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Chemical Soil Properties of Four Suburban Farms in Santiago de Cuba

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Abstract

Context: Soil is an important resource and it is the basis for agricultural forestry exploitation. The chemical properties are linked to nutrient availability. Proper research of the soil chemical nature indicators is needed to understand soil fertility.
Aim: To evaluate the behavior of some chemical properties of the soil on four suburban farms in Santiago de Cuba.
Methods: The soil was dug to collect samples from every soil horizon. After identification, the samples were taken to the laboratories of Oriente Geomining Company. The contents of calcium (Ca^{2+}), magnesium (Mg^{2+}), aluminum (Al^{3+}), sodium (Na^{+}), and potassium (K^{+}) were determined, along with the cationic ratios, the pH, the effective cationic exchange capacity (CICe), base saturation percentage (V), the saturation associated with CICe, and the organic matter (M.O.)
Results: The Ca^{2+}, Na^{+}, and K^{+} contents underwent a variable behavior, whereas Al^{3+} and Mg^{2+} behaved similarly, in all the cases above the soil permissibility limits. The pH was the least variable property, above 7, the V value in all the cases surpassed 85%, and CICe was above 50 cmol.Kg^{-1}. The Ca^{2+}/MG^{2+} showed a favorable balance, Na^{+} saturation was high, and the O.M. content was generally low.
Conclusions: The chemical properties of the farm soils analyzed were a constraining factor to the development of production. Despite the potential fertility and proper nutrient contents, the ratios between the elements makes them so fixed in the soil in forms that cannot be assimilated by the crops.

Keywords: suburban agriculture, nutrition, soil properties.

Introduction

Soil and water keep a close relation as they are elements of the ecosystems for different uses (Rodríguez, 2018). Soil is one of the most relevant resources and it constitutes the basis for farming and forestry exploitation (Paiz, 2019). The United Nations Organization for Food and Agriculture [FAO] (2015) remarked the limited character of this resource, since its loss and degradation cannot be reversed in one human lifetime. Some of its functions include water and nutrient supply to crops; it also intervenes in the water and nutrient cycles (Ferreras, Toresani, Faggioli & Galarza, 2015).

The industrialization processes, globalization, and population increases have expanded the agricultural border. More soil is being used in this activity, deteriorating its properties with an ensuing gradual degradation (Novillo et al., 2018). Particularly, the chemical properties are linked to nutrient and quality water availability for plants (Calderón, Bautista & Rojas, 2018). Me et al. (2018) noted that the chemical fertility is an essential factor of nutrient availability. Hence, proper research of the parameters of fertility and the chemical nature of soils is necessary to understand the physiology of economic crop nutrition, especially in the tropical regions.

Urban and suburban farm soil should have a special treatment. López (2014) noted that making the best use of it is one of the positive aspects of the program. Burgos et al. (2014) pointed out that, as a conditioning factor, it is necessary to know the bases for better management, following a previous study, and to characterize it to know if it is appropriate or not for a particular crop.

Research on suburban farms in Santiago de Cuba has been conducted by Escobar, Vargas, Fuentes, Rodríguez & Molina (2017) and Galindo, Cobas, Martínez, Escobar & Vargas (2019). The two studies are associated with the quality of the soil, though they were based on visual evaluation. Although the results were positive, these studies must be continued to evaluate other properties so that they permit production based on the actual conditions of this resource.

This paper aims to evaluate the behavior of some chemical properties of the soil on four suburban farms in Santiago de Cuba.

Materials and Methods

The research comprised suburban farms in the municipality of Santiago de Cuba, following a selection made by Escobar et al. (2017). La Esperanza (20.047084 north latitude and 75.751690 west longitude, 25 m above sea water), La Caballería (20.047843 north latitude and 75.794819 west longitude, 20 m above sea water), Los Cascabeles (20.057827 north latitude and 75.800777 west longitude, 50 m above sea water), and La Sorpresa (20.038776 north latitude and 75.789878 west longitude, 20 m above sea water). In general, no studies have been done to determine the type of soil of these farms, though the predominant soils of Santiago de Cuba are brown sialitic (Hernández, Pérez, Bosch & Castro, 2015). In a qualitative analysis of the climatic conditions (based on farmers' data), precipitations were classified into abundant to average (with variations toward a decrease) and mid to high temperatures.

