A SYSTEM FOR WHOLE STICK CANE HARVESTING: THE McCONNEL "STAGE 2" MACHINE

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Abstract

Arguments are presented favouring the step-wise introduction of mechanisation into cane harvesting. The multi-pass "McConnel" system of whole stick harvesting offers such a phased introduction. Three machines are introduced in the following order as labour becomes scarcer — a versatile loader, a reaping aid which leaves the cane in orderly swaths "inline", and a pickup cleaner-bundler which takes in the swath tops first. The cleaner-bundler machine ("Stage II") is described in some detail in view of its imminent introduction into the South African industry through a development agreement recently arranged with the South African Sugar Association.

Introduction

The McConnel system is a "stage-by-stage" method of harvesting whole stick cane, including green cane. Much of the overall strategy of the system and a description of the Stage I machine have already been published (Hudson,[3] De Beer[1] and Hudson *et al*[5]).

By the end of the 1975 reaping season 14 Stage I machines had been supplied to the South African industry. The first Stage II machine arrived at the Experiment Station's La Mercy farm in May and a development agreement, having as its aim the further development of the Stage II machine to suit South African conditions, has been signed by the South African Sugar Association Experiment Station and F. W. McConnel Ltd. of England.

Overall strategy — the Stage I machine and the loader

Many cane industries face an actual or imminent shortage of infield harvest labour, but labour availability usually declines only gradually. A method of harvesting green cane is widely needed and whole stick harvesting allows the bulk of existing field equipment, factory reception and expertise to continue in use. Mechanical and machine management skills can for the most part only be acquired gradually. High and sustained machine outputs cannot be expected from fields ill-prepared for machine operation but field improvements take time. Conventional harvesters have proved to be uneconomical where conditions are unsuitable. A farmer's capital is not unlimited.

These considerations have dictated a stage-by-stage and evolutionary (rather than revolutionary) approach to mechanical harvesting of sugarcane.

The Stage I Machine is tractor-mounted and tops, cuts and partially cleans green or burnt cane leaving the cane in an orderly swathe ("sausage") lying lengthways along the cane row. A reduced labour force, using a special knife, recovers the cane from the sausage, trims it and piles it in the usual way. The Stage I machine exploits the two naturally weak points found in all cane stalks, one at the base and one at the junction between the mature and immature portions of the stalk. Severance at these two points provides the perfect milling sample. When the Stage I machine is used in conjunction with Stage II, topping is omitted and its function is solely to present the cleaning machine with an ordered array of base-cut cane.

The Loader is a simple tractor-mounted slew loader able to retrieve cane from a wide area and deliver it into virtually any existing field transport.

The problem of obtaining sufficient output of a low value material

Although sugar must be counted as a highly priced agricultural commodity, sugarcane itself is not. Machines which harvest it must either be much cheaper than equipment like grain combines or have much bigger outputs per unit of cost.

Cane does not offer the harvesting machinery designer a simple task; the only known "cheap" harvester able to stand up to the rigours of the cane field is the machette wielded by hand. Thus the jump from manual to machine harvesting not only demands a big capital outlay but also that the equipment have a much higher output than would be required of most other agricultural machinery.

Economic output from a machine depends primarily on the following:

(*a*) The duration of crop — fortunately cane harvests are comparatively widely spaced.

(*b*) Forward machine speed — usually a compromise between the quality of work and the ability of the driver and mechanisms to handle the terrain and cane condition (the limiting factor with green cane is usually either row following, or the cleaning mechanisms).

(*c*) Cane yield per hectare.

(*d*) Width of each pass — a most serious limitation to the output of single-row cane harvesters.

(*e*) Number of hours worked each week — limited by the mechanical soundness of the machine and/or the speed of repairs, the organisational ability of the owner, the weather, willingness to undertake night-time operation, and, in the case of "combine" harvesters, the availability of transport.

