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THE LABILE CARBON AS INDICATOR OF CHANGES IN TWO SOILS UNDER DIFFERENT USES

Carbono lábil como un indicador de cambios en dos suelos bajo diferentes usos

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ABSTRACT. The soil organic matter is an essential component in the reserve and carbon cycle. The carbon in the soil is incorporated to the continuous contribution of organic material in natural conditions, however, the land´s practice generates the organic carbon decrease while sustainable practices of land use contributes to its capture and accumulation. A frequent practice for evaluating changes of the organic matter quality under different managements is the determination of labile fractions of soil organic carbon. The content of Labile Soil Organic Carbon (COS_L) was compared on the soil layer 0-20 cm of a soil Ferralítico Rojo Típico from Ciego de Ávila with a Ferrítico Rojo Oscuro from Camagüey were undergone to three uses of the soil: Without exploitation, diversified and intensive crop cultivation. COS_L extraction was performed by oxidation with potassium permanganate (0,02 mg L^{-1}) and the determination was made by colorimetry. Independently the use, the content of COS_L is higher on the Ferralític soil than on the Ferrítico one but in both the contents decreased in the areas under intensive cultivation in relation to the ones without any exploitation. In addition to this, in the diversified systems, based on Lands Sustainable Management, this indicator tends to recover. These results suggest the inclusion of the determination of the COS_L, as an alert indicator on how the soil´s uses affect the quality of them.

Key words: organic matter, soil, fertility, biological properties

RESUMEN. La materia orgánica en el suelo es un componente clave en la reserva y ciclo del carbono. En condiciones naturales el carbono se incorpora al suelo a través del aporte continuo de material orgánico; sin embargo, existen prácticas de uso de la tierra que generan una disminución del carbono orgánico en el tiempo, a la vez hay prácticas de uso sostenible que favorecen su captura y acumulación. La determinación de fracciones lábiles de carbono orgánico del suelo, constituye una práctica frecuente para evaluar cambios en la calidad de la materia orgánica bajo distintos manejos. Se comparó el contenido de carbono lábil (COS_L) en la capa 0-20 cm de un suelo Ferralítico Rojo Típico con el de un Ferrítico Rojo Oscuro Típico, sometidos a tres usos del suelo (sin explotación, cultivo diversificado y cultivo intensivo). La extracción del COS_L se realizó por oxidación con permanganato de potasio a 0,02 mg L^{-1} y las determinaciones se hicieron colorimétricamente. Se encontró que independientemente del uso, el contenido de COS_L fue superior en el suelo Ferralítico que en el Ferrítico y que para ambos suelos los contenidos disminuyeron en las áreas bajo cultivo intensivo con relación a las áreas sin explotación; además, en el sistema diversificado, donde se aplican principios de Manejo Sostenible de Tierras, este indicador tiende a recuperarse. Estos resultados sugieren la inclusión de la determinación del COS_L, como indicador de alerta del efecto de los usos del suelo sobre su calidad.

Palabras clave: materia orgánica, suelo, fertilidad, propiedades biológicas

INTRODUCTION

In the last 50 years CO_2 emissions to the atmosphere have increased which has been caused, among other factors, by the pass of natural ecosystems into agricultural production systems (1).

Three basic carbon forms can be found in soils: elemental, inorganic and organic. Organic carbon is the main element that forms part of the organic matter of the soil (2, 3), which is in turn an important reservoir or source of carbon released to the atmosphere thus influencing on the global cycle of this element (1).

Under natural conditions, the carbon of the organic matter is incorporated to the soil through the

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continuous contribution of organic material, mainly of plant origin (3). In this case, the flow of soil organic carbon is influenced by climate, soil type, vegetative ground cover, among other factors (4, 5). However, in ecosystems of low agricultural exploitation, other factors like the influence of different land uses soils are subjected to, are added with particular relevance (4, 6).

