

Chemical characterization of macro elements in soils cultivated with Harton plantain (*Musa* AAB Simmonds) in the department of Cordoba, Colombia

Caracterización química de macro-elementos en suelos cultivados con plátano (*Musa* AAB Simmonds) en el departamento de Córdoba, Colombia

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Abstract

Fertilizer recommendations for harton plantain (*Musa* AAB Simmonds) crop should be done by interpreting the chemical characteristics of soils and principally based in technical adjustments in relation to the nutritional potential of soils. The aim of this study was to evaluate the chemical characteristics of macroelements in soil in 40 farms cultivated with harton plantain in the department of Córdoba, Colombia. The parameters measured were: pH, organic matter (O.M.), P, S, Ca, Mg, Na, K, according to the analytical procedures proposed by Geographic Institute Agustín Codazzi (IGAC). Analysis of variance and mean comparison tests (Tukey) of the data were performed. The analytical results showed that the soils had a moderately acidic reaction, with pH lower than 6 on the High Sinú zone and slightly alkaline with pH 6.5 in the coast zone. The organic matter content was less than 2.1%, P between 16.4 and 35.3 mg kg⁻¹ and S is deficient with values less than 13.5 mg kg⁻¹ in all municipalities. Values of Ca, Mg and K were high, but with a tendency of antagonism of the ion Ca with respect to K.

Key words: Calcareous soils, cationic relations, soil morphological features, soil fertility, plantains.

Resumen

Las recomendaciones de fertilización para el cultivo de plátano (*Musa* AAB Simmonds) deben estar basadas en las características químicas y el potencial de producción de los suelos. El objetivo en este trabajo fue evaluar las características químicas de macro-elementos presentes en suelos utilizados en la producción de plátano en el departamento de Córdoba, Colombia. Las evaluaciones se hicieron en 10 fincas por cada uno de cuatro municipios productores de plátano en el Alto Sinú (Valencia y Tierralta) y la región costanera (San Bernardo del Viento y Moñitos). Los parámetros determinados en el suelo fueron: pH, materia orgánica (M.O.), P, S, Ca, Mg, Na y K, según metodologías químicas propuestas por Instituto Geográfico Agustín Codazzi (IGAC). Los datos obtenidos fueron sometidos a análisis de varianza y pruebas de comparación de medias (Tukey). En los resultados analíticos se encontró que los suelos presentan reacción moderadamente ácida con pH < 6 en la zona del Alto Sinú, a ligeramente alcalina con pH de 6.5 en la zona costanera. Los contenidos de M.O. son < 2.1%, el P varía entre 16.4 y 35.3 mg/kg y el S es deficiente con valores < 13.5 mg/kg en todas las fincas. Los contenidos de Ca, Mg y K son altos, pero con

tendencia a antagonismos iónicos de Ca con respecto a K por las amplias relaciones catiónicas encontradas.

Palabras clave: Características morfológicas del suelo, fertilidad del suelo, plátano, relaciones catiónicas, suelos calcáreos.

Introduction

Plantain (*Musa* spp.) is a fruit of high socio-economic importance in the world; it has a high per-capita consumption and consolidated market inside Colombia. The global per-capita consumption of plantain and bananas in the last 40 years grew 72% (FAO, 2004). In Colombia are cultivated 381,000 ha with plantain representing 7% of the total agricultural area of the country. Coffee area represents the largest cultivated area (234,000 ha) equivalent to 61% of the total area and, the departments of Caldas, Quindio and Risaralda participate with 16% of the national production (Secretaría de Desarrollo Económico y Agroindustrial, 2006).

Historically, the regions of Valencia and Tierralta in the High Sinu and Moñito, the Cordobas, Puerto Escondido and San Antero in the Caribbean Coast of the department of Cordoba, are the responsible of most of the plantain production. In this department there are around 29,840 ha cultivated on a traditional way with a production of 255,977 t, for an average of 8.47 t/ha of fruit (Secretaría de Desarrollo Económico y Agroindustrial, 2006).

Despite that this yields/ha are low, there is a high interest for this crop, as a way of diversification due to its high demand and economical profitability, demonstrating the importance of this production system in the regional and national economy. According to the CCI (2000) fruit consumption changed from 900 t in 1992 to 2000 t for 1999, representing a growth rate of 12.1%; additionally, industrial processors consider that this behavior can be sustained in the next quinquennium, if the consumer interest in this produce continues.

