Agrisost | Vol. 25, No. 2, May-August, 2019:1-5

ISSN-e: 1025-0247

Chemical Properties that Determine Boron Availability in Sugar Cane Soils

Yakelin Cobo Vidal[1], Elio Angarica Baró[2], George Martín Gutiérrez[1], Adrian Serrano Gutierrez[1], Juan Alejandro Villazón[3], Alegna Rodríguez Fajardo[2]

[1]ORCID https://orcid.org/0000-0002-9377-2397, Department of Technological Research and Innovation, Provincial Station of Sugar Cane Research, Guaro, Holguín, Cuba, [2]ORCID https://orcid.org/0000-0002-7129-8372, Department of Technological Research and Innovation, Territorial Research Station on Sugar Cane, Oriente Sur, Palma Soriano, Santiago de Cuba, Cuba, [1] ORCID https://orcid.org/0000-0003-4631-3013, Department of Technological Research and Innovation, Provincial Station of Sugar Cane Research, Guaro, Holguín, Cuba, [1]ORCID https://orcid.org/0000-0002-3020-9396, Department of Technological Research and Innovation, Provincial Station of Sugar Cane Research, Guaro, Holguín, Cuba, [3]ORCID https://orcid.org/0000-0002-2436-0591, Faculty of Natural and Agricultural Sciences, University of Holguín, José de la Luz y Caballero Venue, Holguín, Cuba, [2]ORCID https://orcid.org/0000-0003-3209-4307, Department of Technological Research and Innovation, Territorial Research Station on Sugar Cane, Oriente Sur, Palma Soriano, Santiago de Cuba, Cuba.

Citation: Cobo Vidal, Y., Angarica Baró, E., Martín Gutiérrez, G., Serrano Gutierrez, A., Alejandro Villazón, J., & Rodríguez Fajardo, A. (2019). Chemical Properties that Determine Boron Availability in Sugar Cane Soils. *Agrisost*, *25*(2), 1-5. Recuperado a partir de https://revistas.reduc.edu.cu/index.php/agrisost/article/view/e3016

Received: April 29, 2019 Accepted: May 28, 2019 Published: June 10, 2019

Funding source: undeclared.

Conflicts of interest: no conflict of interest has been declared.

Email: yakelin.cobo@inicahl.azcuba.cu

Abstract

Context: Several factors are limiting the behavior and dynamics of boron (B) in the soil. Few results on assimilable B contents in the soil and its relation to other chemical properties have been published.

Objective: To determine the contents of assimilable B and the chemical properties that condition its availability in three of the main soil types where sugar cane is cultivated.

Methods: The samples were taken at random from the surface (0-20 cm) of three of the main soil types where sugar cane is cultivated in Cuba. Soil assimilable B was determined by extraction with hot water. Classification of assimilable boron concentration relied on category ranges set up by Agrolab, (2005): low (<0.5 mg kg^{-1}), mid (0.5 a 2.0 mg kg^{-1}), and high (>2.0 mg kg^{-1}).

Results: The concentration of assimilable B varied according to the soil type, with a high dependence on chemical properties.

Conclusions: The B contents was highly dependent on variables K_2O, P_2O_5, Mg^+ and Na^+. The average B concentration was within mid-range values in vertisols and low in brown and ferralitic soils, with high variability. The contents of assimilable B should be further studied, along with the effect of limiting chemical, physical, and biological factors on the soil.

Key words: assimilable boron, soils, chemical properties.

Introduction

Boron (B) is very scarce on the surface of the earth, where it is not evenly distributed. It is considered the most motile element among microelements, and the soluble fraction is relatively low. The total boron contents in the soil vary between 2 and 200 mg kg^{-1}; however, only a little fraction (3-5%) is available to crops. The assimilable boron is less than 5 mg kg^{-1} (Arunkumar et al., 2018).

Various authors have mentioned the importance of B to sugar cane, its influence on crop yields and sugar cane. It is a nutrient involved in sugar transport, synthesis of proteins, and structuring of cell walls, which can be seen in the quality of the final product, and therefore, in the efficiency of sugar conversion and the quality of juices (Kirkby & Römheld, 2007).

B efficiency is directly associated with the actions it has, which is evidenced in fields with low stem quality (less diameter and lignification), short internodes, scarce plantlets, and low sugar conversion due to early yellowing of tops, and new leaves (Fageria Baligar & Clark, 2002). Among all micronutrients, B has been reported as one of the scarcest in the soils of most countries (Mellis, Quaggio & Junqueira, 2008; Sainz Rozas et al., 2013;

Torri, Urricariet & Lavado, 2015; Khadka et al., 2018).