Samples from every farm soil were taken using the farm layer method for La Esperanza and Los Cascabeles, whereas La Caballería and La Sorpresa used the zigzag method. The samples (2 Kg) were collected using a shovel and were deposited in a polyethylene bag (18.5 cm x 12.5 cm), then they were labeled. The samples were taken to the Base Company Facility (UEB), the laboratories of Oriente Geomining Company to determine their chemical properties.

The samples were readied for the different analyses in the same laboratories, according to the Cuban standard NC-ISO 11464:1999. The Ca^{2+} content was determined by sample merging (Multielement Atomic Absorption Spectrophotometer AA 300). The Mg^{2+} and Al^{3+} contents were determined sensorially (ICP-OES Induced Coupled Plasm). The Na^{+} and K^{+} were quantified by flame photometry (CORNING-400 liquid emission photometer). In all the cases, the content was measured in cmol.Kg-1. All these data were used to calculate the cationic ratios, CICe, and the V value, as described by Molina (2020).

The CICe base saturation was determined by the procedure described by Toledo (2016), and PSI or Na^{+} saturation was calculated following the description of Alconada (2017). In all the cases, the formulae are shown below:

Ca^{2+} saturation (%)

$$\text{calcium saturation } (\%) = \frac{\text{calcium}}{\text{CICe}} \times 100$$

K^{+} saturation (%)

$$\text{potassium saturation} = \frac{\text{potassium}}{\text{CICe}} \times 100$$

Mg^{2+} saturation (%)

$$\text{magnesium saturation} = \frac{\text{magnesium}}{\text{CICe}} \times 100$$

Al^{3+} saturation:ión (%)

$$\text{aluminum saturation} = \frac{\text{aluminum}}{\text{CICe}} \times 100$$

PSI

$$\text{PSI} = \frac{\text{sodium}}{\text{CICe}} \times 100$$

The pH was determined (Cuban standard NC-ISO 10390:1999), and the M.O content was determined through the Walkley-Black method. The results achieved were certified by the entity, and any partial or total reproduction was forbidden), except by the official client.

The properties of the soil were assessed on each farm, and compared. The statistical analysis of the K^{+} content used a Multiple rank test by LSD, and the Kruskal-Wallis test was used to analyze the other properties. All the statistical processing was analyzed through StatSoft. STATISTICA v10.0.228.8.

Results and discussion

The Ca^{2+}, Na^{+}, and K^{+} contents (Table 1) varied. The highest Ca^{2+} value was observed on La Sorpresa, with significant differences from the other farming systems. Los Cascabeles, La Caballeria, and La Esperanza (by that order); the las two farms in the list showed no significant differences. Generally, the Ca^{2+} content was between 14.1 and 34 cmol.Kg^{-1} considering that 1 Meq.100g=1 cmol.Kg^{-1} can be classified as high, according to the Colombian Agricultural Institute [ICA] (1992), and Ramírez, Velásquez & Acosta (2007).

Table 1. Behavior of cations in the soil absorbing complex on the farms studied

Farms	Content (cmol.kg^{-1}) (cmol.kg^{-1})				
	Ca^{2+}	Na^{+}	K^{+}	Al^{3+}	Mg^{2+}
LE	14.10c	9.90b	5.00 b	6.62c	15.30b
LC	15.80c	11.00b	3.90 c	7.39a	20.50a
LCs	23.00b	5.10c	2.90 d	7.46a	20.80a
LS	34.00a	13.90a	5.75 a	7.05b	16.90b
VC (%)	61.38	42.72	30.69	10.69	20
SEx	7.515	0.833	0.189	0.193	0.951

Legend: LE: La Esperanza, **LC:** La Esperanza, **LC:** Los Cascabeles, **LS:** La Sorpresa, **CV:** Variation coefficient, SE: Standard error

The soil absorbing complex required a greater Ca^{2+} proportion; however, though it was not higher than in La Esperanza and Los Cascabeles, it followed the elements with the highest proportion on the farms. Yfran et al. (2017) said that Ca^{2+} is an important element of the cell membrane, conferring it stability, acting as a cementing element, maintaining their integrity, and being relevant for water economy. It has a close relationship with the merismatic activity, influencing the degradation of enzymatic systems and phytohormone activity.

The Na^{+} content in these soils was lower than the Ca^{2+} content. The highest values were equally reported on La Sorpresa, with statistical differences from the rest. This element did not evidence differences between La Esperanza and La Caballeria, whereas, it was lower in Los Cascabeles. Considering all the Na^{+} content, the values varied between 5.1 and 13.9 cmol.kg^{-1}. According to ICA (1992), this element must be below 1 cmol.kg^{-1} or 5% saturation. Hence, the presence of this element on the farms is slightly high on Los Cascabeles and La Esperanza, whereas it was considered high for La Caballeria and La Sorpresa. The presence of high Na^{+} contents in the soil could be treated carefully, as it is an element that tends to form salts in the presence of others, contributing to its alkalinity.

