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PROPERTIES OF THE FERTILITY OF A CANE SOIL UNDER DIFFERENT TYPES OF ORGANIC AND CONVENTIONAL MANAGEMENT

Propiedades de la fertilidad de un suelo cañero bajo diferentes tipos de gestión orgánica y convencional

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ABSTRACT. The sugarcane is one of the main crops produced in Brazil and is cultivated since the colonial Brazil Times. Soil management in the culture of sugarcane has undergone changes over time, applying new techniques of management and conservation of soil, taking advantage of systematic way the waste from the manufacture of alcohol and sugar, minimizing damage to environment. This aimed to evaluate the chemical attributes of the soil cultivated with sugarcane certified organic with and without soil disturbance, organic certification, conventional with and without straw burning and a remaining area of Cerrado in Goiatuba, Goiás, Brazil. Soil samples were collected in September 2009 in the depths of 0-10 cm and 10-20 cm for chemical analysis. The results were analyzed descriptively by estimating the mean, standard error of the mean and also by means of multivariate analysis, estimating the Euclidean average distance between the treatments with complete connection. There forming groups among the organic cultivation without soil disturbance and the remaining area of Cerrado in the depth 0-10 cm indicating proximity between the evaluated attributes. The organic cultivation without soil disturbance presents phosphorus and potassium far superior to other managements. The results underscore the importance of greater supply of organic waste for improved chemical attributes and maintenance of soil quality.

Key words: *Saccharum* sp., soil chemistry, sustainability

RESUMEN. La caña de azúcar es uno de los principales cultivos producidos en Brasil, desde los tiempos coloniales. La gestión del suelo en el cultivo de la caña ha sufrido cambios en el tiempo, con la aplicación de nuevas técnicas aprovechando sistemáticamente los residuos procedentes de la fabricación de alcohol y azúcar, minimizando el daño al medio ambiente. Por lo tanto, el objetivo del presente trabajo fue evaluar las propiedades químicas del suelo cultivado con caña de azúcar orgánica certificada con y sin alteración del suelo, en certificación orgánica, convencional con y sin quema de residuos agrícolas y un área del Cerrado nativo en Goiatuba, Goiás. Las muestras de suelo se recogieron en septiembre de 2009 en las profundidades de 0-10 cm y 10-20 cm para el análisis químico. Los resultados se analizaron de manera descriptiva, mediante la estimación de la media, el error estándar de la media y también por medio del análisis multivariado con estimación de la distancia media euclidiana entre los tratamientos con conexión completa. Hay grupos de formación entre el cultivo orgánico sin la perturbación del suelo y el área de Cerrado nativo en la profundidad de 0-10 cm, lo que indica la proximidad de los atributos evaluados. El cultivo orgánico sin la perturbación del suelo tiene fósforo y potasio superiores a otras gestiones. Los resultados resaltan la importancia de aumentar la oferta de los residuos orgánicos para la mejora de atributos químicos y mantenimiento de la calidad del suelo.

Palabras clave: *Saccharum* sp., química del suelo, sostenibilidad

INTRODUCTION

The increase in the intensity of land use and the reduction of native vegetation have led to the degradation of natural resources and, in particular, the loss of soil fertility. In Brazil, expansion cultures with sugar cane (*Saccharum* sp.) have occupied large areas that are maintained for long periods of time, resulting in changes, mostly negative, in soil properties (1). A better understanding of the changes in the chemical properties of the soil allows agricultural development on a sustainable basis.

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Brazil is the largest producer of sugarcane and continues to expand its cultivation, mainly in the Midwest region, where Cerrado regions prevail. According to the survey conducted by the National Supply Company (2), for the 2016/2017 crop, the production was 653 million tons in an area of 9 million hectares. The survey also showed that the cultivation of sugar cane is still growing, with a growth of 4.8 % in relation to the previous harvest.

The Brazilian Cerrado is a very peculiar environment, since it presents, in its constitution, from open fields, to dense forest formations. This region covers, mainly, the central part of Brazil, with 206 million hectares, which is equivalent to approximately 23 % of the national territory, constituting the second largest biome in Brazil, mainly in the provinces of São Paulo, Minas Gerais, Mato Grosso do Sul, Mato Grosso, Goiás, Tocantins, Bahia, Piauí, Maranhão and Distrito Federal (3).