Soil organic matter, under conservationist management is increased positively linked to the conservation of soil structure (7), nutrients cycle and the carbon kidnapping (1, 8, 9). The intensive agricultural management promotes soil degradation and carbon release to the atmosphere with the consequent loss of nutrients and reduced fertility (2, 10).

Most of the organic carbon present in soils is in the form of recalcitrants or humified (11). From the productive and quality points of view, total organic carbon present in the organic matter, is less sensitive to the effects of short-term agronomical practices where the decomposition rate gains momentum (12, 13). The quantification of the most sensitive fractions or organic carbon in the soil could provide better information of the effects to management changes (2, 14), since these fractions are used by soil microorganisms for their metabolic activity and the transformation to more complex compounds (10).

The sensitivity of the fractions of labile organic carbon or active carbon in the soil (COS_L), to short-term soil management changes can be closely related to the total organic carbon, the carbon of the microbial biomass and the organic matter in particles, which indicates the possibility of its determination to measure the quality of the soil (11, 15).

Oxidation with potassium permanganate ($KMnO_4$), can separate organic carbon in active and little active (16). The quantity of carbon produced by soil oxidation with $KMnO_4$ at low concentrations is considered as an effective resource in the quantification of COS_L (11, 17, 18), this fraction is also closely related to biological, physical and chemical properties of different type of soils (16).

This research evaluates the effect of three soil uses (without exploitation, diversified crop and intensive cultivation) in two soil types, Typical Red Ferralitic from Ciego de Ávila province and a Typical Dark Red Ferritic from Camagüey province, on the concentration of COS_L.

MATERIALS AND METHODS

The study was conducted from 2011 to 2013, at the Soil Institute of the Ministry of Agriculture with the support of the Soil Outreach Station of Camagüey province. The study areas were selected in two Multicrops Enterprises, one of them in the Sierra de Cubitas municipality, within the territory of La Guanaja water basin, at the North of Camagüey province; and the other one in Ciego de Ávila municipality, within the territory of Limpiolargo water basin in Ciego de Ávila province.

The studied soils were a Typical Dark Red Ferritic in Camagüey province, and a Typical Red Ferralitic Soil in Ciego de Ávila province, as per the New Version of the Genetic Classification of Cuban Soils (19). Three uses for each soil type were selected (Table I).

Table I. Combination of soil types and their uses in the variants under study

Variant	Soil uses	Description
Camagüey. Tipo de suelo: Ferrítico Rojo Oscuro Típico		
S1M1	Sin explotación	Vegetación espontánea: mamey (*Calucarpum sapota*), roble blanco (*Tabebuia angustata*), sigua (*Nectanda coriacea*), guano cana (*Saval parviflora*),
S1M2	Cultivos intensivos	Cultivado de papa (*Solanum tuberosum*) (variedad Romano Nacional). Aplicación de 1,34 t ha^{-1} de fórmula completa (9-13-17) y 0,22 t ha^{-1} de urea.
S1M3	Cultivos diversificados	Plantaciones de plátano (*Musa sp.*), naranja dulce (*Citrus sinensis*), tomate (*Solanum lycopersicum L.*), boniato (*Ipomoea batatas*). Aplicación de abonos orgánicos (*compost* de estiércol vacuno), rotación e intercalamiento de cultivos.
Ciego de Ávila. Tipo de suelo: Ferralítico Rojo Típico		
S2M1	Sin explotación	Vegetación espontánea: ateje blanco (*Cordia Galeottiana*), paraná (*Panicum purpurascens*), guinea cimarrona (*Panicum ghiesbrechtii*), marabú (*Dichrostachys cinerea*).
S2M2	Cultivos intensivos	Cultivado de papa (*Solanum tuberosum*) (variedad Aida). Aplicación de 1,41 t ha^{-1} de fórmula completa (9-13-17) y 0,22 t ha^{-1} de urea.
S2M3	Cultivos diversificados	Plantaciones de café (*Coffea arabica*), plátano (*Musa sp.*), cebolla (*Allium cepa*), frijol negro (*Phaseolus vulgaris*). Aplicación de abonos orgánicos (*compost* de estiércol vacuno), rotación e intercalamiento de cultivos.