(*f*) Working life of the machine — according to Pothecary[6] the most important, yet least known, statistic in costing agricultural equipment. However, it is reasonable to assume that

(i) the simpler the machine the longer the life which can be built into it, and

(ii) that good land preparation will greatly lengthen life.

Since harvest operations can easily cost a third of the price received by the grower for his cane, and since the capital value of harvesting machinery will usually account for half (or more) of the cost per ton reaped by it, the question of output is crucial.

The problems of harvesting green cane

These are well known. They include the serious difficulties of vision, machine chokes because of the volume of matter to be processed, difficulty of cleaning the cane, fire risks, and general post-harvest management including soil decompaction.

Since harvesting green cane presents the larger problem and is one to which a solution is so badly needed, the machinery designed by McConnel's so far has been dominated by the demands of green cane (Hudson[4]). However, no serious difficulties have been encountered when operating in burnt cane (in fact rather the reverse) and none are expected.

Alternative harvesting methods

In reasonably level areas with good stands of cane, when there is a willingness to burn, and a high level of mechanical skill, the existing "combine" single pass harvesters are probably the best way of handling the low value raw material in order to achieve a good relation between output and cost. Nevertheless it must not be overlooked that attendant chopped cane trailers constitute a second machine pass.

In less favoured circumstances, or if green cane is wanted, or when the labour situation (with its political overtones) does not encourage a widespread adoption of wholly mechanised methods, then we believe it is best to employ a multi-pass method. The first pass simply arranges the cane in a form which can be easily dealt with by the more complex second-pass machine which cleans and collects. Thus the machine with the more difficult task does not also have the task of "hacking through the jungle". Furthermore, we suggest that "accompanying transport" in the less favoured areas is a snare to be avoided if at all possible (Smith[8]) and that the second pass machine should leave bundles of whole stick cane for an independent loading operation.

We hasten to say that the above is not novel thinking in agricultural engineering, a number of multi-pass harvesting systems being well known for crops as diverse as potatoes, sugar-beet, grain and vining peas. Nor is it novel for sugar cane harvesting. The best known sugar cane two-stage system is the "Louisiana" method and more recently a high-capacity, two-pass, two-row, in line, system has been pioneered in Florida by Fowler[2]. However, these systems operate exclusively in conjunction with burning.

Multi-pass: A love/hate relationship

Obviously, a simple, light, rugged, single-pass machine able to solve all the problems of cane harvesting, especially of green cane, would be in general demand, but such a machine has not yet been produced.

The typical need for mechanisation is a response to an incipient labour shortage and not to a dramatic, sudden, and total absence of labour. Farmers faced with this situation have three possible courses open to them — to give up producing cane, to suddenly replace all remaining labour with a complete mechanical system, or to introduce a phased mechanisation. We think there are many circumstances where the last course is the best. The advantages of a phased, or stage-by-stage system may be summarised as follows:

Social considerations. Cane harvesting has traditionally been labour intensive. Mechanisation proceeding too fast will probably cause unrest and unwelcome political interference.

Management skills. Jumping overnight from a hand-cut to a completely mechanised method is likely to be a traumatic experience for owners and managers. Time to learn machine techniques is required.

Land preparation. Hand cutting has required only minimal land preparation but if high, economic machine outputs are to be sustained then good land preparation is necessary. This takes time.

Capital cost. We fear that the contrast in capital cost between buying 50 cane knives and buying a fully mechanised harvest system will be a source of continuing sorrow to cane farmers everywhere. The mechanical harvesting of all crops is expensive but a stage-by-stage system does allow the cost to be spread. (Indeed it will not always be necessary to proceed to the end of a progression (Fig. 1) of loader-reaping aid — complete system since labour supply may come into equilibrium with the degree of mechanisation at any point.)

Risks of total stoppage. Any multi-pass system is less vulnerable to total stoppage due to mechanical or organisational problems, including the organisational problem of accompanying transport. (This is one of the main reasons why the Louisiana farmers have stuck to their two-pass system.)

Capability of cutting two or more rows. A multi-pass system is likely to adapt easily to dealing with more than one row without involving very large and complicated machines (Roux[7]).

