SOIL COMPACTION DUE TO MECHANIZED HARVESTING AND LOADING

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ABSTRACT

In Mauritius, the extent of mechanized harvesting and mechanized loading differs (10 and 50% of the crop respectively). There has been increasing concern among cane growers that traffic by heavy machinery would lead to soil compaction and subsequent yield losses. A trial was initiated in a humid area to study the effects of mechanized harvesting and loading on soil physical properties and cane yield using two treatments, namely manual harvesting followed by mechanized loading, and mechanized harvesting and loading. Soil bulk density and moisture content were measured over 3 years, infiltration rates were determined after 6th ratoon and cane yields at harvest were recorded over 5 years. It was found that immediately after harvest, compaction occurred in the rows and inter rows in both treatments and was most important at 10 cm depth, even though highest bulk density was measured at 20 cm. After 1 year, bulk density readings decreased again, most of the changes occurring at 10 cm. Stabilized infiltration rates were similar in interrows where harvesters and/or loaders had been used but were still six times lower than in traffic-free interrows. No significant difference was found in actual cane yields between the two treatments. There were therefore no further yield losses attributed to compaction by mechanized harvesters than those already caused by loaders.

Keywords: Mechanized harvesting, loading, traffic, soil compaction, bulk density, infiltration rate, cane yield

INTRODUCTION

The sugar industry in Mauritius has faced increasing labour shortages over the last decade and has had to adapt to changes in cultural practices, particularly harvesting operations. From the mid-1970s, manual loading of cane has been replaced to a large extent by mechanized loading and the trend is for complete replacement wherever possible. More than 50% of cane production is now loaded mechanically, after reaching a peak of 60% in 1994 (Anon., 1996). Mechanized harvesting is also increasingly practised, both whole-stalk and chopper harvesters being used. Mechanical harvesters were introduced in 1974 but stopped operating one year later and new machines were re-introduced only in the late 1980s. About 10% of total cane production now undergoes mechanized harvesting, with 23 harvesters operating on the island.

The most commonly used mechanized loader weighs about 4 t and a chopper harvester more than 12 t. In addition, infield trailers accompanying chopper harvesters can weigh more than 10 t when fully loaded. Movement of this machinery causes a high amount of pressure to be applied to the soil which was hitherto unknown with manual harvesting and loading. There has been a gradual increase in awareness amongst cane growers that this type of movement could lead to soil compaction and associated effects, such as a decrease in porosity and a lowering of infiltration rates. Compaction is expected to occur with the movement of both harvesters and loaders on wet soil, but concern has been mainly directed at the effects of harvesters.

Effects of compaction on cane yield have been studied in Mauritius, but yield differences were ascribed to stool damage rather than compaction (Ng Cheong et al., 1997). In other cane producing areas, studies have been inconclusive. Thus, traffic-induced compaction has been found either to reduce yields (Swinford and Boevey, 1984) or to have no effect (De Boer, 1993; De Beer et al., 1993). As cane is ratooned for 7 years in Mauritius,
the interrows are not cultivated for 8 consecutive years (save for foodcrop cultivation in some areas in plant and 1st ratoon). There may be a long-term cumulative effect of traffic induced compaction in the interrows which has not been studied elsewhere (Braunack, 1997).

The objectives of this trial were:
- to verify whether compaction was induced by mechanized loaders and harvesters
- to ascertain whether compaction differed between the two types of traffic
- to assess the effects of compaction on subsequent yields
- to quantify the cumulative effects, if any, of compaction.

MATERIALS AND METHODS

The trial was carried out at Deep River Beau Champ Sugar Estate in the east of Mauritius. The site has a Humic Latosol soil (Riche Bois family), approximately equivalent to an Oxic Humitropept according to USDA classification (Parish and Feillafe, 1965), an altitude of 114 m and a mean annual rainfall of 2400 mm. The cane variety grown at the experimental site was R 570. The trial covered five harvests from 1993 to 1997.

Two treatments were applied: A. manual harvesting followed by mechanized loading and B. completely mechanized harvesting using a chopper harvester accompanied by infield trailers. The mechanized loader was a 3-wheeled Bell loader while the harvester was an Austoft 7000 with four pneumatic wheels. The field was burnt prior to harvest in line with normal estate practice. Manual harvesting and loading was not studied since this practice is gradually disappearing in most areas and is likely to remain only where the terrain makes it difficult for machinery operation.

