest yield estimates were very variable, with a range of 115,2 to 164,4 t/ha and a mean of 145 t/ha. Furthermore, due to the fairly large SED and high CV%, these yield estimates could not be used as the intended benchmark for cane yield.

Table 3. Cane quantity and quality analysis - Trial 3.

Treatment	Tons /ha	T suc /ha	Pol %	Purity %	Fibre %	Moist %	Brix % DM
Control	140,78	19,22	13,65	85,64	13,28	70,78	54,66
Treatment 1	141,53	19,19	13,57	85,68	11,77	72,43	57,40
Treatment 2	133,73	18,36	13,73	85,76	12,58	71,41	56,12
CV %	5,6	8,5	6,0	2,7	12,2	1,8	6,9
LSD (0,05)	6,52	1,36	0,70	1,81	1,29	1,11	3,25
p-value	0,04	0,35	0,89	0,99	0,07	0,02	0,24

It must be noted that, to measure small differences (< 5%) in cane yield, would require many more replications. The analysis however indicated that the yield from Treatment 2 (mechanically cut green cane) was significantly lower than the other two treatments.

Cane composition and quality
There was very little in the quality components across the three treatments, except the significantly lower moisture % cane (at the 5% level). The significantly higher fibre % cane (at the 10% level) for the control may be explained by the longer burn-to-crush delay experienced by some of these consignments to the mill.

Infield cane losses using different harvesting systems

Although no direct comparison can be drawn between the three trials due to varying field and crop conditions, it is nevertheless possible to draw the following conclusions:

Mechanical loaders
A summary of the infield cane losses for all three trials using the three different mechanical loading systems is given in Table 4.

The average infield loss (expressed as a % of harvested yield) for the three manual cut, mechanical loading systems ranged between 1,53% and 3,89%. Table 4 shows that the greatest losses occurred in the Tamhe and Cameco push-pile grab loader treatments due to stubble, tops and cane whole stalk pieces that were left behind during the loading operation. In addition, the J&L continuous loading system experienced additional losses from whole and trampled billets.

The amount of stubble and tops gleaned is no reflection of the mechanical efficiency of the various loaders, but rather a function of the harvesting operation. There were statistically significant differences in losses from tops between the treatments in each of the three trials. The reason for the lower losses in Trials 2 and 3 may possibly be ascribed to an improvement in manual harvesting management whereby the cane was topped more accurately.

The results indicate that it would be reasonable to expect higher infield losses when using the manual cut, J&L continuous loader harvesting system than when using the other two manual cut, grab loading harvesting systems.

Chopper harvesters
A summary of the infield cane losses in the three trials from the two makes of chopper harvesters is given in Table 5.

The average infield losses (expressed as a % of harvested yield) for both harvesters in all three trials ranged from 3,69 to 5,56% in burnt cane and 5,5% in both green cane trials.

In all three trials the highest infield losses from using chopper harvesters, are found in the stubble cane and whole and damaged billet categories. Damaged billets (tramped by harvester or following transport) accounted for the highest single loss. Although no special effort was made to determine the causes of the damaged billet losses, it was observed that a large percentage of these losses took place either at the throat of the machine or occurred when billets were dropped by the extractor fans or the elevator itself.

The high stubble cane losses in the chopper harvester treatments were in Trial 1 due to the operator lifting the base cutters to avoid excessive base cutter blade wear in some of the plots containing rocky outcrops. The high stubble and billet losses in the green cane treatments in Trial 3 can be ascribed to poor operator visibility when harvesting a large green crop, and the fact that the specification of the chopper harvester was not ideally suited to harvesting green cane. The harvesting of large green cane crops places severe restrictions on harvester performance and cane quality. Research is under way in Australia to improve the feeding mechanism of chopper harvesters (Norris and Davis, 2001).

In summary, the results clearly indicate that infield cane losses markedly increase when using fully mechanised compared with semi-mechanised harvesting systems. Cane stubble, cane tops and whole stalks make up the majority of losses for the semi-mechanised harvesting systems. Most losses incurred by the fully mechanised harvesting systems are attributable to stubble cane and whole or damaged billets.