All the farms showed significant differences in relation to K^{+}, though La Sorpresa showed the highest value. The K^{+} content values remained between 2.9 and 5.75 cmol.kg^{-1}. As can be seen, all the results were greater than 0.4 cmol.Kg^{-1}, so their presence in the soils studied was high, according to Ramírez et al. (2007). The deficiency of this element is stressing, since it is essential for plant nutrition (Hu et al., 2016). It is the primordial cation and takes place in physiological and metabolic processes. It has effects on energy transduction, ammonium assimilation, growth, and the conversion of amino acids (Ramírez, Magnitskiy, Melo & Melgarejo, 2018).

The highest quantity of Al^{3+} was reported in the soil of Los Cascabeles, which did not differ statistically from La Caballeria. The lowest value was observed on La Esperanza, which did differ from the statistics of the other farms, just like La Sorpresa. This element was found within 6.62 and 7.46 cmol.Kg-1, higher than the 2 cmol.Kg-$^{-1}$ reported by Ramírez et al. (2007) to be considered low. Al^{3+} is an element that must not appear on the soil layer used as nutritional crop substrate. Should it be present, it must have the lowest possible values, and a possible rise should be avoided, since it does not constitute a nutrient.

Rivera, Moreno, Herrera & Romero (2016) said that soluble Al^{3+} is a factor that limits growth and production in acid soils. It leads to a drop in the solubility of other elements in the soil solution and the plant. It causes an alteration of the general metabolism and inhibits root growth, reducing water and nutrient uptake.

The highest content of Mg^{2+} was found in La Caballeria and Los Cascabeles, with no statistical differences between them, through both differed from La Esperanza and La Sorpresa, between which no statistically significant differences were observed. Overall, the range of Mg^{2+} quantity of these farms was 15.3 and 20.8 cmol.Kg^{-1}. Considering this range, the Mg^{2+} contents in the farm soils was thought of as high, over 2.5 cmol.Kg^{-1} referred by the ICA (1992).

Knowing the presence of this element in the soil and its quantity is critical, as it is involved in the photosynthetic activity and the glucidic metabolism of the plant. It activates enzymes that intervene in the synthesis of nucleic acids and influence the green color of the leaves (Reyes, Mora, Morales & Pérez, 2017). It can be explained by the fact that it is one of the most abundant ions in the earth crust and plants, the key element of chlorophyl (Snigdha, Sandeep & Jerry, 2018).

Overall, the different elements evaluated abound in the soils studied. Ultimately, this could be beneficial for the production of these agroecosystems. However, the chemical characterization studies of soils frequently offer a separate interpretation of the elements, overlooking their balance or cationic ratios. This analysis may bring information related to the possible existence of antagonisms between ions.

When the cationic ratios are analyzed (Table 2), the following occurs: In all the production systems that analyze the Ca^{2+}/MG^{2+} ratio is between 0.77 and 2.01 cmol.Kg-$^{-1}$. According to the scale cited by Moro (2015) for La Esperanza and La Caballeria, this ratio is lower than 1, which means that there is Ca^{2+}

deficiency compared to Mg^{2+}. On Los Cascabeles, the value achieved was between 1 and 2, evidencing a low Ca^{2+} level compared to Mg^{2+}. In La Sorpresa, the balance was slightly higher, within the range considered ideal, in which the Mg^{2+} level compared to Ca^{2+} was low, and therefore both elements were assimilable. However, on this farm, this ratio should not diminish, since the balance obtained from the two elements was very close to the range's lower limit (2).

The Mg^{2+}/K^{+} ratio in all the soils varied between 2.94 and 7.17 cmol.Kg^{-1}, within the ideal range (3-18), reported by (2012), except for La Sorpresa, where it was slightly lower. Considering these results, the soils studied evidenced no antagonism between these two elements. Nevertheless, according to the values observed, Mg^{2+} absorption could be slightly affected on La Sorpresa, compared to K^{+}.

The Ca^{2+}/K^{+} balance values, considering all the results, were between 2.82 and 7.93 cmol.Kg-$^{-1}$. These values can be classified as adequate, being under 30, according to the scale mentioned by Moro (2015). Hence, between the two elements there is no antagonism of the farm soils in the study.

