Open Access Library Journal
2024, Volume 11, e11564
ISSN Online: 2333-9721
ISSN Print: 2333-9705

Zinc in Different Soils and Foliar Content in Commercial Corn Planted on Calcareous Soils of Quintana Roo, Mexico

Jorge Humberto Ramírez Silva, Alejandro Cano González*, Nelda Guadalupe Uzcanga Pérez, Genovevo Ramírez Jaramillo

Centro de Investigación Regional Sureste del Instituto Nacional de Investigaciones Forestales, Agrícolas and Pecuarias (INIFAP), Mérida, Yucatán, México
Email: *cano.alejandro@inifap.gob.mx

How to cite this paper: Silva, J.H.R., González, A.C., Pérez, N.G.U. and Jaramillo, G.R. (2024) Zinc in Different Soils and Foliar Content in Commercial Corn Planted on Calcareous Soils of Quintana Roo, Mexico. *Open Access Library Journal*, **11**: e11564.
https://doi.org/10.4236/oalib.1111564

Received: April 12, 2024
Accepted: May 28, 2024
Published: May 31, 2024

Abstract

Corn is a highly demanding Zinc (**Zn**) crop, so it is very likely that deficiencies are present in the calcareous soils of the Yucatan Peninsula where alkalinity limits the availability of this element. High concentrations of Carbonates (CO_3=) and Hydroxides (OH-) can form Low-Zinc solubility complexes, not available to plants when Zinc Hydroxide [$Zn(OH)_2$] or $ZnCO_3$ are induced. Field experience shows that commercial corn suffers from Zinc deficiencies, but this is not properly quantified. Therefore, this work aimed to asses the degree of Zn deficiencies in soil and plants of commercial corn considering eight agricultural locations of ten hectares each with different types of soils such as *Vertisols* (V), *rhodic Luvisols* (ro LV), *chromic Luvisol* (cr LV), *rendzic Luvisol* (rz LV), *rendzic Leptosol* (rz LP). Nine soil samples were taken on each ten hectares using a Systematic Random Model. The soil samples were analysed for available cationic Zinc (Zn++) reported in parts per million (ppm) and, during the reproductive stage of corn, one composite leaves sample, per each location, was taken for Foliar-Zinc analysis. The results were compared with the sufficiency ranges reported by the literature. 87.5% of the locations, with their related soils, showed Zn deficiencies in both soil and foliage. Although there is a good *qualitative* relationship between Soil-Zn and Foliar-Zn the *quantitative* relation was very low with a Determination Coefficient ($\mathbf{r}^2$) of 0.044. Other soil attributes such as pH did not show any good correlation with foliar Zn nor with Soil Zinc.

Subject Areas

Agricultural Engineering

Keywords

Calcareous Soils, Deficiencies, Microelements

1. Introduction

It has been widely commented that soils of the Yucatan Peninsula (YP) of Mexico, being of calcareous origin, may have chemical limitations for the optimal growth of different crops. One-third of the world's soils are of calcareous origin [1], and usually present considerable soil microelements disorders such as Zinc (Zn) due to high concentrations of carbonates (CO3=) and the anionic form such as OH- [2]. Due to these two factors, the microelement Zinc (Zn) is so tired that chemical complexes of low solubility are formed. The availability of this element depends on pH and decreases 100 times for each unit of pH increase.

Corn is a highly demanding zinc crop, but its importance has been minimized due to the daily interest in the primary elements nitrogen, phosphorus and potassium. Zn is currently perhaps the most deficient micronutrient in the world and its deficiency can reduce crop yields by 20% even without showing symptoms known as hidden hunger. The structure and functionality of many enzymes depend on the presence of Zn in the plant and approximately 2,800 proteins depend on Zn. It is required for the synthesis of carbohydrates during photosynthesis and the transformation of sugars into starch. It also participates in the metabolism of hormones by regulating the level of auxin through the synthesis of the amino acid tryptophan [3].

It is very likely that more than the 300 thousand hectares planted with corn in the YP, with very low average yields of 1.09 $t \cdot ha^{-1}$ in the state of Yucatan, 1.15 $t \cdot ha^{-1}$ in the state of Quintana Roo and 2.3 $t \cdot ha^{-1}$ in the state of Campeche [4], have Zn deficiencies not properly quantified until now.

As mentioned, the state of Quintana Roo, in the YP, is an entity with corn yields of only 1.15 $t \cdot ha^{-1}$; and although Zn deficiencies have been observed in different soils, the severity of the problem needs to be quantified. Consequently, this work aims to measure the degree of Zinc deficiencies in different soils and corn plants, as well as the relationship between the nutritional degree and other soil attributes related to carbonates such as the pH.

