Biological Agriculture and Horticulture, Vol. 5, pp. 313–323
0144-8765/88 $5

Printed in Great Britain

Soil Fertility and Mineral Nutrition of an Organic Banana Plantation in Tenerife

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ABSTRACT

The soil fertility of an organic banana planation in Tenerife and its relation to mineral nutrition was studied and compared with the same variables investigated previously in conventional plantations. The pH of the organic banana plantation soils, as well as the levels of available Mg and Na, were similar to those of the conventional banana plantations. On the other hand, the values of organic matter and available P, Ca and K of the organic plantation soils showed averages significantly higher than those of the conventional plantations. As regards mineral nutrition, while the foliar N, K and Mg levels of the organic plantation were similar to those of the conventional plantations, the averages of foliar P, Ca, Fe and Zn were higher in the organic plantation, but the Mn and Cu averages were lower, although they did not fall to deficiency levels.

INTRODUCTION

The fertility of the banana soils of Tenerife and their relation to mineral nutrition and production has been the subject of numerous studies from 1962 to the present day, although they referred only to conventional plantations since the organic system was not introduced until 1981. In this paper the results of this type of study, carried out in an organic banana plantation on the island of Tenerife, are set out and compared with the same variables investigated previously in conventional plantations by Diaz (1975) and Garcia *et al.* (1976, 1977).

It should be pointed out that, in the Canaries, the banana is grown in artificially built terraces, the soil being generally brought from the high zones of the islands whose soils are more fertile than those of the low zones where the banana can be cultivated. Consequently, the chemical fertility of the soils, given over to the cultivation of the banana, varies greatly, not only within the

island, but also within a given district, and even within the same plantation. The annual average fertilizer applied to the conventional banana plant is 330 g nitrogen, 20 g phosphorus and 145 g potassium per plant, plus 25 kg animal manure, which represent a total of 437 g N, 57 g P and 257 g K (Alvarez, 1981). The organic banana plantation subject of this study, receives annually 76.5 kg animal manure and 2.33 litres cow urine, which represents 460 g N, 153 g P and 362 g K. The values for these elements represented by crop residues are not included here since these residues are applied both to the conventional plantations and th organic plantations.

MATERIALS AND METHODS

The study was carried out in an organic banana plantation situated in Puerto de la Cruz (Tenerife) 130 m above the sea level, and with an area of 4 ha. The irrigation system was by micro-sprinkler irrigation and the fertilizers used are described in the introduction.

Three samplings were carried out: one in Autumn, another in Winter and finally one in Spring. The plantation was divided into five plots, from each of which was taken a compound sample consisting of soils from five plants. A compound sample of leaves of the same five plants was also taken. The leaf samples were taken according to the standards agreed in the Seminar of the Standardization of Banana Foliar Analysis (Tenerife, 1975): the third youngest leaf, counting from the last issued one with 1 m or more length in the state of floration of the plant, was chosen for sampling. At a point half way along the leaf a strip 10 cm wide was cut from the limb on both sides. The inner half was that used for analysis. The soil samples were taken in two sites per plant, 30 cms from the pseudostem at a depth of 25 cms, since 85% of the banana roots are found in the upper 25 cms of soil.

Techniques of soil analysis

The samples were dried in air, and passed through a 2 mm mesh. pH was measured in water in a ratio of 2:5, shaken and allowed to settle for 10 minutes. A CRISON digital 501 pH meter was used. Electrical conductivity was measured in the saturated water extract (Lopez & Lopez, 1985) with a CRISON 522 conductimeter.

Organic matter (O.M.) 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" (1973).

Available cations were extracted with an ammonium acetate 1 M solution at pH 7, and determined by atomic absorption spectrophotometry. Soluble

cations were determined from the saturated water extract. Ca and Mg were determined by complexiметric titration and Na and K by flame photometry.

Soluble anions. Carbonates and bicarbonates were determined by the Rettemeier (Rodier, 1981) method. Chloride was measured by titration with silver nitrate (Chapman & Pratt, 1961). Available phosphorus was extracted by the Olsen *et al.* (1954) method, and determined by the Watanabe & Olsen (1965) method.