Table 2. Ratios between the elements evaluated

Ratios (cmol.Kg^{-1})	Farms			
	LE	LC	LCs	LS
Ca^{2+}/Mg^{2+}	0.92	0.77	1.11	2.01
Mg^{2+}/K^{+}	3.06	5.26	7.17	2.94
Ca^{2+}/K^{+}	2.82	4.05	7.93	5.91
$(Ca^{2+}+Mg^{2+})/K^{+}$	5.88	9.31	15.10	8.81
$(Ca^{2+}+Mg^{2+}+K^{+})/Al^{3+}$	5.20	5.44	8.81	8.04

Legend: LE: La Esperanza, **LC:** La Esperanza, **LC:** Los Cascabeles, **LS:** La Sorpresa

To reach the ideal Ca^{2}/Mg^{2+} content compared to K^{+} (Sadeghian, 2012) must be between 10 and 40, which was only achieved on Los Cascabeles. Accordingly, on this farm K^{+} is available, compared to the Ca^{2+} + Mg^{2+}combination. On the other farms, though the ratio was not inadequate, soils must be managed carefully, as there is a potential risk of an antagonism between K^{+} and the Ca^{2+} + MG^{2+} combination, hindering their absorption.

As mentioned during the analysis of Al^{3+}, this element is present abundantly in the soils studied. However, when the Ca^{2+} + MG^{2+} + K^{+} ratio is compared to Al^{3+}, a proper behavior was observed, considering the scale mentioned by Moro (2015), and therefore, there is no need to whitewash looking to raise the soil pH. The fact that these soils do not need whitewashing, despite Al^{3+} is way above the permissible value for farming, owes to its abundant presence (above the permissible limits) of other bases like Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+}, whose contents in the first three are over Al^{3+}. The previously described behavior may explain why the other ratios analyzed on the farm soils studied are generally within the permissible range.

The ratios observed in this research were closer than the ones reported by Combatt, Novoa, Barrera & Violeth (2012), and broader than the ones found by Luiz, Mozena, Cayô, Cavalcanti & Duarte (2019) in Mg^{2+}/K^{+} and Ca^{2+}/K^{+}. Therefore, both balance and nutrient content may influence significantly the capacity of these soils to give or retain these elements.

In the soils of the farms studied, CICe varied between 50.92 and 70.55 cmol.Kg^{-1} (Table 3). According to a MINAGRI scale (1984) referred to by Molina (2020), these values were classified into very high, above 40 cmol.Kg^{-1}, which may be related to the fact that the elements on which this property depends, were present abundantly. Considering these results, the soils of these farms have an intrinsic capacity to store positively-charged nutrients or cations in their colloids, which could favor the soils in this study.

Table 3. CICe and V value

Farms	CICe (cmol.Kg^{-1})	CI	V	CI	
				V	GL
LE	50.92	MA	86.99	A	B
LC	58.59	MA	87.38	A	B
LCs	59.26	MA	87.41	A	B
LS	77.60	MA	90.91	A	B

Legend: LE: La Esperanza, **LC:** La Esperanza, **LC:** Los Cascabeles, **LS:** La Sorpresa, **CV:** Effective cationic exchange capacity, **V**: Base saturation percentage, **CI**: Classification, **GL**: Wash level, **VH**: Very high, **H**: High, **L**: Low

Huerta (2010) noted that CIC expresses the number of positively-charged ion mols absorbed that may be exchanged by dry mass unit, under certain conditions of temperature, pressure, liquid phase composition, and a given mass-solution ratio. A positively-charged mol equals 6.02 x 10^{23} absorbed cation charges.

Additionally, the base saturation percentage of these soils was also high, according on the scale cited by Molina (2020). It can be explained through the value range for this property, which varied between 80.1 and 90.01%, below the 80-95% range established in the scale to be considered that way. Considering this behavior, base washing is low, thus confirming the capacity of these soils to store cations. The farm soils studied can be regarded as saturated.

However, when aspects like base saturation (CA^{2+}, K^{+}, and Mg^{2+}) were analyzed in relation to CICe, exchangeable sodium percentage (ESP), and Al^{3+} saturation (Table 4), the soils were unable to express their full capacity of exchanging, and lose the high cationic content they have, as some of them turn into limiting factors due to the high presence.