Soils under the Cerrado biome tend to require special care to maintain the quality and sustainability of it. The productive capacity of these soils is characterized, above all, by low natural fertility and depends on good agricultural practices to correct acidity, increase fertility and to make sugar cane production sustainable, with the use of organic alternatives, once that crops with the characteristics of sugarcane can improve the quality of soils in relation to conventional systems (4,5).

For decades, the cultivation of sugar cane had its image linked to high environmental impacts, due to the burning of cane in many regions. Currently, this practice has been abolished with the use of new technologies that have contributed to the sustainability of the fields; for example, fertigation with vinasse, green and organic fertilizers, favoring, therefore, the adoption of organic farming.

The understanding and the quantification of the impact of the different systems of management of the biological, physical and chemical attributes of the soil, are of fundamental importance for their conservation, since the changes that result from these systems are usually compared with the original soil developed under the native vegetation.

The chemical properties of the soil are determining factors of the growth and development of the vegetation. However, compared to conventional treatment, there is little information about the production of sugar cane in organic farming, which requires studies to evaluate its effectiveness. Therefore, the objective of the present study was to evaluate the changes in the chemical properties of the soil in the crop with certified organic production of sugar cane (with and without soil alteration), in organic certification, in a conventional manner (with and without burning of straw) and in the area of the native Cerrado in two depths.

MATERIALS AND METHODS

The experiment was carried out in areas of commercial production of sugarcane, in Goiatuba, State of Goiás, Brazil. The region has two well-defined seasons, one with a shortage of rainfall (April to September) and another hot and humid one (October to March) with an average annual rainfall of 1,250 mm. According to the Koppen classification, the climate is of the tropical type, with a dry season in the winter. The predominant soil is classified as Dystrophic Yellow, with medium fertility and low pH around 5.0

The following production areas were selected and evaluated:

- ♦ organic production with soil disturbance (OCR).
- ♦ organic production without soil disturbance (OSR).
- ♦ certification for organic production (OPC).
- ♦ conventional system with burning (CCQ).
- ♦ conventional system without burning (CSQ).

The zones were close to each other, at a maximum distance of 2000 m. All the areas showed a soil classified as red dystrophic Latossolo (6). The soil samples were collected in September 2009 at depths of 0-10 cm and 10-20 cm for chemical analysis. As a reference for the natural system, an area representative of the native Cerrado (RCN) was used, with an argillaceous textural classification.

The management without disturbance of the soil (OSR) was characterized by presenting nine years in organic production system without soil alteration, with clay loam textural classification with mechanical harvest (without burning). The management of organic production with soil disturbance (OCR) was characterized by presenting nine years with the organic production system, but with the renewal of cane and soil preparation in the fifth year after the harvest of sugarcane.

The management of a sugarcane field in the process of certification for organic production (OPC), has been carried out for three years in the organic system with mechanical harvesting without burning of agricultural residues in soil with clay texture. The areas of sugarcane with certified organic management and certification received the same application of 40 t ha^{-1} of pressed cane residue, ash from the boiler, organic compost, application of natural phosphates and application of 180 m^3 ha^{-1} vinasse. The applied doses of each material in each production system differed according to the interpretation of the results of soil fertility analysis. The control of pests and diseases was carried out using recommended practices in organic systems (law 10831 of December 2003 and federal decree of 6323, December of 2007) with biological control of pests and manual removal of weeds.

The sugarcane areas under conventional conditions were managed in different ways, one with burning (CCQ) and the other without burning agricultural residues with mechanical harvesting (CSQ) in soils with five years of age with a sandy clay loam texture. These zones were characterized by the renewal of the plantation after the fifth year of cultivation, use of pesticides and application of chemical fertilizers in the amount of 700 kg ha^{-1} formulated 02: 32: 12 + 0.2 % Zn and 110 m^3 ha^{-1} vinasse, as a technical recommendation.

The areas were divided into four plots of one hectare, collecting in each plot ten simple diagonal samples to form a composite sample. The soil sample was taken with the help of the Dutch type auger. They were then packed in plastic bags, sent to the laboratory, where the routine procedures for soil analysis were carried out. The samples were passed through a sieve with a 2 mm mesh, where the organic residues, such as plants, roots and seeds were removed.