Because of the existing expectations for the amplification of the agricultural frontier of this crop, it is needed to perform a suitable agronomic management and know the main problems that arise during growth and development of plantain crops, like: sowing dis-

tances, pathogen incidences and physico-chemical characterizations of soils. The last one is required for an adequate program of balanced fertilization, since it is one of the most influential factor in productivity as well as in resistance to pathogen attacks. Belalcázar (1991) considers that there should be an adequate balance between soil elements availability and the amount applied as fertilizer, because it is fundamental not only to reach economic yields but, to rationalize the high use of synthetic fertilizers.

Plantain crop is nutrient demanding, especially K, N and P, nonetheless yield differences have been observed in crops growing in equal agroecologic areas in productive zones of Cordoba. This can be associated with the amount of available nutrients present in the soil, the amount of applied fertilizer and the agronomic management of each plantation. In works done by Corpoica (2001) on plantain crops, it is highlighted that the nutritional plans for the crop in the region are not enough to ensure a sustainable production. Sarita and Damatto (2007) indicate that K is the nutrient that is extracted the most by the plantain fruit. Its low availability in soil reduces flowering, increases time to ripening, and reduces fruit size and weight. Additionally, the N deficiency causes foliar area reduction, which affects vegetative cycle and fruit quality. According to Espinosa *et al.* (1998), among the plantain requirements is important an adequate fertilization with N, P and K based on soil analysis, which allows a significant increase in yield. Martínez (1995) established that N as well as K are needed for plantain crop, because its deficiency prevents flowering, and for K, its total absence causes plant death.

This work aimed to characterize the chemical potential of the macro-elements present in soils used for plantain production in the department of Cordoba as a help in the fertilization programs for the crop.

Materials and methods

The first zone of study is localized in Tierralta and Valencia at the south of the department of Cordoba, at 70 MASL with annual average precipitation between 2000 and 3500 mm, 27 to 28 °C, relative humidity of 85%, solar brightness between 4.1 and 5 hours (Palencia *et al.*, 2006). The second zone is located in San Bernardo del Viento and Moñitos at the northwest of Cordoba, at 20 MASL, annual average precipitation between 1350 – 1500 mm, 27.5 and 27.4 °C, relative humidity between 84 and 87%, solar brightness of 5.5 hours (Palencia *et al.*, 2006).

For the soil study in these zones, that have high agroecological conditions variability, it was sampled 10 points in an equal number of plantain farms, with 2 and 3 years old plantations and under traditional management. In each of the 10 selected farms by municipality, 10 subsamples of rhizospheric soil at 30 cm depth were taken. These subsamples were homogenized to obtain a single sample of 2 kg/farm, which were packed, labeled and sent to the laboratory.

Once samples were collected in each zone, and according to the soil characteristics observed in the field, a site was selected to excavate a 1 x 1 x 1 m soil pit in order to describe the modal profile and, to classify the soil taxonomy per municipality according to the Taxonomical Classification of the Department of Agriculture of the United States (Soil Taxonomy, 1999).

In the laboratory, samples were dried at room temperature, grinded and sifted through a 2 mm sieve for their chemical characterization according to IGAC (1990), and approved by the Analytic Control of Soil Labs of the Colombian Society on Soil Science (CALS) and implemented by the Soil and Water Lab of the Universidad de Cordoba.

The analyses done were: pH by the potentiometer method; organic matter (O.M.) by the Walkley – Black method; S by monobasic calcium phosphate extraction and colorimetric determination; Ca, Mg, Na, K interchangeable bases by extraction with normal ammonium, pH 7.0; Ca and Mg by atomic absorption quantification; Na and K by atomic emission spectrophotometry; Cu, Fe, Zn, Mn by the diluted double acid and quantified by

atomic absorption (IGAC, 1990) (data not shown). Obtained data were subjected to analysis of variance and comparison test (Tukey) using the SAS program, version 9.1 (Statistical Analysis System2, 2006).

Results and discussion

Soil classification in the high part of the department of Cordoba

Physiographically most of the established plots with plantain in the municipality of Valencia are located in alluvial and colluvial valleys and in minor proportion in slightly flat to slightly undulated areas, originated from heterogeneous sediments with different fertility levels. In Tierralta, soils with plantain crops are mainly in alluvial valleys and in slightly undulated areas in geomorphological locations of ridges and hills, originated from acid claystones, sandstones and calcareous lenses with moderate to low fertility.

