Micronutrients in Soils and Plants from Organic Farms of Tenerife (Canary Islands)

E. Piqué, C.E. Alvarez and M. Fernández

Instituto de Productos Naturales y Agrobiología, C.S.I.C., Apartado 195, La Laguna, 38206 Tenerife, Spain

ABSTRACT

Soil and plant samples were taken from tropical fruit tree plantations, temperate fruit tree orchards and vegetable gardens grown using organic agricultural methods in Tenerife. Micronutrients Cu, Fe, Mn, and Zn were determined. The micronutrient content of most soils was found to fall within the normal range reported in the literature. Mn was present at low levels in the foliage of many plants, and a negative correlation between foliar Mn and soil organic matter content was observed in avocado and banana plantations. Consequently, maximum levels of soil organic matter content are established for avocado and banana. Cu, Fe, and Zn were also deficient in leaves of some plants.

INTRODUCTION

Micronutrients play important roles in physiological functions of plants. Fe, Mn, and Cu catalyze principally redox processes by electron transfer while Zn and Fe form enzyme-substrate complexes. Zn also enhances enzyme reactions by influencing the molecular configuration of an enzyme or substrate (Römheld & Marschner, 1991). Plant nutrition scientists have endeavoured to learn which levels of these micronutrients are best suited to different plant species and cultivars (Chapman, 1966; Martin-Prével *et al.*, 1987; Jones *et al.*, 1991). In addition to inner plant relationships, micronutrient concentrations in plants depend upon their soil content and availability, and many soil scientists have developed soil testing extractants to predict the capacity of the soils to provide them (Sims & Johnson, 1991).

In practice, soil analysis must be complemented by plant analysis to estimate how plants may grow, the nutritional problems that may arise, and how to handle them in order to improve yields and quality (Jones *et al.*, 1991). On that score, symptoms of Cu deficiency are a reduced or stunted growth with

a distortion of young leaves and necrosis of the apical meristem. In trees, Cu deficiency may cause white tip or bleaching of younger leaves and summer dieback. An excess of copper can induce iron deficiency and chlorosis. Root growth may be suppressed, with inhibited elongation and lateral root formation. As far as iron is concerned, deficiency symptoms consist of interveinal chlorosis of younger leaves. As the severity of the deficiency increases, chlorosis spreads to the older leaves. Iron may accumulate to several hundred mg/kg without toxicity symptoms. Toxicity produces a bronzing of the leaves with tiny brown spots on the leaves. In the case of manganese, reduced or stunted growth with dicots showing interveinal chlorosis of the younger leaves is symptomatic of manganese deficiency. An excess of manganese causes older leaves to show a brown spot surrounded by a chlorotic zone or circle. With respect to zinc, its deficiency appears as a chlorosis in the interveinal areas of new leaves, producing a banding appearance. With increasing severity of the deficiency, leaf and plant growth become stunted, and leaves die and fall off the plant. Excess of zinc produces chlorosis in plants (Jones *et al.*, 1991).

In the Canary Islands, Alvarez & González (1985), Alvarez *et al.* (1988), and García *et al.* (1989) carried out studies of plant nutrition of organic farms, but the micronutrient status of soils from organic plantations had never been tested. In this paper we present results obtained for soils from organic farms, using micronutrient soil extractants recommended by FAO (Sillanpää, 1982). Their relationships with soil organic matter content and plant micronutrient levels were also studied, and the results compared with those found in conventional plantations.

MATERIALS AND METHODS

The study was carried out in Tenerife (Canary Islands) in fourteen organic plantations of seven farmers. They represent so far the whole population of commercial organic farms with six or more years of organic cultivation. The basic characteristics of the farms studied are given in Table 1.

Soil sampling

Soil samples were taken in Autumn, 1992. In fruit tree plantations, two depths of soil were sampled: 0–25 cm and 25–50 cm. A compound sample from five trees in each plantation was collected. In banana farms, soil samples were taken at two sites per plant, 30 cm from the pseudostem at a depth of 0–30 cm, to provide a compound sample from five banana plants in each farm. In vegetable gardens, soil samples consisted of compound samples from several sites for each vegetable species, taken at a depth of 0–25 cm.

