Soil Fertility and Mineral Nutrition of a Biodynamic Avocado Plantation in Tenerife

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ABSTRACT

The soil fertility of a biodynamic avocado plantation in Tenerife and its relation to mineral nutrition was studied and compared with similar variables investigated previously in conventional plantations. The surface soils of the biodynamic plantation showed pH, organic matter and available P, Ca, Mg and K averages significantly higher than those of the conventional plantations. As regards the foliar nutrient levels, the N, P, K, Mg and Cu averages were similar in both types of plantations, while the average foliar Ca and Mn values were significantly lower in the biodynamic avocados, although they fell within the range considered normal. On the other hand, the Zn average was significantly greater in the biodynamic plantation.

INTRODUCTION

Biodynamic agriculture is a production system which excludes the use of compounded synthetic fertilizers, pesticides, growth regulators and livestock feed additives. It relies on crop rotation, crop residues, composting, legumes, green manure and aspects of biological control and use of natural insecticides, or fungicides to maintain soil productivity and tilth, supply plant nutrients and control insects, other pests and weeds. One of its principal characteristics is the use of substances called 'preparations' obtained from medicinal plants, mineral, or manure which are made in a special way, and have a particular action on the compost, soil or plant to which they are applied (Steiner, 1924).

In 1982 cultivation by the biodynamic system was begun in a 6 hectare avocado plantation in Tenerife. Since the avocado is a crop of interest to the Canaries, it is understandable that an attempt was made to ascertain aspects as important for its development as the mineral nutrition of the tree and the fertility of the soil.

As regards avocado plantations in general, it should be pointed out that, in the Canaries, the avocados are grown in artificially-built terraces because they have been used to replace, in part, the banana plants for which the soil was

brought from the upper zones, whose soils are more fertile than the lower, where the banana can be grown. Because of this the soils given over to the cultivation of the avocado vary greatly not only within the island, but also within a given district, and even within the same plantation. This variability within the same plantation was the reason for our carrying out a comparative study with conventional plantations. Only plantations in the northern zone were selected for comparison to avoid adding to the variability of the soils a climatic variability, which would have happened if data from plantations in the southern zone had also been included. The purpose of this study was to compare soil and foliar data from the biodynamic avocado plantation with the findings of García *et al.* (1981, 1983) in 31 conventional plantations as far as soil samples are concerned, and 15 plantations in the case of foliar samples.

Each tree in the conventional plantations received an average of 1,135 g N, 437 g P and 938 g K annually (Alvarez, 1979). The annual application per tree to the biodynamic avocados, the subject of this study, was 5 kg biodynamic compost, 25 kg pine leaf mulch and 26 litres of cow urine which is equivalent to 675 g N, 193 g P and 565 g K.

MATERIALS AND METHODS

The study was carried out in a 6 hectare avocado plantation situated in La Orotava (Tenerife) at a height of 300 m above sea level. The varieties cultivated were Fuerte and Hass, predominantly the latter. In 1986 the trees had completed 5 years under the biodynamic system of cultivation. Watering was by micro-sprinkler irrigation carrying cow urine as a fertilizer. Organic material from plant residues and manure were composted in heaps, or on the surface. Pine needles were used as a mulch.

Six plots of 1,000 m² each were determined, in each of which 5 trees were chosen at random, and marked to monitor their evolution with time by means of soil sampling carried out in Autumn, Winter and Spring, and foliar sampling in Autumn and Winter. The advanced stage of floration in Spring prevented the taking of foliar samples in this season. Two types of soil sample were taken: one surface from 0 to 25 cms and the other deep from 25 to 50 cms which formed a compound sample with the five trees in each plot. The foliar sample was also made up of the 5 trees in each plot. The fourth, fifth or sixth leaf of terminal branches without secondary shoots or fruit were chosen, 10 leaves per tree being taken.

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 (López & López, 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 1M solution at pH 7, and determined by atomic absorption spectrophotometry. Soluble anions were determined from the saturated extract. Carbonate and bicarbonate were determined by the Rettemeir (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 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).

