DOI:http://dx.doi.org/10.17224/EnergAgric.2016v31n2p200-206

REVISTA ENERGIA NA AGRICULTURA
ISSN: 1808-8759 (cd-rom)
2359-6562 (on-line)

CHEMICAL PROPERTIES OF ULTISOL IN DIFFERENT TILLAGE SYSTEMS UNDER SUGARCANE CULTIVATION

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ABSTRACT: The analysis of different tillage systems impact on soil properties is essential to assist farmers with management strategies. Thus, in this study, we aimed to evaluate the soil chemical properties behavior in sugarcane cultivation under different tillage systems. One tillage system consisted in five-steps deep tillage equipment and the other, in conventional method. We calculated the soil erodibility factor, as it is associated to soil chemical loss. We quantified soil organic matter, soil chemical characteristics and availability of principal nutrients, then, compared them between treatments. There was no significant difference between soil organic matter contents from both treatments. After the five-steps deep tillage, the quantity of Boron increased, while other nutrients quantities decreased. After the conventional tillage treatment, Potassium suffered a significant decrease due to soil erosion and due to high leaching characteristics of sandy soils. The soil erodibility factor was considered of high risk, this way, farmers should not flat the terrain overmuch.

KEYWORDS: Soil management, nutrients, erodibility, *Saccharum* spp.

PROPRIEDADES QUÍMICAS DE UM ARGISSOLO EM DIFERENTES SISTEMAS DE PREPARO COM CANA-DE-AÇÚCAR

RESUMO: Analisar os impactos causados pela atividade de manejo do solo é essencial para que se possa indicar ao produtor as melhores estratégias de cultivo. Com isso, **e**ste trabalho teve como objetivo avaliar o comportamento dos atributos químicos do solo em duas áreas de cultivo de cana-de-açúcar sendo uma delas manejada com equipamento de preparo profundo canteirizado e a outra pelos métodos de preparo convencional. O fator de erodibilidade do solo foi calculado, devido a sua ligação à perda de nutrientes. Para os manejos, foram avaliadas e comparadas entre tratamentos, a quantidade de matéria orgânica e as características químicas do solo. A matéria orgânica do solo no primeiro ano de corte da cana-de-açúcar não apresentou valores com diferença significativa entre os tratamentos. No tratamento manejado com equipamento de preparo profundo canteirizado, desde a implantação da cultura até o primeiro corte da cana-de-açúcar, a quantidade de boro aumentou enquanto as quantidades dos outros nutrientes, diminuíram. No entanto, para o tratamento de manejo convencional, houve redução de potássio podendo ser explicada pela erosão hídrica e pela lixiviação ser alta em solos arenosos. O fator erodibildiade do solo foi considerado de alto risco, não sendo aconselhada a retirada de curvas de nível.

PALAVRAS-CHAVE: Manejo do solo, nutriente, erodibilidade, *Saccharum* spp.

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1 INTRODUCTION

In crop systems, tillage is primarily used to prepare the seedbed and to control weed invasion. Some negative aspects associated to tillage practices are soil structure disruption, organic matter decomposition, weed seeds germination acceleration, and soil erosion (Alegre et al., 1991). Erosion is the most significant consequence of soil's inappropriate use; it alters the distribution of nutrients and soil organic matter through the soil profile (Carvalho et al., 2009).

Proper planning the soil management requires the manipulation of basic information aiming to prolong its productive capacity and rationality, as well as its use and conservation (Gomes et al., 1993). The soil erodibility is the integrated effect of processes that regulate the raindrops when they get into contact with the soil and its respective resistance regarding the breakdown of particles and hence their movement, indicating the degree of susceptibility to erosion in relation to inherent soil properties (Arraes et al., 2010). Soil organic matter is crucial for biological, chemical, and physical soil functioning and tillage practices has been reported to reduce its concentrations and increase its decomposition rates (Balesdent et al., 2000).

There are several tools and power machinery used for tillage, and it is important that the farmer understand the potentially usable tillage system to each soil type and its effects on the soil properties. This way, the tillage system can be selected to give the appropriate balance among soil sustainability, high yields, and minimized costs.

The lack of intensive studies on agricultural machines available in the market may result in inappropriate soil management. Thus, in this work, we evaluated and compared the soil erodibility factor, organic matter, and concentrations of chemical elements in two areas cultivated with sugarcane managed with two systems of different tillage intensities.