TABLE 1

Altitude, average rainfall, pH, CEC and USDA classification of the soils of the studied organic farms

Farm	Altitude (m)	Rainfall (mm)	pH	CEC (meq/100 g)	USDA classification
B.'s farms	270-380	525	7.21	40.21	Alfisol
J.B.'s farm	350	550	7.61	19.43	Alfisol
J.D.'s farm	120	243	8.23	44.43	Aridisol
J.J.C.'s farm	610	620	7.74	21.43	Alfisol
M.R.'s farm	290	240	8.66	22.27	Aridisol
M.S.'s farm	770	650	6.03	16.12	Alfisol
R.P.'s farms	550 & 710	550	7.29	23.40	Alfisol

Foliar sampling

Foliar samples were collected from the plants where the soil samples were taken, forming a compound sample of five plants from each tree and banana plantation, and of twenty to thirty plants from each vegetable in vegetable gardens.

Trees were sampled according to López & López (1985) and Jones *et al.* (1991). Bananas leaves were taken following the recommendations of the Seminar of the Standardization of Banana Foliar Analysis (Tenerife, 1975): the third youngest leaf, counting from the last emerged one with 1 m or more length at the time of flowering was chosen. At a point half way along the leaf a strip 10 cm wide was cut from the midrib on both sides. The inner half was used for analysis. Vegetables were sampled as recommended by López & López (1985) and Jones *et al.* (1991).

Techniques of soil analysis

The samples were dried in air, and passed through a 2 mm mesh sieve. 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). Copper and iron were extracted by AAAC-EDTA (acid ammonium acetate-EDTA), and manganese and zinc by DTPA (Sillanpää, 1982), and determined by atomic absorption spectrophotometry.

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. 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). Cu, Fe, Mn and Zn were determined by atomic absorption spectrophotometry, using deionized water to prepare standards. Four repeat determinations were made for each micronutrient. Working standard ranges were 0.5–10 mg/kg for Cu, 1–15 mg/kg for Fe, 1–18 mg/kg for Mn, and 0.5–10 mg/kg for Cu.

RESULTS AND DISCUSSION

Soil analysis

Organic matter content of surface soils from fruit tree plantations was very high in most cases (Tables 2 and 3). This characteristic was also observed in some 25–50 cm soil profiles. In the soils from vegetable gardens (Table 4) only one sample (cauliflower) presented a high O.M. percentage.

The soils from tree and vegetable farms (Tables 2, 3 and 4) showed Cu values considered to be normal (1–16 mg/l) in agricultural soils (Kishk *et al.*,

TABLE 2

Organic matter and micronutrients in soils and plants from tropical fruit organic plantations

Owner	Fruit	Soil Parameters						Plant Micronutrients (mg/kg)			
		cm	%	mg/l				Cu	Fe	Mn	Zn
		Depth	O.M.	Cu	Fe	Mn	Zn				
J.B.	Avocado	0–25	6.7	11.9	885	45.0	12.4	5	78	55	30
		25–50	3.3	5.7	493	10.4	3.4				
B. 1	Avocado	0–25	12.8	10.7	558	8.7	12.5	6	95	25	24
		25–50	7.7	13.7	553	5.6	9.4				
B. 2	Avocado	0–25	12.4	3.7	250	7.8	8.2	10	68	22	32
		25–50	10.1	6.1	478	5.1	6.7				
B. 3	Avocado	0–25	10.7	6.1	530	8.8	10.3	7	72	32	34
		25–50	5.6	7.5	545	6.6	6.8				
J.D.	Avocado	0–25	5.1	6.9	603	9.2	1.1	9	86	67	46
		25–50	3.1	4.6	355	6.2	2.6				
M.R.	Avocado	0–25	1.8	5.2	303	9.5	4.4	13	62	106	30
		25–50	0.4	4.7	193	4.1	4.2				
J.D.	Mango	0–25	4.1	9.2	538	8.4	9.3	10	47	39	23
		25–50	3.8	6.1	343	4.8	4.9				
B. 4	Banana	0–30	8.8	5.4	520	13.4	11.3	10	107	71	29
B. 5	Banana	0–30	10.8	4.7	435	19.6	21.5	3	124	33	24
B. 6	Banana	0–30	8.2	4.1	405	16.1	14.0	6	117	83	21
M.R.	Banana	0–30	2.3	5.0	418	73.0	6.1	6	97	204	25

1973; Sillanpää, 1982), with the exception of one 25–50 cm sample (0.9 mg/l Cu) from the apple plantation of M.S., and another (0.4 mg/l Cu) from the avocado plantation of M.R.. Most soil Cu values, either from tropical fruit plantations, temperate fruit orchards or vegetable gardens, exceeded those from conventional plantations of Tenerife with comparable soils which have a mean of 4.7 mg/l (Fernández-Falcón *et al.*, 1994).