Analysis of the soil physical and chemical characteristics in both municipalities showed that they present an ochric epipedon and a cambic horizon of low pedological evolution; reason why they are classified in the order Inceptisol, suborder Ustepts and to the large groups of Eutropets, Haplustepts y Endoa-cuepts. These results are in agreement with studies done by the Corporacion Valle del Sinu (CVS, 2011) in Tierralta, Cordoba, where it is shown that these areas present Inceptisols, Entisols and Oxisols.

Chemical characteristics of the plantain producing zones in Tierralta-Cordoba

In the soil chemical analyses of Tierralta (Table 1) it was found that these soils have a slightly acid reaction with an average pH around 5.8. These conditions can be influenced by the high precipitation in the area, which allow the clay minerals nature change, reduce their negative charges and, in consequence, increase the change bases loses by lixiviation.

Average O.M. content was 1.9%, which can be considered as a medium value, is explained by the high mineralization and low supply of harvest residues that are reused in these zones. The addition of harvest residues

Table 1. Average, minimum and maximum values of the macronutrients contents in soils of plantain producing farms in Tierralta-Cordoba, Colombia.

Farms	Depth	pH	O.M.	P	S	Ca	Mg	K	Na	CTC	Ca/Mg	Ca/K	Mg/K	(Ca+Mg)
	cm		%	mg/kg				cmol ⁺ /kg-						/K
1	0-24	5.5	2.2	19.0	4.0	14.0	9.5	0.8	0.19	24.5	23.5	17.5	11.9	29.4
2	0-26	6.3	3.1	5.4	2.5	16.5	12.5	0.5	0.20	29.7	29.0	33.0	25.0	58.0
3	0-27-	5.9	1.2	19.0	16	9.5	8.5	0.5	0.10	16.7	18.0	19.0	17.0	36.0
4	0-26	5.7	1.5	34.0	6.0	7.5	9.0	0.6	0.10	17.3	16.5	12.5	15.0	27.5
5	0-23	5.6	1.2	30.0	4.1	11.0	7.0	0.4	0.10	18.5	18.0	27.5	17.5	45.0
6	0-27	6.0	3.4	66.3	3.5	16.0	5.0	1.6	0.10	22.8	21.0	10.0	3.1	13.1
7	0-25	6.0	1.2	41.1	3.5	7.5	10.5	0.6	0.10	18.7	18.0	12.5	17.5	30.0
8	0-29	5.2	1.3	16.0	5.0	11.0	10.0	0.7	0.10	22.2	21.0	15.7	14.3	30.0
9.	0-25	5.9	2.0	22.0	3.0	16.6	13.0	0.5	0.10	29.2	29.6	33.2	26.0	59.2
10	0-28	5.8	1.7	42.1	18	17.5	8.5	0.8	0.30	27.1	26.0	21.9	10.6	32.5
S.D.		0.3	0.8	16.5	5.3	3.7	2.3	0.3	0.1	4.6	4.5	8.0	6.3	13.5
Maximum		6.3	3.4	66.3	18	17.5	13.0	1.6	0.3	29.7	29.6	33.2	26.0	59.2
Minimum		5.2	1.2	5.4	2.5	7.5	5.0	0.4	0.1	16.7	16.5	10.0	3.1	13.1
Average.		5.8	1.9	29.5	6.6	12.7	9.4	0.7	0.1	22.7	22.1	20.3	15.8	36.1
CV (%)		5.0	40.6	55.8	81	28.9	24.2	46	47.1	20.4	20.5	39.5	40.1	37.5

Farms: ¹ Banquito. ² Isidro Peña. ³ Villa Eliana. ⁴ Ricardo B. ⁵ Madrina J. ⁶ Villa Luz. ⁷ Arenal. ⁸ Zone 6.

⁹Camaronera. ¹⁰ Ponderosa.

as organic matter increases the energetic sources in the soil that stimulate and favor the pedological environment for microorganism proliferation, this increments residues mineralization and supply of mineral elements (Muñoz, 1994).

