EFFECT OF THE ORGANIC MATTER AT THE COMPACTION OF NEOSSOLO EUTROPHIC BY THE PROCTOR TEST\textsuperscript{1}

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SUMMARY: The type of management used in the preparation of agricultural soils have direct influence on the physical properties of soils, such as the increase in soil density caused by the trampling of animals and traffic of agricultural machines on the soil, in inadequate conditions. Thus, the aim of this study was to evaluate the effects of the incorporation of different levels of organic matter in the compaction of a Eutrophic Neossolo by method Proctor. The equivalent of one hectare area, used for grazing for ten years and currently cultivated with corn, was divided into four similar areas and soil samples collected, for each one of them from the layers 0 to 0.05 m and 0.05 to 0.10 m deep. The experimental design was a completely randomized blocks, with the treatments arranged in a 3x2 factorial, three treatments and two replications. The three treatments analyzed were: T1 = soil, T2 = soil + 15\% of bovine manure, T3 = soil + 30\% of bovine manure. In general, in response to the incorporation of organic matter in the soil, the maximum density tended to decrease for higher critical moisture levels of compaction.


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EFEITO DA MATÉRIA ORGÂNICA NA COMPACTAÇÃO DE UM NEOMSOLO EUTRÓFICO PELO ENSAIO DE PROCTOR

RESUMO: O tipo de manejo empregado no preparo de solos agrícolas tem influência direta nos atributos físicos de solos, a exemplo do aumento da densidade do solo causado pelo pisoteio de animais e tráfego intenso de máquinas agrícolas no solo, em condições inadequadas. Diante disso, o objetivo desse trabalho foi avaliar os efeitos da incorporação de diferentes níveis de matéria orgânica na compactação de um Neossolo Eutrófico pelo método de Proctor. A área equivalente a um hectare, utilizada para pastagem por dez anos e atualmente cultivada com milho, foi dividida em quatro áreas semelhantes e amostras de solo coletadas para cada uma dessas camadas de 0 a 0,05 m e 0,05 a 0,10 m de profundidade. O delineamento utilizado foi em blocos casualizados, com os tratamentos arranjados em esquema fatorial 3x2, três tratamentos e duas repetições. Os três tratamentos analisados foram: T1 = solo, T2 = solo + 15% de esterco bovino, T3 = solo + 30% de esterco bovino. De modo geral, em resposta a incorporação de matéria orgânica ao solo, a densidade máxima tendeu a diminuir para maiores níveis de umidade crítica de compactação.


INTRODUCTION

Soil compaction is a limiting factor for the growth and development of plants due to effects on soil physical properties, such as, changes in the volume and distribution of pore size and hence the water flows and gases. Among the impacts of soil compaction, there is a reduction in total porosity and increasing on soil density.

Several studies have been conducted in order to assess the role of organic matter in preventing compaction, the results indicate that the improvement in soil structure caused by the addition of organic matter to the soil is related to the formation of larger and more stable aggregates in soils. For the same level of compaction energy, the higher the organic matter content, the lower the maximum soil density and higher critical moisture compaction, thus, reducing the degradation.

There are several ways to measure soil compaction, and the majority of the methods involves analysis of soil samples in the laboratory using physical soil parameters, such as density, porosity and soil moisture. Through a compaction test it is possible to obtain the
correlation between the moisture content and density of the soil at a certain energy of compaction.

The most common compaction test is of Proctor, standardized by ABNT (NBR 7182/86). Different relations between the soil density and moisture are obtained by successive impacts of a standardized socket in the sample, determining the compaction curve, which allows to, to identify the point of maximum compaction based on the correlation between the maximum packing density and the critical soil moisture. Although the test is, principally used for Civil Engineering applications, it has a range of enforcement across several areas of science.

Overall, this study aimed to study the effect of the incorporation of organic matter on the Compaction of a Eutrophic Neossolo by the modified test of Proctor.