Statistical methods

The correlations and Student significance tests were calculated in a Casio FX-702P using the theories of Snedecor & Cochran (1974). The greater variability of the biodynamic plantation soils which, as can be seen in Table 1, in some cases exceeds the chemical soil characteristics of the conventional plantations (due, as we have said in the introduction, to the artificial construction of the cultivation terraces) leads to the conclusion that the comparative study between the biodynamic plantation and the conventional plantations is possible.

TABLE 1

Surface soil analysis of the biodynamic and conventional* avocado plantations.

			pH	% O.M.	ppm P ₂ O ₅	Available cations (meq/100 g)			
						Ca	Mg	Na	K
Biodynamic	Autumn sampling	$\bar{X}$	7.53	10.60	514	32.63	15.80	3.48	9.15
		M	7.67	15.56	604	38.88	17.92	4.73	10.11
		m	7.36	3.31	175	12.34	10.67	2.21	7.18
	Winter sampling	$\bar{X}$	7.79	9.33	457	28.62	17.18	2.66	9.86
		M	8.23	12.37	589	43.16	21.24	3.22	10.89
		m	7.45	3.86	186	19.93	10.81	1.60	8.76
	Spring sampling	$\bar{X}$	7.67	9.68	570	36.15	16.33	3.24	9.24
		M	7.92	12.80	766	44.96	19.30	4.41	10.04
		m	7.52	2.25	260	19.89	10.43	2.12	8.47
Conventional		$\bar{X}$	6.19	2.32	308	7.36	5.65	2.34	3.29
		M	8.21	5.89	647	17.61	14.00	8.38	6.55
		m	4.59	0.54	103	2.99	1.71	0.61	1.10

 $\bar{X}$ = Mean value; M = maximum value; m = minimum value.*Data of Garcia *et al.* (1981).

TABLE 2

Deep soil analysis of the biodynamic avocado plantation.

		pH	% O.M.	ppm P ₂ O ₅	Available cations (meq/100 g)			
					Ca	Mg	Na	K
Autumn sampling	$\bar{X}$	7.54	6.78	454	24.79	14.04	3.48	7.54
	M	7.78	10.80	558	29.63	16.34	4.78	8.76
	m	7.25	1.96	126	16.63	11.15	2.92	5.69
Winter sampling	$\bar{X}$	7.86	5.24	398	27.05	14.52	2.84	8.33
	M	8.22	7.87	591	35.17	17.99	3.48	10.47
	m	7.46	1.76	129	17.03	10.35	1.87	6.32
Spring sampling	$\bar{X}$	7.64	5.46	601	29.89	13.94	3.12	7.93
	M	7.86	9.14	776	43.37	15.53	3.49	9.40
	m	7.44	2.20	251	18.39	10.26	2.49	6.71

 $\bar{X}$ = mean value; M = maximum value; m = minimum value.

TABLE 3

Simple correlations between surface soil variables of the biodynamic plantation.

	O.M.-P ₂ O ₅	O.M.-Ca	O.M.-K	O.M.-Mg	Ca-K	Ca-Mg
Autumn sampling	r = 0.8638 p = 0.05	r = 0.8642 p = 0.05	r = 0.8520 p = 0.05	r = 0.8492 p = 0.05	r = 0.9437 p = 0.01	
Winter sampling	r = 0.8790 p = 0.05	r = 0.8608 p = 0.05	r = 0.8561 p = 0.05			r = 0.8782 p = 0.05
Spring sampling		r = 0.8214 p = 0.05		r = 0.8485 p = 0.05	r = 0.8380 p = 0.05	r = 0.9495 p = 0.01

TABLE 4

Simple correlations between deep soil variables of the biodynamic plantation.

O.M.-P ₂ O ₅		Ca-K	
Autumn sampling r = 0.7830 p = 0.10	Winter sampling r = 0.8782 p = 0.05	Autumn sampling r = 0.8130 p = 0.10	Winter sampling r = 0.8817 p = 0.05

TABLE 5

Simple correlations between surface soil and deep soil variables of the biodynamic avocado plantation.