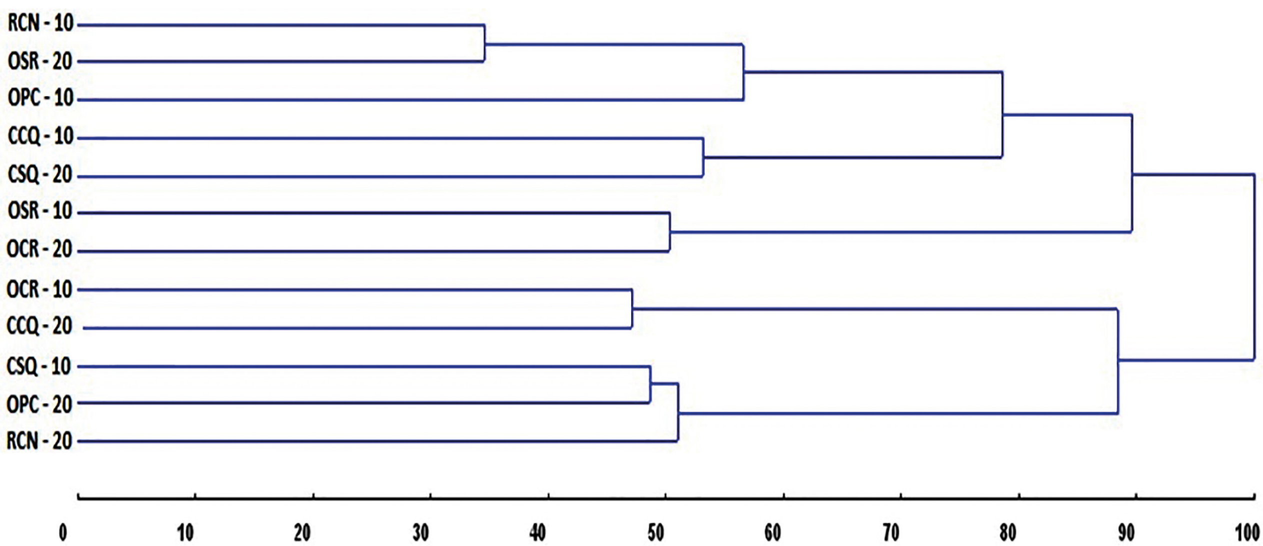
The pH was determined, the concentrations of copper (Cu), iron (Fe), manganese (Mn), zinc (Zn), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), exchangeable acidity (H + Al), potential CIC (T), the percentage of organic matter (MO) and base saturation (V) according to the methodology described (7).

The results of the chemical analyzes were processed descriptively by estimating the mean, the standard error of the mean and also by means of multivariate analysis with estimation of the average Euclidean distance between the treatments.

RESULTS AND DISCUSSION

In the analysis performed by the group of closest neighbors (Figure 1), the formation of two main groups was observed. The first consisted of the procedures RCN 10, OSR 20, OPC 10, CCQ 10, CSQ 20, OSR 10, OCR 20; the second consisted of OCR 10, CCQ 20, CSQ 10, OPC 20 and RCN 20, showing the differences in relation to the chemical properties of the analyzed soils.

Each time a significant variation is received in the Euclidean distance amounts between the accesses to the set of variables considered, a division of groups can be made. In this analysis, the areas were grouped according to their degree of similarity, with the aim of classifying them into groups with greater or lesser homogeneity.



CCQ: sugarcane under conventional tillage with straw burning; CSQ: sugarcane under conventional tillage and without straw burning; OCR: sugarcane with organic management with soil alteration; OPC: sugarcane with organic management in the process of certification; OSR: sugarcane with organic crops and without soil alteration; RCN: representative of Native Closed. 10: depth of 0-10 cm; 20: 10-20 cm depth

Figure 1. Divergence between the different systems in the chemical properties of the soil and its management

When the depths (0-10 and 10-20 cm) are analyzed together, they were not decisive in the characterization of the formation of the groups, which showed that the training can be susceptible to the effects generated by different management systems used, than at the depth of the soil itself. In other studies, the depth was not decisive either, in the microbiological evaluation of the soil in different attributes of the sugarcane under organic and conventional management (8).

It was demonstrated that individual analyzes can be carried out in both depths (0-10 and 10-20 cm), in order to evaluate the individual effect generated by this and the different variants on the chemical properties of the soil, which allows a detailed analysis of the factors involved.