MATERIAL AND METHODS

The experiment was conducted in an area of one hectare, located in the city of Riacho dos Cavalos – PB, Brazil, geographic coordinates of 06°26'34"S and 37°39'03"W, cultivated with corn. The area was divided into four areas of same size and sample collected from each one of them from the layers 0 to 0.05 m and 0.05 to 0.10 m deep experimental design was completely randomized blocks, with treatments arranged in a 3x2 factorial, three treatments and two replications. The three treatments analyzed were: T1 = soil, T2 = soil + 15% BM, T3 = soil + 30% BM.

The regional climate, according to Koppen classification, is the BSWh type, ie, dry and warm, with two seasons: a dry which usually runs from June to January and a rainy season, from February to May, with an annual temperature average of 27°C, and precipitation of 850 mm.

The soil was classified as Fluvisol Ta Eutrophic (EMBRAPA, 2006), originated from the deposit of river sediments. Soil compaction was evaluated at the Laboratory of Soil Dynamics at the Federal Rural University of the Semiarid – UFERSA. The effects of soil-machine interactions on soil compaction were simulated by the modified Proctor test for different proportions of organic matter and moisture levels. The addition of organic matter, in the form of bovine manure, in the soil was occurred for the percentages of 15 and 30%.

The determinations of soil moisture for the samples were performed using standard gravimetric method, were water content was calculated on the weight difference between a wet
and dry soil sample, after drying in an oven (105 - 110°C) for 24 hours, as described by Equation 1.

\[
U = \frac{M_u - M_s}{M_s} \times 100 \quad (1)
\]

where;

- \(U\) - soil moisture mass base (%);
- \(M_u\) - mass of moist soil (g);
- \(M_s\) - dry soil mass (g).

RESULTS AND DISCUSSION

The classification of the level of organic material in the soil was performed according to the methodology of the soil analyzes for the state of Minas Gerais, as described in Table 1.

The means obtained for soil organic matter are shown in Table 2. The obtained results were close to 6.0 g kg\(^{-1}\), equivalent to the average value found by Menezes et al. (2008) for a Regolithic Neossolo and layer of 0 to 0.20 m deep. It was observed that, as expected, higher levels of organic matter were present at surface layer. According to Trindade et al. (2009), the organic matter content is higher at the soil surface layer due to the balance that exists between the deposition of organic materials of secondary vegetation and the effect of microbial activity on decomposition.

The levels of organic matter to the soil prior to the incorporation of organic matter to depths analyzed were classified as very low (Table 1).

The analysis of the organic fraction present on the soil before and after the incorporation of organic matter was carried for the layer 0 to 0.10 m deep. The average values and the corresponding classifications are described in Table 3.

It was found that 4.3% of the bovine manure (BM) consists of organic carbon. The incorporation of 15% bovine manure to the soil reflected on increase of 40.30% in the organic carbon content of the soil, classified as very low content, according to Table 3. While the incorporation of 30% of bovine manure resulted in an increase of 96.29% in the organic carbon content of the soil, also being classified as low. According Mellek (2009), the trend of increase in carbon content is directly attributed to the addition of manure, which is rich in organic material and can be incorporated to the soil organic matter, and in general, produce an almost linear response to manure dose, especially in the surface layer (0 to 0.05 m).
It was also determined the compaction curves for the different treatments, based on sets of values corresponding to density and moisture of the soil to successive compaction tests. In general, the number of tests ranged from 5 to 7, but it can vary depending on behavior presented by each sample, as the, the soil density presented successive drops after reaching the maximum compaction value.

As depicted in Figure 1, from the increase in organic matter in the soil, there was a movement of the compaction curves to the right and downward, which represents a reduction for the maximum soil density and increased critical moisture to reach that maximum density. This increase represents an expansion in the compaction resistance conditions, which enables soil preparation at higher moisture contents.

The data described in Table 4 were obtained for replications one and two during the soil compaction test, for the layer 0 to 0.05 m deep. From these results, it was possible to determine the critical moisture variation and soil density for the addition of 15 and 30% of BM in relation to the original soil without the addition of organic matter. It was found that for the addition of 15% of BM, there was an increase of 52.1 and 36.3% in the critical soil moisture for the replications I and II, respectively. By analyzing the soil density at this moisture content, there was a reduction of 18.9 and 16.7% for the respective replication. However, when 30% of BM was added, it could be seen that the critical moisture in the first replication was 81.8%, while for the second it was equal to 72.4%. In regard the density of the soil, reduction were found to be equal 40.3 and 53.1% for the first and second replication, respectively.