The P and S average values were, respectively, 29.5 and 6.6 mg/kg, consider as medium and very low, with very high variation coefficients caused by the different materials that originate these soils. In the mineral nutrition of the plantain crop, P is considered as the element that contributes to root growth and S is essential for protein formation. Therefore, when establishing this crop in this region it is important to add both nutrients as fertilizers because there is a high possibility of deficiencies due to their low availability. In this sense, the suggestions of Bationo *et al.* (1991) should be taken into account, they indicate that the reactives used in the Bray II method for P extraction are highly acidic, thus the availability of this element can be overestimated.

Interchangeable bases like Ca, Mg and K in this zone show high levels, this indicate a

good reserve of this nutrients, which is attributed to the parental materials that originate this soil, like the claystones, mudstones and conglomerates with calcareous lenses. However, it seems that there is a slow restitution of these nutrients in the soil solution, which means the presence of slightly acidic pH in this zone. These results are opposite to the ones found by Combatt *et al.* (2005) who, on a chemical characterization of Tierralta's forest soils, found that the interchangeable bases are in deficient concentrations and indicate that this is the result of high lixiviation rates and loss of essential nutrients for growth and development of plantations located on hilly and high slope soils.

It is worthy to note that for a plantain fertilization plan, besides knowing the mineral content of the soil, it is also important to analyze the nutrient balance by calculating the cationic relationships. For this area the ratios, in average, are: Ca/Mg = 22.1, Ca/K = 20.3, Mg/K = 15.8 and Ca+Mg/K = 36.1 (Table 1). It is important to indicate that for this crop there is few information on soil cationic ratios that are directly associated with the

Table 2. Average, minimum and maximum values of the macronutrients contents in soils of plantain producing farms in Valencia -Córdoba, Colombia.

Farms	Depth	pH	O.M.	P	S	Ca	Mg	K	Na	CTC	Ca/M	Ca/K	Mg/K	(Ca+Mg)
	cm		%	mg/kg		cmol ⁺ /kg-					g		/K	
1	0-28	5.5	2.2	19.0	5.4	1.7	4.5	4.0	14.0	5.5	0.3	0.1	19.9	19.5
2	0-22	6.3	3.1	5.4	6.2	0.8	5.4	3.5	8.5	5.0	0.6	0.1	14.2	13.5
3	0-25	5.9	1.2	19.0	5.5	1.0	3.5	14	12.5	8.5	0.4	0.2	21.6	21.0
4	0-21	5.7	1.5	34.0	6.5	2.0	50.0	18	19.0	7.0	0.6	0.2	26.8	26.0
5	0-26	5.6	1.2	30.0	6.4	1.2	37.7	12	16.1	6.5	0.7	0.2	23.5	22.6
6	0-24	6.0	3.4	66.3	6.1	0.3	101.0	16	15.0	8.5	0.5	0.2	24.2	23.5
7	0-25	6.0	1.2	41.1	5.8	1.8	4.7	4.0	15.0	11.0	0.7	0.3	27.0	26.0
8	0-27	5.2	1.3	16.0	6.0	2.5	39.1	15	17.5	10.0	0.6	0.2	28.3	27.5
9.	0-28	5.9	2.0	22.0	5.9	1.7	24.0	4.0	16.0	12.0	0.5	0.1	28.6	28.0
10	0-24	5.8	1.7	42.1	6.2	2.2	5.6	14	11.5	7.0	0.2	0.2	18.9	18.5
S.D.		0.3	0.8	16.5	5.3	0.3	0.6	29.6	5.6	2.9	2.2	0.2	0.1	4.4
Maximum		6.3	3.4	66.3	18	6.5	2.5	101	18	19.0	12.0	0.7	0.3	28.6
Minimum		5.2	1.2	5.4	2.5	5.4	0.3	3.5	3.5	8.5	5.0	0.2	0.1	14.2
Average.		5.8	1.9	29.5	6.6	6.0	1.5	27.6	10	14.5	8.1	0.5	0.2	23.3
CV (%)		5.0	40.6	55.8	81	5.7	42.5	107.4	53	20.0	27.3	31	31.0	19.0

Farms: ¹Puerto Rico. ²Los Rosales. ³ Reposito. ⁴ El Carmen. ⁵ Santa Rita. ⁶ El Peñón. ⁷ La Unión. ⁸ No te Canses. ⁹ Nueva Esperanza. ¹⁰ Mila Flor.

content of these elements at the foliar tissue level.