	O.M. _(s) -P ₂ O _{5(d)}	P ₂ O _{5(s)} -P ₂ O _{5(d)}	Ca _(s) -Mg _(d)	Mg _(s) -Mg _(d)	K _(s) -K _(d)
Autumn sampling	r = 0.8931 p = 0.05 pH _(s) -pH _(d)	r = 0.9764 p = 0.001 O.M. _(s) -O.M. _(d)	r = 0.8946 p = 0.05 O.M. _(s) -P ₂ O _{5(d)}	r = 0.7696 p = 0.10 P ₂ O _{5(s)} -P ₂ O _{5(d)}	r = 0.8603 p = 0.05 Mg _(s) -Mg _(d)
Winter sampling	r = 0.8674 p = 0.05 pH _(s) -pH _(d)	r = 0.9269 p = 0.01 O.M. _(s) -P ₂ O _{5(d)}	r = 0.8531 p = 0.05 P ₂ O _{5(s)} -P ₂ O _{5(d)}	r = 0.9760 p = 0.001 Ca _(s) -Mg _(d)	r = 0.8921 p = 0.05 K _(s) -K _(d)
Spring sampling	r = 0.8832 p = 0.05	r = 0.8283 p = 0.05	r = 0.8360 p = 0.05	r = 0.8737 p = 0.05	r = 0.8559 p = 0.05

(s) = Surface soil; (d) = Deep soil.

RESULTS AND DISCUSSION

a) Soil analysis

It should be pointed out that in the conventional plantations, the data of which were used for the comparative study, the soil samples were taken only to a depth of 25 cm. (García *et al.*, 1981). Hence it was impossible to make a comparison with the data of the deep soils.

Tables 1 to 5 set out the results of the soil analyses of the conventional plantations (data of García *et al.*, 1981), and those of the biodynamic plantation in the three samplings carried out, and also the correlations obtained with them. Table 7 shows the comparison of the average of the conventional plantations with the averages of the biodynamic plantation by means of the Student *t* test.

The pH of both the surface and the deep soils showed significant variations between the plots ($p=0.01$ and $p=0.01$ respectively) and the times of sampling ($p=0.01$ and $p=0.001$ respectively), although all were slightly alkaline. The pH of both soil zones were positively correlated, as was to be expected. On the other hand, the average of the surface soils was significantly higher than that of the conventional plantations.

The phosphorus content of the surface and the deep soils varied between the plots ($p=0.01$ and $p=0.001$, respectively), but, while in the former there was no seasonal variation, a sharp increase was noted in the spring sampling of the deep soils. Nevertheless, there was a positive correlation between the phosphorus content of both soil zones. As happened with pH the phosphorus values were significantly higher in the biodynamic plantation soils than in those of the conventional plantations.

The organic matter percentage was also higher in the biodynamic plantation. Within this plantation there were significant differences in the organic matter content both in the surface soils and the deep soils between different plots ($p=0.01$ and $p=0.05$ respectively), but not at the times of sampling. As is natural a positive correlation of the organic matter between the soils of both depths was found. Positive correlations between organic matter and the available nutrients P, Ca and K were noted both in the surface and the deep soils, and Mg in the surface, which can be explained by the solubilizing effect and the P supply of the organic matter, and the increase of the exchangeable cationic capacity in the case of Ca, Mg and K.

The available Ca was significantly greater in the biodynamic plantation than in the conventional plantations. In the former significant differences were found between the plots ($p=0.01$ and $p=0.01$ in surface soils and deep soils respectively), and at times of sampling in the surface soils ($p=0.05$). At both depths positive correlations between available Ca and Mg were found;

which is understandable on the basis that both cations are related to organic matter, as has been mentioned previously.

Available Mg and K were significantly higher in the biodynamic plantation than in the conventional plantations. Significant differences between the plots were noted both in the surface soils and the deep soils for Mg and K ($p=0.01$ and $p=0.05$ for K, and $p=0.05$ and $p=0.01$ for Mg). A seasonal variation was also found for Mg in surface soils ($p=0.01$).

Na was the only available cation which did not differ significantly in its averages between the biodynamic plantation and the conventional plantations. Within the former significant differences were found only between the plots of deep soils ($p=0.05$).

b) Foliar analysis

Table 6 sets out the results of the foliar analysis data in the two samplings carried out and those values found by García *et al.* (1983) in 15 conventional plantations, and the comparison of the averages of the biodynamic plantation by the Student *t* test is shown in Table 8.