Soil sampling was done by randomly networking longitudinal points, accordiong to the Cuban Standard No 36 (20) and an area of 1 ha was studied for each of the variants. Ten compound samples were taken at a depth of 0 to 20 cm, at the same time for each of the variants, at the time of harvesting potatoes.

Determination of labile carbon

COS_L determinations were made at the labs of the Soil Institute of the Ministry of Agriculture taking as a reference, the colorimetric methodology of oxidation with potassium permanganate (11).

Five grams of soil samples screened by 1 mm and kept at room temperature, a solution of potassium permanganate ($KMnO_4$) at a concentration of 0,02 $mg \cdot L^{-1}$, with pH 7,2 was added. It was agitated on an orbital screen for 15 minutes at 200 rpm and it was then centrifuged for 5 minutes at 3000 rpm. Later on, the supernatant was filtrated with semifast filter paper; an aliquot of 0,5 ml was taken and diluted in 25 ml of distilled water. Three replicates per soil sample were used. Determinations were done on a Visible Ultraviolet Spectrophotometer (T-160) at a wave length of 565 nm.

Statistical analysis

A non-lineal behavior of the variables was assumed and non-parametric statistical analysis was developed, due to the restrictions of the experimental design.

A non-parametric analysis of variance with two factors was done: A, soil type and B, soil use; two levels were considered for factor A and three levels for factor B; the interaction among factors was analyzed. The response variable was COS_L. The H Test from Kruskal-Wallis, was used as criterion of difference among means with a 95 % of confidence. The graphic result of this test shows box and mustache graphics showing the grouping of COS_L values, highlighting in dark line the mean of data population. To define whether COS_L, showed significant differences between each of the pairs of independent samples, made up of six combinations of soil and use, the U Test from Mann-Whitney was used.

Statistical data processing was done with the package R Stats (21), compilation R 2.14.1 on Ubuntu 12.04.1.

RESULTS AND DISCUSSION

Soil labile carbon values for each combination of soil type and use

COS_L values and its dispersion for each of the variants are shown in Table II.

Table II. Labile organic carbon on the soil for each studied variant

Variant	COS_L ($X \pm s$) (mg C kg soil $^{-1}$)
S1M1	448,01 ± 43,02
S1M2	226,14 ± 43,99
S1M3	362,32 ± 30,19
S2M1	546,72 ± 36,31
S2M2	371,62 ± 22,96
S2M3	405,52 ± 31,67

(X ± s) = (Media ± Desviación Estándar) (n=10)

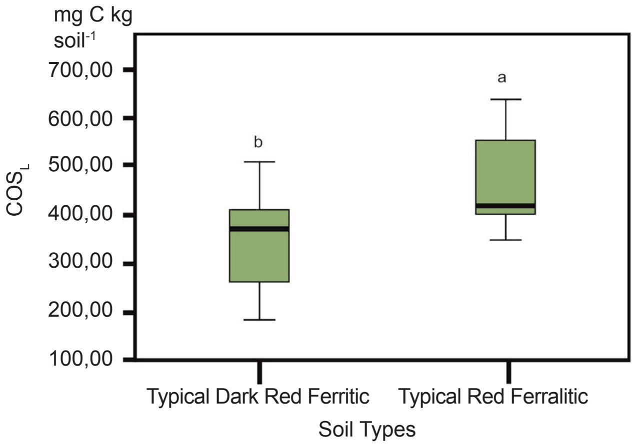
S1M1, Dark Red Ferritic – without exploitation; S1M2, Dark Red Ferritic – Intensive cultivation; S1M3, Dark Red Ferritic – Diversified crop; S2M1, Typical Red Ferralitic - without exploitation; S2M2, Typical Red Ferralitic – Intensive cultivation; S2M3, Typical Red Ferralitic - Diversified crop

COS_L values are within the ranges found by other authors, using the same methodology, for different edaphoclimatic scenarios (11, 22, 23, 24, 25). These authors confirm the efficiency of COS_L determination from the oxidation with potassium permanganate, and refer to the coincidence of their results with other soil quality indicators.