Chemical characteristics of the plantain producing zones in Valencia

In this zone, soils present a slightly acidic reaction, with pH 6 (Table 2). It is localized in flat areas of the municipality, where gain pedological processes take place, therefore lixiviation and mineral loss processes are lower, additionally, the parental materials that originate these soils have high nutrient content (CVS, 2001).

Average O.M. contents are 1.5%, which is considered as a low level and lower than the average in Tierralta's soils. In the same way as for Tierralta, this low O.M. content can be explained by high mineralization and low contribution of harvesting residues due to the agronomical management of the crop. In these conditions is required to design a plan for the management of harvesting residues in order to increase the O.M. in these soils. Bolaños *et al.* (2002) consider that nutrient recy-

cling in the soil by biomass incorporation in plantain crops is a positive factor for rationalization and reduction of chemical fertilization.

The contents, in average, of P and S in these soils are 27.6 and 10.5 mg/kg, which are considered as medium and low, respectively. It is important to indicate that in these conditions there is a high variability in the P content oscillating between 3.5 and 101 mg/kg, due to the different physiographic locations where the plantations are, including alluvial and colluvial valleys with slightly flat to slightly undulated topography and different parental materials with heterogeneous sediments.

For the sustainable management of the crops in these conditions is important to plan the fertilization with P, which is an element forming nucleic acids, phospholipids, NAD and NADP coenzymes and, more importantly as part of the ATP molecule that is the energy transporter compound for the plant. S is essential as part of protein structure and as component of sulphureted amino acids like

cystine, cysteine and methionine (Marschner, 1995).

Interchangeable bases content (cmol/kg) Ca (14.5), Mg (8.1) and K (0.5) can be considered as high, which indicates a good nutritive reserve derived from the parental materials of the zone, where heterogeneous sediments with calcareous materials are predominant. The predominant type of clay is 2:1, mainly illite and montmorillonite (IGAC, 2009) that possess high nutrient content, thus the plantain crops in these areas have higher soil nutrient reserves. According to Junqueira *et al.* (2007) the yield and quality of production, growth and plant development are some of the fundamental aspects of the plantain crops which depend on plant nutrition. Espinosa *et al.* (1998) cite as plantain crop requirements an adequate N, P and K fertilization based on soil analysis. The cationic ratios in the soils of this zone were: Ca/Mg = 22.6, Ca/K = 31.3, Mg/K = 17.5 and Ca+Mg/K = 48.8.

Soils of the Coast side municipalities of the department of Cordoba

Soils in the coast municipalities of Moñitos

and San Bernardo del Viento are composed of an ochric epipedon over a cambic sub-epipedon, predominating 2:1 type of clays. In these zones, in prolonged dry seasons and due to the parental material with calcareous influence, soils present high vertic conditions. Additionally, for the chemical conditions of the area, it could be observed by the profile description, that Vertisols suborder Ustert and the Calcicustert large group are predominant. Also it was found the orders Haplustert and in minor extension, the Haplustepts.

Chemical characteristics of the plantain producing zones in Moñitos

In the soil sampling of this zone it was evident problems with root growth due to the clay type that is dominant and to the cracks that are formed in dry seasons. These soils have a marine influence and parental materials are sedimentary rocks, sandstones and claystones with calcareous influence.

The chemical characteristics of soils (Table 3) showed a reaction close to neutrality pH 6.5. According to IGAC (2009) the parental materials like sedimentary rocks, claystones,

Table 3. Average, minimum and maximum values of the macronutrients contents in soils of plantain producing farms in Moñitos-Córdoba, Colombia.

