EFFECT OF HARVESTING AND HAULAGE EQUIPMENT ON SOIL BULK DENSITY

By

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Abstract

A study was undertaken in which the compactive affect on the soil caused by different types of cane harvesting and haulage machinery and equipment (Volvo truck tractor and Vanguard semi-trailer, Claas and Toft harvester and Toft haulout) was compared with the compactive effect induced with the Proctor method. Soil moisture content where least compaction occurred was also measured. The results clearly show that vehicles fitted with rubber wheels had a more adverse affect on soil compaction than those equipped with steel tracks.

Introduction

Soil compaction in Iran has increased due to agricultural mechanisation and is now a major concern. A simple definition of compaction is the reduction in soil volume due to vertical pressure exerted on the soil, with a resultant increase in bulk density. Increase in bulk density is associated with a reduction in soil porosity, as well as reduced water and air permeability (Rowell, 1994; Behravan, 1995).

Compaction in sugar cane fields in Iran is due mainly to harvesting and haulage operations, during the wet season. The infield presence of heavy machinery with a relatively small soil contact area can cause irreparable damage to the soil. Factors affecting the severity of compaction include soil water content, textural properties of soils, the total machinery mass and the total contact area (Ralph and Terzaghi, 1967; Behravan, 1995). Other points to be considered are whether the equipment is fitted with rubber wheels or steel tracks and the manner in which the machinery is utilised in the field, i.e. whether equipment is stationary or in motion, and whether the equipment is empty or laden.

Methods and materials

A study was undertaken in which the compactive effect on the soil caused by different types of cane harvesters and haulage equipment was compared with that measured by the Proctor method (Joseph, 1981). Diagrams illustrating the Proctor instrument are shown in Figure 1. The trial was conducted on a clay loam soil (28.9% clay, 23.8% sand and 47.3% silt). Soil moisture contents where least compaction occurred were also determined.

The number of Proctor hammer blows (3-4 replications) for each soil layer was calculated as follows:

\[
\text{Force exerted on the soil} = \frac{N \times H \times S \times W}{V_m}
\]

Where \(N\) = number of blows; \(H\) = height from which blow is applied; \(S\) = number of soil layers; \(W\) = weight of hammer; \(V_m\) = volume of mould.

After weighing the soil, samples were taken to determine moisture content. The various stages of wetting, hammering, weighing and sampling for moisture content were repeated several times so that for each replication the maximum weight of the sample was more or less equal. After determining the wet bulk density \(BD_w\) (equation 1), the dry bulk density \(BD_d\) (equation 2) was calculated as follows:

- Equation 1 \(BD_w = \frac{M}{V}\)
- Equation 2 \(BD_d = \frac{BD_w \times 100}{100 + \theta_v}\)

where \(M\) = wet mass of soil; \(V\) = the volume of the soil; \(\theta_v\) = percentage of volumetric soil water content.

The machinery and equipment tested were as follows:

1. Volvo truck tractor and Vanguard semi-trailer (rubber wheels);
2. Claas combine harvester (rubber wheels);
3. Toft 6500 combine harvester (steel tracks);
4. Toft SP6-FT haulout (steel tracks).

Detailed specifications of the above equipment are given in Table 1.

KEYWORDS: Soil Compaction, Trailer, Harvester, Rubber Wheels, Steel Tracks.
Table 1—Specifications of agricultural equipment used in the tests.

