FIELD MECHANISATION AND FACTORY PERFORMANCE

PART 1: FIELD OPERATIONS*

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ABSTRACT

A summary is given of the proceedings of a combined ISSCT workshop of the Agricultural Engineering and Factory Processing Sections. Part 2, concentrating on factory performance, is included in the Factory Processing Section.

The most important field practices affecting factory performance are burning or trashing, increased extraneous matter content, mechanical damage to cane and long delays between burn and/or cutting and crushing. Various policies to overcome the numerous agronomic and managerial factors involved in delivering cleaner and fresher cane to the factory can be implemented. Harvesting cane green will usually result in fresher cane delivered. As more field operations are mechanised, the quality of the product may decrease but this can be offset to some extent by good management. The availability of varieties specially selected for mechanical cutting and loading is of extreme importance. The handling, disposal and/or utilisation of cane residue must be carefully considered. An equitable cane payment system based on quality is a necessity to achieve the best compromise between field and factory requirements.

Keywords: Harvesting, loading, transport, scheduling, deterioration, agronomic measures, varieties.

INTRODUCTION

The ISSCT Agricultural Engineering and Factory Processing Sections held a combined workshop in Veracruz, Mexico in November 1997 to discuss the implications of field mechanisation on factory performance. In this and in Part 2, which is included in the Factory Processing Section, the findings compiled from contributions of invited speakers and the proceedings of the workshop are summarised. The names of the main contributors are listed at the end of the paper.

At present only about 20 % of the nearly 1 000 million tons of cane produced per year is harvested mechanically, mostly by combine harvesters. More than 50 % of all the cane is still cut and loaded completely manually. It can be expected that fully mechanical harvesting as well as mechanical loading systems will increase worldwide. Reasons for mechanising include:

- Unavailability of manual cutters or loaders.
- Cost of manual cutters and loaders.
- Social and political considerations.
- More assured cane supplies to sugar factories.
- Environmental issues.

* Part 2 of this paper appears in the Factory Processing section
Constraints to the implementation of mechanised harvesting systems include:

- Economics.
- Farm size.
- Topography.
- Field conditions.
- Social and political considerations.

It is unfortunate that the more harvesting operations are mechanised, the higher the field losses and the lower the quality of the product delivered to the sugar factories.

CANE DETERIORATION

Many of the following considerations are related to cane deterioration caused by *inter alia* cane damage and cane delay, the time required from burn to crush for burnt cane and cut to crush for green cane. Dextran formation is one of the consequences of damage and delays. The growth and reproduction of *Leuconostoc*, the micro-organisms causing dextran formation, should be minimised and the production of dextran by each micro-organism present should also be minimised. Cooler temperatures and good air circulation will inhibit *Leuconostoc* infection. Conversely, anaerobic conditions and mutilation of cane, by burning and by mechanical harvesting and/or loading, promotes *Leuconostoc* development. Cane piled in the field should be piled cleanly and with minimum ground contact. High levels of muds and trash encourage *Leuconostoc* development as does water remaining on piled cane (Clark, 1997). By reducing delivery times, the extent of dextran development can be curtailed. Burning will invariably cause longer delays before crushing than when harvesting green.

GREEN OR BURNT CANE HARVESTING

Burning of sugarcane whether as standing cane or cane already cut into windrows or heaps improves cutting, loading and transport efficiencies. Leaves and immature tops can account for 20 to 40% of the total weight of the biomass in the field. Burning can, however, cause damage to the cane stalk which results in quicker deterioration of the cane supply. Cane burning melts the wax coating on the cane stalk. Intense fires can effect storage tissue by killing localised areas within the stalk. Stalk surface temperatures of 400°C and 98°C, one mm below the stalk surface can be expected for 3 seconds. Splitting of the rind may occur which allow bacteria to invade the stalk leading to rapid deterioration. Delivery delays will exacerbate this problem. The living tissue inside a cane stalk or billet prevents or delays deterioration when the cane is harvested without burning.