Unaccountable losses

Consideration must also be given to invisible losses (e.g. cane juice and small fragments of cane), which are extremely difficult to recover when using chopper harvesters (Molina and Ripoli, 2001; Richard *et al.*, 1996)**.** One of the aims of these trials was to measure unaccountable losses. This is normally done by adding the mill cane mass to the infield losses and comparing this total across treatments. However, because of the large natural variations in cane yields between the plots, unaccountable losses could not be determined using this method. A more direct method of assessing unaccountable losses is necessary.

The results of Trial 1 suggested that there were ‘unknown’ losses associated with the chopper harvesting system. However, this trend did not recur in Trials 2 and 3, where there appeared to be a net increase in total cane mass in favour of the chopper harvesting system compared with the control system, despite there being no significant differences in cane quality between these systems. To determine unaccountable losses accurately, trials will have to be conducted on a smaller more intense scale in uniformly grown cane and using more direct methods for comparison. These include the possible use of cane yield monitors and other precision farming innovations, and adherence to the comprehensive procedure of the harvester testing procedure described by the International Society of Sugar Cane Technologists (de Beer *et al.*, 1985).

Ratoon crop evaluation for various harvesting systems

The RSSC and SSATS Agronomy Department staff carried out cane re-growth measurements for all treatments on two of the trial sites. A summary of stalk populations measurements following the treatments for Trials 1 and 3 are given in Appendices 1 and 2 respectively. Stalk height measurements for Trial 3 are given in Appendix 3.

Trial 1

The stalk population trends shown in Appendix 1 are typical of cane variety NCo376 showing a rapid increase in stalk population up and until full canopy is achieved (Inman-Bamber, 1991). Thereafter there is a very rapid decrease until a final population of around 100 000 to 130 000 stalks per hectare.

In this trial the stalk populations for the control and Treatment 1 (both hand cut treatments) were similar over the entire observation period. However, although the stalk populations for the mechanically harvested plots lagged behind the manually harvested plots initially, there was no statistical difference between treatments in the final population counts 206 days after applying the treatments. The stalk population trends for Trial 1 are illustrated in Figure 1.

