THE MINI-ROTOR CHOPPER HARVESTER

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Abstract

This is a final report on the development of a simple chopper harvester. The Mini-Rotor was built on an agricultural tractor incorporating components supplied by Santal of Brazil. The machine was tested in the field and its performance was compared with that of other chopper harvesters. The conclusion was that the Mini-Rotor is a viable sugarcane harvester for use in South Africa.

Introduction

The Mini-Rotor chopper harvester is built on a Fiat 1300 agricultural tractor to harvest single rows of burnt cane. It was developed at the Experiment Station (Anon[1], Pilcher[4]) in an attempt to overcome the most serious disadvantages of harvesters that are available commercially. As far as the South African sugar industry is concerned, the advantages of the Mini-Rotor are:

- reduced capital and running costs
- simplified maintenance and repairs because of the simple, open design and construction
- a single rotating drum has replaced the slatted conveyor which required considerable maintenance
- greater manoeuverability because of its short wheelbase and small turning circle
- improved stability because its 3,0 m track allows the machine to operate on the contour on slopes of 10° (18%)
- all components can be manufactured locally except the hydraulics and the prime mover, which is a standard agricultural tractor
- by swivelling and folding the delivery chute hydraulically, the machine can be made to conform to the South African road ordinances. This facility also allows the machine access to cane close to obstacles such as trees and power lines
- the output and projected cost are appropriate for the relatively small daily deliveries of about 150 tons.

The Mini-Rotor was developed initially on the South African Sugar Association Experiment Station's farm at La Mercy and was used to harvest commercial cane on Tongaat-Hulett's Maidstone estates in 1982 and 1983. During this period, problems associated with the machine's design were largely eliminated but its output remained lower than expected. This was mainly due to the poor condition of the cane which had suffered the combined effects of eldana and drought.

Modifications included a narrower left hand rear wheel, to reduce trampling of the next cane row. A problem peculiar to the harvesting of short cane in sandy soils is that low base cutting results in large quantities of sand being fed into the rotor, causing excessive wear and necessitating replacement of the trash screen at the bottom of the rotor drum.

The use of a positive displacement piston pump and radial piston motor on the rotor caused extreme hydraulic pressure pulsations in the supply to the rotor and consequently frequent component failure. An accumulator was fitted to reduce the pulsations and this improved the situation considerably but relief valves still failed after a relatively short period.

At the conclusion of the project the Mini-Rotor was tested in the field in 1984 so that its output, the quality of the cut cane, and the losses in cane resulting from harvesting with the machine could be established in fields which had been prepared for mechanization and in which the cane yields were good.

Methods

The procedure followed was that which was developed when commercial harvesters were tested in Swaziland and the Eastern Transvaal (de Beer and Boevey[3]). This trial with the Mini-Rotor also afforded the Experiment Station the opportunity of evaluating the proposed test procedures preferred by the International Society of Sugar Cane Technologists. The Mini-Rotor was not compared directly in replicated plots with another harvesting system, as was done in previous tests. It was tested for its cane gathering efficiency by comparing the amount of cane it delivered with what was available in the field. For this to be possible, cane yield had to be estimated accurately.

Pre-harvest data

- *Replications*

  There were 12 replications, each consisting of four or five rows of cane 100 m long. The plots yielded between 7,7 and 10,3 tons which was suited to the capacity of the tipping truck used to transport the chopped cane to the mill at Maidstone.

- *Degree of lodging*

  Fifteen samples consisting of all the stalks from 2 m of row were taken from each plot so that the degree of lodging could be assessed. Stalks inclined between ground level and 22½° were classed as recumbent, those between 22½° and 45° as sprawled, and those over 45° as erect. Samples were taken as harvesting proceeded, ie the sampling teams sampled one plot ahead of the harvester.

- *Extraneous matter content*

  This was established by weighing all the stalks collected in the samples. All tops (removed at the natural breaking point), trash and other extraneous matter were removed from the stalks and were weighed again. The tops were weighed separately and the weight of the rest of the extraneous matter was found by subtraction.

- *Yield estimate*

  The mass of the cleaned, topped stalks expressed as tons per hectare, gave an estimate of the yield of the particular plot.

Conducting the test

Cane on Field 402 at the Experiment Station's La Mercy farm was burnt on 7 July, 1984. The field was divided into three blocks having rows that were 100 m long. All cane between and around these blocks was removed before the test began. Five plots were harvested on 10 July and the last seven were harvested on 11 July.

Selecting the forward speed of the harvester and setting the components such as toppers, base cutters and fans, was the responsibility of the operator who was well acquainted with the Mini-Rotor. Cutting speed was recorded.

Harvesting data

- *Cane samples*

  A portable chute was attached to the front of the trailer into which chopped cane was being fed so that samples could be taken directly from the harvesting machine. The driver of the tractor hauling the trailer was signalled to slow down momentarily so that the harvester discharged into the chute. Each row was sampled two or three times and a total sample of about 200 kg was taken from each plot. These samples were divided into millable cane and extraneous matter and the parts were weighed before the next plot was harvested.