Farms	Depth cm	pH	O.M. %	P mg/kg	S mg/kg	Ca	Mg	K	Na	CTC	Ca/Mg	Ca/K	Mg/K	(Ca+Mg) /K
1	0-25	5.6	1.7	70.2	5.0	11.0	5.0	0.9	0.1	17.0	16	12.2	5.6	17.8
2	0-30	5.8	1.3	16.0	3.0	17.5	20.0	0.9	0.3	38.7	37.5	19.4	22.2	41.7
3	0-24	7.0	2.1	60.6	21.4	23.5	10.0	0.7	0.2	34.4	33.5	33.6	14.3	47.9
4	0-36	6.7	1.6	57.4	17.5	20.0	16.5	1.2	0.6	38.3	36.5	16.7	13.8	30.4
5	0-29	5.6	2.3	28.1	20.0	20.0	16.0	2.3	0.2	38.5	36	8.7	7.0	15.7
6	0-27	6.6	2.3	61.4	39.2	28.5	7.5	1.8	0.2	38.0	36	15.8	4.2	20.0
7	0-25	8.9	2.0	22.8	12.1	17.5	10.5	0.9	0.2	29.1	28	19.4	11.7	31.1
8	0-28	7.1	2.9	280.0	10.0	32.5	11.0	1.6	0.1	45.2	43.5	20.3	6.9	27.2
9.	0-25	6.2	1.5	117.0	8.0	18.5	7.0	1.0	0.2	26.7	25.5	18.5	7.0	25.5
10	0-35	5.6	2.3	70.2	16.4	28.0	16.0	1.0	0.2	45.2	44	28.0	16.0	44.0
S.D.		1.0	0.5	76.6	9.8	6.1	4.7	0.5	0.1	8.3	8.1	6.8	5.4	10.7
Maximum		8.9	2.9	39.2	9.1	32.5	20.0	2.3	0.6	45.2	44.0	33.6	22.2	47.9
Minimum		5.6	1.3	3.0	9.4	11.0	5.0	0.7	0.1	17.0	16.0	8.7	4.2	15.7
Average.		6.5	2.0	16.4	9.7	21.7	12.0	1.2	0.2	35.1	33.7	19.3	10.8	30.1
CV (%)		14.9	22.8	466.8	9.7	28.1	39.0	39.2	58.5	23.5	23.9	35.3	50.1	35.4

Farms: ¹Guanábano. ² Villa Cota. ³ Villa mariana. ⁴ Nuevo Oriente. ⁵ Villa Rosmery. ⁶ Villa Merlys. ⁷ Entra si Puedes.

⁸La Sierra. ⁹Temeroso. ¹⁰ Duque.

sandstones, limestones, mudstones have high nutritional potential. Additionally, in these environmental conditions, with an approximate precipitation of 1350 mm/year, there are not predominant lixiviation processes contributing to soil acidity. O.M. contents are lower than 2% indicating a fast mineralization of plant residues coming from the plantain crop management.

P and S contents were in average 16.4 and 9.7 mg/kg, and are considered as medium and low, respectively. In these chemical conditions of high calcium carbonate concentrations, there can be problems of P and S insolubilization due to the possible formation of calcium phosphate and calcium sulfate, which can affect the assimilation of these nutrients. Zhou (2001) found in calcareous soil studies that clay soils with carbonates present the highest part of P adsorption, especially at low concentrations of this nutrient.

The contents (cmol/kg) of Ca (21.7), Mg (12) and K (1.2) are considered high due to the origin of these soils with marine influence. The high contents of these elements can affect the assimilation or absorption of essential nutrients as P and S, because due to insolu-

bilization processes and formation of calcium phosphate and gypsum sulfate their availability is reduced. Therefore, it is needed to incorporate them in the fertilization plans for the plantain crops in this area. The cationic ratios were: Ca/Mg = 33.7, Ca/K = 19.3, Mg/K = 10.8 and (Ca+Mg)/K = 30.1, they are considered as adequate.

Chemical characteristics of the plantain producing zones in San Bernardo

In this zone of study, the analytic results for soils indicate a slightly acid reaction pH 5.9 (Table 4). In these soils, originated from calcareous sources from marine origin, Ca and Mg compounds have low solubility and can affect the low pH values. Average O.M. contents are 2.1% indicating a high mineralization rate and low reposition of residual materials from the crop.

P and S contents were 35.3 and 13.8 mg/kg, which are considered as high and low, respectively. In these conditions it is required to include in the fertilization plans these elements because of their possible insolubilization, also due to the fact that the extraction

Table 4. Average, minimum and maximum values of the macronutrients contents in soils of plantain producing farms in San Bernardo-Córdoba, Colombia.

