Scientific Paper

Resistance to penetration in a Chromic Vertisol with natural pasture

Juan Alejandro Villazón-Gómez[1], George Martín-Gutiérrez[2], Yakelín Cobo-Vidal[2] and Daniel Hernández-Rojas[2]

[1]*Universidad de Holguín, Sede José de la Luz y Caballero. Facultad de Ciencias Agropecuarias, Centro de Estudios de Agroecosistemas Áridos (CEAAR) Ave. De los Libertadores km 3½, Holguín, Cuba*
E-mail: villazon@fca.uho.edu.cu
[2]*Estación Provincial de Investigaciones de la Caña de Azúcar (EPICA), Programa Integral de Manejo Agronómico (PIMA). Holguín, Cuba*

Abstract

The objective of the study was to characterize the resistance to penetration in a Chromic Vertisol with natural pasture. The determinations were made on 61 spots, every 0,50 m, along a 30 m long transept, at the depths of 0-10, 10-20, 20-30 and 0-30 cm. For the univariate description, numeric and graphic methods and the Kolmogorov-Smirnov normality test were used. There was an increase of resistance to penetration in the 10-20 cm layer, where all the position measures were higher except the minimum value, as well as the dispersion ones. The kurtosis results indicated that, in the distribution tails of resistance to penetration in the intermediate layer there was higher quantity of observations than in the tails of a normal distribution. The percentages of resistance to penetration (from the total of observations) were: 29,51 and 74,49 % at the depth of 0-10 cm; 19,67 and 79,30 % at 10-20 cm; and 26,20 and 73,77 % at 20-30 cm. It is concluded that, according to the values found in the three depths, resistance can be classified from moderate to high.

Keywords: soil compaction, grazing, soil physical-chemical properties.

Introduction

Compaction is one of the edaphic limiting factors that are manifested during the performance of agricultural labors (Murillo *et al*., 2014). In agronomic terms, it is the force exerted on the soil by tillage and the traffic of agricultural machinery; which causes the increase of soil density and, thus, the decrease of its porosity (Soil Science Society of America, 2013). It constitutes one of the physical degradation forms of soils (Lal, 2015) which have been stressed in recent years, with the technological advance of agriculture, due to the use of increasingly larger and heavier agricultural machinery (Reichert *et al*., 2007).

It can be indirectly established from certain soil physical properties, among them, resistance to penetration (Hamza and Anderson, 2005); and it is often related with the decrease of agricultural yields (Vaca-García *et al*., 2014), because the root development of plants depends, to a large extent, on the mechanical impedance opposed by the soil. It is generally accepted that the mechanical resistance to penetration is critical when root elongation is stopped (Pilatti *et al*., 2012). Compaction is manifested, in agricultural areas as well as in grazing zones, in a layer that can be localized in the first 20 cm of depth (Reichert *et al*., 2007). In the latter its study is highly important, because, according to the report by Crespo (2015), the root phytomass of pastures represents a substantial source of nutrients that are recycled in the pastureland, especially in the first 10 cm of the soil. In addition, according to Nantes *et al*. (2013), grasses are the main feed source of ruminants in tropical regions.

Vertisols in the eastern region of Cuba are distributed in the strip of dry sub-humid tropical climate, with rainfall below 1 000-1 200 mm per year and below 100-200 m above sea level (Hernández, 2004). These soils show a principal horizon of vertic diagnosis in the first 150 cm of depth, with considerable clay density, plastic in humid state and hard when dry, dark and with a structure in prismatic blocks, with slickensides, deep cracking and gilgai micro-relief (Hernández-Jiménez *et al*., 2015). In the clay fraction smectite minerals prevail (Sotelo *et al*., 2013). Some authors state that an ideal rotation in vertisols should include between 50 and 60 % of pastures and from 40 to 50 % of agriculture, in order to maintain adequate structural conditions (Cerana *et al*., 2006).

Based on the above-stated facts, the objective of this study was to characterize resistance to penetration in a Chromic Vertisol with natural pasture.

Materials and Methods

The work was conducted in 2016, on a Chromic Vertisol soil (Hernández-Jiménez *et al*., 2015) with natural pasture (with an extensive exploitation system) located in areas of the Provincial Sugarcane Research Station of Holguín (20º 40′ 18″ North latitude and 75º 47′ 04″ West longitude). The resistance to penetration was determined in 61 spots located every 0,5 m along a 30 m long transept.