The Fe content of all the sampled soils was greater than the critical level (30 mg/l) established by FAO (Sillanpää, 1982). With the exception of one case (apple plantation soil from M.S.), the soils sampled to a depth equal to or less than 30 cm presented higher Fe values than the mean (110.4 mg/l) reported by Borges-Pérez *et al.* (in press) for conventional plantations of Tenerife with comparable soils.

Mn concentrations of most soils (including 25–50 cm samples) exceeded the deficiency level (5 mg/l) established by Sims & Johnson (1991), though none reached the mean value (67.1 mg/l) observed by Borges-Pérez *et al.* (in press) in Tenerife conventional plantations with comparable soils.

All the soils from tropical fruit plantations (Table 2) showed greater Zn levels than the range (0.5–1 mg/l) considered to be marginal by some authors (Lindsay & Norvell, 1978). The same was true for Zn concentrations in surface soils of temperate fruit orchards (Table 3), and three of the 25–50 cm soil samples from these plantations. In vegetable gardens (Table 4), only the soils from R.P. farm were within the Zn marginal range. The mean Zn content in

TABLE 3

Organic matter and micronutrients in soils and plants from temperate fruit organic plantations

Owner	Fruit	Soil Parameters						Plant Micronutrients (mg/kg)			
		cm	%	mg/l				Cu	Fe	Mn	Zn
		Depth	O.M.	Cu	Fe	Mn	Zn				
J.B.	Mandarin	0–25	7.6	6.9	435	6.2	5.6	2	116	17	17
		25–50	7.2	4.1	363	4.9	0.9				
M.R.	Grapefruit	0–25	8.7	4.4	255	5.9	2.3	4	60	25	10
		25–50	9.4	4.2	205	4.5	1.5				
M.R.	Orange	0–25	8.7	3.6	225	3.8	1.5	5	61	22	9
		25–50	8.8	3.1	155	3.4	0.7				
M.S.	Apple R.	0–25	12.1	2.8	123	4.6	2.1	8	222	32	20
		25–50	9.4	1.5	75	3.5	0.4				
M.S.	Apple F.	0–25	11.7	1.4	92	5.6	2.2	6	246	38	14
		25–50	9.8	0.9	113	4.8	0.3				
R.P.	Pear	0–25	7.5	5.0	325	12.8	2.0	6	203	101	29
		25–50	6.5	4.3	293	10.9	1.1				
J.D.	Fig	0–25	4.6	6.0	293	5.1	2.3	6	182	40	27
		25–50	1.9	4.2	213	4.3	2.3				

TABLE 4

Organic matter and micronutrients in soils and plants from vegetable organic plantations

Owner	Plant	Soil Parameters					Plant Micronutrients (mg/kg)			
		%	mg/l				Cu	Fe	Mn	Zn
			O.M.	Cu	Fe	Mn				
J.J.C.	Beetroot	3.5	7.2	315	15.1	8.0	13	185	78	64
	Kidney bean	3.5	7.8	243	20.9	6.8	12	196	50	43
	Carrot	3.1	6.8	355	16.0	6.3	11	155	34	35
	Chard	3.0	6.4	240	18.6	5.9	14	126	72	50
R.P.	Chard	3.8	2.4	338	23.1	0.9	14	135	68	32
	Spinach	3.6	2.7	360	21.2	0.9	10	252	117	60
B. 7	Cauliflower	9.6	10.5	825	9.7	11.0	6	66	19	28

Tenerife conventional plantations with comparable soils (4.75 mg/l) was lower than soil Zn levels of 51% of the organic farms.