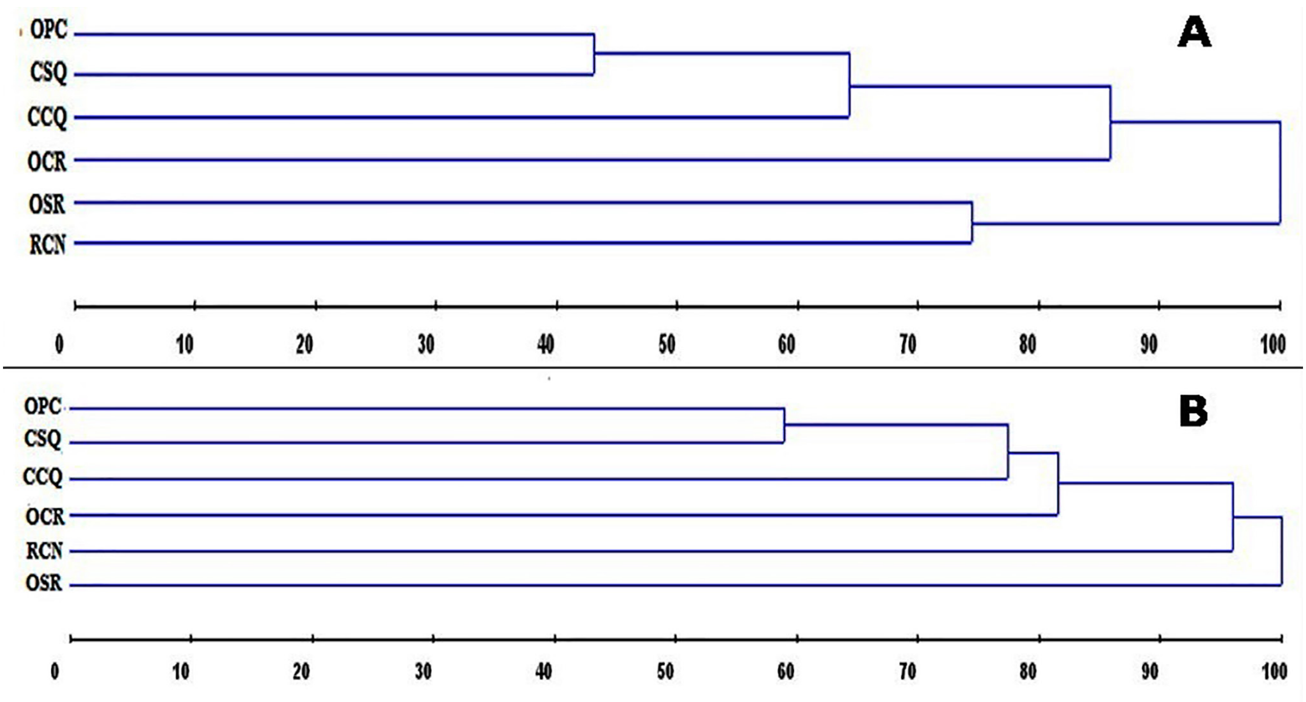
The differentiation of the groups, individually, in each depth (Figure 2A and B), enabled the formation of two groups in each of them.

In the depth 0-10 cm (Figure 2A) there was a grouping between the OSR and the native Cerrrado representative (RCN) and another grouping between the OCR, CCQ, CSQ and OPC. In spite of RCN form grouping with the managements of OCR, CCQ and CSQ. In the depth of 10-20 cm (Figure 2B), this tends to be isolated from the other managements, which shows that although these systems have certain similarities, but presents differences.

In addition, at depth 0-10 greater proximity can be noted between more conventional systems (CSQ and CCQ) and in the process of certification (OPC), a fact confirmed in the depth of 10-20 cm (Figure 2B).

It is important to point out that after three years of the application of conventional to organic agriculture in OPC, this still has characteristics similar to conventional systems, which requires more time for systems in transition to be consolidated as organic.

According to other studies (8-10), in some situations, especially in organic systems with short-term adoption, the content of organic matter cannot be an efficient discriminator of changes in soil quality; however, as time progresses, they tend to have a greater increase in organic matter on the surface of the soil. Soil organic matter has great potential to be used as a key attribute in soil quality, since, in addition to meeting the basic requirement to be sensitive to the changes imposed by the direction adopted, being the main source of nutrients for plants, it influences infiltration and water retention, as well as acting on the nutrient cycle, aggregation and susceptibility to soil erosion (11).



