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EVOLUTION OF SOME CHEMICAL PROPERTIES OF A SOIL AFTER 20 YEARS OF AGRICULTURAL EXPLOITATION

Evolución de algunas propiedades químicas de un suelo después de 20 años de explotación agrícola

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ABSTRACT. The objective of the present work was to study the evolution of some chemical properties of a soil to compare its state of fertility, before and after remaining 20 years under intensive production of several cultivations in the farm "La Asunción". The climate is tropical subhumid and the soil is classified as Nitisol Rodic Eutric. The first sampling to evaluate the fertility of the soil was carried out in 1997 and in the year 2017 repeated the samplings. The content of organic matter was 2,55 % in 1997 and in 2017 was 2,97 %, the Test t (α=0,05) demonstrated that the two stockings are similar to each other. For the pH, in 1997 it was 6,34 and in 2017 ascended up to 7,25 due to the intensive use of watering waters with high content of calcium bicarbonate. For the calcium and the magnesium the values increased, in the calcium, of 8.32 to 17.61 $cmol_c\ kg^{-1}$ and for the magnesium, of 1.45 to 3.31 $cmol_c\ kg^{-1}$; however, in the case of the relationship Ca/Mg was not variations among the two realized evaluations. For the phosphorus it was an increase of the available contents of this element in the soil, of 49.53 $mg\ kg^{-1}$ in 1997 to 1 535 $mg\ kg^{-1}$ in 2017, related with the continuous applications of fertilizers, situation similar with the K_2O, that varied from 0.007 to 1.22 $cmol_c\ kg^{-1}$. For the case of the capacity of exchange bases, it varied from 12,17 $cmol_c\ kg^{-1}$ up to 21.94 $cmol_c\ kg^{-1}$.

Key words: soils, fertilizers, nutrient content

RESUMEN. El objetivo del presente trabajo fue estudiar la evolución de algunas propiedades químicas de un suelo y comparar su estado de fertilidad, antes y después de permanecer 20 años bajo producción intensiva de cultivos varios, se estudió la finca "La Asunción". El clima es tropical subhúmedo y el suelo se clasifica como Ferralítico Rojo Lixiviado. El primer muestreo se realizó en el año 1997 y en el año 2017 se repitieron los muestreos. El contenido de materia orgánica era de 2,55 % en 1997 y en 2017 fue de 2,97 %, la prueba t (α=0,05) demostró que las dos medias son semejantes entre sí. Para el pH, en 1997 fue de 6,34 y en 2017 ascendió hasta 7,25 debido al uso intensivo de aguas de riego con elevado contenido de bicarbonato de calcio. Para el calcio y el magnesio los valores aumentaron, en el calcio, de 8,32 a 17,61 $cmol_c\ kg^{-1}$ y para el magnesio, de 1,45 a 3,31 $cmol_c\ kg^{-1}$; sin embargo, en el caso de la relación Ca/Mg no se encontraron variaciones entre evaluaciones realizadas. Para el fósforo se encontró un aumento de los contenidos disponibles de este elemento en el suelo, de 49,53 $mg\ kg^{-1}$ en 1997 a 1535 $mg\ kg^{-1}$ en 2017, relacionado con las continuas aplicaciones de fertilizantes efectuadas, situación semejante a la encontrada con el K_2O, que varió de 0,007 a 1,22 $cmol_c\ kg^{-1}$. Para el caso de la capacidad de intercambio de bases, varió desde 12,17 $cmol_c\ kg^{-1}$ hasta 21,94 $cmol_c\ kg^{-1}$.

Palabras clave: suelos, fertilizantes, contenido de nutrimentos

INTRODUCTION

During its formation, the soil in natural conditions of the ecosystems acquires properties in balance with the environment. However, man requires the production of food and raw materials, which leads to

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agriculture, which leads to the change of initial natural forests to areas of crops or pastures. These changes undoubtedly cause changes in the properties of soils (1).

One of the economic functions of the soil is to provide and maintain good crop productivity. Soil management, under this premise, should tend to sustain and improve the quality of this natural resource. To quantify it, indicators can be used that must be measured for the evaluation of physical, chemical and biological properties, which must be easy to determine and sensitive to the changes generated by management practices (2).