- *Net cane delivered*

The net quantity of cane delivered at the mill was determined by subtracting the estimated amount of extraneous matter of the cane sample, from the gross mass of the cane (as measured on the weighbridge) and adding the net weight of all samples taken from each plot.

- *Cane left in the field*

Three random sub-plots, 5 m long and spanning three rows, were marked out in each plot after harvesting was completed. All millable cane within the demarcated sub-plots was collected and weighed. Any pieces of millable cane lying across the boundary line were cut on the line and the portion on the inside was collected.

- *Billet quality and length*

Four samples, each of which weighed approximately 20 kg, were taken from the cane delivered by the Mini-Rotor and classed as sound, damaged or mutilated billets. After weighing each class, the billets were sorted into categories according to length. The categories were 0 to 100 mm, and intervals of 50 mm between 100 and 350 mm.

- *Mill analyses*

For various reasons it was not possible to analyse the harvested cane at the mill.

Results

The yield of the 19 month old plant crop of NCo 376 was estimated to be 150,9 tha^{-1}. Rows were 1,5 m apart and 100 m long, and flat culture was practised. The soil was derived from Middle Ecca and it was moist during the test, which was ideal for testing the Mini-Rotor. Under these conditions, the harvester cut at a speed of 2,4 kmh^{-1} giving an average pour rate of 60 th^{-1}.

From the pre-harvest samples the average population density was found to be 154 600 stalks ha^{-1} with an average mass of 0,97 kg stalk^{-1} (Table 1). The total extraneous matter (EM) content of the burnt, standing crop was estimated to be 11,8% with tops alone averaging 9,6%, indicating a good, well burnt crop. It was estimated that on the plots, 91% of the stalks were erect, 5% were sprawled and 4% were recumbent.

Harvest data revealed that cane sent to the mill contained 10,4% EM (Table 2). An average of 8,7 tha^{-1} or 5,7% of the total estimated cane available for harvesting (Table 3), was left behind in the field.

Test results are summarised in Table 3 from which the following performance factors can be calculated:

TABLE 1

Pre-harvest data

Plot	Population 1000 ha^{-1}	Stalk mass kg	Cane erect %	Cane sprawled %	Cane recumbent %	Net cane tha^{-1}	Tops tha^{-1}	Trash* tha^{-1}	Total tha^{-1}	Tops % total	Trash % total
1	159,5	0,96	87,7	4,0	8,3	153,0	15,7	3,4	172,1	9,03	2,07
2	154,2	0,93	93,0	3,9	3,1	144,1	14,7	3,7	162.5	8,99	2,28
3	148.5	0,95	97,4	1,4	1,2	141,6	15,2	3,4	160,2	9,57	2,17
4	150.1	0,88	96,5	1,8	1,7	132,3	14,5	2,9	149,7	9.70	1,94
5	149,2	0,91	95,2	2,7	2,1	135,2	13,6	2,4	151,2	9,00	1,60
6	158.2	0,95	90,1	3,3	6,6	150,5	16,0	3,7	170,2	9,31	2,16
7	158.2	0,97	93.7	3,4	2,9	154,0	17,4	3,6	175,0	9,84	2,09
8	161,5	1,05	89.3	4,8	5,8	169,5	18,8	5,5	193,8	9,66	2,81
9	159.3	0,99	91,7	6,0	2,2	158,3	17,1	4,4	179,8	9.63	2,40
10	145,9	1,00	90,7	4,9	4,4	145,3	15,4	4,0	164,7	9,44	2,47
11	156,0	1,05	90.2	5,5	4,4	164,0	19,5	4,6	188,2	10,29	2,45
12	154,9	1,05	79,7	12,1	8,3	162,4	19,2	3,4	185,0	10.39	1,87
Av	154,6	0,97	91,3	4,5	4,3	150,9	16,4	3,8	171,0	9,57	2,19

* Trash is all extraneous matter excluding tops

TABLE 2

Harvest sample

Plot	Sample mass kg	Cane % total	Tops % total	Other % total	EM % total
1	231,1	91,01	6,56	2,43	8,99
2	235,7	87,86	7,86	4,28	12,14
3	316,7	90,52	5,53	5,00	10,53
4	241,3	90,35	6,03	3,62	9,65
5	217,8	87,88	6,49	5,63	12,12
6	343,0	89,52	6,03	4,45	10,48
7	138,5	89,06	6,71	4,22	10,93
8	187,2	88,62	6,86	4,51	11,37
9	194,8	88,52	5,34	6,14	11,48
10	137,3	93,19	4,30	2,51	6,81
11	181,3	89,43	6,23	4,15	10,38
12	197,4	90,45	5,17	4,38	9,55
Av	218,5	89,67	6,09	4,28	10,37

TABLE 3

Summary of test results

Plot	Estimated net cane tha^{-1}	Cane delivered tha^{-1}	Net cane* delivered tha^{-1}	Cane left behind tha^{-1}	Net cane delivered % estimated
1	153,0	147,2	134,0	6,3	87,6
2	144,1	140,6	123,5	7,2	85,7
3	141,6	141,2	126,3	10,4	89,2
4	132,3	134,8	121,8	4,4	92,1
5	135,2	134,5	118,2	9,5	87,4
6	150,5	150,6	134,8	12,0	89,6
7	154,0	159,5	142,1	10,4	92,3
8	169,5	158,8	140,7	11,3	83,0
9	158,3	152,4	134,9	7,1	85,2
10	145,3	140,8	131,2	7,8	90,3
11	164,0	154,4	138,4	8,9	84,4
12	162,4	152,9	138,3	8,6	85,2
Av	150,9	147,3	132,0	8,7	87,5