Some sugarcane production areas must abide by government legislation, which regulates burning. The complexity of these regulations varies and ranges from a total restriction to controls on how and when fires are ignited. Increasing environmental awareness will eventually force changes to burning practices in most production areas. From an environmental viewpoint the white smouldering smoke from a trash blanket is worse than the black smoke, rising up into the air, from burning standing cane.

In production areas such as Colombia green cane harvesting results in very large quantities of trash left in the field which makes subsequent operations difficult. In some instances there could be as much as 100 tons of trash per hectare. One way of handling such a large quantity of trash is to chop it up and either place it back on the ground or harvest some of it for power generation.

A summary of workshop delegate's combined thoughts on green cane harvesting and its implications for field and factory is listed in the Appendix.
HARVESTING SYSTEMS

Manual cutting and loading:

A well-managed manual operation will give the best quality and least in-field cane loss. However, labour is becoming scarce and/or unwilling to perform these arduous tasks. In many instances they are no longer willing to cut green cane. The task of picking up, carrying and loading cane into waiting transport or into pallets or stacks, is especially becoming repugnant. The time taken to load the vehicle must be included in the total cost, as vehicle utilisation and productivity are usually adversely affected when loading is done manually. Vehicle payloads will usually be higher with manually loaded cane.

Mechanical loading:

A wide range of loading attachments and self-propelled grab, push-pile, slewing and non-slewing loaders are available. For effective operation, cane from 3 to 6 rows must be placed manually or mechanically into either continuous windrows or into small bundles. Disadvantages of mechanical loading are the possibility of including stones, soil and trash with the cane and of uprooting cane stools. Mechanical loading can increase ash content by 200% or more compared with manual loading.

Mechanical loading would be the first logical step for many sugar industries. It is far easier to implement than mechanical cutting or harvesting with much less stringent field requirements. Mechanical loading is cost effective and it can reduce burn or cut to milling delays very considerably, resulting in improved cane quality.

Mechanical cutting:

Cutting devices can be attached to tractors. Some of these only base-cut the cane with labour still required to place the cut cane into windrows or bundles. More sophisticated machines, tractor mounted or self-propelled, can place the cane into windrows or bundles, ready for mechanical loading. None of these devices can handle recumbent cane, nor can they strip the leaves from the cane stalks. Mechanical topping is only effective if the cane is straight and upright.

Mechanical cutting plus mechanical loading plus mechanical topping have not adversely affected the quality of cane delivered on an estate in South Africa. Mechanical topping with a topping attachment fitted to a grab loader was more effective than manual topping.

Because whole stalk cutters cannot handle recumbent cane and cannot remove leaves from the stalks, it can be expected that their use will be limited. However whole stalk harvesters may play a useful role in a combined manual/mechanical harvesting system on larger sugar cane estates. One possibility which may make them more acceptable, would be if free trash ing, erect varieties become available and if the factories become more inclined to accept cane with some dry and green leaves but with the tops removed.

Combine or chopper harvesting:

Combine harvesters can handle erect or recumbent, burnt or green cane, at cane yields of up to 150 t/ha. These machines require higher managerial skills, good field conditions and high utilisation to be economical. Adverse effects of combine harvesting systems are:

- EM levels of 5 to 15% depending on whether the cane is harvested green or burnt, erect or recumbent.
- Cane losses of 5 to 10% compared with manual harvesting systems. There is a compromise between cane loss and EM content — by operating the extractor fans at higher speeds, EM will be reduced but total cane loss will increase.
- Rapid deterioration, especially of damaged billets.
- Soil inclusion with the billets when base cutting too low.
Assuming all leafy material is removed pneumatically, the only component of the top that gets into the factory from a chopper harvesting system is the billet that contains a part of the top. However the mills will be able to accept these top pieces because the purity of the juice from this billet is about the same as the purity of final molasses. Hence they tend to bring in about as much sucrose as is lost in the molasses they produce.

