Chemical fertility of banana soils of Tenerife Island (Canary Islands)

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Abstract — Introduction. Bananas are the most important culture of Tenerife Island from the economic standpoint. To give some hints about management practices to enhance the chemical fertility of the banana plantation soils, analyses were carried out on several soil samples taken in several municipalities of the island. **Materials and methods**. Soil pH and organic matter contents were assessed. After extraction, available cations and phosphorus contents were determined. Electrical conductivity (EC) was measured. **Results and discussion**. Most soils showed neutral or alkaline pH values that could compromise Fe and Mn uptake by bananas in some plantations. EC harmful to salt-susceptible plants like bananas were observed in many soils. Minimum P contents were enough for meeting the needs of the banana plants; meanwhile some maximum levels could hinder zinc uptake. Available Ca, Mg, and K showed high means, though Ca/Mg and K/Mg ratios were unbalanced in many soils in benefit of Mg and K, respectively, which could affect the banana nutrition. Available Na also presented high values that exceeded those of K in many soils, with the consequent threat of toxicity. Phosphorus, pH, organic matter, and available K and Na increased in nearly half the studied municipalities as compared to their levels reported in the ancient literature; meanwhile available Ca contents decreased, and no important changes were observed in available Mg levels. (© Elsevier, Paris)

Canary Islands / *Musa* / chemical composition / soil testing / soil fertility

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Fertilité chimique des sols de bananeraies dans l'île de Ténérife (îles Canaries).

Résumé — Introduction. Économiquement, le bananier est la culture la plus importante de l'île de Ténérife. Afin de formuler quelques recommandations destinées à mieux gérer la fertilité chimique des sols en bananeraies, des analyses ont été effectuées sur des échantillons prélevés dans plusieurs localités de l'île. **Matériel et méthodes**. Le pH et la teneur en matière organique des échantillons de sol ont été évalués. Après extraction, leurs teneurs en phosphore et cations libres ont été déterminées et leur conductivité électrique (CE) a été mesurée. **Résultats et discussion**. La plupart des sols ont montré des pH neutres ou alcalins qui pourraient compromettre, dans certaines plantations, l'absorption du fer et du manganèse par le bananier. Dans de nombreux sols, des valeurs de CE, rédhibitoires pour des plants sensibles au sel comme le sont les bananiers, ont été observées. Les teneurs minimales en phosphore ont été suffisantes pour répondre aux besoins des bananiers, alors que certaines valeurs maximales pourraient gêner l'absortion du zinc. Les teneurs en cations libres (Ca, Mg et K) ont été fortes en moyenne, bien que les rapports Ca/Mg et K/Mg soient apparus déséquilibrés dans de nombreux sols au bénéfice du Mg et du K. Cela pourrait affecter la bonne nutrition du bananier. Le sodium a aussi présenté de fortes teneurs, supérieures à celles de K dans de nombreux sols, occasionnant des risques de toxicité. Si l'on se réfère aux valeurs rapportées par d'anciens travaux, les teneurs en phosphore, matière organique et cations K et Na libres, et le pH, ont augmenté dans presque la moitié des localités étudiées, alors que celles en Ca ont diminué et que celles en Mg n'ont presque pas changé. (© Elsevier, Paris)

Canaries (îles) / *Musa* / composition chimique / analyse de sol / fertilité du sol

1. introduction

Bananas are the most important culture of Tenerife Island (Canary Islands) from the economic standpoint, and they occupy the second place in cultivated surface (4500 ha, approximately) [1]. However, studies on banana soil chemical properties have not been updated since 1977, in spite of the fundamental role that they play for advicing purposes.

In 1970, Fernández and García observed that alkaline pH predominated in banana soils from the south slope of the island, while in the north slope they distinguished three zones: Northwest, with alkaline soils, Central, with acid soils, and Northeast, with neutral to alkaline pH [2]. As far as organic matter was concerned, its percentages in the soils were more related to antiquity of the plantations rather than their locations. Fernández et al. [3] and García et al. [4] came to the same conclusion.