2. Materials

Sampled Locations

Eight Locations (**Table 1**), planted with commercial corn, were selected: two (Nicolas Bravo and Emiliano Zapata) located in *Vertisols* (VR), one (Puerto Arturo) in *rhodic Luvisol* (ro LV), three (Álvaro Obregón, Juan Sarabia 1 and Salamanca) in *chromic Luvisol* (cr LV), one (Juan Sarabia 2) in *rendzic Luvisol* (rz LV) and one (Juan Sarabia 2) in *rendzic Leptosol* (rz LP). The corn plantations were located in the municipalities of Othón P. Blanco and Bacalar both in the south part of the state and José María Morelos and Felipe Carrillo Puerto in the center part of the state. The representative soils sampled in the study are shown in **Figure 1** (*VR*), **Figure 2** (*ro LV*), **Figure 3** (*rz LV*) and **Figure 4** (rz LP).

The pH ranged from 6.65 (Alvaro Obregón-cr LV) to 7.93 (Emiliano Zapata-VR). Five out of eight soils showed pH's classified as *Moderatly Alkaline;* and the other three soils as *Neutral* according to The Mexican Official Standars [5].

Table 1. Locations with commercial plots and related soil orders and pH's in the state of Quintana Roo Mexico.

Location	Soil orders	Municipality	pH
Nicolas Bravo	*Vertisol* (*VR*)	*Othon P. Blanco*	*7.03* (*Neutral*)
Emiliano Zapata	*Vertisol* (*VR*)	*Felipe Carrillo Puerto*	7.93 (*Moderatly Alkaline*)
Puerto Arturo	*Rhodic luvisol* (*ro LV*)	*José María Morelos*	6.86 (*Neutral*)
Alvaro Obregón	*Chromic luvisol* (*cr LV*)	*Othon P. Blanco*	6.65 (*Neutral*)
Juan Sarabia 1	*Chromic luvisol* (*cr LV*)	*Othon P. Blanco*	7.36 (*Moderatly Alkaline*)
Salamanca	*Chromic luvsiol* (*cr LV*)	*Bacalar*	7.73 (*Moderatly Alkaline*)
Juan Sarabia 2	*Rendzic luvisol* (*rz LV*)	*Othon P. Blanco*	7.61 (*Moderatly Alkaline*)
Juan Sarabia 3	*Rendzic leptosol* (*rz LP*)	*Othon P. Blanco*	7.54 (*Moderatly Alkaline*)

Figure 1. Vertisol (*VR*).

Figure 2. Rhodic Luvisol (*ro LV*).

Figure 3. Rendzic Luvisol (*rz LV*).

Figure 4. Rendzic Leptosol (rz LP).

3. Methods

3.1. Soil Samples and Statistical Analysis

Nine individual soil samples, of the first horizon, were taken in each location considering the Systematic Random Model [6] based on taking a first starting georeferenced point from which the other eight points are located considering pre-established distances and directions.

One-kilogram soil samples were taken to each of nine points and Zn content was analyzed by the DTPA (*Diethylenetriaminepentaacetic Acid*) method and determined with an atomic absorption spectrophotometer. The results in parts per million (ppm) were subjected to an Analysis of Variance (ANOVA) using the Stat Graphic program and the means were compared with the Fisher test. The locations and their respective soil types were considered as treatments (8) and the 9 sampling points as repetitions. The results were compared with the references (**3 - 10 ppm**) reported by Phytomonitor (2015) [7].

3.2. Leaf Samples

During the reproductive stage, 30 corn leaves were collected in each location, making a composite sample in the same area where soils were collected. The samples were taken from leaves opposite to the cob and dried in an oven at 65˚C for 36 hours to be ground and analyzed, reporting the Zn content in percentage (%). The results were compared with the sufficiency ranges reported by the literature such as Phytomonitor (2015) (25 - 100 ppm) [7], Ratto and Miguez (2006) (20 ppm) [8] and Barbezan (1998) (25 - 150 ppm) [9]. The relationship between both the Zn content in the foliage vs. the Zn content in the soil, and vs. the soil pH was measured by calculating the Determination Coefficient (**DC** = $\mathbf{r^2}$).

4. Results

4.1. Statistical Analysis and Zinc in Soils

Table 2 displays the ANOVA of soil zinc contents in eight locations with different types of soils. High significant differences were found between locations. After arranging the means from lowest to highest contents, the Fisher Test showed that there were two groups: the first one, formed with seven (87.5%) out of eight locations with Zn deficiencies graded with letter ***A*** and the second one formed with just one location graded with letter ***B*** (Table 3). All locations with the same letter are statistically equal and do not show statistical differences.