Farms	Depth	pH	O.M.	P	S	Ca	Mg	K	Na	CTC	Ca/Mg	Ca/K	Mg/K	(Ca+Mg)
	cm		%	mg/kg				cmol ⁺ /kg-						/K
1	0-24	6.0	2.0	23.0	5.0	15.5	17.5	1.5	0.3	34.8	33	10.3	11.7	22.0
2	0-22	5.4	1.7	18.6	3.5	15.0	12.5	0.5	0.2	28.2	27.5	30.0	25.0	55.0
3	0-27	6.6	1.3	62.5	17.5	17.5	16.5	0.9	0.7	35.6	34	19.4	18.3	37.8
4	0-21	5.6	1.5	26.0	24.2	7.5	5.0	0.2	0.2	12.9	12.5	37.5	25.0	62.5
5	0-26	6.1	1.2	48.3	7.0	22.6	6.0	0.6	0.2	29.4	28.6	37.7	10.0	47.7
6	0-30	5.6	2.3	20.1	35.7	28.0	3.5	0.8	0.4	32.7	31.5	35.0	4.4	39.4
7	0-25	5.6	2.9	38.8	12.1	37.6	10.0	1.2	0.3	49.1	47.6	31.3	8.3	39.7
8	0-27	6.3	2.3	38.8	10.0	25.0	9.0	0.8	0.4	35.2	34	31.3	11.3	42.5
9.	0-28	6.5	3.4	45.2	9.0	28.5	12.0	1.1	0.3	41.9	40.5	25.9	10.9	36.8
10	0-26	5.5	2.4	31.3	14.2	20.0	18.5	1.1	0.3	39.9	38.5	18.2	16.8	35.0
S.D.		0.4	0.7	13.4	9.3	8.1	5.0	0.4	0.1	9.1	8.8	8.6	6.6	10.6
Maximum		6.6	3.4	62.5	35.7	37.6	18.5	1.5	0.7	49.1	47.6	37.7	25.0	62.5
Minimum		5.4	1.2	18.6	3.5	7.5	3.5	0.2	0.2	12.9	12.5	10.3	4.4	22.0
Average.		5.9	2.1	35.3	13.8	21.7	11.1	0.9	0.3	34.0	32.8	27.7	14.2	41.8
CV (%)		7.0	31.9	38.0	67.6	37.3	45.6	41.1	43.0	26.8	26.8	31.2	46.4	25.4

Farms: ¹Villa Ana. ² Quien va Salir. ³ Villa Gloria. ⁴ Fuente Nueva. ⁵ Esperanza. ⁶ Nuevo Tesoro. ⁷ El Espejo. ⁸ Villa Laura. ⁹ Divino Niño. ¹⁰ Villa Nelly.

method by Bray II can overestimate the P contents in calcareous soils, and additionally due to the P retention in soils with relatively high carbonate contents (Tunesi *et al.*, 1999). Moreover, in these conditions is required to use S as a fertilizer due to its role in protein formation. With the addition of this nutrient P absorption is increase because S oxidation in H_2SO_4 is beneficial in alkaline soils to increase nutrient availability by pH reduction (Neilsen *et al.*, 1993). Lindemann *et al.* (1991) consider that the acidity during S oxidation increases P availability in neutral or basic soils, increasing also the plant absorption of other nutrients such as P, Mn, Mg, Ca and SO_4 .

Contents (cmol/kg) of the bases Ca (21.7), Mg (11.1) and K (0.9) are high. In the same way in the Moñitos area, these soils were originated from materials with high content of mudstones and conglomerates with calcareous lenses and influence. The cationic ratios for the zone were: $Ca/Mg = 26.8$, $Ca/K = 31.2$, $Mg/K = 46.4$ and $(Ca+Mg)/K = 25.4$.

Cationic ratios of interchangeable bases in the studied zones soils

In the works about characterization of soil fertilization the interpretation of chemical variables is done individually, without analyzing the cationic ratios. By means of this analysis the ionic antagonisms, which cause deficiencies in crops, can be interpreted. In the cationic ratios analysis in the studied soils the following ranges were found: $Ca/Mg = 22 - 33.7$, $Ca/K = 19.3 - 31.1$, $Mg/K = 10.8 - 17.5$, $(Ca + Mg)/K = 30.1 - 48.8$ (Table 5). These ratios are wider than the ones found by Bolaños *et al.* (2002) in soils in Quindio, Co-

lombia, they found < 4.5 values and by Gonzalez *et al.* (2006) in soils of Palestina, Caldas, Colombia.