Table 4. Behavior of CICe-related saturation

Saturation (%)	Farms			
	LE	LC	LCs	LS
Ca^{2+}/CICe saturation	27.69	26.97	38.81	48.19
K^{+}/CICe saturation	9,82	6.66	4.89	8.15
Mg^{2+}/CICe saturation	30.05	34.99	35.10	23.95
Al^{3+}/CICe saturation	13.00	12.61	12.59	9.99
PSI	19.44	18.77	8.61	19.70

Legend: LE: La Esperanza, **LC:** La Esperanza, **LC:** Los Cascabeles, **LS:** La Sorpresa

Ca^{2+} saturation varied between 26.97% and 48.19%, whereas K^{+} saturation was between 4.89 and 9.82%, and 9.99-13.00% for Mg^{2+}. According to the scale reported by Bianchini (n/a) Ca^{2+} saturation was considered low, being under 60%. Meanwhile K^{+} and Mg^{2+} saturation levels were good, above 3 and 6%, respectively. These results corroborate the above, when the nutrient content of these soils was analyzed, especially the importance that of all the bases (Ca^{2+}, Mg^{2+}, K^{+}, and Na^{+}), Ca^{2+} prevailed. This was only found in Los Cascabeles and La Sorpresa, though on all the farms, the presence of this element in the saturation of bases was considered low.

Al^{3+} contributes to soil acidity and both as an isolated element and in saturation, it reaches levels above the permissible values for farm development, though in the cases studied, acidity was not observed. It occurs thanks to the fact that the PSI is between 8.61 and 19.7%, excessively over 5%, and according to the scale suggested by Alconada (2017), it qualifies as high, except on Los Cascabeles, which is mid. Therefore, these are sodic soils that may tend to alkalinity.

Toledo (2016) said that Al^{3+} causes soil acidity when it reacts with water, releasing hydrogen to the solution (Al^{+3} + H_2O $Al(OH)^{+2}$ + H^{+}). Overall, soil-soluble Al^{3+} is not good for the cultivated plants because it is not essential for their development. In turn, Na^{+} is used by plants in small quantities. however, it may harm them when it occurs in the soil at high concentrations (high salinity or sodium concentrations). Sodium is a problem observed in dry areas; hence, it must be under constant observation. Molina (2020) noted that Na^{+} must not have high values due to its toxic and peptizing character of the soil colloids. He added that over 15% of CICe saturation by this element is enough to think of this soil as sodic, with properties that make it inadequate for crops. Then, the presence of these elements is not only necessary, but also, a proper ratio between them must exist.

So far, the results indicate that though the soils of these farms have an abundant presence of the principal bases, high CICe, and V value, their fertility is unlikely. The high presence of Al^{3+} and Na^{+} in the colloids from the soil, along with a higher incidence of droughts (increasingly occurring), makes many of these elements non-assimilable by plants, and therefore they will not be in condition to express their maximum production potential. Specifically, Na^{+} can contribute to soil alkalinity, thus suggesting that water should be used cautiously and rationally for irrigation, taking into account the clarity of the water-cation balance. Di Gerónimo, Videla, Fernández, Zamuner & Laclau (2018) pointed out that the unbalance of basic nutrients (Ca^{2+}, K^{+} and Mg^{2+}) can generate problems with the pH.

Accordingly, it was one of the priorities that underwent the least variation in the farm soils studied (Table 5). In all the cases, it was over 7 (7.6-8.1 variation), which means that they are basic soils that tend to alkalinity. The highest value of this parameter was observed on La Sorpresa, with statistical differences from the other farming systems, among which no significant differences were observed. This behavior can be the result of the high Na^{+} presence in the soil, and high PSI regarding their CICe.

Table 5. The pH and organic matter content

Farms	pH	O.M. (%)
La Esperanza	7.6 b	1.22b
La Caballería	7.9 b	1.18b
Los Cascabeles	7.7 b	1.42b
La Sorpresa	8.1 a	2.33a
CV (%)	4.17	60.09
SEx	0.08	0.21

Legend: O.M.: Organic matter, **VC:** Variation coefficient, **SE:** Standard error

According to the pH values, soil classification may vary among the experts. However, Huerta (2010), noted that a soil is strongly acidic if their pH is lower than 5 (very deficient bases); moderately acidic if the pH varies from 5 to 6 (moderate base deficiency); slightly acidic when the pH is lower than 7, but higher than 6; neutral if the pH value is equal to, 7; basic when the pH is higher than 7; and alkaline if the pH is higher than 8.5, indicating the presence of Na^{+}. These results corroborate the findings of Soto (2015) in a study in which the soil had a greater pH, the Al^{3+} content dropped compared to the salt-forming elements in the soil. Rivera et al. (2016) noted that to reduce soil acidity, the mineralization of parental minerals with low cation contents should be avoided (Ca^{2+}, Mg^{2+}, K^{+} and Na^{+}).