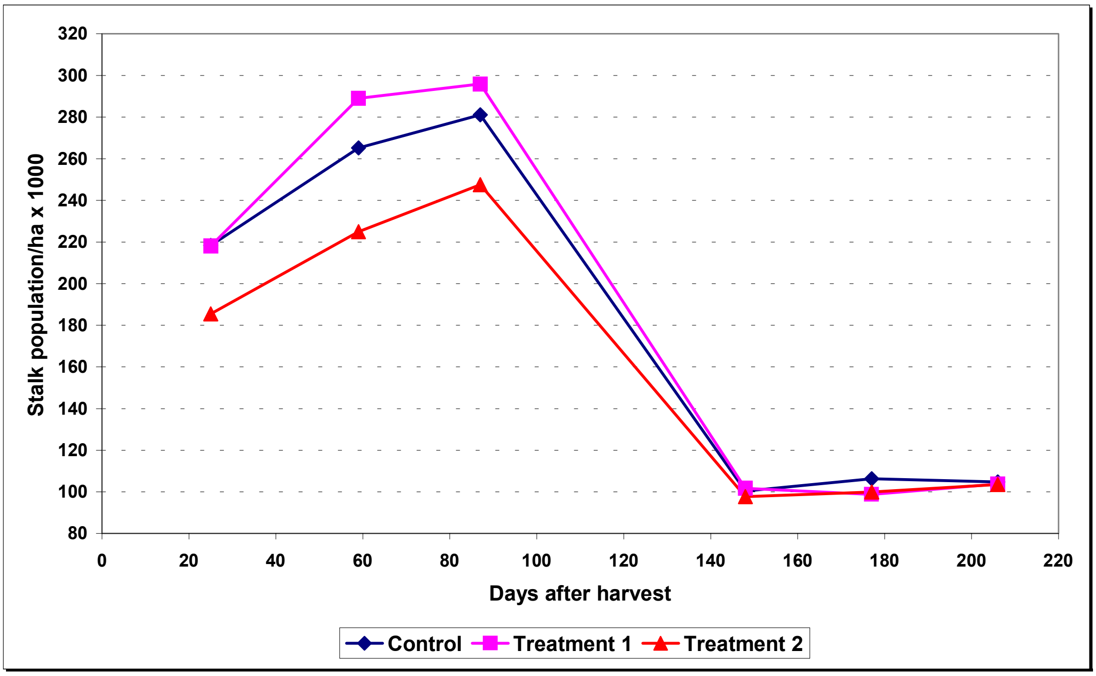

Figure 1. Stalk population – Trial 1.

Trial 3
In this first ratoon crop both stalk population and stalk heights were measured. The data in Appendix 2 shows that there were no significant difference in stalk population for both chopper harvesting treatments compared with the hand cut, mechanical loaded treatment. It should be that all trash was burnt soon after harvest. During the trial it was noticed that the harvester's base cutter height had been set too low and often cut the cane below ground level. However, this does not appear to have had a significant affect on stalk population. It is generally accepted that the risk of cane stool damage is highest in plant cane fields, as the stools are not fully established and the soil profile has not yet had sufficient time to settle. This is borne out by the fact that RSSC do not usually target any plant crop fields for mechanical harvesting. The stalk population trends for Trial 3 are illustrated in Figure 2.

The data in Appendix 3 show that there were no significant differences in stalk height measurements between the control and Treatments 1 and 2.

Where possible, continuous and complete time and motion were recorded. However, where this was not possible (stoppages due to stones or lack of infield transport) instantaneous loading and harvesting rates were recorded and calculated. It is important to note that four infield transport tractor/trailer combinations were used to service either the loader or chopper harvester.

Although no direct comparison can be drawn between the various loader performances because of varying field and crop conditions, useful performance indicators were obtained for each of the conditions experienced in the trials.

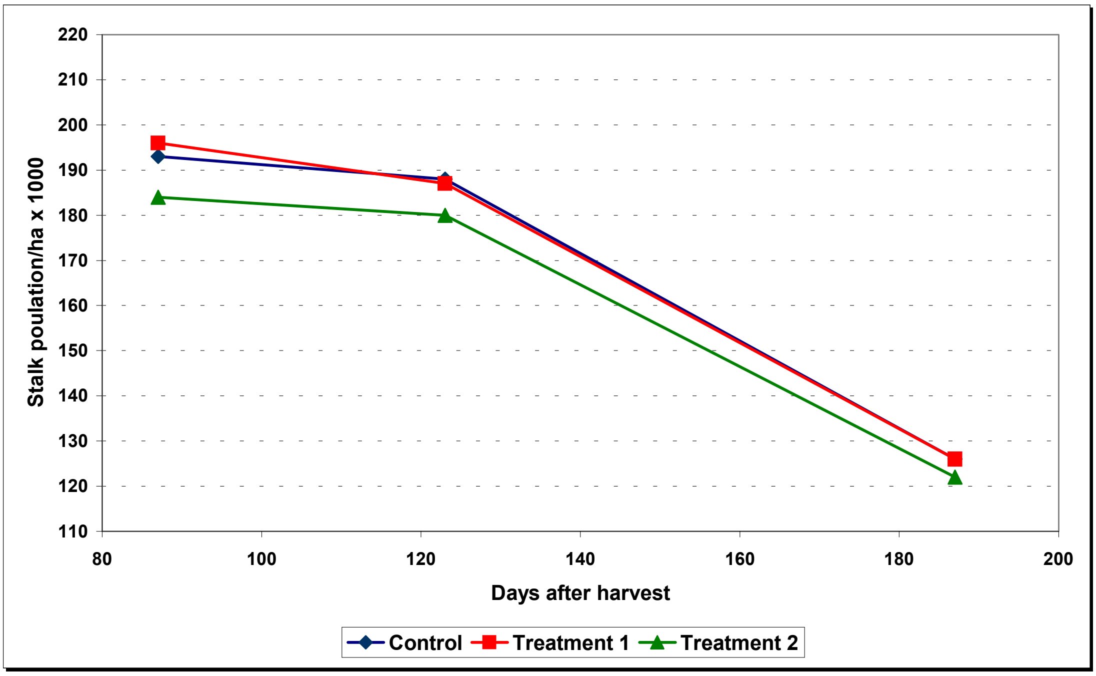

Figure 2. Stalk population – Trial 3.