* Cane delivered excluding EM from Table 2

- Cane harvesting efficiency $= \frac{\text{Net cane delivered to mill}}{\text{Net cane in field}} \times 100$

  $= \frac{132,0}{150,9} \times 100 = 87,5\%$
- Total cane loss $= 100 - 87,5 = 12,5\%$
- Invisible loss $= 12,5 - 5,7 = 6,8\%$

(Invisible loss consists of finely shredded cane particles or juice lost in base cutting, chopping, elevating and cleaning of the cane).

- EM rejection efficiency $= \frac{\text{EM in field} - \text{EM in sample}}{\text{EM in field}} \times 100$

  $= \frac{11,81 - 10,37}{11,81} = 12,2\%$

The data in Table 4 show that 57% of the billets delivered by the Mini-Rotor were considered to be 'sound'. The distribution of the billets according to length is given in Table 5.

TABLE 4
Billet quality

Sample no	Mass kg	Billets		
		Sound %	Damaged %	Mutilated %
1	12,96	49,9	34,1	16,0
2	18,61	62,4	29,0	8,6
3	23,80	58,4	17,6	24,0
4	18,30	55,7	27,3	17,0
Av	-	56,6	27,0	16,4

TABLE 5
Billet lengths

Sample no	Length classes (mm)					
	0-100	101-150	151-200	201-250	251-300	301-350
1	29	34	52	55	18	1
2	11	12	33	109	32	1
3	1	11	56	150	38	5
4	19	13	25	93	38	-
Total	60	70	166	407	126	7

Discussion

The EM rejection efficiency of mechanical harvesters is usually a function of the EM content of the crop prior to harvest. This was the case with the Mini-Rotor which removed only 12,2% of the EM of the cane processed by the machine. If the EM content of the standing crop had been higher, the EM rejection efficiency of the Mini-Rotor would probably have been better. The average EM content of 10,4% in the harvested cane samples nevertheless falls within the range of 6 to 17% normally expected from chopper harvesters (de Beer[2]).

The total loss of cane of 12,5% during the harvesting process was high, particularly as field conditions were good, but this proportion nevertheless falls in the 5 to 16% range which is expected from chopper harvesters. The fact that only 5,7% of the cane was left behind in the field was due as much to the Mini-Rotor's ability to pick up cane as to the good field conditions.

There was much concern that the Mini-Rotor would cause excessive damage to billets because of the method employed to accelerate the billets sufficiently in the rotating drum to throw them via the elevator duct into the trailer. In fact 57% of the billets were classed as 'sound', which compares favourably with figures of 50% and 46% for two harvesters tested in Swaziland (de Beer[2]).

The distribution of billet length was typical of that for chopper harvesters. Most billets were in the 201 to 250 mm category which would result in good payloads. Larger billets would, however, have been preferable from the point of view of cane quality.

The pour rate of 60 th^{-1} achieved by the Mini-Rotor was the best performance ever obtained with this machine and again emphasises the effect of field conditions on the output of a harvester. Depending on the availability of field transport, the Mini-Rotor should be able to maintain outputs of 20 to 25 tons per field hour in cane yielding 90 to 100 tha^{-1}. It should therefore meet its design specification of 150 td^{-1}.

To evaluate the accuracy of the pre-harvest sampling method of estimating cane yield, the Mini-Rotor test was followed by a test with the Midway whole stalk cutter using the same pre-harvest procedures. Average estimated yields were consistently 5% more than actual yields. This result does not necessarily imply that the same bias existed in the Mini-Rotor test but it must cast some doubt on the validity of the procedure used before harvesting to estimate crop yield.

Conclusion

During its period of development and throughout the test described above, it was found that the Mini-Rotor was capable of harvesting cane under field conditions typical of much of the South African sugar industry. The Mini-Rotor was able to harvest cane in small, awkwardly shaped fields, on slopes up to 10° (18%), in dry sand and in wet Middle Ecca-derived soils where flotation of the infield transport (and not that of the harvester) was the limiting factor. Short, diseased cane yielding 30 tha^{-1} and good cane yielding 159 tha^{-1} was handled. Billet quality and cane losses were found to be similar to those experienced with other commercial chopper harvesters. In reasonable field conditions, a harvesting rate of 150 td^{-1} should be achieved.

The Mini-Rotor project has been terminated. The machine will be dismantled and all cane harvesting components will be carefully drawn and specified. If the need were to arise in the future, the Mini-Rotor could be reconstructed.

Experience gained in this trial showed that estimated cane yield cannot be used to measure harvesting efficiency. Harvesters should be tested against a standard harvesting method, whether cutting manually or mechanically, and the performance of the different systems should be compared on randomised, replicated plots.

Acknowledgements

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