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A REVIEW OF MECHANICAL HARVESTING AND ITS EFFECT ON SUGARCANE QUALITY

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From papers submitted to ISSCT Congresses over the past 12 to 15 years, it is clear that the emphasis has shifted from problems involved in implementing mechanical harvesting systems on estates not prepared for this, to a much more thorough look at the effect of the machines on the product delivered to the mill. It is obvious that smaller profit margins are forcing sugarcane and sugar producers into a more critical evaluation of machine performance. For this ISSCT Congress contributions on this aspect of sugarcane production have been submitted from countries such as Australia, Barbados, Brazil, Cuba, Iraq, Peru, South Africa and the United States of America. A number of countries are interested, for different reasons, in harvesting sugarcane without prior burning. Serious concern is thus developing about the capabilities of mechanical harvesters to handle green cane.

This paper will review some of the data published since 1969 on mechanical harvesting and cane quality. Contributions submitted to this Congress are also included.

FIELD EFFICIENCY

First reports on machine output received from countries other than Australia, presented a very poor picture. It was, however, soon appreciated that properly prepared fields were essential if acceptable performances were to be obtained from machines such as chopper harvesters. Papers published in Jamaica(37) and Mauritius(22) indicated that field efficiencies of about 40% could be expected. Twenty-five choppers in the French West Indies(12) gave an average field efficiency of 45%. In South Africa(11) it was established that while actual pour-rates were 60 t/h or more, productivity averaged only 20 t/field hour. Even under ideal conditions, 10% of the total field time was lost when turning on the headlands. Of course, factors such as field layout and availability of infield cane transport will also affect field efficiency. Under good field and management conditions, as they obtain in Australia, field efficiency can be as high as 60%.

EXTRANEOUS MATTER

Increased amounts of extraneous matter will adversely affect haulage payloads, mill throughput and sugar recovery. Clayton and Whitemore(5) reported in 1969 that each one percent of trash content resulted in a loss of 1.5 to 2.0% in...
the value of the sugar produced. South African tests at two mills showed that extraneous matter decreased the crushing rate by 2.2 to 3.0% for every additional 1% of trash (leaves) % cane. Tops did not adversely influence the rate of cane throughput. The effect of trash on sucrose % cane is illustrated by the fact that if clean cane contains 13% sucrose, additions of 5, 10 and 20% trash will reduce this value to 12.35; 11.70 and 10.40% respectively. From a laboratory investigation of the effects of trash it was concluded that both tops and leaves had pronounced adverse effects on juice purities and clear juice quality. In addition, the presence of dead leaves reduced pol extraction. All these effects were found to increase linearly with extraneous matter contents up to 30%.

The total extraneous matter content will largely be determined by field conditions such as variety, degree of lodging and wetness of the crop. Various studies have shown extraneous matter contents of chopper-harvested cane to vary from 6 to 17%, compared to those of hand-harvested cane of 3 to 7%.

Compared to manual cutting and push-pile loading, chopper harvesters, nevertheless reduce substantially the quantity of soil delivered with the cane. In Brazil a reduction in mineral matter of three times, to 0.8%, was recorded in one study while in another soil content ranged from 0.1 to 0.3% for chopped cane as compared to 0.5 to 3.1% for mechanically-loaded cane. Other figures quoted varied from 1.3 to 0.6% for three different choppers tested in Brazil. Australian researchers point out that the amount of loose soil recovered from a sample is generally much less than 50% of that recoverable when washing the billets carefully. Cutting below ground will reduce the loss of millable cane in lodged conditions, but will increase the dirt content.

Using an ashing-technique to analyze 340 samples of push-piled mechanically loaded cane from eight different loaders over a three month period in South Africa, the average soil content was found to be 5.2% d.m., but daily averages periodically exceeded 10% d.m. with individual samples sometimes exceeding 20% d.m. Over the same period, in the same area, 22 samples of hopper harvested cane had a soil content of 2.0% d.m.