For that purpose an impact penetrometer, model IAA/Planalsucar-Stolf (Stolf *et al*., 1983) was used, with the impacting mass of 4 kg regulated at 0,40 m of height. The transformation of the quantity of impacts per decimeters to megapascals (MPa) was done through the mathematical expression proposed by Stolf (1991):

$$RP\ (MPa)=0{,}547+0{,}675N$$

Where RP is the resistance to penetration and N is the quantity of impacts per dm. These results were expressed in constant intervals (10 cm), down to 30 cm of depth and were grouped in the following classes (table 1).

Table 1. Classes according to the level of resistance to penetration.

Classe	Resistance to penetration (MPa)
1	1,2-1,4
2	1,4-1,6
3	1,6-1,8
4	1,8-2,0
5	2,0-2,2
6	2,2-2,4
7	2,4-2,6
8	2,6-2,8
9	2,8-3,0
10	3,0-3,2
11	3,2-3,4
12	3,4-3,6
13	3,6-3,8

The gravimetric moisture was determined, also along the transept, every 3 m and in the ten spots multiple of 6 (6, 12, 18…60). The exploratory analysis of data performed on the gravimetric moisture is shown in table 2.

Statistical analysis. For the univariate description numerical methods (location, dispersion and form measures) and graphics (histograms and normality curves), and the Kolmogorov-Smirnov normality test, were used. In the statistical data processing the software SPSS® 22.0 was used.

Results and Discussion

The performance of center location measures and of the distribution tails of the means of resistance to penetration per depth is shown in table 3. The highest resistance to penetration (highest mean) was found in the 10-20 cm layer; while the lowest value was located in the surface layer (0-10 cm). However, there was not an increase in such indicator after 20 cm. This could have been due to the negative effect of animal trampling on the resistance to penetration, due to inadequate moisture conditions in the soil.

Thus, Villazón *et al.* (2015), in a Chromic Vertisol soil under natural pasture, determined an increase of resistance to penetration below 10 cm of depth, without the existence of remarkable variations of soil compaction in the layers placed at higher depth.

On the other hand, the inversely proportional effect of moisture on the resistance to penetration is observed. Baio *et al.* (2017), when studying such indicator in a Red Latosol soil planted with corn, found that, in the row as well as the space between rows, the decrease of soil moisture stimulated the increase of resistance to penetration values. Also Elisei (2017), when studying Argiudol soils under agricultural system lots with more than 10 years of direct planting, modeled inverse and exponential equations between soil (gravimetric) moisture and resistance to penetration.

The closeness of the mean and median values indicated that there were no extreme observations of resistance to penetration, in the data sets, that displaced the first-mentioned location measure. In the 20-30 cm layer the differences between these two measures were less noticeable.

The minimum values were equal in the first two layers and higher in the deepest horizon; while the maximum value was found in the 10-20 cm layer, followed by the depths 20-30 and 0-10 cm. The performance per depth of the minimum and maximum values indicated a higher range in the intermediate layer. Thus, the distribution tails of the RP values in the 10-20 cm layer appeared further from the center than in the other depths.

Regarding the dispersion measures, it was observed that the intermediate layer showed the highest values of variance, standard deviation and

Table 2. Performance of the location, dispersion measures and distribution form of the gravimetric moisture values.

Dep. (cm)	Mean	Median	SE ±	Minimum	Maximum	Variance	SD	VC (%)	Asymmetry	Kurtosis
0-10	0,212	0,210	0,005	0,190	0,246	0,000	0,017	7,97	0,763	0,457
10-20	0,208	0,206	0,005	0,189	0,237	0,000	0,015	6,96	0,830	0,498
20-30	0,254	0,258	0,007	0,217	0,290	0,001	0,023	9,20	-0,217	-0,755
0-30	0,225	0,222	0,004	0,208	0,246	0,000	0,012	5,41	0,705	-0,155

Dep.: depth, SD: standard deviation, VC: variation coefficient.

Table 3. Performance of the location, dispersion measures and form of the distribution of resistance to penetration values per depth.