When a two-pass system is applied to two-row cutting the result is effectively a single pass one-row system. Additionally, this will minimise soil compaction both by the development of two row cutting and because a succession of lightly loaded wheel passes are less compacting than a smaller number of heavily-loaded passes. Perhaps even more important to the farmer with much sloping land is the much greater stability conferred by a 2-row approach.

However, the fact that there are some very important short-term advantages of a multi-pass system, and perhaps even more important long-term advantages, does not blind us to the fact that psychologically many farmers will resist the multi-pass idea and that we shall often be accused of putting the cane back on the ground. "Thou shalt not drop ..." is accepted by many engineers as an inviolate rule. But we question its absolute validity under all circumstances. In daily life countless articles are put down only to be picked up again with clear advantages to the overall purpose; witness the pallet loads of components moving round a factory. The crux of the argument lies in the ease (and low cost) with which correctly designed equipment can pick up again, and one of the key components of the multi-stage system is the method of picking up cane in the Stage II machine.

The long and the short

The modern trend is to chopper harvesters. The deciding factors which governed this swing include:

(*a*) The difficulty of handling sprawled and lodged cane with whole stick machines which try to deal with it as if it were erect.

(*b*) The need for a second independent loading pass if cane is dropped as bundles or windrows.

(*c*) The extra possibilities for obtaining a clean sample when the cane is chopped and passed under an extractor fan.

(*d*) The higher load density possible with chopped cane.

However, experience has suggested that for an industry just starting to mechanise, the disadvantages of chopped cane (faster deterioration, organisational demands of accompanying transport, the total capital cost (including trailers) and cost and timing of factory modifications) usually outweigh the advantages. We have, therefore, concentrated our first efforts on the handling of whole stick cane, but with the proviso that nothing in the system must depend on it.

Sword or club

Traditionally, people have hacked their way through jungles with sharp blades. In at least some circumstances, however, it would be nice to do without sharp edges. Sharp edges need maintaining; in stony soils they may be inoperable; they need to be positioned carefully. The development of our multi-pass system has shown that sharp edges are not essential to a satisfactory cane harvesting system.

The stalks of many cane varieties break quite neatly at ground level if the cane is pushed over firmly and where the break is only partial it can be completed by a karate blow delivered by a relatively slow moving, ground following, sweep. Where stones or similar hazards are likely to be encountered this exploitation of the self-harvesting character of many varieties may be the only route to satisfactory work in unburnt cane since the driver cannot normally see obstacles in the path of the base cutter, and accurate height adjustment of a sharp blade is very difficult for the same reason. The exploitation of this basal breakage by ground-following sweeps also makes it possible to complete the severing of stalks after the cane has been pushed flat, thus permitting a tractor to travel over the cane before base severing, so that self-propulsion or side-mounting is no longer necessary.

Of course, in circumstances where the stools are not well anchored in the soil or the variety does not break well at ground level, this karate cutting will lead to some uprooted bits of stumps. We emphasise, however, that the total system is not dependent upon this method of base cutting and suitable sharp-edged machines can be devised for laying the cane down for the second pass machine (in fact some possibilities have already been devised as reaping aids by South American companies). Since all the early work on this system was carried out in an island with stony soils and irregular field preparation we have so far concentrated on exploiting the method of karate base cutting.

The overall concept

The foregoing is now summarised into a more positive outline of our overall concept:

(1) A system which can be introduced in phased stages to
   (*a*) match labour availability
   (*b*) spread the capital investment over a long period
   (*c*) give time to learn and study
   (*d*) give time for land preparation and cultural changes
   (*e*) give time for adaptation of management, operators, factories and back-up services.

(2) Three basic machines are involved (Figure 1)
   (*a*) *Loader* with characteristics which make it efficient not only for independent use but in conjunction with all subsequent machine introductions.
   (*b*) *A reaping aid* (Stage I)
   (*c*) *A cleaner/batcher* (Stage II).