Machinery performance for different harvesting systems

Mechanical loaders
A summary of the performances of the Tamhe grab loader, J&L continuous loader and the Cameco grab loader used during the three trials is given in Table 6.

Tamhe grab loader
This type of loader was used only in the first trial. The study showed that the Tamhe loader's forward speed ranged from 0,8 to 1,0 km/h and averaged 0,9 km/h. Loading rates varied from 51 to 70 t/h and averaged 62 t/h.

J&L continuous loader
The J&L continuous loader's forward speed ranged from 2,2 to 4,4 km/h and averaged 3,0 km/h and loading rates varied considerably between 151 to 270 and averaged 212 t/h. The J&L whole stalk cane loading system on RSSC has been discontinued and has been replaced by the Cameco SP 2254 push-pile grab loading system.

Cameco SP 2254 grab loader
In Trials 2 and 3 only the Cameco loader was used. In Trial 2 (Table 6) there was little difference in the loader's average forward speed or instantaneous loading rate. However, due to the variability in cane yield the loaders forward speed and loading rate varied between 1,4 and 2,1 km/h and 67 and 108 t/h respectively. In Trial 3 (Table 6) the Cameco loader achieved an average forward speed and instantaneous loading rate of 1,1 km/h and 115,8 t/h respectively. It was possible to record several complete time and motion studies (which included time taken to turn at the end of the windrow and all downtime) for the loader in this trial. The loader achieved an average forward speed, instantaneous and overall loading rates of 1,3 km/h and 131,6 t/h respectively. It should, however, be noted that the loader's instantaneous loading rate, even under the favourable field conditions found in Trial 3, varied between 99 and 145 t/h. The effect that cane yield has on instantaneous loading rates can clearly be seen when comparing the loader's performance in Trials 2 and 3.

Table 6. Summary of mechanical loader performances.

Trial No	Cane condition	Loader type	Infield transport	Mass/plot (tons)	Av. op. speed (km/h)	Instantaneous loading rate (t/h)
1	Burnt	Tamhe grab loader	10 ton bins	48,96	0,91	61,89
		J&L continuous loader	10 ton bins	38,81	3,03	211,57
2	Burnt	Cameco SP 2254 grab loader	10 ton bins	36,50	1,90	89,03
		Cameco SP 2254 grab loader	Landtrain spiller trailers	30,89	1,82	85,54
3	Burnt	Cameco SP 2254 grab loader	10 ton bins	45,83	1,14	115,76

Chopper harvesters
A summary of the Case Austoft and Cameco chopper harvester performances during the three trials is given in Table 7.

Case Austoft 7000 harvester
The harvester's instantaneous harvesting rate, also referred to as pour rate, varied considerably between plots in Trial 1 despite the relatively uniform plot yields. The harvester's forward speed and pour rates were between 4,55 and 6,41 km/h and 64 and 110 t/h, mainly due to outcrops of shale and stones in certain plots. In Trial 2 (Table 7), the harvester achieved similar forward speeds and instantaneous harvesting rates while being followed either by bins or hi-lift trailers averaging between 5,6 and 5,7 km/h and 68 and 75 t/h respectively.

Table 7. Summary of chopper harvestser performances.