Variation in the content of labile organic carbon according to the type of soil

Ferritic and Ferralitic soils have several similarities because they have an advanced development of their genesis, they are deep, the red color is predominant in their profile, however, their chemical, physical and biological properties permit separating them (26) and determining the differences found in the COS_L, values attained in each soil type.

COS_L, values in the Ferritic soil were lower to those recorded in the Ferralitic one, regardless the use they were subjected to (Figure 1); which is related to the lower fertility in the Typical Dark Red Ferritic, compared to the Typical Red Ferralitic (10). This fact coincides with several authors who found that COS_L is associated to fertility (27).



(Different letters represent differences for a 95 % of probabilities, regardless the type of soil n=60)

Figura 1. Content of labile organic carbon for each studied soil

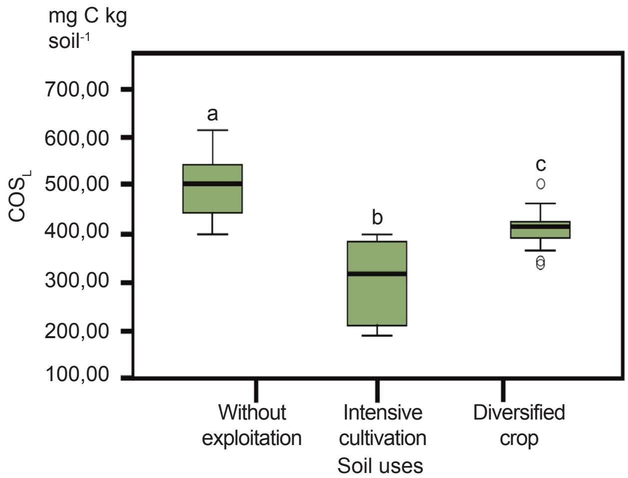
The low contents of COS_L in Ferritic soils, are coherent with the strong process of intemperismo that has caused a nearly total washout of all soil basis leaving a high quantity of iron oxide III (Fe_2O_3) and causing its low fertility. This result is also associated to the physical chracteristics of these two types of soils, where the Ferritic ones show a great emproverishment of clays with high contents of iron particles, while the Ferralitic ones have a good structure that tends to the formation of stable aggregates (26).

On the other hand, the highest COS_L levels on the Ferralitic soil compared to the Ferritic one are influenced by the organic matter content due to the quantity and quality of the incorporated biomass (28). In general, Ferritic soils show a low biological quality (10, 26), which makes difficult the process of organic matter mineralization that is closely linked to microorganism activity (23), with the consequent reduction of COS_L. This process is very much associated to the rizodeposition of the involved species affecting the quality of edaphic biota which in turn, depends from other edaphic factors, mainly in the management of species very different from the native ones (9), like in the variants S1M2 and S1M3.

It is important to emphasize that the forms of organic material more often found in Ferritic soils are huminas, while in Ferralitic soils the forms are little-polymerized humic compounds of low stability to microbial attack (10), some of which are sensitive to be oxidized with $KMnO_4$.

Influence of the soil use on the labile organic carbon

There were significant differences of COS_L, among the three analyzed uses, regardless the soil type where they were established (Figure 2).



Different letters represent differences for a 95 % of probabilities, regardless the type of soil n=60

Figure 2. Influence of the soil use on the contents of labile organic carbon of the soil

In the area used as reference, soils without exploitation reached the highest COS_L contents (Figure 2) which coincides with (6, 29). The main cause of the organic carbon loss in soils is the pass from conserved ecocystems to agro-ecosystems, which can be measured from the presence of COS_L, since this is a fraction sensitive to changes caused by the use of land and its close relationship with the physical, chemical and biological properties that determine the productive capacity of soils (30, 31).