The fertility of soils, particularly chemistry, is considered a determining factor in the availability of nutrients for cultivated plants. It is difficult to understand the physiology of the nutrition of economic crops, without an adequate study of the indicators that make up the fertility and chemical nature of soils, especially in tropical regions (3).

In addition, the knowledge of the levels of nutrients in the soil, their physico-chemical composition, the levels of extraction of the different crops and the nutritional status of these is the initial phase of any attempt at a quantitative and qualitative improvement of production, as well as the basic element to achieve a rational and balanced use of fertilizers that will make it possible to avoid economic waste (4).

That is why fertilization has as a fundamental objective to increase the natural fertility of the soil, to guarantee the nutritional needs of the crops and to avoid the loss of the natural reserves of the same.

Soil sampling is the first of a series of steps within the process that leads to the recommendation of fertilization and soil correction (source, dose, moment and form). Precedes analysis of samples, interpretation of results and diagnosis (5).

That is why the analysis of the state of soil fertility and its evolution over the years, becomes vital in the study of fertilizer recommendation systems and amendments in agricultural systems. Linked to this, the objective of this work was to study the evolution of some chemical properties of a soil to compare its fertility status, before and after remaining 20 years under intensive production of various crops.

MATERIALS AND METHODS

The farm “La Asunción” belongs to the Cooperative of Credits and Services (CCS) “Nelson Fernández”, ofrom San José de las Lajas municipality, Mayabeque province, Cuba. It is located at 22º98’11’’ of North latitude and 82º14’14’’ of West Longitude, at 132 m a.s.l. The climate is subhumid tropical (Aw) with a warm and humid season between the months of May to October and less hot and dry from November to April.

The soil is classified as Leached Red Ferralitic, according to the Classification of the Soils of Cuba 2015 (6), located in the Havana-Matanzas Red Plain, on limestone. Until 1990 the farm was dedicated to the intensive production of forages (*Pennisetum purpureum*) and after that date, went to usufruct of the farmers, who began the production of various crops.

The farm has a total area of 22 ha, of which 18 ha are dedicated to the sowing of various crops and the rest is occupied by houses, warehouses, stables, pigsty and areas of perennial fruit trees: mango (*Manguifera indica*), avocado (*Persea americana*), mamey (*Pouteria sapota*), guava (*Psidium guajava*) and coconut trees (*Coccus nucifera*).

The area of various crops is divided into ten lots, with different areas, which produce: corn (*Zea mays*), sweet potato (*Ipomoea batata*), cassava (*Manihot esculenta*), tomato (*Solanum lycopersicum*), banana (*Musa* sp.), papaya (*Carica papaya*), beans (*Phaseolus vulgaris*) and red pepper (*Capsicum annuum*) as main crops.

In the farm, in general, the custom of sowing in constant succession of crops is followed, keeping the soil covered throughout the year. The preparation of soil is done in a traditional way, with two or three plow passes and two of harrow. Fertilization is carried out applying doses of approximately 5 t ha^{-1} $year^{-1}$ of urea, complete formula (9-13-17) and KCl. Over the years they have applied different plant growth stimulating bioproducts and biofertilizers, such as Biobras®, FitoMas®, EcoMic®, Azofert®, among others. The crops that are most fertilized are papaya, tomato, beans, plantains and red peppers. Except in the rainy season, irrigation is applied every 7-10 days and chemical control of pests is carried out.

The first sampling to evaluate soil fertility was carried out in 1997. For this, all the lots of the farm where the annual crops are planted were sampled. In the year 2017, the samplings carried out were repeated, in the same lots that the producers keep as areas within the farm for their management.

In both 1997 and 2017 ten soil subsamples were taken for each batch, in simple random sampling form (7), at a depth of 0-20 cm (arable layer), which formed a sample composed of batch. The chemical analyzes performed on each sample, as well as the methodology used, are shown in Table 1.