2 MATERIALS AND METHODS

Experimental area - The study was conducted in Sao Paulo midwest. The soil from this area is classified as an Ultisol Red-Yellow of medium sandy texture (EMBRAPA, 2013). According to Köppen's classification (1948), the climate is Cwa, with a dry season that runs from April to August and a rainy season that covers the months from September to March. January is the wettest month (Cunha et al., 1999). Figure 1 shows the precipitation from January 2012 to August 2013, period that the experiment was conducted.

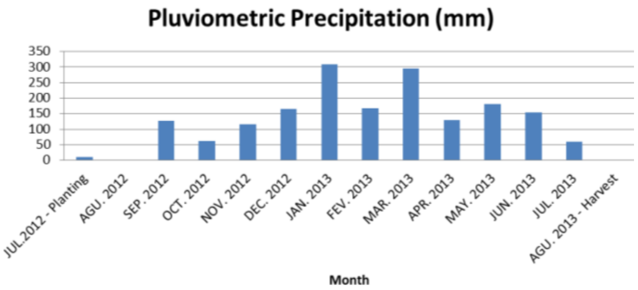

Figure 1 *- Precipitation variation during the study period.*

The soil water retention curve is characterized in Figure 2. The permanent wilting point of Ultisol of medium sandy texture is 0.12 kg kg^{-1} of soil water content, and its field capacity is 0.26 kg kg^{-1}.

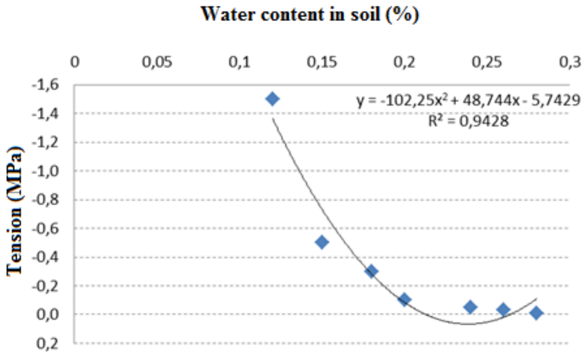

Figure 2 *- Soil water retention curve of the experimental area.*

The determination of the water retention curve is important because it informs the volume of water available to the plants within each voltage range in a given sample. Greater volume of water available at low voltages reflects lower energy expenditure by the plant to absorb it (Fermino, 1996).

Experiment design - The experiment area was divided into two plots of 2.5 ha each, being 500 m long and 100 m wide. The plot borders were 30 m wide from the carrier and each treatment was divided into four sub-plots of 100 m in length following the planting row. Each plot was manage differently: one with the Five-steps Deep Tillage (PPC) and the other, with the Conventional Tillage (PC) system.

The PPC is characterized by the use of an equipment of intensive preparation that allows for in-five operations or functions at the same time. This equipment has a subsoiler rod applicator corrective mechanism, a mechanism to apply fertilizer with optional variation of depth (0.40 and 0.80 m), a rotary hoe to unpack the soil and a system to perform the formation of banded beds.

The PC, here called conventional due to be widely used in sugarcane cultivation, is characterized by preparing the soil with a heavy grade and then a light one.

The experimental area relief was corrected removing the terraces and readjusting the planting lines, according to the computer program Keyhole Markup Language (KML), a free version used to measure distances.

In both treatments, the plants used were derived from the variety RB 966 928. They were planted with 0.90 m between plants and 1.50 m between rows, with 2.40 m between traffic lines centers. The first harvest was done when they were 15 months old.

Chemical characterization of the soil - To do the soil chemical characterization, five simple deformed samples were collected from 0 to 0.15, 0.15 to 0.30, and 0.30 to 0.45 m layers, and a composite sample from each respective system treatment was made.

The Soil Organic Matter (SOM) was determined by the method of Walkley and Black, adapted and described by Raij et al. (2001). The SOM samples were collected from the same layers that the chemical samples were collected. The traffic lines and plants lines SOM samples, from both treatments, were subjected to analysis of variance using the Tukey test ($\alpha = 10\%$).

Both attributes were analyzed at three distinct moments: at the moment when the experiment was established, after tillage, and after harvest (at the 15th month).