Phosphorus levels were high, within a range from 100 ppm up to 500 ppm. These levels depended on plantation age, due to their continual inputs [2, 3]. Potassium also showed high concentrations (1.5 mEq·100 g^{-1} up to 5 mEq·100 g^{-1} in most soils), which placed these banana soils among the richest in potassium content in the world [5]. Average Ca levels varied considerably between the North slope (17 mEq·100 g^{-1}) and the South one (11.4 mEq·100 g^{-1}), whereas Mg averages (8.5 mEq·100 g^{-1} and 9.43 mEq·100 g^{-1}, respectively) hardly showed differences between them [4, 5].

In this paper, we try to discuss the current chemical characteristics of banana soils of Tenerife, to determine whether an evolution of them has taken place since the studies of the referred authors, and to give some hints about management practices to enhance the chemical fertility of these soils.

2. materials and methods

Data of 1244 banana soil samples from Tenerife Island were used for our study. Agronomists took 85% of the soil samples, and trained farmers took the remaining 15%. These samples were brought to the farmer service of our institute from January 1989 to December 1995. The samples were air-dried, and passed through a 2-mm mesh. After shaking soil:water ratios of 2:5, then allowing to settle for 10 min, pH was measured.

Organic matter was determined by the Walkley and Black method as modified by the Comisión de Métodos analíticos del instituto de Edafología y agrobiología 'José M. Albareda' [6].

Available cations were extracted with a 1-mol ammonium acetate solution at pH 7, and determined by atomic absorption spectrophotometry. Available phosphorus was extracted by the Olsen et al. method [7], and determined by the Watanabe and Olsen method [8].

Electrical conductivity (EC) was determined from the saturated water extract [9].

3. results and discussion

Location order within the tables follows a ring Southeast–Southwest–Northwest–Northeast distribution with the municipality of Güimar (near the capital of the island) as the starting point.

3.1. pH levels

All the mean pH levels in the South slope are nearly neutral to alkaline, and 60% of them exceed the value of 7.5, compromising Fe and Mn uptake by plants [10]. In the North slope, the same tendency is observed, though there are two locations (La Orotava and Valle Guerra) with slightly acid mean pH (*table I*). As opposed to Fernández and García [2], we did not detect any particular distribution of mean pH differences by specific zones. In comparison with mean pH values reported by Fernández and García [2] and Fernández et al. [3], an increase is observed in 50% of the average pH levels. In both slopes minimum pH values are acid, with three exceptions, while all the maximum levels range over the alkaline interval

Table I.
Values of pH and phosphorus contents in the banana soils of Tenerife Island.

Location	pH			Phosphorus (ppm of P_2O_5)		
	Average	Minimum	Maximum	Average	Minimum	Maximum
South of Tenerife Island						
Güimar	7.294	6.12	8.46	230.5	30	570
Arico	7.319	5.07	8.67	268.9	4	750
Granadilla	7.381	5.09	8.55	526.9	56	1 007
Arona	7.869	5.24	9.13	219.0	23	636
Las Galletas	7.925	3.43	9.20	258.5	5	976
Adeje	7.865	4.21	8.84	295.9	10	945
P. San Juan	8.039	7.03	9.20	303.6	1	690
Alcalá	7.902	6.89	8.48	298.1	49	570
Guía de Isora	7.933	5.28	8.94	328.8	76	483
Santiago	7.362	5.91	8.10	219.9	30	840
North of Tenerife Island						
Buenavista	7.895	6.16	8.76	251.3	30	729
Los Silos	7.844	6.28	8.86	253.1	49	829
Garachico	7.473	4.28	8.56	290.3	27	1 074
Icod	7.854	6.27	8.88	293.6	23	816
La Guancha	7.994	7.16	8.41	282.6	76	483
San J. Rambla	7.601	5.26	8.18	182.6	36	351
Los Realejos	7.307	5.07	8.75	276.2	63	525
Puerto Cruz	7.967	7.40	8.80	383.2	289	570
La Orotava	6.347	3.81	7.89	488.7	165	1 039
Valle Guerra	6.508	5.38	7.71	286.3	63	793
Tejina	7.343	6.04	8.16	335.9	119	602
P. Hidalgo	7.730	7.41	8.21	204.0	112	396

(*table I*). Most of the minimum pH values exceed the ones referred to by Díaz [5], whereas this only happens with 46% of the maximum pH levels. In accordance with the above discussion, we encourage soil acidification in most cases.