Table 1. Properties evaluated in the soil on the farm and methodologies used

Evaluation	Methodology used
pH	potentiometric, with soil ratio: 1:2,5 (8)
Soil organic matter (%)	Walkley y Black (9)
P assimilable (mg kg^{-1})	extraction with H_2SO_4 0,1 Mol L^{-1} in relation to soil: solution 1:25 (10)
Exchangeable cations ($cmol_c$ kg^{-1})	extraction with NH_4Ac 1 Mol L^{-1} a pH 7 (11) • complexometry (Ca y Mg) • flame photometry (K)
K_2O	By calculation, from the interchangeable K, expressed in mg kg^{-1},
Relation Ca/Mg	By calculation
Basis Exchange Capacity (CIB)	By sum of the exchangeable bases determined, expressed in $cmol_c$ kg^{-1}

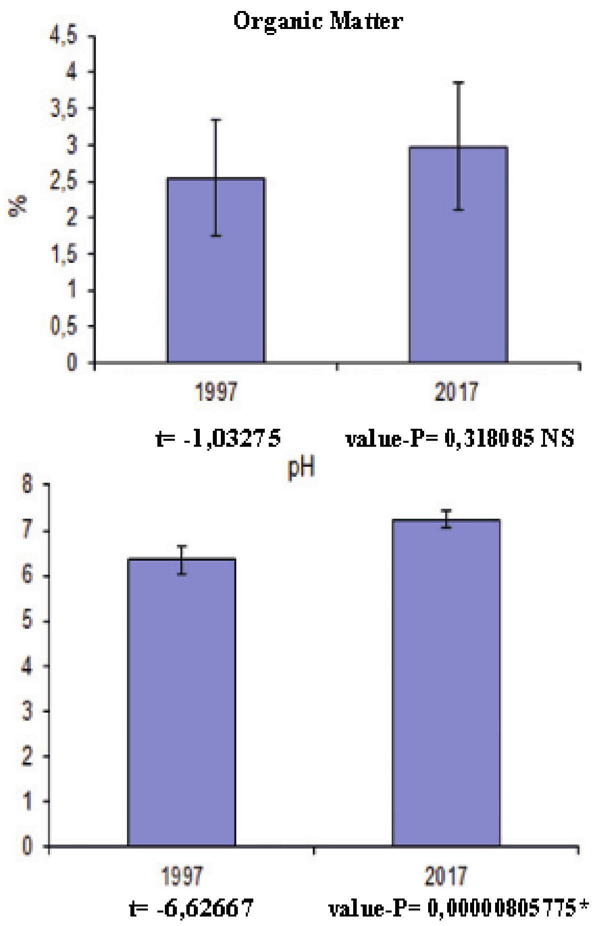
The means were calculated to the results of each year evaluated. Subsequently, a comparison analysis of paired samples was carried out, using the t test (α = 0.05), proposing as a null hypothesis that the samples of the two years evaluated are equal and as an alternative hypothesis that the samples differ from each other. All statistical analyzes were carried out using the statistical package STATGRAPHICS Centurión XV (12).

RESULTS

Figure 1 shows the results of organic matter content and soil pH. In 1997, the content of organic matter was 2.55 % and in 2017 it was 2.97 %, the t test showed that the two means are similar to each other. In the case of pH, in 1997 it was 6.34 and in 2017 it rose to 7.25, the averages in this case being different from each other.