CCQ: sugarcane under conventional tillage with straw burning; CSQ: sugarcane under conventional tillage and without straw burning; OCR: sugarcane with organic management with soil alteration; OPC: sugarcane with organic management in the process of certification; OSR: sugarcane with organic crops and without soil alteration; RCN: representative of Native Closed

Figure 2. Divergence between the different systems in the chemical properties of the soil and its management in the depth of 0-10 cm (A) and 10-20 cm (B)

It is known that managed systems with differences in the mix and composition of soil vegetable residues alter the chemical properties of the soil, which affects the quality and productivity of crops (12). The management and preparation of the soil for cultivation favor the oxidation reactions, by increasing the partial pressure of oxygen and the exposure of new surfaces for the microbial attack. The net balance of this effect is the reduction of organic matter levels in systems with intensive soil preparation. What may highlight the fact that the OCR management is part of the first group, both in the depth of 0-10 (Figure 2A) or in the 10-20 cm (Figure 2B), since this is maintained in its organic system already consolidated, but with the disturbance of the soil.

In the second group that was formed in 0-10 cm (Figure 2A), the proximity between the OSR managements (nine years under administration in the organic production system without disturbance of the soil) and the representative of the native Cerrado (RCN) is shown.) which shows that well-established organic systems without soil disturbance can be similar to natural systems.

This group is possibly related to the content of organic matter, CIC and some micronutrients that tend to improve the quality of the environment, which allows a sustainable agriculture, reducing negative external effects, replenishing little by little the stability of the soil, avoiding erosion. In turn, the representative of the native Cerrado has several unwanted chemical characteristics for most crops, such as low pH (13-15).

Similar results were observed in another study (16), where there is group formation between consolidated organic coffee crops and native areas of rainforest fragments. According to research (17), the evaluation of soil properties in grasslands subject to different management, also finds formation of groups between conservation systems and native forest. The authors attribute the formation of such groups, mainly due to a greater accumulation of organic matter derived mainly from the large amount of biomass accumulated in the soil surface in the conservation systems.

In work done by other authors (18), organic carbon was increased by 4.0 t ha^{-1} in treatments with sugarcane straw (without burning) compared to treatment with burns, after a period of nine years. The content of C in the soil is generally recognized as an important component of fertility and the processes related to soil physics.

Additionally, there is a strong correlation between the content of organic matter and the microbial activity of the soil, very important factors for the sustainability of the system.

The depth of 10-20 cm (Figure 2B), isolated the OSR management of RCN. Possibly this is due to the low fertility and high acidity present in the soils of the native Cerrado, together with the high levels of P and the predominance of the roots of sugarcane present in this depth in OSR management. This behavior was reported by other authors in the evaluation of the grazing areas in relation to the regions of native Cerrado (19), which indicated that the roots of the herbs helped to be at depths of 10-20 cm highly conservative in environment with greater accumulated organic matter.

The fasciculate roots tend to have a greater physical protection of the organic matter against the microbial action exerted by the soil structure (20). In addition, the cultivation of sugar cane is responsible for 11% of the product of the residual crop currently produced in the world (15), highlighting its important role of carbon transfer in the soil, which could also have contributed to a greater amount of organic matter in depth in OSR management (Table 1).

The chemical analyzes were carried out in order to characterize the soils in the study areas (Table 1). The understanding of changes in soil properties, derived from the cultivation of sugar cane in different ways, provides information for production in a sustainable manner.

In general, all chemical variables evaluated were maintained or their values were reduced in the soil profile (Table 1). In relation to soil pH, lower values were observed for the representative of native Cerrado (RCN), since the same in this biome tend to have a high acidity (13-15).

Among the areas of sugarcane cultivation, high pH values were evidenced in the area of OPC, OCR, CSQ and OSR, in the superficial layer of the soil (0-10 cm) and the lowest in CCQ. Soils with low straw deposition tend to have the acidification of the surface layers due to their low damping effect, which apparently did not occur for the active neutralization of soil acidity (21).

On the other hand, in areas with prolonged cultivation of sugar cane, the increase in pH can be observed in the horizon of the surface, thanks to the application of corrective or amendment (14). There was a tendency for higher pH values in the areas dedicated to conservationist crops, coinciding with what was reported by other authors (14).