The N, P, K and Mg values fell within the ranges considered normal by Embleton & Jones (1966), and did not show significant differences with the data of García *et al.* (1983) for conventional plantations. A negative correlation was found between foliar N and Fe ($r=0.9135$, $p=0.05$), but the cause was not clear. A similar correlation was noted by Díaz (1975) in banana plantations in Tenerife.

The Ca concentration showed an average significantly higher than that of the conventional plantations, although all the values noted lay within the range indicated by Embleton & Jones (1966) as normal.

The Mn contents were significantly less in the plantation under study than in the conventional plantations, and although they were within the range given as normal by the researchers quoted above, according to Barroso (1984) there could have been a Mn deficiency in the plants of plot 6.

The Zn average was significantly higher than that shown by the conventional plantations. This greater amount of Zn may be supplied by the compost in which 350 ppm of Zn were detected. The use of organic matter as a source of Zn has been indicated by Chaney & Giordano (1977). The low Zn concentration found in plot 1 may, however, be due to a lower Zn absorption since the rootstocks are different.

It was noteworthy that while the Mg, K, Na, Fe, Cu and Zn contents were very similar at the times of sampling a significant increase of Ca, Mn, N and P was observed in winter sampling.

TABLE 6

Foliar analysis of avocado trees from the biodynamic and conventional* avocado plantation.

		%					ppm					
		N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	Na	
Biodynamic	Autumn sampling	$\bar{X}$	2.26	0.17	0.90	1.33	0.85	105	41	39	13	173
		M	2.35	0.18	0.96	1.55	1.00	132	47	48	15	253
		m	2.21	0.15	0.82	1.15	0.76	90	31	28	9	104
	Winter sampling	$\bar{X}$	2.49	0.14	0.93	1.58	0.95	93	51	50	12	159
		M	2.70	0.15	1.03	1.89	1.10	119	68	78	13	190
		m	2.30	0.14	0.85	1.41	0.80	75	33	28	9	131
	Conventional	$\bar{X}$	2.18	0.13	0.77	1.72	0.93	76	135	23	15	161
		M	2.81	0.19	1.60	2.48	1.35	105	630	32	42	500
		m	1.61	0.10	0.43	1.33	0.69	63	16	18	6	75

 $\bar{X}$ = mean value; M = maximum value; m = minimum value.*Data of Garcia *et al.* (1983).

TABLE 7

Comparison, using Student's *t* test, between soil variables from the biodynamic plantation and those from conventional plantations.

	pH	O.M.	P	Ca	Mg	Na	K
<i>t</i> value	2.859	9.091	3.158	11.419	7.264	1.495	7.828
Significance level	0.05	0.001	0.01	0.001	0.001	no sig.	0.001

TABLE 8

Comparison, using Student's *t* test, between foliar nutrients of avocados from the biodynamic plantation and those from conventional plantations.

	N	P	K	Ca	Mg	Na	Fe	Mn	Cu	Zn
<i>t</i> value	-0.289	0.525	0.901	-2.639	0.650	1.667	1.468	-2.087	-0.069	6.892
Significance level	no sig.	no sig.	no sig.	0.05	no sig.	0.05	no sig.	0.05	no sig.	0.01

c) Soil-plant relations

Only one of the relations of the chemical characteristics of surface and deep soils with the foliar nutrients was repeated in the autumn and winter samplings. The correlations in question were those between available K in deep soils and foliar Zn ($r=0.8166$, $p=0.05$ in the autumn sampling and $r=0.8912$, $p=0.05$ in the winter sampling). The reason for this correlation, previously noted by Diaz (1975) in banana plantations, was not clear.

CONCLUSIONS

The soil fertility of the biodynamic avocado plantation studied was similar to that of the conventional plantations sampled by Garcia *et al.* (1981) although the averages of the pH, O.M. content and available P, Ca, Mg and K averages were higher than the averages of the conventional plantations.

As regards mineral nutrition, the macro and micronutrient contents fell within the range considered normal, as also did those of Ca and Mn although their levels were lower than the averages of those found by Garcia *et al.* (1983) in conventional plantations. The opposite was true of the Zn content.

These facts indicate that the fertilization and management of the biodynamic plantation can produce crops similar to those of the conventional plantations. This is confirmed by the level of production which, with an average of 40 metric tons per year may be considered good for the zone where the plantation is situated.

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