   All machines are designed to work with standard medium horsepower tractors; in all cases tractors can be easily freed for other work.

(3) A capability to handle both green and burnt cane including handling lodged cane, not by trying to stand it upright, but by combing it into an orderly array on the ground.

The Stage II machine

The basic machine is still much as that described by De Beer.[1] Figure 2 shows the latest machine in photographic and diagrammatic form.

General operation and design [Figure 3]

The Stage II moves in the *opposite* direction to Stage I; cane is therefore gathered tops first (c.f. all single-pass harvesters where the cane comes in butts-first), is lifted up a ramp (which stones cannot climb) and engaged by a conveyor. At the head of the conveyor is a pair of counter-rotating, accelerating drums which wind off the tops and accelerate the cane rearwards into the bin. Two counter-rotating cleaning drums situated rearwards of each accelerating drum assist the removal of tops and confirm the flow of trash round the accelerating drums.

The machine is built with a 120° centre-pivot which is hitched to the tractor by a novel use of the lower link arms. These transfer the weight of the machine to the forward ends of the links, so preventing the front of the tractor from rearing upwards.

Gathering. Cane is gathered into the machine by ground-following hinged sweeps. These sweeps are a modified version of those which complete the base severing in the Stage I machine. Gathering tops-first greatly facilitates this operation and a slow rotation is sufficient. The occasional "uncut" stalk will receive a "karate" blow to part it from the stool. Rocks are pushed sideways from the 1,2 m wide throat because they cannot climb the ramp up which the cane is passed on to a conveyor. Since the sweeps have to stand up to occasional severe loading the hinge consists of a series of 18 coarse threads working in a grease bath. Each sweep is pushed against the ground by an adjustable spring and pivoted in such a way that the downward pressure is nearly uniform over the range of tip movement.

Accelerating. From the conveyor each cane is nipped by two sets of counter-rotating, rubber-clad accelerating drums (the "hurlers") about which the tops are wound but which also accelerate (by a factor of approximately 10) the stalks rearwards into the bin. In perfect conditions there will be only two or three stalks in this accelerator at any time, so giving ample detopping and detrashing opportunity, but mutual interference and poorer cleaning is noticed when more than about 10 stalks are passing simultaneously. Therefore, every effort is made in the conveyor section to thin the cane mat. Detrashing occurs partly at the head of the conveyor because trash, unlike stalks, is incapable of rapid acceleration and partly by the wrapping action of the accelerating rollers. To deal with occasional cane bunching (e.g. resulting from old irregular plantings) the upper accelerator drum is spring loaded and able to rise.

The cleaning drums ("fans") located behind each accelerating roller (and away from the line of flight of the canes) are counter-rotating. The original function of the paddles on these drums was to strike at the half broken-off top as the cane was ejected by the accelerator and complete its removal. It was later found that by increasing the paddle speed, and so increasing the air flow, removal of trash was improved. We have been unable so far to analyse the aerodynamics of the airflow from such rotating paddles and the present arrangement of cut-offs and shrouds is empirical. We do know, however, that the airflow is poor in relation to power consumption and that there is room for improvement.

The Bin has to be able to accommodate stalks up to 3 m long and accounts for nearly half the machine's length. In the present design the bin can be set to form a bundle to either side of the centreline, allowing offset dumping when the floor is lowered. This facility will not be needed with 2-row operation.