Dry bulk density was considered the most appropriate parameter for compaction assessment and the gamma-neutron probe was chosen for reliability of results with little disturbance to soil (Soane et al., 1981). The probe was an MC-S-24 manufactured by Campbell Pacific Nuclear Inc. (CPN), previously field-calibrated on different Mauritian soils. It is composed of two rods; one rod emits gamma rays and neutrons and measures slow neutrons, and the other one measures gamma rays. The two rods are linked to a central processor which records counts and converts them to volumetric moisture content and wet bulk density. Dry bulk density is calculated by difference.

For each treatment, four measurement positions (in the cane row and inter-row) were chosen for monitoring at monthly intervals. At each position, two pairs of holes were drilled into the soil parallel to the cane row. Cane rows are spaced at 1.6 m and the distance between the two pairs of holes was 0.7 m. These holes were plugged with PVC tubes which were removed at each sampling date, thus ensuring that readings were taken at the same position each time. Readings were taken at 10, 20 and 30 cm depth, previous experience having shown that no effect was apparent below those depths (Ng Cheong et al., 1997). Readings were taken from October 1995 to May 1998, covering 4th to 6th ratoon harvests.

Saturated infiltration rates were measured at the end of the 6th ratoon using a CSIRO disc permeameter. Five measurements were made in the interrows of the two treatments. A third set of readings was taken in the traffic-free interrows of the manually harvested treatment. Other soil physical properties that were measured in the laboratory included susceptibility to compaction using a modified Proctor test (Siegmund and Ducreux, 1982).

Trial design was in randomized blocks with 8 replicates, with 12 and 16 cane rows (135 m long on average) for manual and mechanical harvesting respectively, of which the middle 4 were considered to be experimental. Cane in the experimental rows was harvested, loaded and weighed industrially and yield data were calculated.
from estate weighings. As from 4th ratoon, the amount of extraneous matter mixed with cane was also determined and clean cane yield was extrapolated.

RESULTS AND DISCUSSION

Rainfall and soil moisture data for the site from 4th to 6th ratoons are given in Figure 1. Cane was harvested in November when the soil was relatively dry, with an average volumetric moisture content of around 40% in the profile. From the modified Proctor test, the soil was most prone to compaction at volumetric moisture contents of the order of 48% when a maximum dry bulk density of 1.26 g cm⁻³ may be attained. It therefore appears that cane was generally harvested at a time when the soil was not prone to compaction.

Fig. 1 Rainfall and soil moisture

Bulk density results are illustrated in Figures 2(a) and 2(b) for cane row and interrow respectively. Three bulk density profiles are given for each harvest, showing the initial status, the profile immediately after harvester and/or loader traffic and finally the status after 1 year (except for 6th ratoon where the last status was for 6 months after harvest).
Fig. 2 (a)Bulk density profiles - can now 1: Before harvest 2: Just after harvest 3: 12 months after harvest

Mechanized harvesting

Manual harvesting

Depth (cm)

Bulk density (g cm⁻³)

Depth (cm)

Bulk density (g cm⁻³)
1: Before harvest  2: Just after harvest  3: 12 months after harvest

Fig. 2 (b) Bulk density profiles - cane interrow
Immediately after harvest, compaction was observed in both rows and interrow of the two treatments, particularly in 4th and 5th ratoons. Changes in dry bulk density were not obvious for the 6th ratoon harvest. Dry bulk density in the cane rows increased at a similar extent in both treatments in 4th ratoon but a larger increase was noted with mechanized harvesting in 5th ratoon. For the interrows, increases were equally important for 4th and 5th ratoons for the two treatments. It therefore appears that cane rows and interrows were compacted to a similar extent by harvest and loader traffic.