Plant analysis

The foliar Cu levels of avocado (Table 2) were within the range (5–15 mg/kg) recommended by Jones *et al.* (1991), and no difference appeared among our samples and the foliar Cu values observed by García *et al.* (1983) in avocados of conventional plantations. On the contrary, banana leaves from conventional banana plantations sampled by Díaz (1975) showed significantly higher Cu concentrations ($p = 0.01$) than those from organic farms. Moreover, one sample of banana leaves (B. 5) did not reach the Cu concentration (6–25 mg/kg) stated to be sufficient by Jones *et al.* (1991). Two citrus foliar samples (Table 2) showed lower Cu values (< 5 mg/kg) than those indicated by Chapman (1966) and Jones *et al.* (1991). Apple, pear and fig trees, and vegetables presented normal foliar Cu levels (Tables 3 & 4).

Avocado showed normal foliar Fe concentrations, within the range (50–200 mg/kg) established by Jones *et al.* (1991), and their Fe values were similar to those detected in conventional plantations (García *et al.*, 1983). Concentrations of Fe in banana leaves fell within the limits (76–300 mg/kg) determined by Jones *et al.* (1991), yet organic banana foliar Fe significantly exceeded ($p = 0.01$) the values reported by Díaz (1975) for conventional plantations. Only mango showed inadequate foliar Fe content compared with Jones *et al.* (1991).

Low levels of Mn (less than the 30 mg/kg indicated by Jones *et al.*, 1991) were observed in two samples of avocado leaves, and coincided with soils that had the highest O.M. percentages (Table 2). We detected a negative correlation between foliar Mn and surface soil O.M. (Figure 1) that was confirmed by a similar one ($r = -0.9219$; $p = 0.0089$) with 25–50 cm soil O.M. In addition,

we found another negative correlation between these two variables (Figure 2) in banana plantations, where only one foliar sample reached the Mn lower limit of sufficiency (200 mg/kg) stated by Jones *et al.* (1991). These findings may be explained by the formation of manganese-organic complexes of low solubility, such as complexes with humic acids and other high molecular weight components of organic matter (Stevenson, 1991). Foliar Mn concentrations in both avocado and banana were similar to those from conventional plantations (Diaz, 1975; García, 1983).

Only grapefruit presented normal leaf Mn contents (25 mg/kg) among the citrus. Mango did not reach the lower limit of sufficiency (50 mg/kg) for foliar Mn, neither did carrot nor cauliflower (50 mg/kg, and 25 mg/kg, respectively), according to limits suggested by Chapman (1966), Martin-Prével *et al.* (1987), and Jones *et al.* (1991). The other plants had normal foliar Mn levels.

Foliar Zn of avocado and banana, with the exception of B.1, was within the normal range of 30–50 mg/kg for avocado, and 13–50 mg/kg for banana (Jones *et al.*, 1991). Zinc concentrations of avocado leaves significantly exceeded ($p = 0.001$) those from conventional plantations observed by García *et al.* (1983), but no difference was detected when we compared foliar Zn levels of banana

FIGURE 1. Regression of foliar manganese concentration on soil organic matter content of avocado plantations.

FIGURE 2. Regression of foliar manganese concentration on soil organic matter content of banana plantations.

from both kinds of agricultural system.

Grapefruit and orange did not reach the lower limit of foliar Zn content (25 mg/kg) established by Jones *et al.* (1991), neither did one of the apple cultivars of M.S. (foliar Zn level < 20 mg/kg, according to the same authors) The remainder of the plants showed normal foliar Zn concentrations.

CONCLUSIONS

The soils of the sampled plantations had sufficient Cu, Fe, Mn, and Zn to supply the plant nutritional needs of these micronutrients, except Mn in citrus and apple orchards, and Zn in one vegetable garden. Nevertheless, only citrus trees reflected low Mn levels in Mn deficient soils.

The higher concentration of most micronutrients in soils from organic plantations than in those from conventional plantations might be due to the use of compost (principally made with weeds, pine needles and manure) and manure (cow manure in most cases) in the former. These organic materials

supply micronutrients, while conventional farmers normally rely on nitrogen, potassium and phosphorus fertilizers that do not contain micronutrients or have them at exceedingly low concentrations.

Some plants did not reach the minimum micronutrient content recommended in the literature, although their soils were well provided with them. Related to this fact is the negative correlation between soil organic matter and foliar Mn of avocados and bananas that was detected. This finding suggests the need to control the quantity of organic matter supplied to these plants. Taking into account the regression data, we recommend a maximum soil organic matter level of 10% for surface soils for avocado, 6% at 25–50 cm in the soil, and 7% for banana soils.