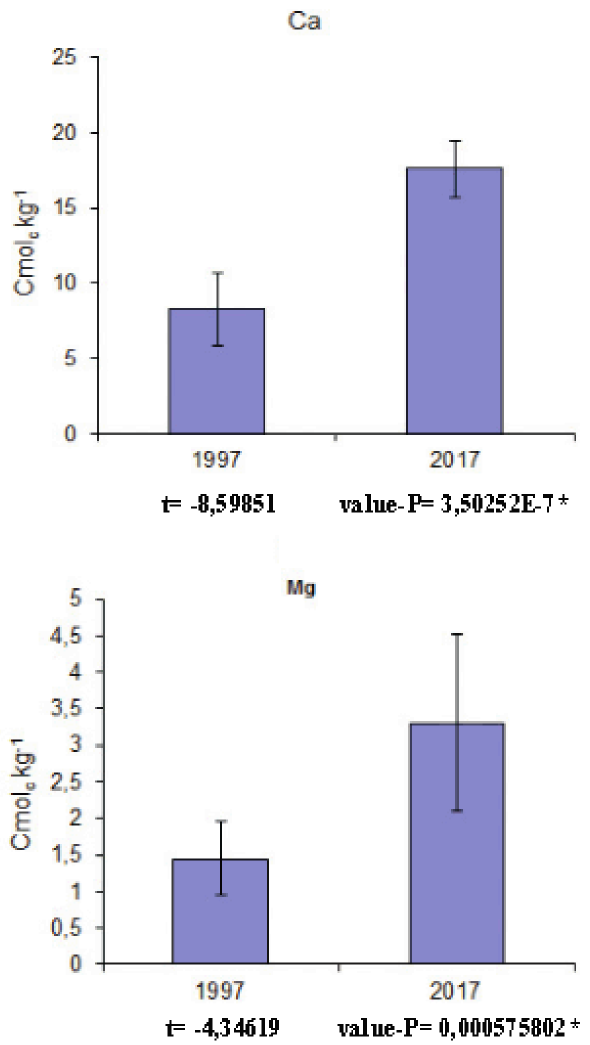
Figure 2 shows the assimilable calcium and magnesium contents found in the soil. For both elements, the values increased in the 20 years of agricultural operation, ranging from 8.32 cmolc kg^{-1} to 17.61 cmolc kg^{-1} for Ca and 1.45 cmolc kg^{-1} to 3.31 cmolc kg^{-1} for Mg. For both cases, a statistically significant difference was found ($p < 0.05$).

However, in the case of the Ca/Mg internutrients ratio (Figure 3), no variations were found in the years between the two evaluations, ranging between 6.08 and 6.06, which are within the range optimal reported by the literature (13) for a balanced content between both nutrients in the soil. In the case of phosphorus (Figure 3), the difference was statistically significant ($p < 0.05$), with an increase in the available contents of this element in the soil, which in 1997 was 49.53 mg kg^{-1} and increased up to 1 535.96 mg kg^{-1} in 2017, the phosphorus content.



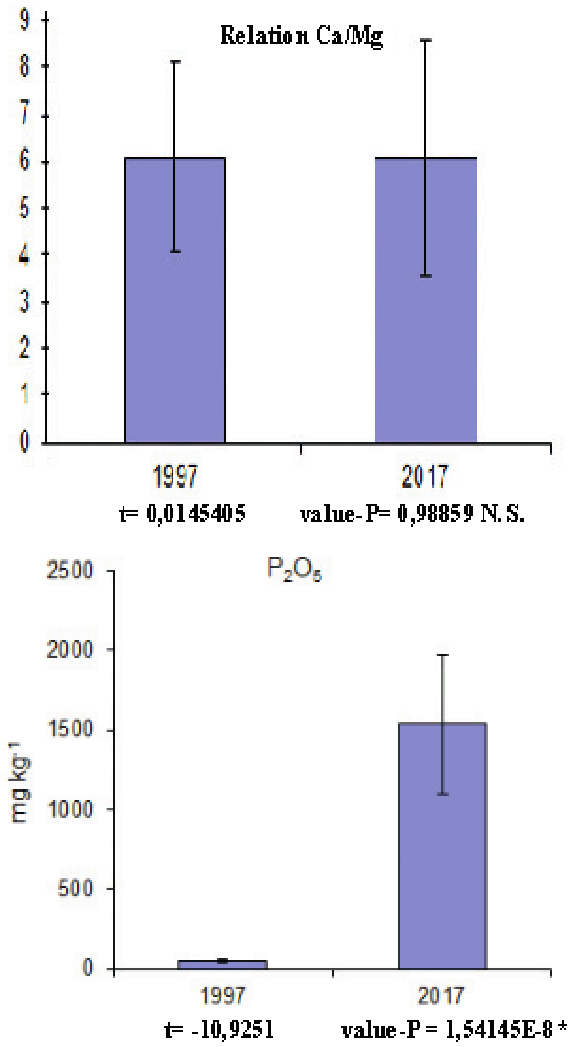
Vertical bars: standard deviation of the averages
t = statistical test t, p = p value of the t test
* uneven means (p>0.05)

