ORIGINAL ARTICLE

Edaphic factors that involved in the availability of microelements in Vertisols planted with sugarcane

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Factores edáficos que intervienen en la disponibilidad de microelementos en Vertisoles plantados con caña de azúcar

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ABSTRACT: The objective of this study was evaluate the influence of the limiting factors of production: effective depth, slope, erosion, texture, drainage and salinity on the availability of Mn, Fe, Co, Ni, Cu and Zn in Vertisols planted with sugarcane from the Region of Cuba. A total of 262 soil samples were obtained by stratified random sampling. The available forms of microelements were determined with the diethylenetriaminepentacetic acid solution by the atomic absorption method. To explain the relationship between both sets of variables was used the Canonical Correlation Analysis. The results showed a strong correlation between the limiting factors drainage, salinity, slope, effective depth and texture and the availability of Co, Ni and Zn. It recommended appropriate agronomic practices that improve physical fertility and that favor the displacement towards the available forms of the microelements in Vertisols.

Keywords: Nutriments, Physical Fertility, Chemical Fertility.

RESUMEN: El estudio se realizó con el objetivo de evaluar la influencia de los factores limitativos de la producción: profundidad efectiva, pendiente, erosión, textura, drenaje y salinidad sobre la disponibilidad de los microelementos Mn, Fe, Co, Ni, Cu y Zn en Vertisoles plantados con caña de azúcar de la Región Oriental de Cuba. Se obtuvieron por muestreo aleatorio estratificado 262 muestras de suelos. Las formas disponibles de microelementos se determinaron con la solución ácido dietilentriaminpentacético por el método de absorción atómica. Para explicar la relación entre ambos conjuntos de variables se empleó el Análisis de Correlación Canónica. Los resultados mostraron una fuerte correlación entre los factores limitativos drenaje, salinidad, pendiente, profundidad efectiva, textura y la disponibilidad de Co, Ni y Zn. Se recomienda realizar prácticas agronómicas adecuadas que mejoren la fertilidad física y favorezcan el desplazamiento de los microelementos hacia las formas disponibles en Vertisoles.

Palabras clave: nutrimentos, fertilidad fisica, fertilidad química.

INTRODUCTION

The soil is a living and dynamic system that functions through a unique balance in the interaction of its physical, chemical and biological components (Moreno *et al.*, 2015). Its fertility is an important factor in the mineral nutrition of crops, therefore that its understanding is essential to provide better management of the nutrition (Garbanzo-León *et al.*, 2017).

The Vertisols soils are representative of the Eastern Region of Cuba, they cover important areas in the Granma and Holguín provinces and are used intensively for the production of sugar cane. The main characteristics and properties have been described by Hernández-Jiménez *et al.* (2014); Marín *et al.* (2015); Cid *et al.* (2016), Where the great physical and hydrophysical limitations stand out despite its good chemical fertility.

The loss of physical fertility is associated with production limiting factors. In this regard, Herrera-Puebla *et al.* (2011) detected that the provinces of Camagüey, Las Tunas, Holguín and Granma have

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more than 50 % of the agricultural area affected by poor drainage and in the latter more than 45 % is in salinity conditions. Álvarez y Rimski (2016) determined that the decrease in effective depth corresponds to less availability of water and nutrients. On the other hand, the low infiltration rate and poor drainage conditions are associated with salinization due to the use of poor quality water without drainage in low places with a saline water table close to the surface Cid *et al.* (2016); Guida-Johnson *et al.* (2017).

Microelements are part of plant nutrition and their content in soils is in balance with macroelements, since they originate from the same rock weathering process, are essential for plant life and perform non replaceable functions. Its availability in the soil is due to changes in chemical and physical-chemical properties and variations in the limiting edaphic factors in the soil landscape scenario in question.

The most complete studies on the availability of microelements in Vertisols were carried out by Falóh (1981) en Camagüey y Companioni (1981) in sugarcane soils of Cuba; however, the issue of forecasting the behavior of available microelements based on the variation of limiting edaphic factors of the production is not addressed.

Due to the above, the objective of this research was to evaluate the influence of production limiting factors on the availability of microelements in Vertisols planted with sugar cane in the Eastern Region of Cuba.

MATERIALS AND METHODS

The study was developed in Vertisols planted with sugarcane in the Eastern Region of Cuba Hernández *et al.* (1999; 2015), which includes the provinces of Camagüey, Las Tunas, Holguín, Granma and Santiago de Cuba and represents 44.7 % of the study area. The soil samples were taken in the surface horizon (0 - 20 cm) through stratified random sampling, the grouping of soil established the homogeneous zone and the number of samples was determined using the procedure proposed by Hernández (2003). A total of 262 georeferenced samples were taken, made up of 30 sub-samples that made up a sample of one kg of soil per Minimum Management Unit (field), according to the methodology of Villegas *et al.* (2007).