Trial No	Cane condition	Chopper harvester	Infield Transport	Mass/plot (tons)	Av. op. speed (km/h)	Instantaneous loading rate (t/h)
1	Burnt	Case Austoft 7000	10 ton bins	47,71	5,14	80,55
2	Burnt	Case Austoft 7000	6 ton hi-lift trailers	39,29	5,63	67,60
		Case Austoft 7000	10 ton bins	45,12	5,74	74,65
	Green	Case Austoft 7000	10 ton bins	42,75	4,92	64,55
3	Burnt	Cameco CHW 2500	10 ton bins	50,78	4,10	104,42
	Green	Cameco CHW 2500	10 ton bins	44,78	2,84	70,71

Cameco CHW 2500 harvester
In Trial 3 the Cameco harvester achieved an average forward speed, pour rate and overall harvesting rate of between 3,2 and 4,5 km/h, 97,3 and 112,6 t/h and 43,6 and 78,3 t/h respectively. In green cane these performance parameters varied between 2,3 and 3,1 km/h, 73,5 and 87,1 t/h and 21,7 and 46,9 t/h respectively.

Again it is important to note the differences in chopper harvester performances when operating in low and high yielding burnt cane fields (see Table 7, Trials 2 and 3). The above mechanical harvesting rates are comparable with previous research (Meyer, 2001).

The variations highlighted above can be ascribed to stony ground in some of the plots as well as to operator proficiency.

There are many factors that affect mechanical loader and chopper harvester performances, infield losses and quality of cane delivered to the factory (Ridge and Dick, 1985; Ridge *et al.*, 1996; de Beer and Purchase, 1999; Meyer, 1998; Meyer, 1999; Meyer, 2001). Examples include cane yield, erect or lodged cane, burnt or green cane, field layout, machine condition and operator proficiency.

Conclusions

The trials have resulted in the gathering of useful information concerning various aspects of semi-mechanised and fully mechanised chopper harvesting systems.

- The quantity of cane delivered to the factory varied between trials and between treatments. In two of the trials the quantity of cane delivered by the combine harvester treatments in burnt cane were greater than the hand cut, mechanically loaded treatments.

- The quality of cane delivered to the factory in all three trials indicated that there were no significant quality differences between the various harvesting systems used in the trials.

- The results in all three trials clearly showed that, where cane was manually cut and mechanically loaded, infield losses were lower compared with cane that was chopper harvested. Furthermore, when using chopper harvesters, infield cane losses were higher in green cane than in burnt cane.

  The infield losses for the semi-mechanised harvesting system (manual cut and mechanical load) used in these trials were comparable with losses recorded during trials conducted at Mhlume Sugar Co during the late seventies (de Beer, 1980) using a predominantly manual harvesting system (manual cut and stack). Chopper harvester infield losses recorded during the recent trials were marginally lower compared with those recorded at Mhlume (de Beer, 1980).

  Due to the relatively large scale of the trials it was not possible to determine the unaccountable losses when using chopper harvesters, as the variation in cane yield masked these losses. Direct methods of assessment are needed.

- The variations in yield, crop and soil conditions allow one to compare performance over a wide range of situations. These trials therefore provide data that can benchmark different situations and conditions.

  The trials showed that there were significant differences in performance between the various mechanical loaders. Instantaneous loading rates varied from 62 to 212 tons per hour. The instantaneous harvesting rate of the chopper harvester in burnt cane in Trials 1 and 2 varied between 67 to 80 tons per hour. These rates are comparable with those of previous trials conducted in Swaziland (de Beer and Boevey, 1979; de Beer, 1980). However, the chopper harvester instantaneous rate when operating in burnt cane averaged in excess of 100 t/ha in Trial 3. This increase in performance was mainly due to the higher cane yield in Field 1218. In both Trials 2 and 3 the chopper harvester output was lower in green cane than in burnt cane.

These trials clearly indicate the importance of high cane yield and erect cane, with fields free of stones or obstacles for efficient mechanical harvesting which can result in relatively small losses when compared with hand cut semi-mechanised systems in burnt cane. Further work is needed to reduce losses by improving machinery operation and performance. In the meantime the efficiency of hand gleaning needs improvement. Additional work is needed to improve the performance of chopper harvesters in green cane where field losses are highest.