Chemical fertility of soils in the studied zones

Statistical analyses showed that there are no differences ($P > 0.05$) for the chemical characteristics pH, O.M., P, S and Mg in the studied soils (Table 6); this condition allows their characterization as slightly acids with high contents of some interchangeable bases. Thus, the O.M. (1.87%) and S (11.53 mg/kg) are low, which is explained for the low contribution of N and S originated in the O.M. mineralization. In these conditions there are deficiencies of these nutrients that have to be compensated by the addition of synthesis fertilizers. Grisales and Lescot (1994) recommend to fertilize with N only when the O.M. content es $< 3\%$. Combatt *et al.* (2004) in San Juan de Uraba, Antioquia, Colombia, found that the plantain crop responded to additions of 200 kg/ha of N and to an equivalent doses of K.

The average P content was high (42.6 mg/kg), however, its availability can be limited by the formation of insoluble Ca compounds. Afif *et al.* (1993) found that the absorption of high rates of available P in the soil is negatively correlated with the available Ca. Tunesi *et al.* (1999) studied the relative importance of the reactions taken place in the top of the soil and precipitation in P retention, and they concluded that in soils with large reserves of interchangeable cations precipitation is the predominant factor in the available P reduction. Rincón *et al.* (1997) consider that a range between 10 and 20 mg/kg of P in

Table 5. Average values of cationic ratios in soils cultivated with plantain in farms of municipalities of the department of Cordoba, Colombia.

	Cationic ratios			
	Ca/Mg	Ca/K	Mg/K	(Ca+Mg)/K
S.D.	4.3 - 8.7	6.8 - 11.5	5.4 - 7.4	10.6 - 18.2
Maximum	28.0 - 47.6	33.2 - 57.5	22.2 - 3.0	47.9 - 92.5
Minimum	12.5 - 16.5	8.7 - 14.1	3.1 - 14.7	13.1 - 22.5
Average	22.0 - 33.7	19.3 - 31.2	10.8 - 17.5	30.1 - 48.8
CV (%)	19.2 - 26.8	31.1 - 39.6	40.1 - 50.1	25.3 - 37.4

Table 6. Chemical variables in plantain producing soils of farms in the department of Cordoba, Colombia.

Municipality	pH	O.M.	P	S	Ca	Mg	K	Na	CIC
	1:1	(%)	Mg/kg		cmol ⁺ /kg--				
Tierralta	5.79	1.88	29.4	6.56	12.71 b	9.35	0.70 b	0.13 b	22.67 b
Valencia	6.00	1.52	27.5	10.5	14.51 b	8.10	0.51 b	0.18 b	23.30 b
Moñitos	6.51	2.00	78.3	15.26	21.70	11.95	1.23 a	0.23 ab	35.11 a
San Bernardo del Viento	5.92	2.10	35.2	13.82	21.72	11.05	0.87 ab	0.33 a	33.97 a
Average	6.05	1.87	42.66	11.53	17.66	10.11	0.82	0.22	28.76
P (0.05)	ns	ns	ns	ns	*	ns	*	*	*
C.V %	9.99	36.16	100.4	71.62	33.32	39.41	44.59	51.13	25.4

Averages followed by the same letter in the column do not significantly differ by the Tukey's test ($P \leq 0.05$).

soil is adequate for the production of Harton plantain. According to Borges and Oliveira (2000), P is required in low amount by plantain crop, but it is important to keep suitable levels in the soil in order to maximize productivity; this, due to the fact that 50% of the P absorbed by the plant is exported by the fruits and it can generate a deficiency in this element affecting vegetative growth and root development.

High contents of Ca, Mg and K interchangeable bases were found, showing the high fertility of these soils. According to Ramos *et al.* (2006) soils in the plantain zone of Moñitos and San Bernardo del Viento had high K contents, but it is mainly found in not available forms for the plants.

Conclusions

- Soils used by plantain crops in municipalities of the Alto Sinu have a slightly acidic pH, low organic matter, phosphorous and sulfur from medium to deficient and high base contents.
- In conditions of the Coast zone of Cordoba where plantain is grown, soils have a slightly alkaline to slightly acid reaction, organic matter is medium to low, high phosphorus and deficient sulfur, and high contents of interchangeable bases.
- For plantain crop sowing in these conditions using fertilizers with nitrogen, sulfur and phosphorus have to be taken into account because of the low organic contents and tendency to insolubilization of

phosphorus and sulfur in both studied zones.

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