The chemical and physical-chemical analyzes were carried out in the laboratories of the Sugarcane Research Institute (INICA). The samples were air dried, crushed, sieved through a 1 mm mesh and ready for analysis. The variables analyzed were: pH (H_2O) and pH (KCl) NC- 2001-2015 (2015) and soil organic matter (SOM) NC- 51- 1999 (1999). The analyzes of Mn, Fe, Co, Ni, Cu and Zn available were determined by Atomic Absorption Spectrophotometry in a Brand Spectrometer SOLAAR 929 from UNICAM GB, belonging to the Nickel Research and Development Center (CEDINIQ-Moa).

The samples were sieved through a mesh of 0.5 mm and ready for analysis. For the extraction of the available microelements was used the solution of 0.005M diethylenetriaminepentacetic acid (DTPA) + 0.1M triethanolamine (TEA) + 0.01M CaCl2 according to ISO 14870: 2001 (2001). The evaluation of the limiting factors: texture, slope, drainage, erosion and salinity was determined from the information according to the Methodological Standards for Soil Studies and Comprehensive Management of Sugarcane (ESMICA) (INICA-Cuba, 2003). The effective depth was evaluated for the categories proposed by Arzola-Pina y Machado de Armas (2015).The characterization of the physiographic conditions and the magnitude and intensity of the limiting factors in the agricultural surface were evaluated to the MINAG soil map 1:25,000 (Instituto de Suelos, 1975).

The normality was tested with the Shapiro-Wilk W test. Descriptive statistics were used to measure the attributes of the population. The coefficient of variation (CV) was estimated according to the criteria of Nielsen *et al.* (1986) where values less than 12%, between 12 and 60% and greater than 60% are considered low, medium and high variability, respectively. The relationship between the limiting factors of production and the contents of available microelements were determined by canonical correlation analysis (CCA) (Gauch Jr y Wentworth, 1976). The statistical treatment of the data was carried out using STATISTICA version 8 software.

RESULTS AND DISCUSSION

The fertility status of the Vertisols in the study area is shows in the Table 1. In the surface horizon were found pH values that ranged between neutral and moderately alkaline. These results agree with those of Villegas *et al.* (2015) that report 65% of the samples from the national database of SERFE between neutral and alkaline. The SOM content showed a medium supply level, due to the balance established in monoculture areas with sugarcane for more than 60 years, similar to what was proposed by Socarrás-Armenteros *et al.* (2019) in intensively worked soils and Marín *et al.* (2015) when studying poorly drained soils in Cuba.

The distribution of available microelements in the surface horizon showed high variability in all elements, influenced by unfavorable hydrophysical properties, seasonal variation of chemical properties and oxidation-reduction processes in an environment of alternating humidity, characteristic of Vertisols. The surface analyzes showed that the order of abundance of the microelements was Mn > Fe > Cu > Ni > Zn > Co (Instituto de Suelos, 1975).

TABLE 1. Chemical and physical-chemical properties in the surface horizon (0-20 cm)

Variable	Unit .	Med.	Min	Max.	SD	CV (%)
pH_{H2O}	$-log[H^+]$	7,64	6,00	8,20	0,46	7,32
pH_{KCl}		6,80	5,10	7,32	0,49	6,14
MOS	%	2,67	1,62	4,00	0,56	20,13
Mn	mg kg^{-1}	25,95	0,89	184,45	42,17	99,84
Fe		8,81	1,56	45,70	8,62	73,21
Co		0,43	0,06	1,52	0,32	64,91
Ni		2,58	0,18	9,05	2,06	65,59
Cu		2,79	0,08	14,41	2,39	65,86
Zn		0,65	0,18	4,53	0,68	77,63

Med. Median; Min. minimum; Max. maximum; DS. standard deviation; CV. coefficient of variation

The evaluative scenario where sugarcane develops on Vertisols describes that the effective depth varied from shallow to medium deep (Table 2). The slope from flat to undulating predominated, that favored an erosion among light and moderate. A clay texture prevailed with traces of silty clay, presence of smectitic minerals that conditioned drainage from imperfect to poorly drained and some areas with weakly saline features.

The results of the Canonical Correlation Analysis (CCA) showed the canonical correlations on two axes with high significance values (0,87 and 0,79). The low expression of the Willk Lamda (0,04 and 0,18) which means a greater precision of the relationship between the correlated canonical variables (U and V) (Table 3).

The factors with the greatest contribution to the total variance in the first axis were represented by Ni and Co (U_1) influenced by salinity, slope, effective depth and texture (V_1). In the second axis, drainage, slope and salinity (V_2) were confirmed as limiting production that affected the availability of Zn (U_2) (Table 4). Although a greater effective depth favors the concentration of available microelements, the conditions of slope relatively flat promote poor drainage that causes salinization in Vertisoils. In this regard, Guida-Johnson *et al.* (2017) stated that salinity is generally associated with the presence of the mineralized water table, close to the surface, related to poor drainage problems.