The highest increases in bulk density immediately after harvest were detected at 10 cm whereas little change was noted at 30 cm depth. This confirms the observation in Colombia that compaction tends to be confined to the shallower part of the profile (Torres et al., 1990). A common feature was that soil was most compact at a depth of 20 cm. Thus, harvesting operations had an important compacting effect down to 20 cm but did not significantly affect the soil at 30 cm depth. In South Africa, an average 5% increase in bulk density was noted after compaction with different loads and a wet bulk density of 1.8 g cm\(^{-3}\) was deemed to be likely to cause problems (Swinford and Boevey, 1984). Apart from 6th ratoon results, increases in bulk density at 10 cm were higher, of the order of 10%, and wet bulk density did not exceed 1.65 g cm\(^{-3}\). It would thus appear that the Oxisols of Mauritius have a relatively low bulk density which renders them more susceptible to compaction at shallow depths. This is explained by the porous nature and fine granular structure of the topsoil, with a relatively high organic matter content of 5%.

With time, the bulk density decreased again and these changes were again most obvious at 10 cm. The effects of compaction on shallow soil was therefore not permanent and were seen to decrease with time. Since no decompaction measures were taken, it is probable that this phenomenon is caused by natural processes, such as soil fauna activity, root development and wetting and drying processes. The soil structure is modified by these processes with the formation of new pores and enlargement of existing ones. As a result, dry bulk density decreases over the twelve months between each harvest season. A similar conclusion was reached in Barbados where there was no residual effect on soil due to previous machine harvesting and this was attributed to soil swelling and shrinking (De Boer, 1993), but no in situ bulk density measurements were available. The soils were similar to those of Mauritius, with high clay content of either kaolinite or montmorillonite.

Saturated infiltration rates at the end of 6th ratoon are given in Table 1. With mechanized harvesting, the harvester and accompanying infield trailer drove over each interrow twice. There was little difference in the infiltration rates of the sites with harvester or loader traffic. These rates were much lower than those observed for traffic-free interrows, the difference being about six-fold. Infiltration rate was reduced by traffic irrespective of equipment type, indicating soil compaction as reported elsewhere (Soane et al., 1981).

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Stabilized rate (mm h(^{-1}))</th>
<th>95% confidence interval (mm h(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical</td>
<td>40</td>
<td>18</td>
</tr>
<tr>
<td>Manual (with loader traffic)</td>
<td>58</td>
<td>25</td>
</tr>
<tr>
<td>Manual (traffic-free)</td>
<td>306</td>
<td>214</td>
</tr>
</tbody>
</table>

Total cane yields were higher in treatment B (mechanized harvesting) in all years except 1994 which was a cyclonic year. The differences were significant only in 1995 and 1996. However, when extraneous matter was taken into account, there was no difference in cane yield (Table 2b). Thus, there was no yield difference between the two treatments for the five ratoons under experimentation and this result is in line with the observation that both treatments were equally affected by traffic-induced compaction.
Table 2a. Total cane yields at harvest (t ha\(^{-1}\))

<table>
<thead>
<tr>
<th>Harvest year</th>
<th>Ratoon</th>
<th>Manual harvest</th>
<th>Mechanized harvest</th>
<th>LSD (p = 0.05)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993</td>
<td>2(^{nd})</td>
<td>91.5</td>
<td>94.4</td>
<td>4.2</td>
</tr>
<tr>
<td>1994</td>
<td>3(^{rd})</td>
<td>83.2</td>
<td>82.8</td>
<td>3.2</td>
</tr>
<tr>
<td>1995</td>
<td>4(^{th})</td>
<td>93.3</td>
<td>103.6</td>
<td>7.1</td>
</tr>
<tr>
<td>1996</td>
<td>5(^{th})</td>
<td>96.5</td>
<td>106.3</td>
<td>7.5</td>
</tr>
<tr>
<td>1997</td>
<td>6(^{th})</td>
<td>104.1</td>
<td>106.5</td>
<td>5.1</td>
</tr>
</tbody>
</table>

Table 2b. Clean cane yields at harvest (t ha\(^{-1}\))

<table>
<thead>
<tr>
<th>Harvest year</th>
<th>Ratoon</th>
<th>Manual harvest</th>
<th>Mechanized harvest</th>
<th>LSD (p = 0.05)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>4(^{th})</td>
<td>88.9</td>
<td>92.6</td>
<td>6.5</td>
</tr>
<tr>
<td>1996</td>
<td>5(^{th})</td>
<td>88.7</td>
<td>88.4</td>
<td>6.5</td>
</tr>
<tr>
<td>1997</td>
<td>6(^{th})</td>
<td>96.8</td>
<td>92.7</td>
<td>4.6</td>
</tr>
</tbody>
</table>

CONCLUSIONS

Even though the soil was relatively dry at time of harvest, compaction occurred in both treatments. Increases in dry bulk density were most marked at a depth of 10 cm for both cane rows and interrows but the highest bulk density was observed at 20 cm depth. One year after harvest, there was a marked decrease in bulk density at 10 cm depth. The stabilized infiltration rate of the soil was reduced by traffic-induced compaction and at the end of 6\(^{th}\) ratoon, this had led to a six-fold reduction in infiltration rate.