Soil Erodibility Factor - The soil particle density of the experimental area was 2.70 g cm^{-3}, defined using Danielson and Sutherland method (1986).

Soil Erodibility Factor (K) was calculated by an indirect method, using the expression of Bouyoucos (Bertoni and Lombardi Neto, 1990):

$$K = \left(\frac{A+S}{Ar}\right) \text{x } 100 \qquad (1)$$

Where:

K = Soil Erodibility Factor (t ha h (ha MJ mm)$^{-1}$);
A= Respective fraction of sand (%);
S = Respective fraction of silt (%);
Ar = Respective fraction of clay (%).

3 RESULTS AND DISCUSSION

In the PPC treatment, from the implementation of the culture to the first harvest, the quantity of Boron (B) increased while the other nutrients decreased. In the PC treatment, Calcium (Ca) and B increased, as the Base Saturation (V%) degree, while the other components quantity, decreased (Table 1).

Table 1 - *Granulometric characterization of 0.0 to 0.15; 0.15 to 0.30; and 0.30 to 0.45 m soil layers from the experimental area.*

	Size fractions					
	Sandy (g kg^{-1})			Silt (g kg^{-1})	Clay (g kg^{-1})	Texture
Layers (m)	Thick	Thin	Total			
0.0 – 0.15	357	496	853	129	18	Sandy
0.15 – 0.30	394	489	883	102	15	Sandy
0.30 – 0.45	436	446	881	103	16	Sandy

The nutrients losses could be related to chemical leaching or to the adsorption of chemicals to sediments that were carried away by surface flow (Walton et al., 2000).

In sugarcane cultivation, the V% should be increased in 60%, to better control the soil acidity (Van Raij et al., 1983). In the PC treatment, the variable V% increased by 23% (Table 2).

Table 2 - *Soil Chemical attributes after tillage (AT - 2012) and after harvest (AH - 2013), for each treatment PPC and PC.*

Period	AT - 2012		AH - 2013			
Element	PPC	PC	PPC	PPCR	PC	PCR
pH (CaCl2)	5.6	5.1	5.6	5.2	5.8	5.4
M.O. (g dm-3)	32	16	8	11	11	11
Presina (mg dm-3)	18	26	8	16	12	16
Al3+ (mmolc dm-3)	2	1	0	0	0	0
H+Al (mmolc dm-3)	17	19	14	20	13	15
K (mmolc dm-3)	2.50	3.10	2.16	2.73	1.75	1.80
Ca (mmolc dm-3)	26	14	25	21	23	22
Mg (mmolc dm-3)	12	6	8	5	6	5
SB (mmolc dm-3)	41	22	35	28	31	28
CTC (mmolc dm-3)	58	42	49	49	44	44
V% (mmolc dm-3)	70	54	69	58	70	65
S (mg dm-3)	16	7	4	6	8	7
B (mg dm-3)	0.18	0.18	0.37	0.33	0.29	0.35
Co (mg dm-3)	0.60	0.60	0.52	0.45	0.49	0.63
Fe (mg dm-3)	51	54	20	44	26	51
Mn (mg dm-3)	6.60	5.80	1.13	2.54	1.55	5.56
Zn (mg dm-3)	0.60	0.80	0.31	0.59	0.50	0.45

pH: hidrogênico potential; OM: organic matter; Presina: Phosphorus extracted with resin; Al3 +: aluminum; H + Al: hydrogen + aluminum; K: potassium; Ca: calcium; Mg: Magnesium; SB: sum of bases; CEC: cation exchange capacity; V%: base saturation; S: sulfur; B: boron; Co: copper; Fe: iron; Mn: Manganese; Zn: zinc. PS: soil preparation; AC: after harvest; PPC: five-steps deep tillage; PPCR: five-steps deep tillage run; PC: conventional tillage construction; PCR: conventional tillage rotated.

Demattê (1986) also observed an increase in Ultsoil V% with application of gypsum (1.0 t ha^{-1}) in sugarcane plantation. The supply of Ca was 40% higher than the indicated by the calculated soil acidity correction (70%) and the Magnesium (Mg) remained stable (Table 2).

Although there was an application of 4 g l^{-1} of vinasse, the Potassium (K) quantity remained steady in the PPC treatment (Table 2).