When the soil with 30% addition of BM was comparated to the 15%, it was observed an increase of 19.6 and 26.5% for in the critical moisture content, for the first and second replication, respectively. However, for the soil density, it was verified reduction of 20.1 and 31.2%. Therefore, it could be observed that the addition of organic matter in the soil contributes significantly to increase the critical moisture interval, thus reducing soil compaction for this considered interval. Soils with high organic matter content are likely to stand to mechanical tillage effects.

According to Braidia et al. (2010), the accumulation of soil organic matter tends to increase its resistance to compaction, also reducing its effect on water retention, cohesion and soil density, which are strongly correlated to the susceptibility to soil compaction.

The accumulation of organic matter will directly influence on soil resistance, increasing the bond strength between the mineral particles and the change in the arrangement, ie,
contributes significantly to the increased porosity and soil density (EKWUE, 1990; HORN & LEBERT, 1994; ZHANG, 1994, TRANNIN et al., 2008).

According to Stumpf et al. (2009) compaction alters the physical properties of soil, increasing the density to the detriment of total porosity. The organic matter and clay have a fundamental role because they help the soil's ability to resist mechanical stresses, acting as energy transfer bridges between the particles and increasing the strength of soil structure.

The specific values for critical moisture referred to the maximum compaction and soil density were obtained by derivation of the compaction curve of the equation generated for each treatment, as described in Tables 4 and 5, and depicted shown on Figure 3.

The data summarized in Table 5 were obtained for replications I and II for the Eutrophic Neossolo compaction test. From these results it was possible to obtain the compaction curves for different treatments and layers of 0.05 to 0.10 m deep.

According Braida (2006), for a same level of energy, the higher the content of organic matter in the soil, the lower the maximum density value obtained and the greater the water content required to achieve that maximum density. Similar behavior could be seen in Figure 3, where the addition of 15% BM to the soil at a deep 0.05 to 0.10 m caused a great increase in the critical moisture, from 40.28% to 37.79, for replications I and II, respectively. For soil density, it was observed a reduction of 15.57% for the replication I and 26.11% for the replication II.

For the addition of 30% of BM to the soil, it was observed an increase in the critical moisture of 71.43 and 55.05% for the replications I (Figure 5A) and II (Figure 5B), respectively. With respect to soil density, with the addition of 30% organic matter, a reduction of 26.14% for the replication I and 34.69% for the replication II. When comparing the average results of tests for the layer 0.05 to 0.10 m to the layer of 0 to 0.05 m deep, it was observed that there was little change in the critical moisture and soil density. According to Braida (2006), the susceptibility to compaction, measured by the Proctor test, becomes smaller as the amount of organic material in the soil increases.

According to the data obtained for both 15 and 30% of BM incorporated to the soil, it is noted that addition of organic matter favors the soil structure, resulting in reduction of the maximum soil compaction and increase on the critical moisture compaction to achieve it. According to Barbosa et al (2007), one of the main effects of organic matter in the soil physical properties it is associated with increased soil aggregation, reduced soil density and increased total soil porosity.
According to Figure 3, the increase in the percentage of BM incorporated to the soil led to a reduction of the maximum soil compaction density for higher critical moisture levels. With respect to BM, incorporated percentages of 15% was less efficient than adding 30%, which resulted in a greater reduction in the maximum density of soil compaction and increased the critical moisture point of soil compaction for the same compaction energy.

CONCLUSIONS

For all treatments, the effect of organic matter showed the same tendency to reduce the maximum density point for more critical moisture values of compaction, by the modified Proctor test.

The addition of 30% of bovine manure to the soil generated more satisfactory results in relation to the addition of 15%. Demonstrating the tendency of higher reduction in soil compaction for higher levels of organic material in the soil.