Tops frequently comprise 70% of the total extraneous matter in chopper harvested cane. The problem is that if, due to recumbancy, the external topper does not remove the tops, there is little chance of their being removed later. If the extractor fans are adjusted to remove these tops, too high a percentage of billets will also be lost in the process.

By improving the quality of the burn during poor weather conditions, through the use of chemicals such as Gramoxone, the total trash content of mechanically-harvested cane can be substantially reduced. This was found to be so in Iraq where S.W. Baxter, personal communication
trash content was reduced from 13.7 to 2.4% \(^{(3)}\).

The Bureau of Sugar Experiment Stations in Australia has developed a convenient method to sample the cane delivered by a chopper harvester \(^{(1,8)}\). A portable, light-weight chute is attached to the back of the haulout bin or trailer. Samples are taken by signalling the haulout driver to move forward briefly so that the harvester discharges directly into the chute. A bag attached to the bottom of the chute then catches the sample. This sampling method allows the harvester to cut without any interruptions, and the sample is likely to be quite representative.

**FIELD LOSSES**

Field losses of sugarcane due to chopper harvesting consist of cane left behind in the field and losses of juice and cane fragments so small that they cannot be gleaned (invisible losses). Cane left behind can easily be determined by the careful gleaning of marked-off plots immediately following harvesting. Typical values for this part of the cane loss vary from 2 to 10% \(^{(10, 26, 34, 41)}\).

Invisible losses are more difficult to determine, especially under actual operating conditions. A survey of invisible losses was made when using six chopper harvesters in Florida in 1974.* This followed on reports from Australia \(^{(39)}\) that losses were 19% and up to 30% when pre-weighed cane was fed through harvesters. In the Florida study, harvesting mechanisms and extractor fans were operated at normal speeds and pre-weighed cane was fed through the machines. After the tests, all cane found inside the machine was added to that which dropped out of the harvester. There was still a shortfall of 3.2%, which was regarded as an invisible loss, probably due to the disintegration of billets and lost juice. According to a Mexican study carried out in 1975 \(^{(7)}\) two chopper harvesters delivered 78% of available millable cane as compared to 94% from manual cutters. Both “cane left behind” and “invisible losses” were probably included in these figures.

A 1976 study at Rio Grande Valley Sugar Growers,\(^{(31)}\) comparing hand cutting with a chopper harvester, indicated that little, if any, juice was lost in the mechanical harvesting operation. However, when testing eight different models of chopper harvesters in 1977 \(^{(28)}\) in a field averaging 133 t/ha, it was found that 15% of the pol available after burning was lost during the harvesting operation. This loss was made up of 1% pol recovered with the trash, 10% lost in scrap left behind in the field and 4% an undetermined or invisible loss. These values were determined by comparing the pol % cane and fiber of hand cut samples and the net cane component of the gross cane delivered by the machines.

During 1976 it was reported in Hawaii \(^{(19)}\) that the extraction fans of a specially-built chopper harvester removed 2.0 tons recoverable pol/ha from 261 tons of sugarcane/ha. South African tests,\(^{(9, 10, 36)}\) based on direct comparisons

*Jose E. Clayton, personal communication
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of millable cane delivered by machine and by manual cutting, gave invisible losses due to chopper harvesting of 4 to 15% in excess of those due to manual cutting. The lower values were found with well maintained machines, while the higher values were for machines obviously in need of attention.

As a comparison, a South African study of the results from 243 samples taken on three different estates, showed a loss of millable cane due to hand cutting and mechanical loading of 3.0%. This was reduced to 1.7% with subsequent manual gleaning(10).

A different approach to establish losses during harvesting was followed in Brazil, where the effects of two chopper harvesters were compared with those of manual cutting and mechanical loading(15). In this case the main parameter studied was the ton pol/ha delivered at the mill. Samples were taken at the mill, shredded and the juice expressed. The manually harvested treatment gave the best values for pol % cane, fiber % cane, juice % cane, reducing sugar % juice and juice purity. Manually cut cane also resulted in higher tonnages of cane and pol harvested per ha. For the variety CB41-76, for example, manual cutting resulted in 13.8 ton pol/ha compared to 9.3 and 12.4 ton pol/ha respectively for the two harvesters.