In the other hand, the K quantity decreased in the PC treatment until the first harvest, as observed by Guadagnin (2005) the K decrease started at the beginning of the cycle of four different crops. Some phenomena that could explain the reduction of K are as follows, soil erosion, plants uptake, and sandy soils high potential for leaching.

The amounts of SOM after tillage and after harvest (Tables 3 and 4) did not differ between both treatments.

Table 3 - *Soil organic matter (SOM) from treatments PPC and PC, after tillage.*

	Layer (m)		
Treatment	0 - 0.15	0.15 - 0.30	0.30 - 0.45
PPC	7.29 a	7.39 a	9.45 a
PC	9.35 a	11.31 a	10.67 a

Means with the same letter in the column do not differ by Tukey test (α = 0.10) test. SD: 2.5; CV: 2%. PPC – five-steps deep tillage and PC - Conventional Tillage.

Table 4 - *Soil Organic Matter (SOM) from treatments PPC and PC, after the first harvest.*

	Layer (m)		
Treatment	0 - 0.15	0.15 - 0.30	0.30 - 0.45
PPC	12.76 a	10.11 a	6.78 a
PC	14.03 a	10.30 a	11.21 a

Means with the same letter in the column do not differ by Tukey test (α = 0.10) test. SD: 2.5; CV: 2%. PPC – five-steps deep tillage and PC - Conventional Tillage.

As the evaluations of this work were carried out in an area where only one rotation of sugarcane cultivation was conducted, it is natural that the organic matter content did not fluctuate, since it is considered a short time for changes to occur. This was also observed by Nardin (2007), who pointed out that a first application of any source organic matter into the soil with non-satisfactory climatic conditions to deep root development, would result in no changes in this parameter.

Besides the importance of soil aeration and water infiltration, attention should be paid that the adequacy of terrains relief and the deep preparation do not favor the occurrence of water content above the field capacity, at which the plant does not absorbs the soil solution, or neither below the wilting point, at which the plant may suffers from water deficiency. Farmers tend to flat the terrain excessively, without taking the soil type as basic information. Therefore, the erodibility factor would help orientate them on how remove terraces regarding the soil characteristics. This study area has a soil type with an erodibility factor considered very high, for all layers (Table 5).

Table 5 *- Soil erodibility factor of the experimental area, for each soil layer.*

Layer (m)	K - factor (t ha h (ha MJ mm)-1)
0 -0.15	0.07
0.15-0.30	0.09
0.30-0.45	0.09

In addition to consequences caused by the management changes used in this experiment, the interaction of factors such as evapotranspiration, type of culture established, planting density, rooting depth, soil profile, and impediments to drainage also influence the soil water retention curve (Carvalho et al., 1999). To Cassel and Nielsen (1986), the soil water retention capacity is directly related to the matrix and the spatial distribution of pores.

Dexter (2004) indicates that increasing compaction modifies the characteristic of soil water retention curve and reduces its hydraulic conductivity, decreasing water availability to plants.

Soils with a sandy texture have percentage of sand particles higher than 70% and less than 15% of clay. Thus, they are porous, lightweight, with low water retention capacity, highly susceptible to erosion, requiring special care as the replacement of organic matter into the soil and conservation practices. These soils are limited to furrow irrigation method, due to the low capacity of water retention, which leads to a high rate of water infiltration into the soil and, consequently, high chemical leaching loss (Klein, 2008).

4 CONCLUSIONS

The nutrients losses from both treatments could be highly associated to chemical leaching as well as to the adsorption of chemicals to sediments that were washed by surface flow.

The decrease of K in the PC treatment area after the first harvest may be explained by erosion or plant withdrawn and even by the sandy soils high leaching characteristic.

The permanent wilting point of the area soil type is 0.12 kg kg^{-1}, the water content in the soil and its field capacity is as 0.26 kg kg^{-1}.

The soil erodibility factor was considered of high risk, and the activity of relief adequacy requires more careful evaluations.

The soil organic matter values after the first harvest showed no significant difference between treatments. This was already expected, due to the short period of crop cultivation in the experiment area.

5 ACKNOWLEDGEMENT

Thanks to CAPES (Coordenação de aperfeiçoamento de Pessoal de Nível Superior) for providing the doctoral assistenship for the first author of this article.

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