Several factors limit the behavior and dynamics of this element in the soil, some of which include low native content, slightly acidic-basic reaction, high saturation of changeable cations, growing demand over the crop, and nutritional unbalance induced by the excessive utilization of fertilizers (Carmona, Díaz & Mira, 2007).

In Cuba, little evidence of B contents in the soil and its association with other properties have been found. The existence of deficiencies in certain crops, and the types of soils have encouraged deeper analysis of availability and studies of this element, due to its importance for the nutritional balance of plants. The aim of this paper is to determine the content of assimilable B and chemical properties that condition its availability in three of the main soil types where sugar cane is cultivated.

Materials and Methods

The study was conducted at the Provincial Station of Sugar Cane Research, in Holguin, Cuba. The samples were taken at random from georeferenced sites, on the surface horizon of three of the main soil types where sugar cane is cultivated in Cuba: Ferralitic, Brown, and Vertisol (Hernández et al. (2015), with the evaluation of 42, 42, and 45 samples (0-20 cm).

The samples were processed according to the Fertilizers and Amendments Recommendations Service (SERFE). The variables of the study were determined, pH in H_2O and pH in KCl (potentiometric method, soil solution ratio 1:2,5), assimilable P_2O_5 and K_2O (H_2SO_4 0.1 N), organic matter in the soil (DMS) using the Walkley-Black method, changeable cations (cmol kg^{-1}), calcium, magnesium, sodium and potassium (Ca^{2+}, Mg^{2+}, Na^+ y K^+), and Cationic Exchange Capacity (CEC), extraction with ammonium acetate 1N, buffered pH=7, according to the standards set by INICA (1990). The assimilable B in the soil was determined by extraction with hot water at the Unit for Laboratory Projects (ULP), Center for Nickel Research (CEDINIQ)- Moa. The category ranges set by Agrolab, (2005) were used to classify the concentration of assimilable boron in the soil: low (<0.5 mg kg^{-1}), mid (0.5 a 2.0 mg kg^{-1}), and high (>2.0 mg kg^{-1}).

The data were standardized using Gaus's Z value, considering all the data inside the population, with ± 1.96 standard deviation. The means and standard errors were determined case by case. Analyses of variance were performed and the Tukey (p<0.5) test for multiple mean comparisons was applied. Statistical processing was done using STATISTICA 8, StatSoft.

Results and discussion

Table 1 shows the statistical parameters of the chemical properties that characterize the Ferralitic, Brown, and Vertisol soils in the study. The ferralitic soils showed a slightly acidic pH, the average CEC was 18.22 cmol kg^{-1}, the DMS contents were medium, and the interchangeable values of Ca were low. The pH of brown and vertisol soils were near neutral, CEC > 50 cmol kg^{-1}, DMS was found in the middle, and Ca^{2+} concentration was high in the change complex.

The Na^+ concentration was normal in ferralitic and brown soils, whereas it was 3.79-fold higher than K^+ in vertisols. The assimilable P_2O_2 was significantly abundant, with a great variability in the three types. The ferralitic soils ranked mid-high, and the brown and vertisols were high to very high, according to the indexes set up by SERFE.

Table 1. Descriptive statistics of the chemical properties of ferralitic, brown and vertisol soils with sugar cane

Variable	U/M	Ferralíticos			Pardos Sialíticos			Vertisol		
		n	X±Sx	CV	n	X±Sx	CV	n	X±Sx	CV
pH(H_2O)	$-log_{10}(H^+)$	44	6.57±0.06	11.48	41	7.25±0.09	10.78	40	7.49±0.06	12.52
pH(KCl)		45	5.57±0.07	10.41	42	6.19±0.10	11.98	42	6.20±0.09	8.57
MOS	%	44	3.26±0.08	22.5	41	3.12±0.05	18.76	39	2.86±0.04	17.14
P_2O_5	mg $100g^{-1}$	42	4.76±3.26	98.32	40	7.75±6.35	101.1	41	12.20±10.36	67.15
K_2O		42	17.25±5.27	53.76	42	19.81±10.87	42.62	41	26.05±17.33	40.68
Ca^{2+}		44	13.36±2.15	28.45	41	39.87±24.18	42.69	41	40.89±28.53	33.26
Mg^{2+}		39	3.78±0.17	28.44	40	7.17±2.53	57.6	42	14.79±8.88	51.29
Na^+	cmol kg^{-1}	34	0.34±0.02	22.54	41	0.70±0.03	67.78	41	3.00±.2.41	109.41
K^+		43	0.43±0.04	45.37	32	0.83±0.01	32.21	42	0.79±0.04	64.92
CIC		43	18.22±2.34	21.76	42	50.39±31.44	36.45	40	60.96±43.56	27.56
BORO	mg kg^{-1}	38	0.49±0.02	78.43	40	0.41±0.01	65.28	42	0.88±0.08	82.63

n: number of cases; X: mean value; Sx: standard error; VC: variation coefficient.