Figure 1. Evaluation of the organic matter and pH of the soil of the farm "La Asunción" in the two years evaluated



Vertical bars: standard deviation of the averages
t = statistical test t, p= p value of the t test
* uneven means (p>0.05)

Figure 2. Changes in the calcium and magnesium content in the soil of the "La Asunción" farm in the two years evaluated



Vertical bars: standard deviation of the averages
t = statistical test t, p= p value of the t test
* uneven means (p>0.05)

Figure 3. Ca/Mg evaluation and assimilable P content in the soil of the "La Asunción" farm in the two years evaluated

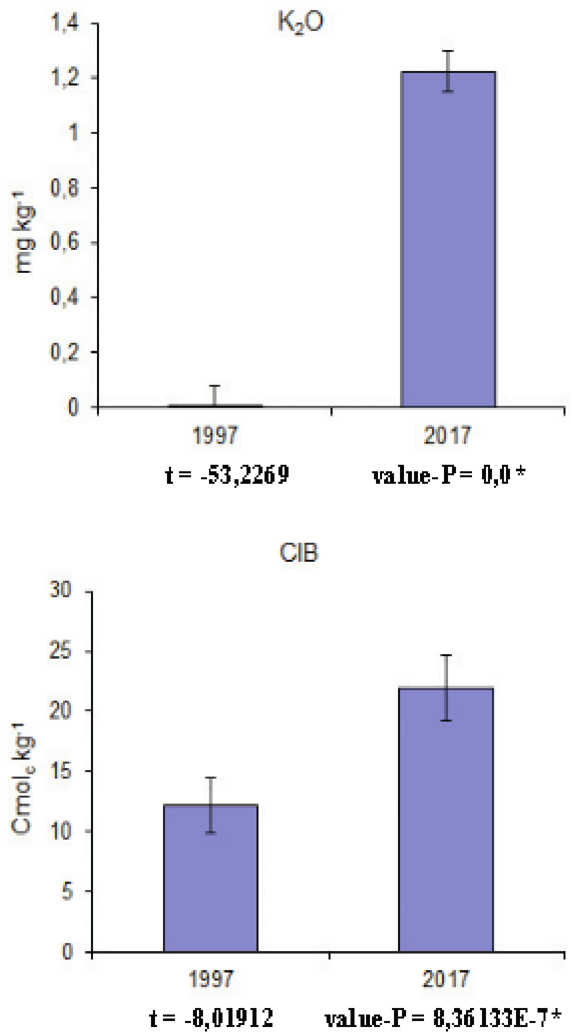
The available potassium contents and the base change capacity are shown in Figure 4. The K_2O increased considerably, from 0.00718 mg kg^{-1} in 1997 to 1.22 mg kg^{-1} in 2017. For the case of the Change capacity, ranged from 12.17 cmolc kg^{-1} to 21.94 cmolc kg^{-1}. For both cases, a statistically significant difference was found ($p < 0.05$).

DISCUSSSION

In general, the results of this research show that over 20 years of intensive agriculture, the systematic use of chemical fertilizers (personal communication Rolando Muñoz Casas, producer of Farm "La Asunción"), has caused an increase in the values of the pH, K_2O, P_2O_5, Ca, Mg and CCB, the content of organic matter and the Ca: Mg ratio remaining similar.

Reports on the effect of fertilizer application on soil properties are divergent, which can be attributed to the diversity of soil ecosystems on which they are applied, as well as to the chemical nature of the products applied (14).

Thus, in Argentina it has been found that in agricultural soils, the evaluated chemical properties showed lower values in all the quantified indicators, with respect to uncultivated soils, due to tillage and other practices of intensive agriculture (2).