There was no significant difference in cane yield for the five harvest seasons. It is therefore concluded that harvester traffic has no further detrimental effect on cane yield or soil compaction than that already caused by loader traffic under the conditions prevailing at Beau-Champ Sugar Estate.

ACKNOWLEDGEMENTS

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REFERENCES


**COMPACTACION DEL SUELO PROVOCADA POR EL CORTE Y ALCE MECANIZADO**

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**RESUMEN**

En Mauricio, el 50% de la caña se cosecha con el sistema semi-mecanizado (alce mecanizado) y el 10% con corte y alce mecanizado. Existe una preocupación creciente entre los cultivadores con respecto al tráfico de equipos pesados que pueden conllevar a daños por compactación y consiguientes pérdidas en producción. En una zona húmeda se realizó un experimento para estudiar los efectos del corte y alce mecanizado sobre las propiedades físicas del suelo y la producción usando dos tratamientos: corte manual con alce mecanizado y corte mecanizado con alce mecanizado. La densidad aparente del suelo y el contenido de humedad fueron registrados durante tres años, la tasa de infiltración fue medida después de siete cortes y la producción fue registrada en un período de cinco años. Se encontró que después de la cosecha, la compactación ocurrió en los surcos y entre-surcos y fue más severa en los primeros 10 cm de profundidad; los mayores valores de densidad aparente se registraron a 20 cm de profundidad. Después de un año los valores de la densidad bajaron nuevamente, la mayoría de los cambios ocurren en los primeros 10 cm. Los valores de la infiltración en los entre-surcos con tráfico fueron similares para los dos sistemas de cosecha. Por otro lado, la infiltración en la zona sin tráfico, de los entre-surcos, fue seis veces superior. No se observaron pérdidas en producción por compactación de las cortadoras mecánicas superiores a los ya causados por las alzadoras.
LE COMPACTAGE DU SOL CAUSE PAR LA RÉCOLTE ET LE CHARGEMENT MECANISÉS

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RÉSUMÉ

A l’Ile Maurice, il y a une grande différence entre les superficies récoltées ou chargées à la machine (10% pour la récolte comparé à 50% pour le chargement). La communauté des planteurs de canne est de plus en plus inquiète quant aux possibles effets de compactage causés par le trafic lourd associé à la mécanisation, ce qui entraînerait des chutes de rendement. Un essai fut mis en train dans une zone humide pour étudier les effets de la récolte et du chargement mécanisés sur les propriétés physiques du sol et le rendement à travers deux traitements, notamment récolte manuelle et chargement mécanique, et récolte et chargement mécaniques. La densité apparente du sol et son taux d’humidité furent mesurés pendant trois ans, la perméabilité du sol fut déterminée après la sixième repousse et les rendements en canne furent enregistrés pendant cinq ans. Il fut constaté que, juste après la récolte, il y avait du compactage dans les lignes et entrelignes de canne pour les deux traitements, avec un effet plus conséquent à 10 cm de profondeur, alors que la densité apparente sèche la plus forte était enregistrée à 20 cm. Après la récolte, la densité avait tendance à baisser et était bien moindre au bout d’une année, particulièrement à 10 cm. La perméabilité du sol était comparable pour les entrelignes soumises au trafic, que ce soit pour la récolte ou le chargement, mais était quand même six fois plus faible que celle enregistrée dans les entrelignes sans trafic. Aucune différence significative ne fut notée dans les rendements en canne des deux traitements. Il n’y avait donc pas plus de perte de rendement qui ait pu être causée par le compactage lié à la récolte mécanisée en comparaison avec le chargement mécanisé.

Mots-clés: récolte et chargement mécanisés, trafic, compactage, densité apparente sèche, perméabilité, rendement canne