<table>
<thead>
<tr>
<th>Type of equipment</th>
<th>Empty mass (kg)</th>
<th>Laden mass (kg)</th>
<th>Contact area (cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volvo truck tractor + Vanguard semi-trailer</td>
<td>22 500</td>
<td>43 500</td>
<td>587 (per tyre)</td>
</tr>
<tr>
<td>Claas harvester</td>
<td>11 590</td>
<td>N/A</td>
<td>12 914 (total)</td>
</tr>
<tr>
<td>Case Austoft harvester</td>
<td>15 000</td>
<td>N/A</td>
<td>7 711 (total)</td>
</tr>
<tr>
<td>Case Austoft haulout</td>
<td>12 290</td>
<td>18 290</td>
<td>29 676 (total)</td>
</tr>
</tbody>
</table>

Results and discussion

Compactive effect

Pressure exerted and the number of Proctor hammer blows required to simulate the compactive effect caused by the different vehicles and equipment used are:

**Volvo truck tractor and Vanguard semi-trailer (rubber wheels)**
- Each wheel of the empty, stationary trailer applied a pressure on the soil equivalent to 1.97 kg/cm², and 8 blows of the standard Proctor hammer were needed to obtain the same soil bulk density.
- The pressure applied by each wheel of the fully laden, stationary trailer was 3.37 kg/cm², equivalent to 14 blows of the Proctor hammer.
- As the tyres on the Volvo truck tractor and three-axle trailer follow the same path, it can be realistically assumed that the repeated pressure exerted by all the wheels running in the same track would be greater than that applied by a single wheel. The number of blows of the Proctor hammer needed to obtain an equivalent soil bulk density would therefore be more than 14.

**Claas combine harvester (rubber wheels)**
- When in motion both front and rear wheels follow the same track. The total pressure put on the soil was equivalent to 3 kg/cm² and the number of hammer blows required to obtain a similar compactive effect was ≈ 12.

**Toft combine harvester (steel tracks)**
- The total pressure placed onto the soil was only equivalent to 0.51 kg/cm², and the number of hammer blows required was 2.

Soil moisture content

The soil water content at which maximum bulk density was obtained when testing the above machinery and equipment were as follows:

- Volvo truck tractor and Vanguard semi-trailer empty and stationary 17.5%;
- Volvo truck tractor and Vanguard semi-trailer laden and stationary 18.2%;
- Volvo truck tractor and Vanguard semi-trailer empty and in motion 17.6%;
- Claas combine harvester in motion 19.3%;
- Toft combine harvester followed by empty Toft haulout in motion 20.5%;
- Toft combine and laden Toft haulout in motion 22.0%.

Figures 2 and 3 show bulk density versus soil moisture content for the Vanguard semi-trailer, empty and in motion, and the Claas 6500 harvester, respectively.
Conclusions

Based on the above results, the following conclusions can be drawn:

- The Vanguard trailer pulled by the Volvo truck tractor caused the greatest amount of soil compaction.
- The Toft harvester and laden Toft haulout, both fitted with steel tracks, had the least compactive effect on the soil.
- These results clearly show that machinery and equipment fitted with tracks cause less soil compaction than machinery fitted with rubber tyres.
- The soil moisture content at which maximum bulk densities were obtained is the worst condition to have as this will cause most soil compaction. Even at lower soil moisture levels, some soil compaction will take place. To avoid severe soil compaction, it is proposed that when soil moisture reaches 1% below the maximum, the machinery and equipment described in this paper should not be allowed to enter the fields.

Acknowledgments

The author would like to thank the people who gave their amicable and sincere help and assistance in preparing this paper, especially Mrs. Rafieazad and Mr. Karimi.

REFERENCES

EFECTOS DE LOS EQUIPOS DE COSECHA Y TRANSPORTE SOBRE LA DENSIDAD APARENTE DEL SUELO

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Resumen
Se realizó un estudio para analizar el efecto comparativo de la compactación de suelo causada por diversos tipos de máquinas y equipos de cosecha y transporte de materia prima (camión Volvo, semi trailers Vanguard, cosechadoras Claas y Toft, entre otros), en relación con el efecto de compactación producido por el método Proctor. Se midió el contenido de humedad del suelo cuando se presentó una mínima compactación. Los resultados muestran claramente que los vehículos montados sobre ruedas de gomas convencionales tuvieron un mayor efecto adverso en términos de compactación de suelo que aquellos equipados sobre orugas metálicas.

Palabras claves: compactación de suelo, remolque cosechadora, ruedas de gomas, orugas.