3.2 phosphorus contents

Phosphorus is present in high amounts in most of the soils (*table I*), which corroborates previous findings [2, 3, 5]. With four exceptions for which P concentrations are lower than 20 ppm, minimum P levels are enough to meet the needs of the banana plants [5], however, some maximum levels can hinder Zn absorption by the plant, according to Díaz [5], who had observed a negative correlation between soil P levels and Zn concentrations in leaves of Dwarf Cavendish bananas; that confirmed the well-known antagonism between these two nutrients [11]. Mean phosphorus soil content has increased in 45% of the municipalities in relation to the levels reported by Fernández and García [2] and Fernández et al. [3]. Maximum P contents are also higher in 64% of the municipalities than those reported by Díaz [5]. From these results, it is clear that farmers should decrease and, in some cases, avoid the use of P fertilisers in their banana plantations.

3.3. organic matter contents

Organic matter content of the banana plantations range from very deficient (less than 0.5%) to exceedingly high (*table II*).

Table II.
Values of organic matter and electrical conductivity in the banana soils of Tenerife Island.

Location	Organic matter (%)			Electrical conductivity ($dS \cdot m^{-1}$)		
	Average	Minimum	Maximum	Average	Minimum	Maximum
South of Tenerife Island						
Güimar	2.389	0.01	5.16	3.175	1.26	7.09
Arico	1.282	0.25	2.35	2.399	1.00	5.61
Granadilla	2.281	0.60	6.67	3.429	0.91	9.80
Arona	1.613	0.32	5.36	2.274	0.27	6.69
Las Galletas	1.971	0.10	15.90	2.023	0.30	9.20
Adeje	2.398	0.10	10.72	2.620	0.62	11.11
P. San Juan	1.823	0.16	3.89	1.843	0.62	5.93
Alcalá	2.019	0.05	4.38	4.042	1.26	11.10
Guía Isora	2.323	0.10	12.59	2.112	0.76	6.80
Santiago	2.581	0.10	6.42	2.728	1.09	7.09
North of Tenerife Island						
Buenavista	2.454	0.10	6.53	1.854	0.61	4.19
Los Silos	3.057	0.25	12.68	2.040	0.43	6.96
Garachico	2.516	0.07	6.33	2.532	0.52	6.88
Icod	4.402	1.82	8.71	1.673	0.10	3.34
La Guancha	3.462	1.88	6.34	2.356	1.16	3.50
San Juan	2.791	0.05	7.18	3.530	1.28	7.11
Los Realejos	4.874	1.34	13.05	1.585	0.30	4.03
Puerto Cruz	2.447	1.56	4.57	2.509	1.07	15.97
La Orotava	6.883	1.04	13.05	2.678	0.84	5.94
Valle Guerra	2.655	1.08	6.38	1.867	0.54	4.53
Tejina	3.209	0.64	8.05	2.356	1.08	4.70
P. Hidalgo	2.704	1.95	4.85	3.043	1.47	5.56

Piqué et al. [12] found that organic matter levels greater than 7% diminished Mn uptake by the banana plant with the consequent deficiency of this nutrient. Average organic matter contents in banana soils of the Northern slope are significantly higher (t = 3.124, p = 0.005) than those of the Southern slope. As banana plantations from the North are generally more ancient than those from the South, these results agree with previous findings [2–4], which suggested that the organic matter content of banana plantation soils depended on the antiquity of these plantations. The values detected in our study exceed the ones reported by these authors in 48% of the municipalities.

3.4 electrical conductivity

Determination of electrical conductivity (EC) of the soils of banana plantations from Tenerife Island is nowadays of great importance because overexploitation of water resources have increased water salinisation [13], with its concomitant effect on total salt content of soils. Many banana farmers carry out water management practices to avoid water salt effects on the soils and on the banana plants. These practices were not so important 25 years ago, because there was more water of better quality [14]. That is why no mention of EC is found in the previous works [2–5] conducted in the Canary Islands. In our study, we have observed high mean values (*table II*) of EC (more than 2.5 $dS \cdot m^{-1}$) that could be harmful to salt susceptible plants [9] like bananas. Taking into account these high EC values and that most maximum EC levels are greater than 5 $dS \cdot m^{-1}$, we encourage banana farmers encountering this problem to perform water management practices to decrease the salt content of the soils.