According to an Australian harvester manufacturer, efforts to improve the efficiency of extraction by increasing air flows have produced unacceptable cane losses due to millable cane pieces passing through the extractors. A compromise setting, resulting in a 3% cane loss, is normally used(40).

BILLETT QUALITY

Most work on billet quality has been done in Australia. In 1977 the BSES commenced performance testing of harvesters with a view to establishing _inter alia_ the effect of different machines on billet length and billet damage. Procedures to grade billets into “sound”, “damaged” and “mutilated” classes have been proposed. Results showed that the speed of harvesting had very little effect on billet quality, provided the machines were well maintained. Lodged crops, on the other hand, reduced the proportion of sound billets. Massey-Ferguson chopping mechanisms gave the most consistent supply of sound billets and the least variability in length (17, 25). Toft chopper knives required frequent replacement but in these machines this is a relatively easy and quick operation. If the chopper blades of Claas harvesters were not sharpened for 23 hours, the proportion of sound billets fell from 60% to 12%. Typically, 50 to 80% of billets cut by the machines mentioned were classed as having well cut ends.

GREEN CANE HARVESTING

Harvesting green cane in Texas in 1977 with eight different chopper har-
vesters resulted in a reduction of 68% in pour rate compared to that for burnt cane at 66 t/ha\(^{(28)}\). Australian researchers\(^{(17)}\) found that a Claas 1400, MF205, Toft 4000 and a Toft 6000 were all capable of harvesting green, erect crops of Q90 with extraneous matter levels similar to those obtained in burnt cane. Pour rates were, however, reduced by 30 to 40% compared to those for burnt cane. Another Australian study\(^{(25)}\) showed that the efficiency of trash removal was largely dependent on the quantity of trash present in the field. Chopper harvesters removed a higher percentage of the trash contained in green than in burnt cane. It is interesting to note that, compared to burnt cane, green cane harvesting will often result in a larger percentage of tops being removed. This is due to the lodging effect of burning which may place a large number of tops beyond the reach of mechanical topers\(^{(25, 30)}\).

The performance of a number of Class 1400 harvesters was studied recently in Texas while harvesting 812 ha and 3,687 ha of green and burnt cane respectively\(^{(30)}\). Green cane harvesting increased both the trash content and the amount of cane left behind in the field. In comparison with burnt cane, green cane harvesting sustained a loss of 7.4% of sugar recovery, even though the quality of the juice was superior. Green cane harvesting increased production costs by 9.2% through reducing harvester, transport and milling efficiencies. It was concluded that with the present returns for sugar, green cane harvesting by chopper harvesters was not economically justifiable.

**CURRENT RESEARCH INTO HARVESTER DESIGN**

In addition to the development work being undertaken as a matter of course by harvester manufacturers, various research organizations are investigating basic machine component performance requirements in an effort to improve cane quality and harvesting capabilities and to reduce power requirements.

In Cuba it was discovered that for a particular machine configuration, the loss of cane through cleaning fans was not influenced by variations in feed rates. The power consumption of cleaning mechanisms was directly proportional to the initial extraneous matter content and it was affected more by the amount of cane passing through axial fans than by an equivalent mass of removed extraneous matter. Trash removal efficiency remained almost constant, with only a slight reduction as feed was increased\(^{(25)}\). The effect of chopping mechanisms on cane and juice losses has been studied by means of high-speed photography\(^{(27)}\), and mathematical models are being developed to evaluate topper effectiveness\(^{(24)}\). A relationship between cane yield and extraneous matter content of the harvested sample has been established, indicating that top and total trash content decrease from 9% to 6% and from 12% to 4% respectively as the yield increased from 107 to 158 t/ha\(^{(1)}\). Pendulum cutting devices are used in Brazil to study the effect of knife speed, cutter geometry and the sharpness of cutting edges on the power required to cut through cane. One conclusion was that relatively blunt base cutter blades require three to six times as much power as does a sharp hand-held cane knife\(^{(41)}\).