Dep. (cm)	Mean	Median	SE ±	Minimum	Maximum	Variance	SD	VC (%)	Asymmetry	Kurtosis
0-10	2,322	2,235	0,061	1,391	3,440	0,228	0,477	20,57	0,448	-0,284
10-20	2,535	2,589	0,073	1,391	3,729	0,328	0,573	22,60	0,154	-0,692
20-30	2,337	2,235	0,054	1,511	3,681	0,175	0,419	17,93	0,611	0,611
0-30	2,398	2,388	0,050	1,602	3,172	0.150	0,388	16,16	0,110	-0,726

Dep.: depth, SD: standard deviation, VC: variation coefficient.

variation coefficient; and that, in the case of the last dispersion measure, in no depth the resistance to penetration exceeded 30 % considered by Espino and Arcia (2009) as the maximum limit accepted for agronomic studies.

The dispersion (variability) of resistance to penetration, especially in the first two depths, could have been given by the heterogeneous spatial distribution of animal trampling, according to Zerpa *et al*. (2013); who, in soils under pastures, found a higher variation coefficient above 20 cm of depth.

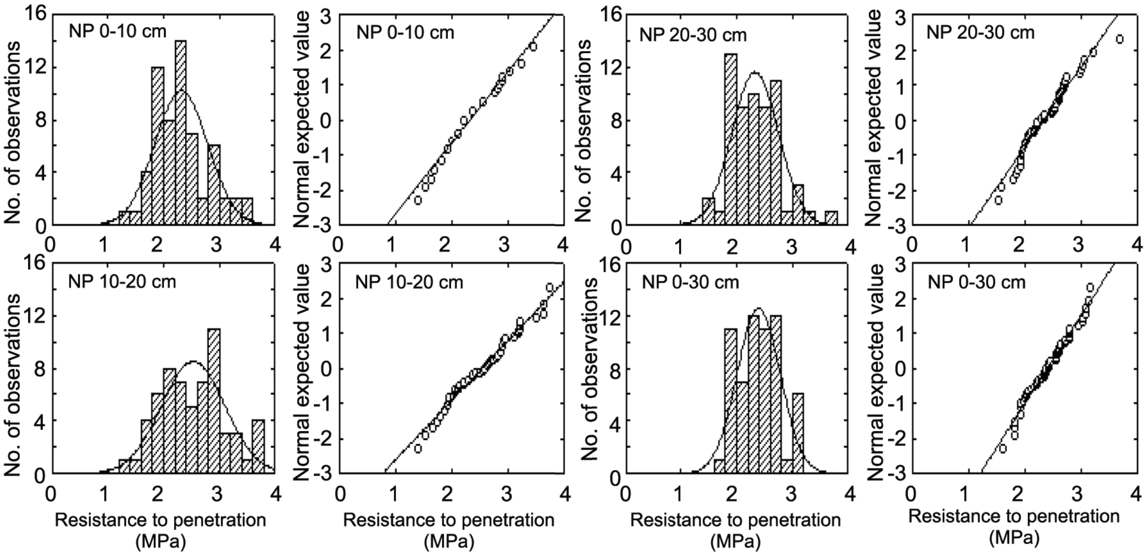
In the case of form measures, the lower asymmetry was found in the 10-20 cm layer. In this layer, just like in the other two, asymmetry had values close to 0; for which all the distributions, which in general never showed symmetry with any value, were positively biased, showing the distribution tail towards the right.

In addition, the performance of kurtosis in the three depths indicated that the distribution of the resistance to penetration had a less acute peak (platykurtic kurtosis) than the normal distribution, by showing values lower than 1 (Freixa *et al*., 1992); this indicates that in the tails there were more accumulated values than in the tails of a normal distribution.

Figure 1 shows the histograms and normality curves of the resistance to penetration per depth. In the 0-10 cm layer, the resistance to penetration along the transept was classified within the moderate (1-2 MPa) and high (2-4 MPa) categories, according to Arshad *et al*. (1996), for 29,51 and 74,49 % of the total observations, respectively. The highest trend of resistance to penetration was localized in the sixth class, which grouped the values between 2,2 and 2,4 MPa (22,95 %); in the fourth class, with a range between 1,8 and 2,0 MPa, with 12 sampling spots (19,67 %); and in the fifth class that concentrated the values between 2,0 and 2, MPa, with eight spots (13,11 %).