3.5. calcium and magnesium contents

Average available Ca contents range from 7.826 to 19.551 $mEq \cdot 100\ g^{-1}$ (*table III*). Though these values may be considered normal to high, Fernández and García [2] and Fernández et al. [3] detected higher levels in 59% of the municipalities, and Díaz [5] found higher minimum values in 86% of them. Although 64 % maximum available Ca contents of our study exceed those reported by Díaz [5], the overall data suggest a decrease of the levels of this nutrient, which may be related to a more judicious use of liming materials, because farmers rely more on soil analysis results and technician advice than 25 years ago.

Available magnesium levels (*table III*) remain nearly at the same range found in previous works [3–5]. Its contents are sufficient to meet banana plant needs even with most of the mimimum values. Yet the Ca/Mg ratio is unbalanced in many soils in benefit of the latter. It may be due to Mg contribution from irrigation water that keeps

Table III.
Values of calcium and magnesium contents in the banana soils of Tenerife Island.

Location	Calcium ($mEq \cdot 100\ g^{-1}$)			Magnesium ($mEq \cdot 100\ g^{-1}$)		
	Average	Minimum	Maximum	Average	Minimum	Maximum
South of Tenerife Island						
Güimar	12.750	5.90	20.65	7.664	3.77	14.10
Arico	7.826	4.45	11.25	9.091	2.95	13.94
Granadilla	14.615	5.50	32.40	9.346	4.10	12.55
Arona	11.428	4.00	24.05	11.576	4.51	24.27
Las Galletas	10.988	1.95	25.2	10.166	1.64	20.83
Adeje	14.260	6.50	26.80	9.228	2.71	15.66
P. San Juan	15.950	4.30	34.20	7.637	3.61	11.81
Alcalá	13.759	4.30	18.65	9.806	5.41	28.86
Guía Isora	13.978	4.55	36.25	9.992	4.59	25.91
Santiago	17.935	6.85	56.26	7.720	3.41	12.92
North of Tenerife Island						
Buenavista	13.459	6.70	22.30	11.260	5.25	17.14
Los Silos	14.773	7.85	29.35	11.416	4.94	20.09
Garachico	21.610	5.75	36.55	12.571	4.10	37.39
Icod	13.284	8.10	20.10	8.382	4.10	12.71
La Guancha	13.877	9.00	17.10	8.380	6.57	10.66
San Juan	12.430	6.40	18.45	8.683	3.94	14.59
Los Realejos	15.430	2.60	28.60	7.919	2.46	15.99
Puerto Cruz	14.564	11.1	18.25	8.987	6.56	11.46
La Orotava	18.918	3.85	30.06	6.631	1.72	14.92
Valle Guerra	14.325	7.40	23.80	8.718	4.76	13.53
Tejina	19.551	8.35	29.68	11.534	1.20	18.45
P. Hidalgo	18.531	8.60	24.75	10.460	5.41	13.61

Table IV.
Values of potassium and sodium contents in the banana soils of Tenerife Island.

Location	Calcium (mEq·100 g^{-1})			Magnesium (mEq·100 g^{-1})		
	Average	Minimum	Maximum	Average	Minimum	Maximum
South of Tenerife Island						
Güimar	12.750	5.90	20.65	7.664	3.77	14.10
Arico	9.524	1.62	14.72	6.793	1.89	17.55
Granadilla	4.670	1.21	8.08	2.788	1.00	7.78
Arona	3.949	0.50	7.66	2.755	0.93	6.11
Las Galletas	3.874	0.47	9.94	2.938	0.69	8.70
Adeje	5.076	1.02	9.55	2.868	0.80	9.17
P. San Juan	5.272	1.65	13.91	2.641	0.83	7.06
Alcalá	7.576	3.64	21.92	4.105	2.50	8.19
Guía Isora	4.186	0.20	10.38	2.872	0.78	14.22
Santiago	3.124	0.24	6.89	2.699	1.36	3.98
North of Tenerife Island						
Buenavista	3.284	1.25	6.21	2.436	0.46	7.00
Los Silos	3.414	0.91	8.72	2.657	0.33	6.28
Garachico	3.571	0.43	11.70	3.626	0.78	12.48
Icod	3.604	1.84	6.29	3.067	1.33	6.11
La Guancha	4.804	2.48	6.56	3.924	2.22	5.89
San Juan	4.431	1.48	7.16	2.058	3.15	44.65
Los Realejos	3.330	0.48	7.61	2.474	0.50	6.72
Puerto Cruz	8.722	2.85	12.93	5.141	1.52	7.11
La Orotava	3.424	1.61	6.05	1.747	0.33	4.19
Valle Guerra	2.179	0.89	5.88	2.558	1.35	4.35
Tejina	2.991	0.78	4.86	2.067	1.37	4.61
P. Hidalgo	4.114	2.57	5.50	2.866	1.80	3.46