Juan Sarabia 3 with the stony rz LP had the lowest value with 0.50 ppm followed by Emiliano Zapata (*VR*), Alvaro Obregon (*cr LV*), Juan Sarabia 1 (*cr LV*), Nicolas Bravo (*VR*), Puerto Arturo (*ro LV*), Juan Sarabia 2 (*rz LV*) with 0.61, 0.71, 0.97, 1.61, 1.83, 1.86 and 9.28 respectively. Juan Sarabia 2 (*rz LV*) being the location with the extremely highest level of Zinc in the soil.

Table 2. Analysis of Variance (ANOVA) for Zinc content (ppm) in soils dedicated to corn production in eight locations of Quintana Roo Mexico.

Source of variation	Square Sum	Degree of freedom	Mean square	F	P
Between Locations	538.636	7	76.948	14.03	0.00
Inside Locations	350.995	64	5.4843		
Total	889.631	71			

Table 3. Zinc content (ppm) in different soils and locations dedicated to corn production in Quintana Roo Mexico.

Location	Average	Comparison of means	Degree of suficiency
Juan Sarabia 3 (rz LP)	0.50	A	Defficient
Salamanca (cr LV)	0.61	A	Defficient
Emiliano Zapata (VR)	0.71	A	Defficient
Alvaro Obregon (cr LV)	0.97	A	Defficient
Juan Sarabia 1 (crLV)	1.61	A	Defficient
Nicolas Bravo (VR)	1.83	A	Defficient
Puerto Arturo (ro LV)	1.86	A	Defficient
Juan Sarabia 2 (rz LV)	9.28	B	Suficient

4.2. Foliar Analysis of Commercial Corn in Different Locations

It is observed in Table 4 that 87.5% of the locations (7) present Zn deficiencies in corn leaves. Only Puerto Arturo with LVcr presents Zn contents above the critical limit of 20 ppm suggested by Ratto and Miguez (2006) [8] and also by ranges established by Phytomonitor (2015) of 25 to 100 ppm [7] and from 25 to 150 ppm of Barbezan (1998) [9].

5. Discussion

The eight locations indicated in both red (7 locations) and green (1 location) in Table 3 could not be the same classification when taking other references like those suggested by Lindsay and Norvell (1978) of 0.8 ppm [10], as optimum level, for corn in calcareous and non-calcareous soils. In that way, only three (37.5%) out of eight locations would be showing Zinc deficiencies.

However, it seems that most of the soils with Zinc deficiencies in red color (Table 3) considering the critical contents of Phytomonitor [7] matched perfectly with those of Table 4 related to Zinc in the leaves. However, the relationship between Zinc in the soil vs. Zinc in the foliage was quantified by the Determination Coefficient (r^2) as is shown in Table 5. It is considered that a **DC** (r^2) of 1 is when the changes of a Variable-Y depend 100% on changes of another Variable-X.

It was found a very poor **DC** ($r^2 = 0.044$) between Foliar-Zn vs. Soil-Zn. The same trend happened with the relationship between Soil-pH and Soil-Zn with a **DC**, $r^2 = 0.044$. However, the best, but still very poor relationship, was found between Soil-pH vs. Foliar-Zn with a DC of 0.21. It means that just 21% of the values founded in the Foliar-Zn can be explained by changes in the Soil-pH.

No soil attribute like the Soil-Zinc and the Soil-pH clearly explains the Zn content in the leaves and therefore deficiencies and/or sufficiencies should be explained by other factors. The studies by Buffa and Ratto (2005), in soils of Córdoba Argentina, suggest the need to better understand, the role of mineralogy and organic components to explain the availability of soil microelements such as Zinc.

Table 4. Zn content (ppm) in commercial corn leaves in different soils and locations in Quintana Roo, Mexico.

Location	Average	Grade of sufficiency
Juan Sarabia 3 (rz LP)	12	Defficient
Salamanca (cr LV)	10	Defficient
Emiliano Zapata (VR)	13	Defficient
Alvaro Obregon (cr LV)	14	Defficient
Juan Sarabia 1 (crLV)	10	Defficient
Nicolas Bravo (VR)	14	Defficient
Puerto Arturo (ro LV)	31	Suficient
Juan Sarabia 2 (rz LV)	17	Defficient

Table 5. Determination Coefficients (r^2) considering Foliar-Zn, Soil-Zn and Soil-pH when comparing them to each other.

Location-Soil	Foliar-Zn (ppm)	Soil-Zn (ppm)	Soil-pH
Juan Sarabia 3 (LPrz)	12	0.50	7.54
Salamanca (LVcr)	10	0.61	7.73
Emiliano Zapata (VR)	13	0.71	7.93
Alvaro Obregon (LVcr)	14	0.97	6.65
Juan Sarabia (LVcr)	10	1.61	7.36
Nicolas Bravo (VR)	14	1.83	7.03
Puerto Arturo (LVcr)	31	1.86	6.86
Juan Sarabia 2 (LVrz)	17	9.28	7.61
r^2 (Foliar-Zn vs. Soil-Zn) = 0.044			
r^2 (Soil-pH vs. Soil-Zn) = 0.016			
r^2 (Soil-pH vs. Foliar-Zn) = 0.21			

6. Conclusions

Under field conditions, commercial corn suffers from Zinc deficiencies, but this is not properly proven even though corn is a highly demanding zinc crop. The importance of Zinc has been minimized due to the daily interest in the primary elements such as nitrogen, phosphorus and potassium. It was proposed to prove that zinc is a limited element in the calcareous soils of the YP in Mexico and therefore commercial corn suffers for Zinc deficiencies under field conditions.