Techniques of foliar analysis

The samples were washed in distilled water, and dried in an oven at 80°C, after which they were ground to powder. 0.2 g of this powder were used to determine N by the Kjeldahl (Cottenie, 1980) method. 1 g of the powder was ashed in an oven at 480°C and then it was mineralized by dry ashing with 6 M hydrochloric acid (Chapman & Pratt, 1961). K, Ca, Mg, Na, Fe, Mn, Zn and Cu were determined by atomic absorption spectrophotometry, and P by the vanadate-molybdate method (Chapman & Pratt, 1961).

RESULTS AND DISCUSSION

TABLE I

Analysis of the soils from the organic and the conventional* banana plantations

						Available cations (meq/100g)			
			pH	% O.M.	ppm P_2O_5	Ca	Mg	Na	K
Organic Plantations	Autumn sampling	X	6.77	10.41	515	26.80	9.94	3.44	5.93
		M	6.91	13.87	730	30.51	11.59	3.90	7.01
		m	6.51	7.68	391	23.90	7.69	2.90	5.38
	Winter sampling	X	6.59	11.21	527	31.09	10.21	3.26	6.83
		M	7.13	17.05	615	42.46	13.86	4.10	8.77
		m	6.27	7.09	457	27.49	8.21	2.47	6.20
	Spring sampling	X	6.68	14.31	749	32.12	11.91	2.36	7.60
		M	6.94	17.88	793	40.15	13.46	2.94	11.54
		m	6.44	10.98	719	26.80	9.53	1.89	6.25
Conventional Plantations		X	6.18	4.52	318	17.59	8.49	2.32	2.59
		M	8.21	8.20	620	26.50	13.40	4.10	4.60
		m	4.59	1.31	110	11.09	4.29	1.01	1.52

X = mean value; M = maximum value; m = minimum value.
*Data of Diaz (1975).

a) Soil analysis

Tables 1 and 3 set out the results of the soil analysis carried out in the samplings, as well as the correlations obtained with them. Table 1 details results of the values obtained in 16 conventional plantations (data of Diaz, 1975). Table 2 details the comparison of data from organic and conventional plantations by means of the Student t test.

It can be seen that the pH of the organic plantation soils could be considered to be normal, and it was positively correlated with the available cations K, Ca, Mg and Na. Similar correlations, except for K were found by Diaz (1975) and Garcia *et al.* (1976).

As was to be expected, the greatest difference in the soil characteristics of the two types of plantation was found in the organic matter, since these reach values of up to 17.9% in the organic plantation. As a result the averages were significantly higher in this plantation than in the conventional plantations. The correlations between O.M. and the available cations K, Ca, Mg and Na is explained by the increase of the exchange capacity which this material implies.

The phosphorus values were significantly higher in the organic plantation than in the conventional plantations. Its positive correlation with the O.M. had already been pointed out by Garcia *et al.* (1977), who attributed it to the phosphate content of the O.M. and an effect which made the phosphorus more available to the plants.

As regards the available cations, the amounts of Ca and K were significantly higher in the organic plantation, while those of Mg and Na were similar in both types of plantation. The positive correlation between Ca and Mg should be emphasized. This is in agreement with the findings of Diaz (1975) in conventional plantations. A positive correlation between Mg and Na was also found, similar to that pointed out by Garcia *et al.* (1977) in conventional plantations and which they attributed to the fact that Na and Mg are carried at the same time by irrigation water.

TABLE 2

Comparison, using student's t test, between soil variables from the organic banana plantation and those from conventional* plantations

	pH	O.M.	P_2O_4	Ca	Mg	Na	K
T value	1.290	7.0318	5.5054	6.8050	2.2778	1.9232	9.2246
Significance level	no sig.	0.001	0.001	0.001	0.05	no sig.	0.001

*Data of Diaz (1975)