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APPENDIX 1
Results of crop regrowth data – Trial 1 stalk populations

Treatment	Manual cut, Tamhe loader burnt cane	Manual cut, J&L loader burnt cane	Case Austoft chopper harvester burnt cane	CV %	LSD (0,05)	p-value
Days after harvest	Stalk population /ha x 1000	Stalk population /ha x 1000	Stalk population /ha x 1000			
25	218,36	218,07	185,51	12,2	22,1	0,05
59	265,21	289,02	224,93	13,2	30,2	0,02
87	281,12	295,97	247,49	11,5	27,7	0,03
148	100,37	101,61	97,61	9,4	8,2	0,72
177	106,28	98,75	99,90	7,5	6,7	0,50
206	104,75	103,70	103,51	7,0	6,4	0,73

APPENDIX 2
Results of crop regrowth data - Trial 3 stalk populations

Treatment	Manual cut, mechanical load burnt cane	Cameco chopper harvester burnt cane	Cameco chopper harvester green cane	CV %	LSD (0,05)	SIGNIFICANCE
Days after harvest	Stalk population /ha x 1000	Stalk population /ha x 1000	Stalk population /ha x 1000			
87	193	196	184	14,90	24,00	NS
123	188	187	180	11,00	17,00	NS
187	126	126	122	10.10	11,00	NS

APPENDIX 3
Results of crop regrowth data - Trial 3 stalk height

Treatment	Manual cut, mechanical load burnt cane	Cameco chopper harvester burnt cane	Cameco chopper harvester green cane	CV %	LSD (0,05)	p-value
Days after harvest	Stalk height (cm)	Stalk height (cm)	Stalk height (cm)			
87	23	22	22	5,87	1,11	0,17
123	50	48	46	8,40	3,40	0,11
187	164	161	158	4,94	6,76	0,20

Table 4. Summary of mechanical loader infield cane losses.

Trial No	Cane condition	Loader type	Infield transport	Harvested yield (t/ha)	Stubble cane	Tops cane	Whole stalk	Whole stalk pieces	Damaged stalks	Damaged stalk pieces	Whole billets	Damaged billets	Total loss (t/ha)	Total loss %
1	Burnt	Tamhe Grab loader	10 ton bins	106,79	0,61	1,13	0,88	0,77	0,00	0,00	0,00	0,00	3,39	3,17
		J&L Continuous loader	10 ton bins	109,87	0,83	1,13	0,06	0,00	0,04	0,00	0,93	1,28	4,27	3,89
2	Burnt	Cameco SP 2254 Grab loader	10 ton bins	78,73	0,45	0,37	0,06	0,86	0,03	0,36	0,00	0,00	2,13	2,71
		Cameco SP 2254 Grab loader	Landtrain Spiller trailers	82,02	0,50	0,46	0,04	1,06	0,06	0,60	0,00	0,00	2,72	3,32
3	Burnt	Cameco SP 2254 Grab loader	10 ton bins	142,97	0,43	0,61	0,14	0,53	0,16	0,32	0,00	0,00	2,19	1,53

Table 5. Summary of chopper harvester infield cane losses.

Trial No	Cane condition	Chopper harvester	Infield transport	Harvested yield (t/ha)	Stubble cane	Tops cane	Whole stalk	Whole stalk pieces	Damaged stalks	Damaged stalk pieces	Whole billets	Damaged billets	Total loss (t/ha)	Total loss %
1	Burnt	Case Austoft 7000	10 ton bins	99,20	1,07	0,38	0,01	0,00	0,01	0,00	0,78	1,64	3,89	3,77
2	Burnt	Case Austoft 7000	6 ton hi-lift trailers	79,70	0,33	0,09	0,02	0,16	0,00	0,24	1,28	2,13	4,25	5,06
		Case Austoft 7000	10 ton bins	86,30	0,18	0,05	0,00	0,04	0,02	0,20	1,68	2,88	5,05	5,53
	Green	Case Austoft 7000	10 ton bins	81,80	0,34	0,26	0,06	0,16	0,29	0,39	1,04	2,28	4,82	5,56
3	Burnt	Cameco CHW 2500	10 ton bins	141,53	0,99	0,35	0,00	0,20	0,03	0,01	1,11	2,74	5,43	3,69
	Green	Cameco CHW 2500	10 ton bins	133,73	1.23	1,23	0,10	0,16	0,33	0,09	1,62	3,03	7,79	5,50