The main findings of this work were the next:

1) The ANOVA of soil zinc contents in the eight locations, with different soils, showed significant statistical differences.

2) The Fisher Test showed that there were seven (87.5%) out of eight locations with Zn deficiencies.

3) Juan Sarabia 3 with the stony *rz LP* had the lowest Soil-Zinc value with 0.50 ppm

4) 87.5% of the locations (7) presented Zn deficiencies in corn leaves. Only Puerto Arturo with *cr LV* presents Zn contents above the critical limit.

5) Just 21% of the values found in the Foliar-Zn can be explained by changes in the Soil-pH.

6) No soil attribute like the Soil-Zinc and the Soil-pH clearly explains the Zn content in the leaves and therefore deficiencies and/or sufficiencies must be explained by other factors.

7) It is suggested to better understand, the role of other constraining factors such as the mineralogy and organic components to explain the availability of soil microelements such as Zinc.

Acknowledgements

We thank the National Institute of Forestry, Agricultural and Livestock Research (INIFAP) of MEXICO for financing this work, as part of the project: ***Manejo***

Integral de la Heterogeneidad de los Suelos Mecanizables de la Península de Yucatán. (***Comprehensive Management of the Heterogeneity of the Arable Soils of the Yucatan Peninsula***).

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Adams, M. (1995) Fundamentos de química de suelos. Universidad Central de Venezuela Consejo de Desarrollo Científico y Humanismo, Caracas, 385 p. https://books.google.co.ve/books?id=rjeVU6XFajEC&printsec=copyright&hl=es#v=onepage&q&f=false

[2] Silva, J.H.R., González, A.C. and Pérez, N.G.U. (2023) Zinc in Soil and Corn Leaves in a Calcareous Rhodic Luvisol from Yucatan Mexico with Acid and Subsoiling. *Open Access Library Journal*, **10**, e11014. https://doi.org/10.4236/oalib.1111014

[3] Fertilab (2024) La Importancia del Zinc en las Plantas y su Dinámica en el Suelo. https://www.fertilab.com.mx/Sitio/notas/Importancia%20del%20zinc%20en%20las%20plantas.pdf

[4] Servicio de Información Agroalimentaria y Pesquera (SIAP) (2023) Anuario Estadístico de la Producción Agrícola. https://nube.siap.gob.mx/cierreagricola/

[5] Norma Oficial Mexicana. Nom-021-Semarnat-2000. http://www.ordenjuridico.gob.mx/Documentos/Federal/wo69255.pdf

[6] Iglesias Martínez, L. (1998) Muestreo de areas: Diseño de muestras y estimación en pequeñas áreas. Tesis Doctoral. Departamento de Economía y Ciencias Sociales Agraria. Escuela Técnica Superior de Ingenieros Agrónomos, Universidad Politécnica de Madrid, 214 p. https://oa.upm.es/394/1/LUIS_IGLESIAS_MARTINEZ.pdf

[7] Phytomonitor (2015) Análisis de Fertilidad de suelos y niveles de suficiencia. Reportes de Laboratorio, Culiacán Sinaloa. https://phytomonitor.com.mx/

[8] Ratto, S.E. and Miguez, F.H. (2006) Informaciones Agronómicas de Hispanoamérica (Northern Latin America, Mexico and Central America). A Publication of the International Plant Nutrition Institute (IPNI), 8-15. http://www.ipni.net/publication/ia-lahp.nsf/issue/IA-LAHP-2006-4

[9] Barbezan, M. (1998) Análisis de plantas, y síntomas visuales de deficiencia de nutrientes. Facultad de Agronomía. Universidad de la Republica Montevideo-Uruguay, 27 p. https://exa.unne.edu.ar/biologia/fisiologia.vegetal/Analisisdeplantasysintomasdedeficiencias.pdf

[10] Lindsay, W.L. and Norvell, W.A. (1978) Development of a DTPA Soil Test for Zinc, Iron, Manganese and Copper. *Soil Science Society of America Journal*, **42**, 421-428. https://acsess.onlinelibrary.wiley.com/doi/abs/10.2136/sssaj1978.03615995004200030009x https://doi.org/10.2136/sssaj1978.03615995004200030009x