Vertical bars: standard deviation of the averages
t = statistical test t, p= p value of the t test
* uneven means (p>0.05)

Figure 4. Changes in available potassium and the ability to exchange bases in the soil of the farm "La Asunción" in the two years evaluated

In Mexico, the change in land use from forest to agriculture implied a decrease in the contents of organic matter and CEC and acidification of the pH product of the addition of nitrogen fertilizers and biocides (14). However, in this investigation, the results do not coincide with what was proposed by these authors.

In the farm "La Asunción", after 20 years of intensive agriculture, the pH increased by almost one unit, which means that it increased by 10 times the amount of OH^- ions present in the soil. These data corroborate what was stated by other authors who state among the main environmental problems linked to the degradation of Red Ferralitic soils in the Havanan provinces, the alkalization of more than 40 % of the surface occupied by these soils (15). The process of alkalinization of these soils is related to anthropic factors (3,16), such as the use, for decades, of hard water (calcium bicarbonates) for agricultural irrigation and the increase in soil temperature by 0.6 ºC, due to the influence of climate change.

Regarding the content of organic matter, no differences were found in the values of this indicator in the two years evaluated, apparently, as a result of which, as usual agricultural practice, the producers incorporate crop residues into the soil and maintain it with cover vegetable (crops) as long as possible.

A possible explanation for this could be related to the fact that the incorporation of waste into the soil and its permanent coverage are agroecological practices that favor the conservation and increase of soil organic matter (17) and in this case, due to the intensive agriculture applied to the farm, this indicator is found in a kind of "balance" between conservationist practices and those of intensive agriculture that are applied equally in the farm and that have caused that no statistical differences were found between the values obtained in 1997 and 2017.

Analyzing the contents of P_2O_5 and K_2O, its high content in the soil is in correspondence with the high levels of chemical fertilization that are carried out in the farm, according to the producers' own reference. It should be noted that these two elements accumulate in the soil, especially in agricultural systems with mineral fertilization (18).

In this regard, since the 90s in Cuba it was suggested that Red Ferralitic soils are oversupplied with P and K, and these contents do not correspond to those observed for those same soils under natural conditions, which demonstrates the chemistry effect of the fertilizers that carry these elements, which have been applied continuously in the intensive agriculture carried out on these soils (19).

In relation to the contents of Ca and Mg, its increase can be a consequence of the continuous applications of fertilizers made, because these cations are sometimes part of the own fillings of the fertilizer product. These increases in the interchangeable bases have resulted in the raising of the CCB of the farm's soils. However, when assessing the Ca: Mg ratio, the average is optimal, oscillating between 2 and 6, which is why imbalances in inter-nutrition relationships are not yet present (13).

In summary, the chemical and physical indicators characterize the properties of the soil and acquire importance by facilitating the agro-ecological diagnosis, especially when they are analyzed together evaluating their change in the long term. The knowledge of appropriate indicators for each zone allows to evaluate the changes produced by the productive systems, the management and the productive intensification (2).

CONCLUSIONS

When carrying out evaluations of the soil with an interval of 20 years, an increase in pH, CIB, K_2O, P_2O_5, Ca and Mg of the soil was found, maintaining the contents of organic matter and the Ca: Mg ratio stable, all of which allows to consider that the fertility of the soil has increased with the intensive agriculture that is applied in the farm “La Asunción”.