REFERENCES


**Table 1.** Levels of organic matter used in the interpretation of soil analyzes for the state of Minas Gerais. Costa et al., (2008)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Unit</th>
<th>Very Low</th>
<th>Low</th>
<th>Medium</th>
<th>Good</th>
<th>Very Good</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic Matter</td>
<td>dag kg$^{-1}$</td>
<td>≤ 0.70</td>
<td>0.71 – 2.00</td>
<td>2.01 – 4.00</td>
<td>4.01 – 7.00</td>
<td>&gt; 7.00</td>
</tr>
</tbody>
</table>

dag kg$^{-1}$ x 10 = g kg$^{-1}$

**Table 2.** Average organic fraction for the Eutrophic Neossolo, cultivated with corn, before the incorporation of organic matter

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Soil organic carbon (g kg$^{-1}$)</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00 – 0.05</td>
<td>6.46</td>
<td>Very Low</td>
</tr>
<tr>
<td>0.05 – 0.10</td>
<td>5.40</td>
<td>Very Low</td>
</tr>
<tr>
<td>0.10 – 0.20</td>
<td>5.57</td>
<td>Very Low</td>
</tr>
</tbody>
</table>

**Table 3.** Average organic fraction for the Eutrophic Neossolo cultivated with corn after the incorporation of organic matter

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Depth (m)</th>
<th>Soil organic carbon (g kg$^{-1}$)</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil</td>
<td>0.00 – 0.10</td>
<td>5.93</td>
<td>Very Low</td>
</tr>
<tr>
<td>15% of OM</td>
<td>0.00 – 0.10</td>
<td>8.32</td>
<td>Low</td>
</tr>
<tr>
<td>30% of OM</td>
<td>0.00 – 0.10</td>
<td>11.64</td>
<td>Low</td>
</tr>
<tr>
<td>Bovine Manure (BM)</td>
<td>x</td>
<td>43.25</td>
<td>x</td>
</tr>
</tbody>
</table>
Table 4. Critical moisture values ($U_c$) and soil density of the critical moisture ($\rho_{uc}$) in the layer 0 to 0.05 m depth, for different treatments and replications I and II

<table>
<thead>
<tr>
<th>Repetition</th>
<th>Soil</th>
<th>Soil + 15% BM</th>
<th>Soil + 30% BM</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>$U_c$ (%)</td>
<td>$\rho_{uc}$ (g cm$^{-3}$)</td>
<td>$U_c$ (%)</td>
</tr>
<tr>
<td>II</td>
<td>12.10</td>
<td>1.95</td>
<td>18.40</td>
</tr>
<tr>
<td></td>
<td>12.40</td>
<td>1.96</td>
<td>16.90</td>
</tr>
<tr>
<td>Average</td>
<td>12.25</td>
<td>1.95</td>
<td>17.65</td>
</tr>
</tbody>
</table>

Table 5. Critical moisture values ($U_c$) and soil density of the critical moisture ($\rho_{uc}$) in the layer 0.05 to 0.10 m depth, for different treatments and replications I and II

<table>
<thead>
<tr>
<th>Repetition</th>
<th>Soil</th>
<th>Soil + 15% BM</th>
<th>Soil + 30% BM</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>$U_c$ (%)</td>
<td>$\rho_{uc}$ (g cm$^{-3}$)</td>
<td>$U_c$ (%)</td>
</tr>
<tr>
<td>II</td>
<td>12.25</td>
<td>1.93</td>
<td>16.88</td>
</tr>
<tr>
<td></td>
<td>12.86</td>
<td>1.98</td>
<td>18.04</td>
</tr>
<tr>
<td>Average</td>
<td>12.55</td>
<td>1.96</td>
<td>17.46</td>
</tr>
</tbody>
</table>

Figure 1. Compaction curves for the Eutrophic Neossolo from the layer 0 to 0.05 m deep, for different treatments and replications I (A) and II (B).

Figure 2. Compaction curves for the Eutrophic Neossolo in from the layer 0.05 to 0.10 m deep, for different treatments and replications I (A) and II (B).
Figure 3. Maximum density in function of critical soil moisture content under different proportions of bovine manure incorporated to the soil.