The mean contents of assimilable B (Table 2) shows the following assimilation sequence: Verstisol > ferralitic > brown soils, respectively. These concentrations characterize vertisols as mid-supplied, and differ significantly from ferralitic and brown soils, which are near the critical limit of availability, according to Agrolab (2005), and they have no statistical differences. Low availability results of B were observed by Sainz Rozas et al. (2013) and Khadka et al. (2016). Khadka et al. (2018) reported low assimilable B contents, with mean values of 0.21 mg kg^{-1}.

Table 2. Concentration of assimilable B in ferralitic, brown and vertisol soils with sugar cane

Soil type	Boron (mg kg^{-1})
Ferralitic	0.48^b
Sialitic brown	0.41^b
Vertisol	0.88^a
ESx	0.27

Note: superscript values with unequal letters indicate significant differences for $p< 0.05$.

However, in the conditions of the soils studied, B was not a limiting nutrient, at least in vertisol. Khadka et al. (2015) found assimilable B values inside the mean range of availability in soils with the pH between 7.11 and 8.3. Although the brown soils have similar properties to vertisol, the low tenors of B in the former are associated to better draining conditions which can easily wash away B from the surface. According to Torri et al. (2015) with the pH around 7, the predominant form in the soil is H_3BO_3, and it washes out easily.

The content of B in the soil was very variable (Table 1). The VC of the three types swung between 78.43% and 82.63 %, the highest value found in ferralitic and vertisol soils. This behavior is strongly influenced by the type of parental material, remains of meteorites, physical and chemical properties, and environmental factors that originated them. B concentrations at high variability have been found by Khadka, et al. (2017a), Khadka et al. (2017b), and Khadka et al. (2018), with VC of 123.27% and 120.40%, respectively. Other authors, like Hernández & Francisco, (2017) reported VC of 53%, particularly, in soils with the pH between neutral and alkaline.

The soil properties show a high influence on the concentration of B (Table 3). The pH is closely associated to the availability of micronutrients, and their concentrations decreased with higher pH. However, the concentration of molybdenum is increased at pH neutral or alkaline. The availability of B is not largely affected by the pH of the soil, because it is soluble in most forms. However, its concentration in the solution of the soil was slightly greater at acidic or neutral pH (Torri et al., 2015). Generally, the correlation of B with the pH was weak, and the soil types did not undergo any significant changes after the reaction with the soil.

Table 3. Concentration ratio of assimilable B to soil properties

Variables	All	Ferralitic	Brown	Vertisol
	Correlation coefficient			
B & pH(KCl)	0.22*	- 0.03	0.11	- 0.09
B & pH(H_2O)	0.26*	- 0.46*	0.22	- 0.02
B & P_2O_5	0.35**	- 0.01	0.06	0.29
B & K_2O	0.52**	0.53*	0.41*	0.50**
B & DMS	- 0.23*	- 0.04	0.08	- 0.35
B & Ca^{2+}	0.24*	0.01	0.19	- 0.06
B & Mg^{2+}	0.37**	- 0.01	0.14	0.01
B & Na^{+}	0.53**	0.29	0.49**	0.37*
B & K^{+}	- 0.08	0.14	0.39*	- 0.48**
B & CEC	0.36**	0.10	0.27	0.05

**highly significant $p<0.01$, *significant $p<0.05$

In the brown and vertisol soils, B has a highly significant positive correlation with monovalent ions. The synergic or antagonist interaction with most nutrients (N, P, K, Ca, and Mg) may have an influence on the regulation of B in the soil, and the availability to plants (Arunkumar et al., 2018). Sainz Rozas et al. (2013) found significant correlations with the pH, CEC, and DMS in Argentinian soils.