TABLE 3

Simple correlations between soil variables of the organic banana plantation

		Ca	Mg	Na	K	P_2O_5
pH	Autumn sampling	r = 0.9771 p = 0.01	r = 0.942 p = 0.05	r = 0.9594 p = 0.01	r = 0.9707 p = 0.01	
	Winter sampling	r = 0.9440 p = 0.05	r = 0.9381 p = 0.05		r = 0.9467 p = 0.05	
	Spring sampling	r = 0.9570 p = 0.05	r = 0.9656 p = 0.01	r = 0.9568 p = 0.05		
O.M.	Autumn sampling		r = 0.8898 p = 0.1			r = 0.9757 p = 0.01
	Winter sampling	r = 0.9384 p = 0.05	r = 0.9335 p = 0.05			r = 0.9107 p = 0.05
	Spring sampling	r = 0.9929 p = 0.01	r = 0.9846 p = 0.01	r = 0.9818 p = 0.01	r = 0.8923 p = 0.1	r = 0.9394 p = 0.05
Ca	Autumn sampling		r = 0.9821 p = 0.01			
	Winter sampling		r = 0.9937 p = 0.001			
	Spring sampling		r = 0.9865 p = 0.01			
Mg	Autumn sampling			r = 0.9171 p = 0.05		
	Spring sampling			r = 0.9775 p = 0.01		

b) Foliar analysis

Tables 4 to 6 set out the results of the foliar analysis carried out in the three samplings, as well as the correlations obtained with them. Table 4 details the results of the values found by Diaz (1975) in 16 conventional plantings, and in Table 5 is the comparison by means of the Student t test of the average values of the conventional plantations and those from the organic plantation.

The N percentages fell within the range considered normal and were correlated positively with Ca, Zn, Cu and Fe, which agrees with the findings of Diaz (1975) in conventional plantations. In this study a positive correlation was found between N and P, which had not previously been noted in Canary banana plantations, and could be due to the fact that the concentrations of both nutrients depend on the supply of organic matter. This is confirmed by the positive correlations between O.M. and the foliar levels of these elements,

TABLE 4

Foliar analysis of the bananas from the organic and the conventional* banana plantations

			% × dry matter weight					ppm				
			N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	Na
Organic Plantation	Autumn Sampling	X	2.68	0.15	3.82	1.15	0.44	107	79	35	10	177
		M	2.81	0.16	3.96	1.38	0.46	126	111	38	11	208
		m	2.56	0.14	3.55	1.04	0.42	93	55	29	9	143
	Winter sampling	X	2.89	0.20	3.96	1.13	0.37	119	95	52	8	192
		M	3.18	0.21	4.19	1.29	0.41	156	122	80	10	212
		m	3.20	0.19	3.58	0.96	0.34	92	67	35	7	171
	Spring Sampling	X	2.72	0.24	3.56	0.70	0.35	147	94	27	9	235
		M	3.11	0.28	3.74	1.04	0.39	185	151	34	12	260
		m	2.38	0.19	3.26	0.35	0.29	122	56	25	7	215
Conventional Plantations		X	2.88	0.23	3.92	0.74	0.37	87	177	20	11	
		M	3.17	0.26	4.22	0.90	0.49	109	589	24	15	
		m	2.68	0.18	3.40	0.44	0.26	69	73	15	7	

X = Mean value; M = maximum value; m = minimum value.
*Data of Diaz (1975)

TABLE 5

Comparison, using student's t test, between foliar nutrients of bananas from the organic banana plantation and those from conventional* plantations

	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu
t value	-1.4229	-2.1409	-0.4226	3.4478	0.7549	5.0775	-2.5321	4.524	-2.750
Significance level	no sig.	0.05	no sig.	0.001	no sig.	0.001	0.05	0.001	0.05

*Data of Diaz (1975).

as can be seen in section c. It is natural that this correlation is not found in conventional plantations, since the nutrients N and P are supplied as fertilizers of a different nature, at different times and also in different amounts.

Reflecting the values found in the soil, foliar phosphorus was significantly higher in the organic plantation.

The foliar K and Mg percentages were similar in the plants of both types of cultivation, while Ca was higher in the organic plantation. It should be emphasized that the antagonisms K-Ca and K-Mg, pointed out by Garcia *et al.* (1977b) did not seem to apply to the organic plantation. The positive correlations between K and the nutrients P, Mn and Zn as well as those of Mg with Na and Ca were, however, noted. These had previously been reported by Diaz (1975) in conventional plantations. For the first time correlations between K and the nutrients Fe and Cu were detected, and these occurred in the organic plantation.