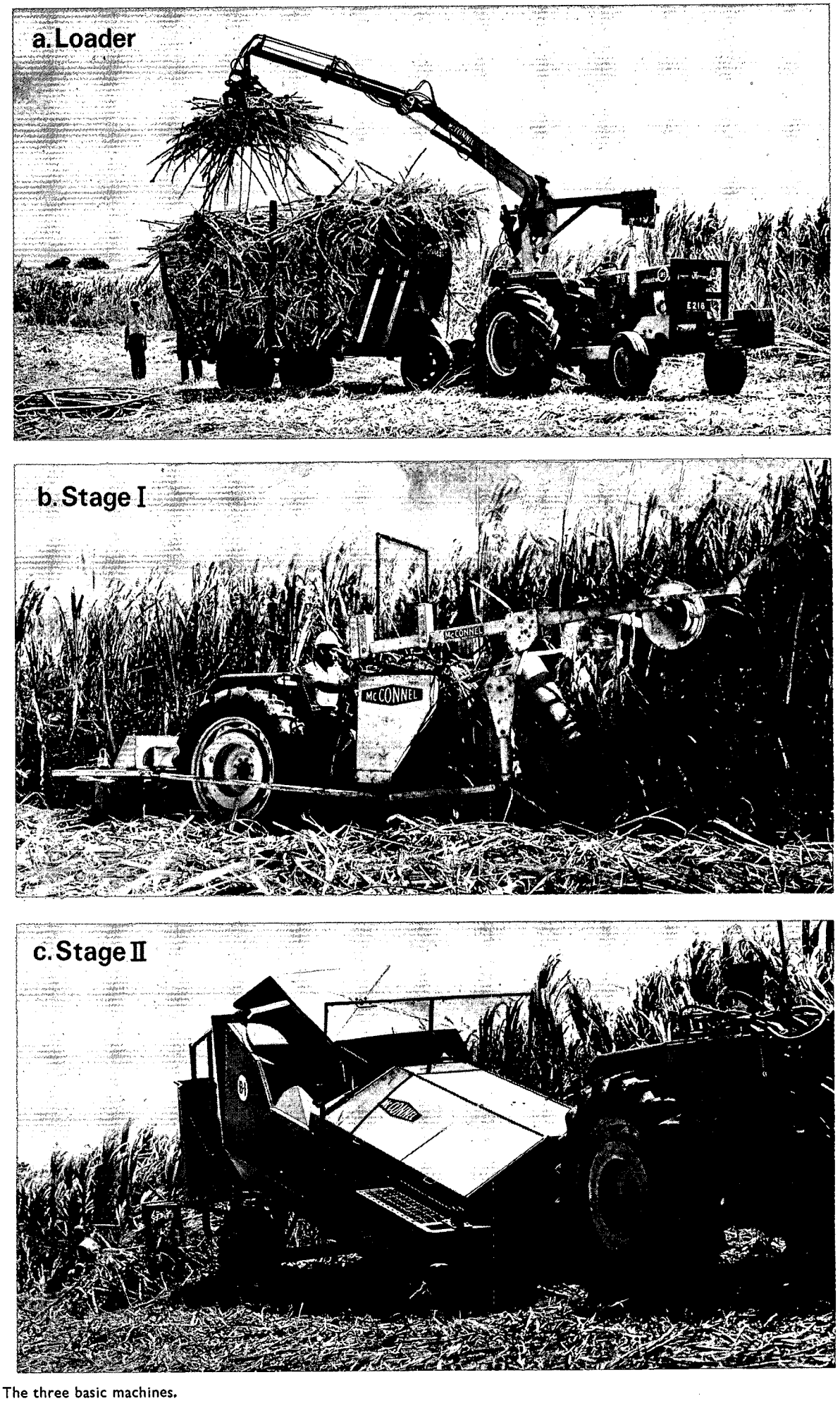
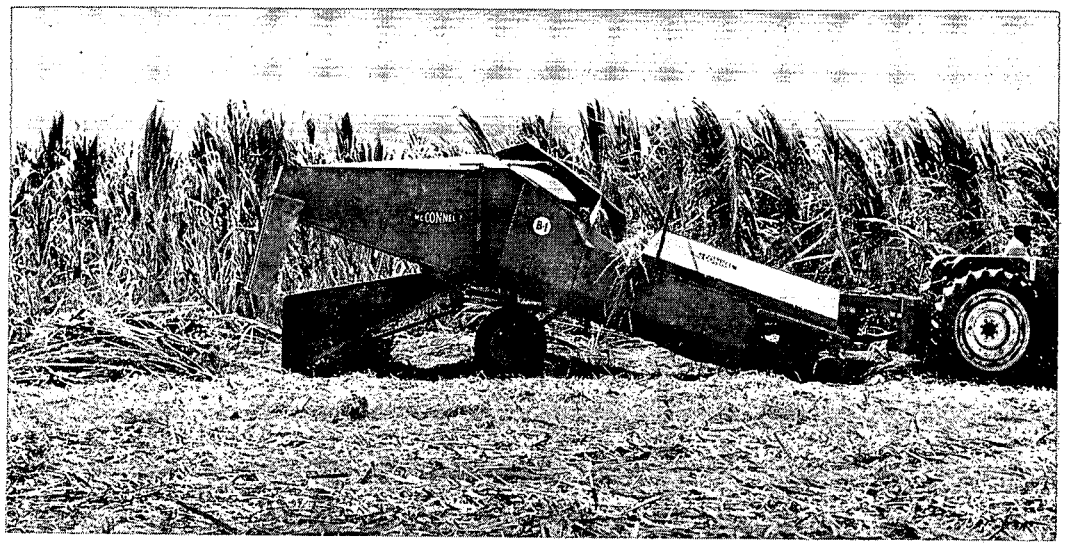