Table 1. Mean values of the chemical attributes evaluated in the two depths studied. Goiás, Brazil

Mana-gement	pH	Cu	Fe	Mn	Zn	P	K	Ca	Mg	H+Al	T	MO	V
				mg kg^{-1}					cmolc kg^{-1}			%	%
0-10 cm													
CCQ	5,2	2,3	41,8	16,9	0,3	2,0	53,5	1,7	0,6	3,0	5,4	1,4	45
ESx	0,1	0,1	0,7	0,7	0,1	0,3	2,8	0,1	0,1	0,3	0,2	0,2	4,5
CSQ	6,1	2,7	36,0	32,3	0,6	2,8	75,3	2,0	0,6	2,3	5,1	1,8	55
ESx	0,1	0,1	1,8	2,7	0,1	0,6	7,6	0,2	0,1	0,4	0,3	0,1	1,9
OCR	5,6	2,7	37,8	24,4	0,6	1,4	72,8	2,4	0,8	2,8	6,2	1,9	55
ESx	0,1	0,3	1,1	4,3	0,1	0,9	5,7	0,2	0,1	0,2	0,4	0,2	1,8
OPC	6,0	4,4	43,4	29,7	0,5	2,7	79,3	2,6	0,9	2,6	6,3	2,1	59
ESx	0,2	0,4	3,0	3,9	0,1	0,4	2,7	0,3	0,1	0,3	0,5	0,2	1,3
OSR	5,9	2,1	35,1	26,6	0,9	7,0	136,8	3,4	0,9	2,7	7,4	2,4	63
ESx	0,1	0,1	0,9	2,9	0,2	1,1	12,0	0,3	0,1	0,1	0,3	0,1	2,3
RCN	4,6	2,7	44,8	43,9	0,7	1.1	84,3	2,2	1,0	7,4	10,8	3,0	32
ESx	0,1	0,1	0,8	10,3	0,4	0,4	5,4	0,8	0,3	0,7	1,1	0,3	7,1
10-20 cm													
CCQ	5,4	2,3	41,8	16,9	0,3	1,1	1,2	1,2	0,6	2,6	4,4	0,9	41
ESx	0,2	0,1	0,7	0,7	0,1	0,3	0,2	0,2	0,1	0,3	0,2	0,5	6,3
CSQ	6,1	2,7	36,0	32,3	0,6	1,5	3,3	2,3	0,5	2,2	5,0	1,4	56
ESx	0,1	0,1	1,8	2,7	0,1	0,2	0,2	0,2	0,3	0,1	0,4	0,4	6,2
OCR	5,8	2,7	37,8	24,4	0,6	0,7	2,0	2,0	0,8	2,7	5,5	1,2	51
ESx	0,2	0,3	1,1	4,3	0,1	0,1	0,4	0,4	0,1	0,1	0,5	0,1	3,2
OPC	6,1	4,4	43,4	29,7	0,5	1,2	2,4	2,4	0,9	2,4	5,7	1,7	58
ESx	0,1	0,4	3,0	3,9	0,1	0,1	0,3	0,3	0,1	0,1	0,5	0,0	2,1
OSR	5,8	2,1	35,1	26,6	0,9	8,4	2,6	2,6	0,7	2,7	6,0	1,7	55
ESx	0,0	0,1	0,9	2,9	0,2	4,6	0,40	0,4	0,1	0,2	0,5	0,3	2,2
RCN	4,6	2,5	35,8	17,7	0,2	0,6	0,7	0,7	0,4	6,4	7,5	1,1	15
ESx	0,1	0,2	2,8	1,8	0,0	0,3	0,2	0,2	0,0	0,5	0,4	0,2	2,9

ESx: average standard error
CCQ: sugar cane under conventional tillage with straw burning
CSQ: sugar cane under conventional tillage and without straw burning
OCR: sugarcane with organic management with soil disturbance
OPC: sugarcane with organic management in the process of certification
OSR: sugarcane with organic crops and without soil alteration
RCN: representative of Native Closed

The increase in pH is directly related to the practice of organic fertilization, which suggests that the addition of organic compounds helps to cancel the positive charges of the mineral soil matrix, by specific adsorption of organic anions, resulting in low acidification of the soil (14). The highest value for interchangeable acidity (H+Al) was observed for the RCN area, which is in agreement with the results of some studies, where a native area of references adjacent to sugar cane areas is used (21) . Among the areas of sugar cane cultivation, H+Al values were evaluated very close at different depths (0-10, 10-20 cm).