In the 10-20 cm layer, 19,70 % of the observations were included within the category of moderate resistance to penetration and 79,30 % was considered high. The ninth class concentrated the highest quantity of observations (11 in total, for 18,03 % of the sampling sites with a resistance to penetration in a range of 2,8-3,0 MPa), followed by classes fifth (with eight observations, for 13,11 %), sixth (with seven sampling spots, for 11,48 %) and eighth (also with seven observations), which grouped the sampling sites where the resistance to penetration was 2,0-2,2; 2,2-2,4 and 2,6-2,8 MPa, respectively.

In the 20-30 cm layer, 26,20 % of the observations were classified as moderate, while 73,80 % were included within the category of high ones. The highest tendency was accumulated in the fourth class, in which 13 observations were grouped, for 21,31 %. To this class the eighth, sixth, fifth and seventh ones are added, which comprised 33 sampling spots (69, 93 %) with a penetration resistance that varied between 2,0 and 2,8 MPa.



NP: Natural pasture

Figure 1. Histograms and normality curves in the different depths.

Thus, in the surface layer (0-10 cm), 40 sampling spots showed resistance to penetration lower than 2,5 MPa, for 65,57 % of observations below the critical limit proposed by Pilatti *et al.* (2012). In the intermediate layer (10-20 cm) the number of sampling sites below 2,5 MPa decreased, with regards to the surface layer, because only 28 observations were found, which represented 45,90 % of the total samplings carried out. In the lowest layer (20-30 cm) an increase of the spots with resistance to penetration lower than the critical limit was observed (37 sampling sites, for 60,66 %). When evaluating the performance of compaction down to 30 cm of depth a resistance to penetration was observed below 2,5 MPa in 36 sampled spots, for 59,02 %.

The results of the Kolmogorov-Smirnov normality test (table 4) showed that in the 0-10 and 20-30 cm layers there was not a normal distribution of the data. The resistance to penetration behaved differently in the 10-20 and 0-30 cm depths, where the normality tests showed results with a significance of 0,200.

Table 4. Results of the Kolmogorov-Smirnov normality test ♦.

Depth (cm)	Statistic	Significance
0-10	0,126	0,013
10-20	0,086	0,200♦♦
20-30	0,104	0,098
0-30	0,071	0,200♦♦

♦Lilliefors significance correction, ♦♦ Lower limit of the true significance

Thus, the resistance to penetration data in the 10-20 and 0-30 cm depths did not significantly differ from a normal population.

Conclusions

The highest resistance to penetration was found in the 10-20 cm layer, followed by the 20-30 cm layer. The lowest mean was determined in the surface layer (0-10 cm). In the 10-20 cm layer the difference between the minimum and maximum values was also higher, and the dispersion measures were higher. The kurtosis results indicated that in the distribution tail of resistance to penetration in the intermediate layer there was a higher quantity of observations than in the tails of a normal distribution. Likewise, in the three depths, the values of resistance to penetration were classified within the moderate and high categories.

Bibliographic references

Arshad, M. A.; Lowery, B. & Grossman, B. Physical test for monitoring soil quality. In: J. W. Doran and A. J. Jones, eds. *Methods for assessing soil quality*. Special Publication 49. Madison, USA: Soil Science Society of America. p. 123-142, 1996.

Baio, F. H. R.; Scarpin, I. M.; Roque, C. G. & Neves, D. C. Soil resistance to penetration in cotton rows and interrows. *Rev. bras. eng. agríc. ambient*. 21 (6):433-439, 2017.

Cerana, J. A.; Wilson, M.; Battista, J. J. de; Noir, J. & Quintero, C. Estabilidad estructural de los Vertisoles de Entre Ríos en un sistema arrocero regado con agua subterránea. *RIA*. 35 (1):87-106, 2006.

Crespo, G. Factores que influyen en el reciclaje de nutrientes en pastizales permanentes, avances en el desarrollo de su modelación. *Rev. cubana Cienc. agríc*. 49 (1):1-10, 2015.

Elisei, J. Influencia de la humedad del suelo en la resistencia a la penetración vertical. *Rev. tecnol. agropecu*. 10 (33):18-20, 2017.