ACKNOWLEDGEMENT

Many thanks to the farmers who let us take the samples in their plantations. We also acknowledge Raquel Acosta, Andrés Hernández, Pedro Riverol and Pilar Trujillo for helping us with the analyses.

References

- Alvarez, C.E., García, C. & Carracedo, A.E. (1988). Soil fertility and mineral nutrition of an organic banana plantation in Tenerife. *Biological Agriculture & Horticulture*, **5**, 313–323.
- Alvarez, C.E. & González, C.J. (1985). Factores que inciden en la fertilidad de los suelos y producción vegetal en las plantaciones ecológicas de las Islas Canarias. In *Congreso Científico Europeo de Agricultura Biológica*, pp. 74–83. Ministerio de Agricultura, Pesca y Alimentación; Madrid.
- Borges-Pérez, A., Fernández, M., Pérez, J.F. & Borges, A.A. (in press). Available micronutrients in agricultural soils of Tenerife (Canary Islands). II: Iron and manganese. *Agrochimica*.
- Chapman, H.D. (1966). *Diagnostic Criteria for Plants and Soils*, University of California. Division of Agronomic Sciences; Riverside.
- Chapman, H.D. & Pratt, P.F. (1961). *Methods of Analysis for Soils, Plants and Waters*. University of California, Division of Agricultural Sciences; Riverside.
- Comisión de Métodos Analíticos del Instituto de Edafología y Agrobiología 'José María Albareda' (1973). Determinaciones analíticas en suelos. Normalización de métodos: pH, materia orgánica y nitrógeno. *Anales de Edafología y Agrobiología*, **32**, 1153–1172.
- Díaz, A. (1975). *Estudio de la Fertilidad de los Suelos y Nutrición Mineral de los Cultivos de Plátanos de Tenerife*, Doctoral Thesis. University of La Laguna.
- Fernández-Falcón, M., Borges, A., Pérez, J.F., Borges, A.A. & López, I. (1994). Available micronutrients in agricultural soils of Tenerife (Canary Islands). I: Copper and zinc. *Agrochimica*, **32**, 268–276.
- García, C., Alvarez, C.E., Carracedo, A.E. & Iglesias, E. (1989). Soil fertility and mineral nutrition of a biodynamic avocado plantation in Tenerife. *Biological Agriculture & Horticulture*, **6**, 1–10.
- García, V., Bravo, J.J., Díaz, A., Altares, M. & Fernández, M. (1983). Niveles foliares de las plantaciones de aguacates de las Islas Canarias Occidentales. *Anales de Edafología y Agrobiología*, **42**, 741–751.
- Jones, J.B., Wolf, B. & Mills, H.A. (1991). *Plant Analysis Handbook*. Micro-Macro Publishing Inc.; Athens.
- Lindsay, W.L. & Norvell, W.A. (1978). Development of a DTPA soil test for zinc, iron, manganese and copper. *Soil Science Society of America Journal*, **42**, 421.
- López, J. & López, J. (1985). *El Diagnóstico de Suelos y Plantas*. Ed. Mundiprensa; Madrid.
- Martin-Prével, P., Gagnard, J. & Gautier, P. (1987). *Plant Analysis as a Guide to Nutrient*

Requirements of Temperate and Tropical Crops. Lavoisier Abonnements; Paris.

Römheld, V. & Marschner, H. (1991). Function of micronutrients in plants. In *Micronutrients in Agriculture* (J.J. Mortvedt, F.R. Cox, L.M. Shuman & R.M. Welch, eds.), pp. 297–328. SSSA Book Series: 4; Madison.

Sälanpää, M. (1982). *Micronutrients and the nutrient status of soils: a global study*. FAO Soils Bulletin, 48; Rome.

Sims, J.T. & Johnson, G.V. (1991). Micronutrient soil tests. In *Micronutrients in Agriculture* (J.J. Mortvedt, F.R. Cox, L.M. Shuman & R.M. Welch, eds.), pp. 427–476. SSSA Book Series: 4; Madison.

Stevenson, F.J. (1991). Organic matter-micronutrient reactions in soil. In *Micronutrients in Agriculture* (J.J. Mortvedt, F.R. Cox, L.M. Shuman & R.M. Welch, eds.), pp. 145–186. SSSA Book Series: 4; Madison.

(Received 1st November, 1994; accepted 20th March, 1995)