The K_2O had a positive correlation with B in the three soil types. The content of B in vertisol might be linked to high concentrations of K_2O found in them, compared to the values found in ferralitic and brown soils. Yamada, (2004) said that the absorption of potassium is increased with the presence of boron, and in many cases, the deficiency of potassium may be caused by the boron deficiencies. The positive and significant correlation of B with Na^+ in brown and vertisol soils is linked to a flat topography, generally low, associated to hydromorphic processes and risk of salinization due to the proximity of the water table. Gupta et al. (1985) considered that B, like Na, is soluble, and accumulates where salts are deposited, which explains why saline and sodium soils are frequently rich in B. The antagonist association of B with interchangeable K found in vertisol soils may be caused by an excess of K in the absorbing complex that leads to unbalances in the absorption of B.

Conclusions

The contents of B were highly dependent on variables K_2O, P_2O_5, Mg^+, and Na^+. The average concentration of B was within mid-range values in vertisols, and low in brown and ferralitic soils, with a high variability. The contents of assimilable B should be further studied, along with the effects of limiting chemical, physical, and biological factors on the soil.

Author contribution

Yakelin Cobo Vidal: research planning, assembling, analysis and interpretation of results, manuscript redaction, final review.

Elio Angarica Baró: research planning, statistical analysis of results, manuscript redaction, final review.

George Martín Gutiérrez: Analysis and interpretation of results, redaction of the final manuscript, final review.

Adrián Serrano Gutierrez: Sample collections, analysis of results, redaction of the manuscript, final review.

Juan Alejandro Villazón Gómez: Sample collections, analysis of results, redaction of the manuscript, final review.

Alegna Rodríguez Fajardo: analysis of results, Georeferencing and location of sample collection sites, redaction of the manuscript, final review.

Conflicts of interest

The authors declare no conflicts of interest.

Acknowledgments

The authors appreciate the collaboration of the Unit for Laboratory Projects (ULP), Center for Nickel Research (CEDINIQ)- Moa, for the soil analyses.

References

Agrolab. (2005). *Guía de referencia para interpretación de análisis de suelo.* México: Agrolab. Análisis Técnico, S.A. de C.V., Laboratorios Acreditados ISO 17025:2005. Retrieved on May 7, 2017, from: http://www.agrolab.com.mx/sitev002/sitev001/assets/interpretacion_fertsuel.pdf

Arunkumar, B. R., Thippeshappa, G. N., Anjali, M. C. & Prashanth, K. M. (2018). Boron: A critical micronutrient for crop growth and productivity. *Journal of Pharmacognosy and Phytochemistry, 7*(2), 2738-2741. Retrieved on March 25, 2019, from: http://www.phytojournal.com/archives/2018/vol7issue2/PartAM/7-1-371-833.pdf

Carmona, M, A., Díaz, M. M. & Mira, C. J. (2007).*Compatibilidad de fungicidas en mezcla con micronutrientes quelatados en la zona de Urabá para el control de la Zigatoka negra el cultivo del banano.* Colombia: Asociación de Bananeros de Colombia Augura. Centro de Investigaciones del banano Cenibanano, Cosmoagro.

Fageria, N. K., Baligar, V. C. & Clark, R.B. (2002). Micronutrients in Crop Production. *Advances in Agronomy*, *77*, 185-268. Retrieved on September 27, 2014, from: https://www.researchgate.net/publication/221995345_Micronutrients_in_Crop_Production

Gupta, U. C., Jame, Y. W., Campbell, C. A., Leyshon, A. J. & Nicholaichuk, W. (1985). Boron toxicity and deficiency: a review. Can. *J. Soil Sci*., *65* (3), 381-409. Retrieved on June 6, 2017, from: https://www.nrcresearchpress.com/doi/pdf/10.4141/cjss85-044

Hernández González, M. M. & Francisco Betancourt, D. A. (2017). Estimación de la fertilidad en suelos volcánicos (Tenerife, España) para el cultivo de trigo por medio de teledetección y SIG. SJSS. *Spanish Journal of Soil Science*, *7*(3), 201-221. Retrieved on January 10, 2019, from: https://sjss.universia.net/article/viewFile/2789/2398

Hernández Jiménez, A., Pérez Jiménez, J. M., Bosch, Infante, D. & Castro Speck. N. (2015). *Clasificación de los suelos de Cuba.* Mayabeque, Cuba: Instituto Nacional de Ciencias Agrícolas. Retrieved on February 16, 2019, from: http://ediciones.inca.edu.cu/files/libros/clasificacionsueloscuba_%202015.pdf

Instituto Nacional de Investigaciones de la Caña de Azúcar. (1990). *Normas Metodológicas del Departamento de Suelos y Agroquímicas.* (Tomo I y II). La Habana: Departamento de Suelos y Agroquímicas.