Espino-Soto, Ayda & Arcia-Porrúa, J. *Estadística aplicada para las ciencias y la docencia. Estadística aplicada a las ciencias biológicas y agrícolas*. La Habana: Editorial PUBLINICA, 2009.

Freixa-Blanxart, Montserrat; Salafranca-Cosialls, L. & Guàrdia-Olmos, J. *Análisis exploratorio de datos: Nuevas técnicas estadísticas*. Barcelona, España: Poblagràfic S. A., 1992.

Hamza, M. A. & Anderson, W. K. Soil compaction in cropping systems. A review of the nature, causes and possible solutions. *Soil and Tillage Res*. 82 (2):121-145, 2005.

Hernández-Jiménez, A. Impactos de los cambios globales en los suelos de las regiones secas. *Agricultura Orgánica*. 2:8-9, 2004.

Hernández-Jiménez, A.; Pérez-Jiménez, J. M.; Bosch-Infante, D. & Castro-Speck, N. *Clasificación de los suelos de Cuba*. Mayabeque, Cuba: Instituto Nacional de Ciencias Agrícolas, Instituto de Suelos, Ediciones INCA, 2015.

Lal, R. Restoring soil quality to mitigate soil degradation. *Sustainability*. 7:5875-5895, 2015.

Murillo, J.; Rodríguez, G.; Roncallo, B.; Rojas, Leila A. & Bonilla, Ruth R. Efecto de la aplicación de prácticas sostenibles en las características físicas, químicas y microbiológicas de suelos degradados. *Pastos y Forrajes*. 37 (3):270-278, 2014.

Nantes, Nayana N.; Euclides, Valeria P. B.; Montagner, Denise B.; Lempp, Beatriz; Barbosa, R. A. & Gois, P. O. de. Desempenho animal e características de pastos de capim-piatã submetidos a diferentes intensidades de pastejo. *Pesq. Agropec. Bras*. 48 (1):114-121, 2013.

Pilatti, M. A.; De Orellana, J.; Imhoff, Silvia del C. & Silva, Á. P. da Actualización de los límites críticos del intervalo hídrico óptimo. *Cienc. suelo*. 30 (1):9-21, 2012.

Reichert, J. M.; Sanches-Suzuki, L. E. A. & Reinert, D. J. Compactação do solo em sistemas agropecuários e florestais: identificação, efeitos, limites críticos e mitigação. *Tópicos em Ciencia do Solo*. Viçosa, Brasil: Sociedade Brasileira de Ciência do Solo, 2007.

Soil Science Society of America. *Glossary of soil science terms*. Madison, USA: Soil Science Society of America, 2013.

Sotelo-Ruiz, E. D.; Gutiérrez-Castorena, María del C.; Cruz-Bello, G. M. & Ortiz-Solorio, C. A. Physical, chemical and mineralogical characterization of vertisols to determine their parent material. *Interciencia*. 38 (7):488-495, 2013.

Stolf, R. Teoria e teste experimental de fórmulas de transformação dos dados de penetrômetro de impacto em resistência do solo. *R. Bras. Ci. Solo*. 15:229-235, 1991.

Stolf, R.; Fernández, J. & Furlani, V. L. Recomendação para uso do penetrómetro de impacto medelo IAA/planasucar-Stolf. *Revista STAB-Açúcar, Álcool e Subprodutos*. 1 (3):235-241, 1983.

Vaca-García, V. M.; Martínez-Villanueva, J. J.; González-Huerta, A.; Morales-Rosales, E. J.; Zamudio-González, B. & Gutiérrez-Rodríguez, F. Compactación de un Vertisol bajo tres sistemas de labranza en maíz (*Zea mays* L.). *Rev. Mex. Cienc. Agríc*. 5 (8):1495-1507, 2014.

Villazón, J. A.; Martín, G.; Rodríguez, Y. & Cobo, Yakelín. Resistencia a la penetración en un Vertisol Crómico con diferentes usos, manejos y sitios de muestreo. *Pastos y Forrajes*. 38 (2):162-169, 2015.

Zerpa, G.; Sosa, O.; Berardi, J.; Bolatti, J. P.; Galindo, A. & Maldonado, J. La resistencia mecánica a la penetración en pasturas. *Agromensajes*. 35:64-68, 2013.

Received: January 19, 2018
Accepted: June 4, 2018