There will be problems when changing from manual to chopper harvesting. However, experiences in Florida have shown that most problems can be overcome by tightened management and by modifications in the factory. A moderate tonnage variety with high sucrose, tillering and ratoning capability is preferred for chopper harvesting. Varieties should be disease resistant because base cutters and extraction systems of chopper harvesters will spread diseases rapidly. Harvesting equipment should be sanitised on a regular basis and at least when moving between fields. Harvester operators should be properly trained. Colour has not become an issue. Dextran formation was a problem; especially where cane was stockpiled. Cane should be milled less than 20 hours after harvest. It is better to store billets in trailers or in bins rather than on pads as this allows for better control. Good sanitation is required in mills and mill yards. Harvesting of severely freeze-damaged cane is a problem and such cane should perhaps be harvested green.

In Argentina different weather conditions at different times of the year result in various quantities of EM in the sample. Chopper harvesting systems are more effective during dry periods and when maturity of cane is high. Semi-mechanised systems are better at the start and end of the season when cane is immature and humid weather prevails. Coupled to frost damage, mechanical harvesting losses can be severe, especially at the end of the season. Due to high labour costs in Argentina, chopper harvesting is presently the cheapest cane harvesting option.

A trial was done in the Dominican Republic over 4 ratoons and 4 commercial varieties to compare chopper harvesting with manual cut and loaded systems. Cane and sugar losses from chopper harvested cane were much higher for all varieties. Fibre % cane averaged 9.3% higher for chopper harvested cane. Smut incidence showed an alarming increase in chopper harvested fields.

Experiences in Venezuela have shown distinct advantages resulting from mechanical harvesting. There is a more assured flow of cane so scheduling is easier and more accurate. Loss in cane is made up by better quality due to freshness with 66% of cane delivered within 24 hours. Chopper harvesting is much cheaper and there is far less hassle in negotiating with people.

A large sugar estate in Argentina plans to mechanise all harvesting except on steep fields. Using a fleet of modern chopper harvesters in burnt cane, trash varies from 7.5 to 9% and from 10 % to 12 % in green cane. Three percent of the cane is left behind in the field. Losses due to the operation of the extractor fans have not been determined.

Commercially available harvesters are mechanically much improved but basic design principles have not changed since inception. Harvester manufacturers will steadily improve the performance of their machines, especially for green cane harvesting, but there is perhaps an opportunity for new concepts to radically change the way cane is harvested mechanically.

MEASURES TO REDUCE THE IMPACT OF MECHANISATION ON FACTORY PERFORMANCE

Variety development:

Cane selected for harvestability, for both manual and mechanical cutting, should have very specific traits to ease the harvesting operation and for maximum potential quality of the product delivered to the sugar factory. Varieties with the following characteristics should be selected:

- High sugar yield.
- Erectness: Lodged cane results in slower harvesting rates and higher extraneous matter levels as it renders mechanical topping devices ineffective. Lodging also promotes suckering which reduces quality.
- Low population density.
- Uniform stalk height.
- Thick and high-density stalks will reduce the level of cane loss during pneumatic cleaning.
- Brittleness results in higher losses during harvesting and also during mechanical loading.
- Short tops.
- Self trashing or loose trash habit.
- Low residue/cane ratio. Final EM levels in the cane supply are closely related to initial EM in the field.
- Tolerant to trash blankets.
- Early and robust tillering.
- Non-flowering cane.
- Resistant to pest and diseases.
- Absence or low incidence of suckering.

Agronomic measures:

For both mechanical and manual harvesting of cane the presentation of the crop for harvest has a significant effect on quality of cane delivered to the factory. Typical factors affecting quality include leaf and trash levels, suckers, dead cane, roots, soil and ERS levels. Usually adverse agronomic practices cannot be completely offset by improved harvester design or harvesting practices and it is important that agronomic practices be closely aligned to harvesting requirements:

- Reduce lodging by harvesting earlier, growing less vigorous varieties on fertile soil and reducing nitrogen fertiliser rates. For some varieties deeper planting and more effective hilling-up may reduce lodging.
- Burning of cane has a significant impact on trash levels supplied to the factory but usually has little effect on the level of tops attached to the top-most billet from chopper harvesters.
- Chemically ripened cane burns more effectively and results in better quality of the harvested product.
- Ash in sugar is related to factors including potassium fertilisers, soil salinity, cane variety and the level of tops in the cane supply.
- Soil in cane is affected by:
  - Shape of the row profile determines whether cane can be cut at or close to ground level without taking in soil.
  - Too narrow row spacing leads to excessive soil intake because the base cutter will be off-centre from the cane row to prevent the harvester wheels from running down cane in the adjacent row. The base cutter then has to be set deeper to gather all the cane.
  - Some varieties are associated with high soil levels in cane with the main factor being susceptibility to lodging and stool tipping.
  - Cane harvested from older ratoons have significantly higher soil levels due to factors such as changes in hill shape, pest damage and the tendency of the cane to grow from the side of hills.
  - Wet weather is the overriding factor affecting soil levels in cane. Improved surface and subsurface drainage, minimum tillage with trash blanketing and avoidance of poorly drained soils during wet weather will help.

Mechanical loading:

To reduce soil in mechanically loaded cane the following measures can be implemented:
- Place the cane across one row or across two cane rows so that the prongs of the loader travel on either side of the cane row without digging into the ground.
- Place cane from as many rows as possible into one windrow.
- Place cane in grab size bundles so that push-piling is eliminated.
- Smooth land surface.
- Introduce effective surface water control measures.
- Remove stumps, rocks and stones.
- Prepare suitable row/interrow profiles. Non-slewing grab loaders operate best on flat culture, whereas push-pile loaders are more effective if cane is grown on ridges of uniform height.
- Equip push-pile loaders with ground following devices to prevent prongs/forks digging into the ground.
- Equip push-pilers with table pilers or other cane cleaning devices.
- Maintain loading equipment, especially push-piler and grab assemblies in good condition.
- Train operators to load clean cane.
- Introduce operator incentive schemes based on cane quality rather than quantity.

**Cane transport systems:**

The prime objective of any haulage system is to transport the cane as quickly as possible after harvest from the field to the factory, at the most economical rate. Where infield conditions are suitable, direct delivery from field to factory is usually the cheapest option. However where field conditions preclude the use of high capacity payload vehicles, transloading may be indicated.

The risk of increasing the amount of soil delivered to the factory is relatively low when transloading chained bundles of whole stalk cane. However, where cane is dumped in loose form on the ground and then reloaded into road or rail transport, increases in soil and extraneous matter levels are likely, as is cane wastage.

Advantages and disadvantages of direct cane delivery systems compared with indirect systems are:

- Simpler with fewer machines required.
- Significant cost savings are possible.
- Less capital investment required.
- Less labour required.
- Harvest to crush delay reduced.
- Fresher and cleaner cane delivered.
- Less cane wastage.
- Often restricted to flatter terrain.
- Possible soil compaction and cane stool damage from heavier equipment.
- Better infield layout and extraction roads required.
- Higher management skills required.
- Less flexible.
- More susceptible to bad weather.

**Transport scheduling:**

The objective is to move cane in an organised manner from the field to the factory in the shortest possible time.
to ensure a continuous and steady supply of fresh cane. An understanding is required of the interaction between various factors affecting equipment utilisation such as weather, harvesting policies, harvesting rate, delivery rate, crushing rate, service, queuing, loading, unloading and travel time. Many tools have been used to optimise sugarcane deliveries. These tools can be simple manual procedures or complex computerised techniques involving linear programming and scheduling algorithms, queuing theory and simulation modelling, as well as a Global Positioning System to monitor vehicle locations.

The principle reasons for scheduling cane transport are:

- Optimising vehicle numbers.
- Vehicle selection, mix and module sizes.
- Ensuring rateable deliveries.
- Avoiding factory stand time due to cane shortages.
- Controlling cane quality by minimising harvest to crush delays.
- Optimising crushing season length.
- Minimising transport costs.
- Minimising infield and transloading costs.