FIGURE 1 The three basic machines.



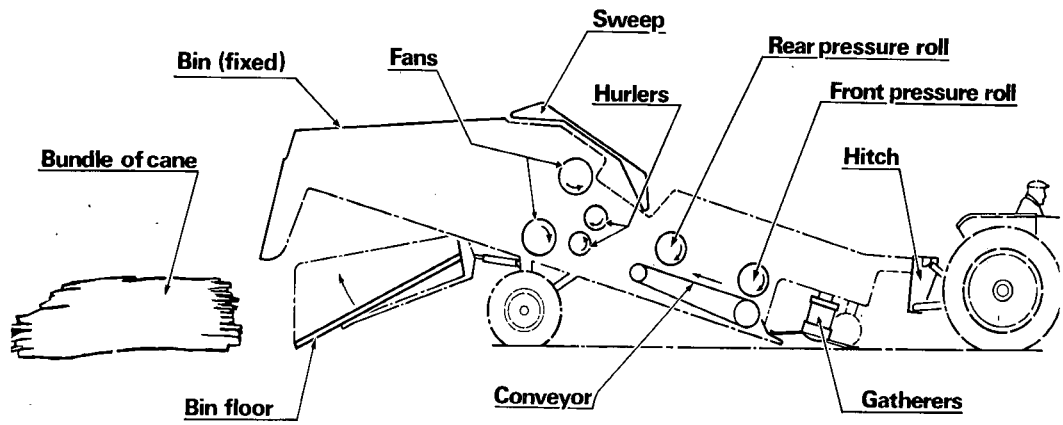


FIGURE 2 The Stage II machine at work in Barbados. Diagram of key components.