In the second combination of canonical variables, the behavior of drainage, slope and salinity associated with water-soil relationships and geomorphology, negatively impact the availability of Zn. In the opinion of Herrera-Puebla *et al.* (2011); Marín *et al.* (2015); Cid *et al.* (2016), the high distribution of Vertisuelos in the Cauto Valley and in the entire Eastern Region, except Guantánamo, with many of the areas affected by poor drainage and salinity, need the benefit of surface drainage, to achieve rapid evacuation of the water depending on the demand of the crop, depending on the soil, climate and topography. The dispersion between the limiting edaphic factors and the available microelements (Figure 1) was adjusted to a linear regression equation, with a high canonical correlation coefficient (r= 0.87) and a determination coefficient R^2= 0,75, This means for which can be inferred that 75 % of the variation of the microelements available in the Vertisols is explained by the intensity with which the limiting factors of production considered in this study are manifested.

TABLE 2. Behavior of the limiting factors in the surface horizon

Effective depth			Slope			Erosion		
Category	#	%	Category	#	%	Category	#	%
Half Deep	60	22,90	Flat	162	61,83	Light	149	56,87
Medium Deep	202	77,10	Waby	100	38,17	Moderate	113	43,13
Texture			**Drainage**			**Salinity**		
Category	**#**	**%**	**Category**	**#**	**%**	**Category**	**#**	**%**
Clay	216	82,44	Medium Well Drained	31	11,83	Not saline	184	70,23
Silty Clay	46	17,56	Imperfectly Drained	167	63,74	Weakly saline	78	29,77
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Medium.Well Drained: Moderately Well Drained, Imperfect. Drained: Imperfectly Drained,

TABLE 3. Analysis of canonical correlations for the limiting edaphic factors and available microelements

	Axis value	Canonical Correlation	Wilks Lambda	Chi Square	df	p
1	0,752	0,87	0,04	125,71	36	0,0000
2	0,617	0,79	0,18	69,22	25	0,0000

TABLE 4. Canonical correlation coefficients obtained from the sets of canonical variables

First combination of variables				Second combination of variables			
U_1		V_1		U_2		V_2	
Ni	-0.9791	Effective depth	-0.4583	Ni	0.1108	Effective depth	0.0704
Co	1.0192	Slope	-0.5030	Co	-0.3969	Slope	-0.5158
Fe	0.2551	Salinity	-1.0259	Fe	-0.2194	Salinity	0.4132
Mn	0.1980	Erosion	0.0937	Mn	0.3753	Erosion	0.2439
Zn	-0.2272	Texture	0.4667	Zn	-0.6570	Texture	-0.0488
Cu	0.3992	Drainage	0.0342	Cu	0.2544	Drainage	-0.7339

U= Set of available Microelements, V= Set of Limiting Factors
Highlighted the variables with the greatest contribution in each canonical correlation

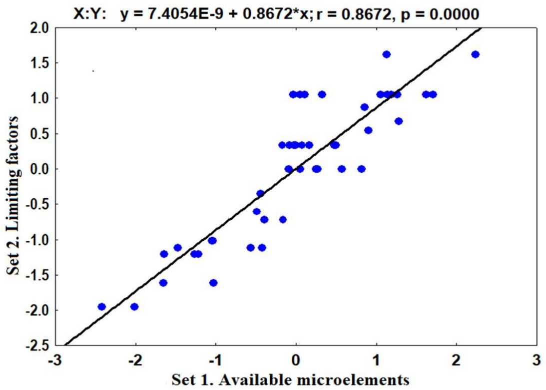

FIGURE 1. Scatter graph between the available microelements and the edaphic factors limiting the production of the Vertisol grouping.

The physical and chemical properties of Vertisols can be improved or modified with appropriate agronomic management measures according to Torres-Guerrero *et al.* (2016). The purposes are carry out soil preparation tasks according to the effective depth, prioritizing the non-inversion of the prism to minimize the incorporation of carbonates to the surface and thus avoid the adsorption of Cu and Zn by them. Use surface and subsurface engineered irrigation and drainage systems that favor the balance of oxidation-reduction processes and maintain the stability of the available forms of Fe and Mn. Maintain constant monitoring of the quality of irrigation water and the levels of the groundwater table to avoid the rise of salts to the horizons where roots predominate. It is considered to efficiently manage the waste coverage to increase the annual mineralization of the SOM that allows a large part of the absorbed Cu and Zn to be released into available forms. Alternatively apply biofertilizers or inoculants of microbial origin and exploit their capacity to mobilize nutrients with a minimum of non-renewable resources, accompanied by rational applications of biostimulants. Establish comprehensive research in Vertisols, which favors the displacement of microelements towards available forms, taking into account that there are no fertilization systems, based on these nutrients established in sugarcane.

CONCLUSIONS

The results showed that there is a strong correlation between the limiting factors drainage, salinity, slope, effective depth, texture and the availability of Co, Ni and Zn. It is recommended to apply appropriate agronomic practices that improve physical fertility and favor the movement towards the available forms of microelements in Vertisols.

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