The COS_L values in the areas of diversified crops, regardless soil type, were higher than in those of intensive cultivation (Figure 2), COS_L variations depend on the intensity of soil exploitation and conservation measures applied (32). In this regard, the specialization of agricultural systems stands out since it causes considerable COS_L losses which some other authors have dealt with (6, 29).

Recent research have shown that COS_L, is related to the content of organic materials added to the soil (15, 33), which could explain the high contents of this fraction registered in areas of diversified crops where compost from cow manure is applied compared to the variants of intensive cultivation where fertilization is only mineral (Figure 2).

Mineral and organic fertilization causes changes in COS_L contents though the most significant increase of this carbon fraction in the soil are seen in the combination of organic and mineral fertilizers (25).

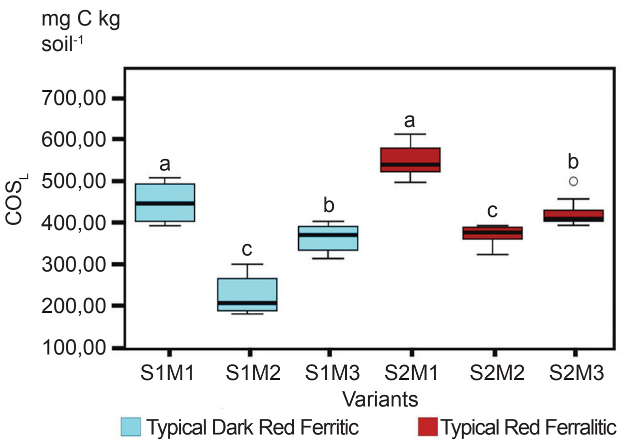
In general, these results confirm that the use of soil for intensive potato growing without the application of organic fertilizers and other soil conservation practices, can be the cause of reduced COS_L contents. Other more conservationist uses as diversified crops, favor the quantities of COS_L (34). These results also suggest that this indicator is sensitive to evaluate the changes for the use of soil (18).

Effect of combining the use and type of soil on the content of organic labile carbon in the soil

The analysis of the interaction between the type of soil and its use shows significant differences between each variant for the soils under study (Figure 3).

When comparing COS_L contents in the studied variants for each type of soil, it can be seen that COS_L contents in soils with diversified crops (S1M2 and S2M2), are higher than in soils where intensive cultivation is practiced (S1M3 y S2M3). This result can be associated to the application of Land Sustainable Management principles that do not influence with the same intensity on both soils.

The recovery of the Typical Dark Red Ferritic Soil was higher than the Ferralitic one (Figure 3). This phenomenon intensified because in fragile soils, from the ecosystemic point of view, the continued exploitation with exotic species means a higher damage, and also a slower recovery when native species are re-established (35).



Different letters represent differences for a 95 % of probabilities, regardless the type of soil n=20
S1M1, Dark Red Ferritic – without exploitation;
S1M2, Dark Red Ferritic – Intensive cultivation; S1M3, Dark Red Ferritic – Diversified crop; S2M1, Typical Red Ferralitic - without exploitation; S2M2, Typical Red Ferralitic – Intensive cultivation; S2M3, Typical Red Ferralitic - Diversified crop

Figure 3. Influence of the use in each type of soil on the labile organic carbon concent

The variation in the COS_L, contents to management practices in the variant of diversified crops, coincide with the results of other authors who confirm the fast increase of fertility in Typical Dark Red Ferritic soils with the application of organic fertilizers which can be proven by higher productions. This increased fertility is more obvious due to the low natural fertility of these soils (26). The lowest COS_L recovery in the Typical Red Ferralitic Soil subjected to similar management practices is the consequence of a historical overexploitation process (26, 36, 37). These soils show a gradual increase of the apparent density closely related to the loss of COS_L. On the other hand, due to their continuous plowing and growing, they have been exposed to a substantial loss of their humus content which is difficult to recover (9, 26).

CONCLUSIONS

The contents of labile organic carbon are sensitive as indicator of the soils changes generated by the implementation of different soil uses.

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