It can be seen that Mn varies from 55 to 151 ppm, its average being significantly less than that of conventional plantations, although its values were always above the deficiency level indicated by Marchal and Martin-Prével (1971).

As regards Zn, the average is significantly higher in the organic plantation. The opposite occurred with Cu. The Cu foliar values, however, were usually low and not taken into account in the diagnosis of the mineral nutrition of the banana (Marchal & Martin-Prével, 1971).

c) Soil-plant Relations

Table 7 sets out the results of the correlations between the chemical characteristics of the soil and the foliar nutrients of the organic plantation.

The pH showed positive correlations with foliar Na, Ca and Mg, which is understandable because the values of these elements in available form in the soil are also positively correlated with the pH, as has been indicated in section a).

TABLE 6

Simple correlations between foliar nutrients of the bananas from the organic banana plantation

	K – Fe	K – Cu	K – Mn	K – Zn	K – P	Ca – Mg	Ca – N
Autumn sampling	r = 0.9817 p = 0.01	r = 0.9617 p = 0.01	r = 0.8785 p = 0.05	r = 0.9650 p = 0.01	r = 0.9869 p = 0.01	r = 0.9848 p = 0.01	
Winter sampling	r = 0.9259 p = 0.05	r = 0.9718 p = 0.01	r = 0.9122 p = 0.05		r = 0.9869 p = 0.01	r = 0.9825 p = 0.01	r = 0.9520 p = 0.05
Spring sampling	r = 0.9279 p = 0.05			r = 0.9366 p = 0.05	r = 0.9514 p = 0.05	r = 0.8909 p = 0.05	
	Mg – Na	Mg – N	Fe – N	Cu – N	Zn – N	N – P	
Autumn sampling	r = 0.9487 p = 0.05	r = 0.9927 p = 0.001	r = 0.9627 p = 0.01	r = 0.9482 p = 0.05	r = 0.9594 p = 0.01	r = 0.9946 p = 0.001	
Winter sampling	r = 0.9958 p = 0.001		r = 0.9107 p = 0.05	r = 0.9412 p = 0.05	r = 0.9534 p = 0.05		
Spring sampling	r = 0.9861 p = 0.01	r = 0.9497 p = 0.05			r = 0.8898 p = 0.05	r = 0.8817 p = 0.05	

TABLE 7

Simple correlations between soil variables and foliar analysis

	Soil pH – Foliar Ca	Soil pH – Foliar Mg	Soil pH – Foliar Na	Soil Ca – Foliar Mg	Soil Mg – Foliar Mg	Soil O.M. – Foliar Fe
Autumn sampling	$r = 0.9710$ $p = 0.01$	$r = 0.9970$ $p = 0.001$	$r = 0.9342$ $p = 0.01$	$r = 0.9600$ $p = 0.01$	$r = 0.9978$ $p = 0.001$	
Winter sampling	$r = 0.9259$ $p = 0.05$	$r = 0.9691$ $p = 0.01$	$r = 0.9661$ $p = 0.01$		$r = 0.8787$ $p = 0.05$	$r = 0.9188$ $p = 0.05$
Spring sampling		$r = 0.9759$ $p = 0.01$	$r = 0.9863$ $p = 0.01$	$r = 0.9283$ $p = 0.05$		$r = 0.9501$ $p = 0.05$

Soil O.M. – Foliar Cu (Autumn sampling)	Soil O.M. – Foliar Zn (Spring sampling)	Soil O.M. – Foliar N (Spring sampling)	Soil O.M. – Foliar P (Spring sampling)	Soil Ca – Foliar Ca (Autumn sampling)	Soil P_2O_5 – Foliar P (Spring sampling)	Soil K – Foliar K (Autumn sampling)
$r = 0.9083$ $p = 0.05$	$r = 0.9501$ $p = 0.05$	$r = 0.8890$ $p = 0.05$	$r = 0.9483$ $p = 0.05$	$r = 0.9147$ $p = 0.05$	$r = 0.9397$ $p = 0.05$	$r = 0.9773$ $p = 0.001$