**CANE PAYMENT SYSTEMS**

Ownership systems, distribution between growers and millers and effectiveness of quality incentives must be considered. Different bases for payment, from weight only to weight plus individual analysis and relative payment schemes are used. These aspects are fully elucidated in Part 2 of this paper.

**CONCLUSION**

The most important field practices affecting factory performance are:

- Burning or trashing.
- Increasing extraneous matter content.
- Mechanical damage to cane.
- Long delays between cutting and crushing.
- Choice of cane variety.

Various policies to overcome the numerous agronomic and managerial factors involved in delivering cleaner and fresher cane to the factory can be implemented. An equitable cane payment system based on quality will be the surest way to achieve these objectives.

The unanimous consensus of participants was that this joint cane production/milling workshop has given the grower and miller a better understanding of each others’ problems, limitations and expectations as far as cane cleanliness and freshness and their impact on sucrose extraction by the factory is concerned. It was appreciated that these problems affect the profitability of both the farming and milling sectors and that neither sector can afford to ignore this any longer.

**ACKNOWLEDGEMENTS**

The contributions of individuals, institutions and companies are acknowledged in Part 2 (FPr 17).
REFERENCES


LIST OF PRESENTERS

The following workshop participants made formal presentations on field operations:

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APPENDIX

DELEGATES' COMBINED THOUGHTS ON GREEN CANE HARVESTING AND ITS IMPLICATIONS FOR FIELD AND FACTORY

EFFECTS ON THE GROWER

Advantages:

- Unexpected wet weather will not isolate burnt cane in the field.
- Slower deterioration in green cane provides extra income for the grower as well as the miller where allowed by cane payment systems.
- Trash blanket conserves soil and soil moisture.
- Trash blanket provides no cost or at least reduced cost weed control.
- Trash blanket can reduce field damage under wet conditions.
- Trash blanket can be beneficial for pest control.
- There are indications of improved cane productivity due to improved soil organic matter.
- Savings in water evaporation after irrigation.
- Tops are available for animal feed.
- Tops can provide income for the cane cutters.
- Increased income due to increased leaf in the cane supply where growers are paid just on cane weight.
- Cost savings due to reduced field operations, including eliminating the cost of cane burning.
- Electrical power failures due to cane fires near power lines are eliminated.
- Improved social life - more leisure time.

Note: A partial trash blanket may be nearly as effective as a full trash blanket.

Disadvantages:
- Harvesting costs are higher.
- Income is reduced because cane losses during harvesting are higher.
- In wet or cool regions a trash blanket slows germination and regrowth because soil temperatures are reduced or water is prevented from evaporation. In extreme cases germination may be prevented.
- The trash blanket will greatly impede ploughout, planting and other mechanical operations.
- Flood irrigation may be more difficult.
- Pest control problems may be increased.
- Fires in the trash blanket can cause problems such as killing young ratoons.
- A trash blanket can give a false sense of security for weed control.
- In cool climates the trash blanket will enhance frost damage.
- The change to green cane harvesting could require considerable expense.
- The cane yield may increase but not necessarily the sugar yield.

EFFECTS ON HARVESTING AND TRANSPORT OPERATIONS

Advantages:
- Less lodging of the cane results in easier harvesting.
- Will lead to the development of varieties more suitable to green cane harvesting.
- May be able to haul out more easily under wet conditions with a trash blanket.
- Some aspects of harvesting conditions are more comfortable.

Disadvantages:
- Decreased cane cutter output.
- Increased accident risk to manual cane cutters.
- Some aspects of harvesting conditions are abhorrent to manual cutters.
- Harvester operation more difficult due to restricted operator visibility.
- Increased maintenance required of harvesting machinery.
- Increased fire danger around machinery due to trash build up.
- Increased fuel consumption and consequently increased hydrocarbon air pollution.
- Decreased availability of mechanical harvesting system options, e.g. there is no commercially available whole stalk green cane harvesters.
• Decreased harvester productivity.
• Increased leaf in cane reduces payload and increases transport costs.
• Can get build up of leaf on tyres in wet weather that prevents effective operation.