Mg concentration in the soil – magnesium is rarely used as a fertiliser in banana plantations –, while a reduction in liming materials causes a decrease in soil Ca levels as already stated. Banana farmers should try to balance the soil Ca/Mg ratio because it may directly affect the Ca + Mg + K relationship that plays such an important role in banana nutrition [15].

3.6. potassium and sodium contents

In spite of the fact that many Canarian soils are well supplied with K by nature [16], farmers always fertilise with this element. That explains the very high mean available K contents we found in the soils (*table IV*); these contents increased in 55% of the municipalities when compared to those reported in the previous works [2–5]. This percentage amounted to 91% of maximum available K values. These high K levels are similar to available Mg contents in some soils, and the banana plants may suffer from an unbalanced K/Mg nutrition, as described by García et al. [17]. In some soils, available K contents are so high that farmers could cut out K fertilisers without threatening banana nutrition, development, and yield, especially when the K/Mg ratio is approximate to 1.

Available Na ranges from 0.33 to 44.65 mEq·100 g^{-1} (*table IV*). Mean values are usually greater than 2 mEq·100 g^{-1}, and they exceed 3 mEq·100 g^{-1} in 32% of the cases. Because Na may have toxic effects on plants [11], these high soil concentrations are a matter of concern. Forty-five percent of average and minimum values approach those reported by Díaz [5], while 77% of maximum levels and 37% of mean values are higher. Data suggest an important increase of available Na in the banana soils that may menace K nutrition of the plants, due to the antagonism between these cations [10]. Fortunately, the high contents of available K of the soils may counteract the effect of Na ions in some instances. When it does not occur, farmers should increase K fertilisation and wash Na ions down by liming and irrigation.

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Fertilidad química de los suelos de platanera de la isla de Tenerife (Islas Canarias).

Resumen — Introducción. La platanera es el cultivo más importante de la isla de Tenerife desde el punto de vista económico. Para dar recomendaciones sobre prácticas de manejo para mejorar la fertilidad química de los suelos de platanera, se llevaron a cabo análisis en una amplia cantidad de suelos tomados en diversos municipios de la isla. **Material y métodos**. Se determinaron el pH y el contenido de materia orgánica de los suelos; el fósforo y cationes asimilables se evaluaron tras su extracción, y se midió la conductividad eléctrica. **Resultados y discusión**. La mayoría de los suelos tenían un pH neutro o alcalino que podría comprometer la absorción de Fe y Mn por las plataneras en algunas plantaciones. El contenido mínimo de P era suficiente para satisfacer las necesidades de las plataneras, mientras que algunos valores máximos podrían dificultar la absorción de zinc. El Ca, Mg y K asimilables presentaron medias elevadas, aunque las razones Ca/Mg y K/Mg estaban desequilibradas en muchos suelos en beneficio del Mg y del K, respectivamente. Esto podría afectar la nutrición de la platanera. El Na asimilable también mostró valores elevados que excedían a los de K en muchos suelos, con el consiguiente peligro de toxicidad. El fósforo, el pH, la materia orgánica, así como el K y el Na asimilables se incrementaron en casi la mitad de los municipios estudiados cuando se compararon con los niveles indicados en la antigua bibliografía, mientras que el contenido de Ca disminuyó, y no se observaron cambios importantes en los niveles de Mg asimilable. (© Elsevier, Paris)

Islas Canarias / *Musa* / composición química / análisis del suelo / fertilidad del suelo