Moreover, soils have a different capacity of change depending on the pH. At low pH, the hydrogen ions are strongly held in the particle surface, though at high pH. The hydrogens of the carboxylic (first) and hydroxyl radicals (later) dissociate, and the H^{+} can be changed by cations (Mosquera, 2017), which could be facilitated by the low O.M. contents. Valenzuela & Visconti (2018) found that the chemical properties, including the pH, CIC, and saturation of interchangeable bases, are ideal to interpret the conditions of the soil as a chemical medium. The physico-chemical conditions of the soil affect the organic carbon, with the pH as one of the most influential. O.M. can also generate acidity through the active carboxyl and phenolic groups that dissociate the soil, releasing hydrogen (Abrego, 2012; Quezada, 2020).

The highest O.M. content was observed on La Sorpresa, with significant differences from the other farming systems, among which no differences were observed. Overall, the O.M. content in the soils of these farms is low, except on La Sorpresa, where it is moderate. According to the scale mentioned by Molina (2020), lower O.M. levels than 2 are considered low, whereas 2-4 are moderate. In turn, La Sorpresa should perform soil management with caution to maintain or raise that property, as the O.M content found was near the lower limit of the classification threshold.

Perhaps, the behavior of the other properties analyzed before is linked to the O.M. results found. Surely, the state of this property in the soils is highly relevant. Wolff & Ovalle (2016) noted that O.M. determines the soil structure, by participating in the formation of aggregates, enhancing erosion resistance, improving the infiltration capacity, water storage and retention, and participating in the capture and sequestering of a part of the atmospheric carbon.

Consequently, a soil's fertility is not only dependent on the presence of elements in it, or that if it has adequate CICe, but on the existence of proper O.M. content. Medina, Volke, Galvis, Cortés & Santiago (2017), found it is an essential component of edaphic processes, with a positive effect on the productivity of agricultural systems. Through breakdown and mineralization, it provides nutritional elements to plants, increases CIC (reducing mineral loss by lixiviation), and protects them from fixation by the clay in the soil.

Mosquera (2017) and Mora, Alcalá, Rosas & González (2017) noted that the soil CIC is the total quantity of negative charges available, mainly in the clay and O.M. (both having colloidal properties). These parameters constitute soil fertility indicators; hence, to determine the proper quantity and depth is essential. Very high values of CIC and O.M. indicate that the conditions of the soil tend to have proper fertility. The CIC values of O.M. vary between 200 and 400 cmol.Kg^{-1}, much higher than the minerals in clay (10-150 cmol.Kg^{-1}). Therefore, the type and quantity of clay, as well as the O.M. influence CIC greatly. As the clay and/or O.M. contents rise in the soil, there will be a higher CIC. The capacity of retaining and increasing cations is a direct indicator of fertility (Abrego, 2012; Quezada, 2020).

The above shows that the O.M. content in the soils from the different farms has a negative effect on fertility. Although they have the elements and high capacity for exchanges, they are retained, mainly due to the low CIC supplied by the O.M. Additionally, the high pH (tending to alkalinity), which also indicates high Na^{+} presence. When this element is abundant in the interchangeable portion of the soil, other elements become non-assimilable. This fact is aggravated by the unfavorable Ca^{2+} and Mg^{2+} ratio.

The high levels of interchangeable bases in the soils studied indicate that they are a good reservoir of these nutrients, but they are largely unavailable for farming. On all the farms included in the research, the soil with the best features was found on La Sorpresa, though it still has potentially limiting conditions to grow crops. Overall, the O.M. contents of these soils require the inclusion of organic fertilizers and harvest stalks.

Conclusions

The chemical properties of the farm soils analyzed were a constraining factor for the development of production. Despite the potential fertility and proper nutrient contents, the ratios between the elements fixes them in the soil in forms that cannot be assimilated by the crops.

Author contribution statement

Belyani Vargas Batis: research planning, analysis of the results, redaction and proof-reading and final review.

Yatniel Escobar Perea: research design, analysis of the results, redaction and proof-reading and final review.

Rubert Rodríguez Fonseca: bibliographic search, analysis of the results, proof-reading and final review.

Yordi Mauro Ramos García: bibliographic search, proof-reading and final review.

Ernesto Jesús Rodríguez Suárez: field work, final review.

Onelkis Fuente Miranda: field work and final review.

Conflicts of interests

There are no conflicts of interest.

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