SJSS
SPANISH JOURNAL OF SOIL SCIENCE

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Effect of the application of two plant residues on the density and porosity of soils subjected to compaction

Efecto de la aplicación de dos residuos vegetales sobre la densidad y porosidad de suelos sometidos a compactación
Efeito da aplicação de dois resíduos vegetais na densidade e porosidade de solos submetidos a compactação

Received: 06.02.2020 | **Revised:** 21.05.2020 | **Accepted:** 30.05.2020

ABSTRACT

This study evaluates the effect on the density and porosity of three differently textured soils when they were subjected to different degrees of compaction, following the addition of two crushed vegetable residues, palm leaf and hay straw. Mixtures were prepared incorporating the plant residues to each soil following the proportions: 10%, 20%, 30% and 40% (*V/V*). To quantify the incidence of compaction on physical properties, cylindrical PVC containers were used. The soil-waste mixtures were subjected to pressures of 0 (kg/cm^2), 1.12 (kg/cm^2) and 2.24 (kg/cm^2). The results obtained showed that the addition of the residues reduces the apparent density in the three soils, with the use of hay straw having the greatest decrease. As an example, in soil 1, without applying compaction, the apparent density varies with the application of palm leaf from 1685 (kg/m^3) to 890 (kg/m^3) and with the straw reaches values of 781 (kg/m^3).

RESUMEN

El presente estudio evalúa el efecto de la incorporación a tres suelos de diferente textura, de dos residuos vegetales triturados (hoja de palmera y paja de heno) sobre la densidad y porosidad de los suelos cuando son sometidos a diferentes grados de compactación. Se prepararon mezclas incorporando, a cada suelo, las siguientes proporciones de cada uno de los dos residuos vegetales: 10%, 20%, 30% y 40% (V/V). Para cuantificar la incidencia de la compactación sobre las propiedades físicas, se emplearon recipientes cilíndricos de PVC. Las distintas mezclas suelo-residuos, introducidas en ellos, fueron sometidas a presiones de 0 (kg/cm^2), 1,12 (kg/cm^2) y 2,24 (kg/cm^2). Los resultados obtenidos muestran que la adición de los residuos, hace disminuir la densidad aparente en los tres suelos, siendo esta disminución mayor con el empleo de la paja de heno. Como ejemplo, citar que en el suelo 1, sin aplicar compactación, la densidad aparente varía con la aplicación de hoja de palmera desde los 1685 (kg/m^3) a los 890 (kg/m^3) y con la paja llega a valores de 781 (kg/m^3).

DOI: 10.3232/SJSS.2020.V10.N3.06

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RESUMO

O presente estudo avalia o efeito da incorporação, em três solos de diferentes texturas, de dois resíduos vegetais triturados (folha de palmeira e palha de feno), na densidade e porosidade dos solos quando submetidos a diferentes graus de compactação. As misturas foram preparadas incorporando, para cada solo, as seguintes proporções de cada um dos dois resíduos vegetais: 10%, 20%, 30% e 40% (V/V). Para quantificar a influência da compactação nas propriedades físicas dos solos foram utilizados recipientes cilíndricos de PVC. As diferentes misturas de solo-resíduos introduzidas nos cilindros foram submetidas a pressões de 0 kg/cm², 1,12 kg/cm² e 2,24 kg/cm². Os resultados obtidos mostram que a adição dos resíduos reduz a densidade aparente dos três solos, sendo esta diminuição maior com o uso da palha de feno. Como exemplo, refira-se que no solo 1, sem ser submetido a compactação, a densidade aparente varia com a aplicação da folha de palmeira de 1685 kg/m³ a 890 kg/m³ e com a palha atinge valores de 781 kg/m³.

KEYS WORDS
Hay straw, palm tree leaf, physical properties, soil sealing.

PALABRAS CLAVE
Hoja palmera, paja heno, propiedades físicas, sellado de suelos.

PALAVRAS-CHAVE
Folha de palmeira, palha de feno, propriedades físicas, impermeabilização do solo.

1. Introduction

Soil is the basis of all terrestrial ecosystems and makes life on the planet possible (Porta et al. 2014). Therefore, we must preserve its characteristics and promote sustainable actions that improve its quality in accordance with European guidelines (European Comission 2012). In this sense, using organic by-products as soil amendments is a desirable practice to increase nutrient levels, soil carbon and improve certain physical properties, such as soil density and porosity (Metting et al. 2001). Soil bulk density is considered one of the fundamental soil physical properties. It is required to calculate, estimate, and evaluate many other soil physical properties, such as total porosity, water retention, compressibility, compaction, and infiltration (Heuscher et al. 2005). In addition, soil bulk density is used in many soil management and engineering applications, such as forestry, agriculture management, terrestrial ecosystem management, and land reclamation (De Vos et al. 2005; Benites et al. 2007) and it is used as an indicator of soil quality, and soil compaction (Suuster et al. 2011).