Several studies have shown the reduction of the interchangeable Al in the soil, with the use of animal manure (20), attributing the complexity of aluminum by chelating agents existing in organic materials as the main cause. Therefore, low levels of Al are expected in soils with organic management, which is desirable, especially since aluminum is toxic in high concentrations, contributing to potential acidity (10).

Values of high effective capacity of cation exchange (CIC) were observed for the RCN zone, in comparison with the areas planted with sugarcane, observing the tendency of the high values for the areas of ecological agriculture. The CEC of the soil has a direct relationship with organic matter, given its high specific surface area and chemical composition (organic groups) and may be higher in systems that provide increased carbon stocks in the soil, such as sugar cane cultivation without burning the waste (17). In other investigations, no differences were found in the content of CIC between the system and conventional tillage (10), which can be attributed to variable time. However, other authors observed a significant increase in the CEC of the soil after 20 years of direct seeding (17).

On the other hand, high values of base saturation (V) were observed for conservationist crops (OSR, OCR and OPC) without burning residues. These results highlight the importance of a greater offer of organic waste for the improvement of chemical attributes and maintenance of soil quality. The results obtained in areas with organic crops showed higher values of V % compared to the conventional system (10).

Base saturation (V) is an excellent indicator of the general conditions of soil fertility and is used in soil classification as a measure of eutrophism (16). On the basis of the data presented, there was good chemical reserve and the eutrophic nature of these soils, demonstrating high natural fertility, with saturation of bases higher than 50 %.

Regarding the content of organic matter (OM), the low tendency was found with the increase of the depth, the greater quantities were observed in the superficial layers, due to the frequent deposition of organic materials. The highest MO content for RCN was observed, compared to other areas. It is normal to find low levels of OM in tropical soils, in comparison with warm climates, mainly because it is difficult to increase this variable in tropical regions. Similar results were obtained in studies carried out by other authors (16,17) where higher MO contents were observed in native vegetation areas.

Among the areas cultivated with sugarcane and organic farming (OSR, OCR and OPC) presented the high levels of MO in the superficial layers (0-10 cm) and the lowest in CCQ, which was to be expected, since the burning reduces the organic matter content of the soil, which is seen as a key when assessing the attribute of soil quality, which has an important role in the supply of nutrients and improvement of the physical and chemical properties of the soil (10).

The combustion of organic matter is greater in areas prone to fire (11), and the upper layers of the soil are more affected by this practice. The soils with burned pastures each year also have a lower amount of organic matter (10), which may have influenced the results of this work.

It was also observed that a reduction in OM content in OCR occurred in the depth 10-20 cm, probably due to the practice of soil disturbance that occurred in this type of management. Other researchers, comparing recently planted areas with old-growth monocultures, with the conventional practice of soil disturbance (11), also found low organic matter content in the deep layers of the soil.

In areas with higher waste inputs (OSR, OCR and OPC), the trend in the increase of Ca and Mg was higher, which is in agreement with the results of other studies (10,11,14). It was also observed in another investigation (18), a tendency in the increase of the content of Ca and Mg, in the system of direct sowing, in comparison with the conventional system, after six years of cultivation.

The high P and K values were found in the OSR zone. It is possible that the high values of these elements are associated with the continuous supply of crop residues in this type of system (Table 1), which favors the retention of these nutrients; In addition, the absence of soil tillage favors the accumulation of nutrients over time (16).

A tendency to accumulate higher values of micronutrients (Cu, Fe, Mn and Zn) was observed for the area cultivated in organic systems, a factor also found in other studies carried out (14,16,18). According to research (16,18), production systems that offer a higher and frequent intake of crop residues that improve the chemical, physical and biological properties of soil tend to provide higher amounts of micronutrients in the system.

CONCLUSIONS

- The chemical properties of the soils (genetic type) at a depth of 0-10 cm allow the formation of groups between organic cultivation without alterations of the soil and the representative of Cerrado Native.
- The increase in the incorporation of organic waste in the soils for cane production improves the chemical properties and maintains the agroproductive quality of the soil.
- Organic farming without soil disturbance has phosphorus and potassium superior to other management.

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