EFFECTS ON THE FACTORY

Advantages:
• Greatly reduced dextran levels hence easier processing of older cane.
• Higher total sucrose available (depending on cane cleanliness, cut-to-crush delays, the level of trash and leaf in the cane, etc.)
• Increased boiler fuel availability.
• Can start harvesting earlier because no delay waiting for cane to dry before burning.
• Wax from the outside of the stalk is retained.

Disadvantages:
• More leaf in cane implies:
  • more molasses and higher sugar loss
  • reduced milling/grinding capacity
  • increased capacity required in low-grade equipment areas
  • reduced income because of increased cane losses during harvesting.
• More wax entering the factory.
• More colour entering the factory.
• Increased handling problems.
• Increased starch.
• Green leaf can reduce the ability of trash to burn in the boilers due to its higher moisture content.
• Can result in increased fly ash because green leaves will not burn as well.
• Possible need to install a dry cleaning plant so that the leaves can bypass the extraction system. This implies that additional electric power must be generated to drive the cane cleaning plant.

Note: Must take into account the differences associated with clean green cane and dirty green cane.
MECANIZACION DEL CAMPO Y DESEMPEÑO DE LA FABRICA

PARTE I: OPERACIONES DE CAMPO

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RESUMEN

Se presenta un resumen de las conferencias presentadas en el taller combinado de Ingeniería Agrícola y Procesos de Fábrica. La parte 2, se concentra en el desempeño de la fábrica, y está incluida en la Sección de Procesos de Fábrica.

Las prácticas de campo que más afectan el desempeño de la fábrica son las quemas y los residuos, los altos contenidos de materia extraña, los daños mecánicos a la caña y los tiempos transcurridos entre la quema-corte y molienda. Se pueden establecer estrategias agronómicas y de manejo para entregar caña más limpia y fresca a la fábrica. La cosecha de la caña en verde generalmente resulta en la entrega de cañas más frescas a la fábrica. En la medida en que la operaciones de campo son mecanizadas la calidad del producto puede disminuir, pero esto se puede compensar en cierto grado con un buen manejo de la caña. La disponibilidad de variedades seleccionadas especialmente para el corte y alce mecanizados son de mucha importancia. El manejo y/o utilización de los residuos deben ser seriamente considerados. Un sistema de pago basado en la calidad de la caña es una necesidad para alcanzar un punto de equilibrio entre el campo y los requerimientos de la fábrica.

MECANISATION AGRICOLE ET PERFORMANCES INDUSTRIELLES

PARTIE 1: OPERATIONS AGRICOLES

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RESUME

Un résumé des débats de l’atelier ISSCT qui s’est tenu à l’initiative des sous-comités “machinisme agricole” et “process industriel” est fourni en annexe. La deuxième partie, sur les performances industrielles est incluse dans la section “process industriel”.

Les pratiques agricoles qui affectent le plus les performances industrielles sont la récolte après brûlage ou en cannes vertes, le taux élevé de non canne, les dommages causés par les machines agricoles sur la canne et les longs délais entre le brûlage et / ou la coupe et le broyage. Diverses méthodes compatibles avec les contraintes agronomiques et d’exploitation qui favorisent la livraison aux usines de cannes fraîches et propres peuvent être testées. La récolte de cannes vertes conduira très souvent à l’obtention de cannes fraîches. Avec la mécanisation des opérations culturales, la qualité du produit devrait baisser, mais ceci peut être évité par une gestion d’exploitation adéquate. La disponibilité de variétés spécialement sélectionnées pour une coupe et un chargement mécaniques est d’extrême importance. Le traitement, l’évacuation et/ou l’utilisation de résidus de canne doivent être sérieusement considérés. Un système de paiement équitable basé sur la qualité est une nécessité si l’on veut atteindre le meilleur équilibre entre les exigences culturales et industrielles.

MC: récolte, chargement, transport, prévisions, baisse de qualité, mesures agronomiques, variétés.