Soil compaction and sealing, because of anthropic actions, causes undesirable processes and situations such as a decrease in porosity, difficulty in the movement of water in the soil, loss of productivity and increased erosion. Therefore, proper soil management and maintenance of the carbon level through the contribution of organic by-products can contribute to soil quality (Dexter et al. 2008).

The objective of the present work was to quantify the effect of the addition of two plant residues: palm leaf and hay straw, to three soils of different texture, evaluating the changes in bulk density and porosity when soils are subjected to different degrees of compaction.

2. Material and Methods

Three long-term agricultural soils (topsoil 0-20 cm was taken), Anthrosols (IUSS Working Group WRB 2006), with different textures, were mixed with two plant residues in this experiment. The soils are calcareous, and their main characteristics are the following (texture and soil organic matter respectively): soil 1 (clay loam, 1.19%), soil 2 (silty loam, 0.25%) and soil 3 (sandy clay loam, 1.13%). Two organic residues were selected with different densities: crushed palm leaf (0.12 g/cm^3) and crushed hay straw (0.07 g/cm^3).

Mixtures were prepare with the soil sieved at 2 mm and the dry residues were crushed (4 cm length). Five mixtures (v/v) were prepared adding: 0%, 10%, 20%, 30% and 40% of plant residue. The compaction tests were carried out, by triplicate, in PVC tubes of 10 cm diameter and 13 cm length. Three pressure treatments were applied: T0 (0 kg/cm^2), T1 (1.12 (kg/cm^2) and T2 (2.24 kg/cm^2) to each mixture. The bulk density of the mixtures, the particle density of soils, residues and mixtures and porosity were determined following the analytical procedures based on the MAPA (1986) and UNE (2008) methods for soils and organic by-products. Descriptive statistics and ANOVA F test were used to check the significance of the results by using EXCEL (Office, v. 2013) and SPSS (v. 21).

3. Results

The additions of organic wastes reduced the bulk density of soils; further decreasing the volume of waste was used in mixtures. The bulk density, which is a signal of soil compaction (Di et al. 2001), increased in all the treatments when soils were compacted (T0 to T2), as was expected. **Table 1** shows, as an example, the evolution of the values of the bulk density in the experiment carried out with soil 1.

Table 1. Evolution of bulk density (Db), standard deviation (σ) and F test for the soil 1. Effect of palm waste doses and compaction treatments

	Treatment					
	T0		T1		T2	
% Palm	Db (kg/m^3)	σ	Db (kg/m^3)	σ	Db (kg/m^3)	σ
0	1685 a	11	1721 a	13	1783 a	12
10	1134 b	21	1316 b	33	1390 b	40
20	1097 c	33	1255 c	58	1314 c	84
30	1041 d	16	1182 d	35	1243 d	28
40	890 e	47	1060 e	56	1153 e	44
F	1349***		420***		310***	
% Hay straw						
0	1685 a	13	1721 a	13	1783 a	12
10	1086 b	45	1292 b	31	1383 b	52
20	982 c	31	1192 c	78	1227 c	34
30	957 c	55	1169 c	37	1211 c	26
40	781 d	49	817 d	32	1148 d	48
F	828***		656***		564***	

***, **, * indicates significance at 0.001, 0.01 and 0.05, respectively. Means followed by a common letter are not significantly different by the F-test at the 5% level of significance.

The incorporation of wastes into the soil increases the porosity. As an example, in all the soils for T0, the porosity increases with the dose of palm leaf applied from 20% to 39% (soil 1), from 34% to 36% (soil 2) and from 37% to 39% (soil 3). Both plant residues had positive effects preventing soil compaction when they are subjected to different pressures. Thus, we can indicate that in soil 1 (initial porosity of 20%), after being subjected to a pressure of 2.24 kg/cm^2, porosity was reduced to 16%, while in mixtures with 40% of palm leaf residue, the porosity was maintained at 21%.

4. Conclusions

The use of organic residues of palm leaf and hay straw decreases the bulk density of soils and prevents soil compaction. The use of organic by-products of local origin, such as palm leaves, can improve the soil physical properties and could have environmental benefits. This strategy seems to be on line with what is expected in European waste reuse policies -Zero Waste Programme- (European Commission 2014) favouring the sustainable development.

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