Khadka, D., Lamichhane, S., Thapa, B., Rawal N., Chalise, D. R., Vista, S. P. & Lakhe, L. (24-25 March, 2015). Assessment of Soil Fertility Status and Preparation of Their Maps of National Wheat Research Program, Bhairahawa, Nepal. En KB Karki, et al. (editors), *Proceedings of the Second National Soil Fertility Research Workshop.* (pp. 330-340). Lalitpur, Nepal: Soil Science Division, Khumaltar. Retrieved on May 29, 2017, from: https://www.researchgate.net/publication/328758860_Assessment_of_soil_fertility_status_and_preparation_of_their_maps_of_National_Wheat_Research_Program_NWRP_Bhairahawa_Nepal

Khadka, D., Lamichhane, S., Thapa, B., Baral, B. R. & Adhikari P. (2016). An Assessment of Soil Fertility Status of National Maize Research Program, Rampur, Chitwan, Nepal. *Imperial Journal of Interdisciplinary Research, 2*(5), 1798-1807. Retrieved on April 29, 2019, from: https://www.onlinejournal.in/IJIRV2I5/324.pdf.

Khadka, D., Lamichhane, S., Tiwari D. N. & Mishra K. (2017a). Assessment of soil fertility status of National Rice Research Program, Hardinath, Dhanusha, Nepal. *International Journal of Agricultural and Environmental Research, 3*(1), 86-105. Retrieved on April 30, 2019, from: https://www.ijaaer.com/papers/IJAER-09-2017-V3i1.pdf

Khadka, D., Lamichhane, S., Shrestha, S. R. & Pant, B. B. (2017b). Evaluation of soil fertility status of Regional Agricultural Research Station, Tarahara, Sunsari, Nepal. *Eurasian Journal of Soil Science, 6* (4) 295-306. Retrieved on April 20, 2019, from: http://ejss.fesss.org/10.18393/ejss.303512/pdf.

Khadka, D., Lamichhane, S., Bhantana, P., Ansari, A. R, Joshi, S. & Baruwal P. (2018). Soil fertility assessment and mapping of Chungbang farm, Pakhribas, Dhankuta, Nepal. *Advances in Plants & Agriculture Research, 8*(3), 219 – 227. Retrieved on April 30, 2019, from: https://medcraveonline.com/APAR/APAR-08-00317.pdf

Kirkby, E. & Römheld, V. (2007). Micronutrientes en la Fisiologíade las plantas: funciones, absorción y movilidad. [Versión en español] Proceedings 543. York, UK.: The International Fertilizer Society. Retrieved on February 16, 2019, from: http://exa.unne.edu.ar/biologia/fisiologia.vegetal/MicronutrientesenlaFisiologia.pdf

Mellis, E.V., Quaggio, J.A. & Junqueira, L.A. (2008). *Zinc Fact Sheet: Sugarcane.* Retrieved on May 29, 2014, from: http://www.zinc.org/wp-content/uploads/sites/4/2015/04/pdf_Sugarcane-fact-sheet.pdf

Sainz Rozas, H. R., Eyherabide, M., Echeverría, H. E., Barbier, P., Angelini, H., Larrea,G. E.,… Barraco, M. (22 a 23 de mayo, 2013) ¿Cuál es el estado de la fertilidad de los suelos argentinos? Conferencias. En *Simposio Fertilidad 2013.* (pp. 62-72). Rosario, Argentina: IPNI-FERTILIZAR. Retrieved on February 16, 2019, from: https://inta.gob.ar/sites/default/files/inta.estado-fertilidad-suelos-argentinos.pdf

Torri, S. I, Urricariet, A. S. & Lavado, R. S. (2015). Micronutrientes y Elementos Traza. En F. García F & H. Echeverría (eds.), *Fertilidad de suelos y fertilización de cultivos.* (2da ed., pp. 189-203, 525). Argentina: EEA Balcarce. Retrieved on May 10, 2017, from: https://www.researchgate.net/publication/283492275_Micronutrientes_y_Elementos_Traza.

Yamada, T. (2000). BORO: ¿Se están aplicando las dosis suficientes para el adecuado desarrollo de las plantas? POTAFOS: *Informaciones Agronómicas,* (41), 8-13. Retrieved on January 10, 2018, from: http://www.ipni.net/publication/ia-lahp.nsf/0/2FF1BD79ED23FCBF852579A300799E60/$FILE/Boro.pdf