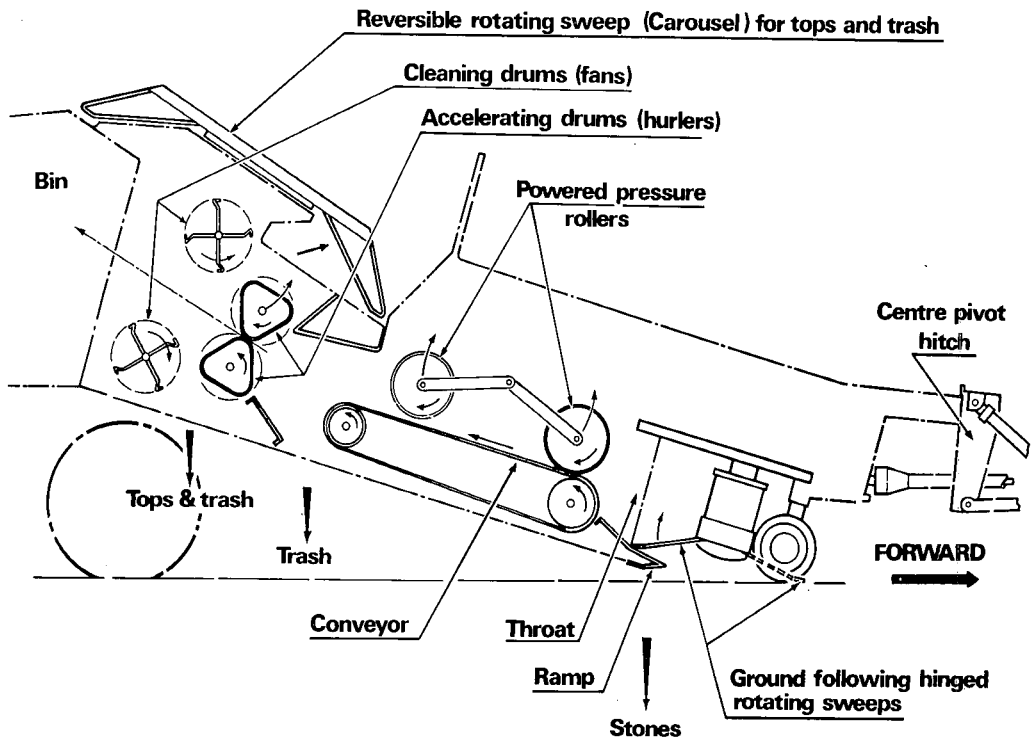


FIGURE 3 Details of operation & design of Stage II

Topping process

When the Stage II machine is being used the first Stage I pass does not need to top and all topping is done by the Stage II. As the leaves wind round the "hurlers" they are moving more or less at right angles to the direction in which the rigid cane is being propelled, and an effective snap at the "coot" (or junction of mature and immature portions of the cane) is achieved. In theory it is possible to obtain 100% topping efficiency with this method since it is independent of cane length.

Extraneous matter

At the time of writing only a small number of bundles from the new Stage II have been analysed for extraneous matter in green cane and the following results are quoted from the prototype machine (1975).

Number of bundles fully analysed	49
Worst extraneous matter total	21,2%
Best extraneous matter total	3,2%
Average for 49 samples	9,7%
Comparative figure for 155 samples of hand-cut, hand-piled, mechanically loaded, unburnt cane	9,2%

Miscellaneous data

At the time of writing the following information was known: weight of Stage II — 4 000 kg; typical weight of bundle dropped — 300 to 450 kg; forward speed in 70 tons/ha — about 2 km/hr in green cane and about 4 km/hr in burnt cane. Gradients up to 10° have been handled and there seems to be plenty of scope for improvement. Cane of 120 tons/ha has been handled green, depending on variety, but the limit in burnt cane is not yet known. Wet weather performance is limited by the grip on the rubber accelerating drums. Any culture cut satisfactorily by Stage I can be handled; flat cultures have given the best results so far.

Preparation for Stage II operation

Only cane first cut and laid by Stage I can be accepted by Stage II to obtain satisfactory cleaning, and Stage II is therefore dependent on prior Stage I working. (Since topping is not carried out in the Stage I pass the forward speed of the Stage I is typically about doubled.)

It has been said before, but it will bear repeating, that although Stage I is able to perform in a wide range of non-ideal situations, there is a big difference between "getting through" and achieving sustained outputs of neatly windrowed cane. This brings us back full circle to the earlier part of the paper which argued the benefit of the phased mechanization which ensures that Stage II is introduced into a well-organised system of culture, suitable varieties, and adequate mechanical skills which are the product of experience with the Stage I machine.

Conclusion

The first steps in creating this phased harvesting system were taken six years ago. Both the loader and the Stage I are in commercial use already and the time has now come to put the Stage II into commercial use. No doubt the conditions of the South African sugar industry are going to require at least some adaptations of the machine and these will be achieved by working with local agricultural engineers and cane farmers during this coming crop.

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