BIBLIOGRAPHY

1. Hernández A, Morales M, Borges Y, Vargas D, Cabrera JA, Ascanio MO, *et al*. Degradación de las propiedades de los suelos Ferralíticos Rojos Lixiviados de la Llanura Roja de La Habana, por el cultivo continuado. Algunos resultados sobre su mejoramiento. San José de las Lajas, Mayabeque, Cuba: Ediciones INCA; 2014. 156 p.
2. Marelli H, Arce J, Marelli P, Conde B, Juárez IM. Indicadores de sustentabilidad del suelo en diferentes áreas del centro-sur de la Provincia de Córdoba. Informaciones Agronómicas de Hispanoamérica. 2017;(27):27–30.
3. John-Louis CM, Vantour-Causse A, Tamayo AA. Estado de la fertilidad química de los suelos ferralíticos rojos de la granja Los Pinos. Revista Ingeniería Agrícola. 2017;7(3):17–22.
4. Villar EM, Rodríguez MSA. Fertilidad del suelo y parámetros que la definen [Internet]. 3ra ed. España: Logroño: Universidad de La Rioja, Servicios de Publicación; 2014 [cited 2018 Aug 30]. 29 p. Available from: https://dialnet.unirioja.es/servlet/libro?codigo=267902
5. Carretero R, Marasas PA, Souza E, Rocha A. Conceptos de utilidad para lograr un correcto muestreo de suelos. Archivos Agronómicos. 2016;(15):1–11.
6. Hernández A, Pérez J, Bosch D, Castro N. Clasificación de los suelos de Cuba. Mayabeque, Cuba: Ediciones INCA; 2015. 93 p.
7. Bautista F, Heydrich SC, Cervantes IS. Suelos. In: Bautista F, editor. Técnicas de muestreo para manejadores de recursos naturales [Internet]. 2da ed. México: Universidad Nacional Autónoma de México (UNAM); 2011 [cited 2018 Aug 31]. p. 227–58. Available from: http://bibliotecasibe.ecosur.mx/sibe/book/000050337
8. NC ISO 10390. Determinación de pH. La Habana: Oficina Nacional de Normalización; 1999.
9. NC 51. Determinación del por ciento de materia orgánica. La Habana: Oficina Nacional de Normalización; 1999.
10. NC 52. Determinación de las formas móviles de fósforo y potasio. La Habana: Oficina Nacional de Normalización; 1999.
11. NC 65. Determinación de la capacidad de intercambio catiónico y de los cationes intercambiables del suelo. La Habana: Oficina Nacional de Normalización; 2000.
12. STATGRAPHICS® Centurion XVI. Manual de usuario [Internet]. Estados Unidos de América: StatPoint Technologies, Inc.; 2010. 305 p. Available from: https://www.statgraphics.net/wp-content/uploads/2015/03/Centurion-XVI-Manual-Principal.pdf
13. Cruz E, Cruz A, Aguilera LI, Norman HT, Velázquez RA, Nava G, *et al*. Efecto en las características edáficas de un bosque templado por el cambio de uso de suelo. Terra Latinoamericana. 2012;30(2):189–97.
14. Cánepa Y, González AJ, González A, Hernández A. Situación actual de los suelos tabacaleros de la empresa “Lázaro Peña” de la provincia Artemisa. Cultivos Tropicales. 2015;36(1):80–5.
15. Hernández A, Cabrera A, Borges Y, Vargas D, Bernal A, Morales M, *et al*. Degradación de los suelos Ferralíticos Rojos Lixiviados y sus indicadores de la Llanura Roja de La Habana. Cultivos Tropicales. 2013;34(3):45–51.
16. Martinez F, Gómez L. La fertilización de los cultivos bajo una perspectiva agroecológica. In: Sembrando en Tierra Viva. Manual de Agroecología. 1ra ed. La Habana, Cuba; 2015. p. 67–86.
17. Kai T, Mukai M, Araki KS, Adhikari D, Kubo M. Analysis of chemical and biological soil properties in organically and conventionally fertilized apple orchards. Journal of Agricultural Chemistry and Environment. 2016;05(02):92–9. doi:10.4236/jacen.2016.52010
18. Orellana R, Valdés M, Hernández O, Quintero PL. Consecuencias de la aplicación excesiva de fertilizantes minerales en el estado físico de los suelos. Revista Agricultura Orgánica de la ACTAF. 1996;2(1):23–4.
19. Herrera Altuve JA, Ramírez Santoyo LF. Análisis químico para caracterizar la fertilidad de los suelos. In: Métodos de evaluación de la fertilidad de suelos y la necesidad de nutrición de los cultivos. Tomo 2. Análisis químicos como indicadores. 1ra ed. México-Cuba: Universidad de Guanajuato-Instituto Nacional de Ciencias Agrícolas; 2016. p. 2–180.

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