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Available micronutrients in agricultural soils of Tenerife (Canary Islands). II: Iron and manganese

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INTRODUCTION. — It is known that total micronutrients contents of soil, even though having an influence on the soluble fraction or on the amounts available to the plants, are in general poor estimates of the available fractions. Often, extractable or available micronutrients are used as a diagnostic criterion in order to identify deficient conditions for plants (ADRIANO, 1986, JOKINEN & TÄHTINEN, 1987). The critical level has been defined as that level below which a significant response to micronutrient fertilization would occur. Since the critical values vary with the method used to determine them, it may be more practical, and of more value in soil test interpretation, to identify deficiency, transitional or marginal, and sufficiency zones (HAVLIN 1986). Transition zones are defined as a non definitive range of soil test values where a response to fertilization cannot be accurately predicted.

Symptoms of micronutrient deficiency have been widely observed in crops in most agricultural areas of Tenerife (GARCIA *et al.*, 1984; BARROSO *et al.*, 1985). In a previous report (FERNANDEZ-FALCON *et al.*, 1992), we evaluated available Cu and Zn contents in agricultural soils of Tenerife. The present paper shows the results concerning available Fe and Mn levels in these soils.

Iron is the fourth most abundant element in the Earth's crust, with an average concentration of 51 g Kg^{-1} by weigh (RONOV & YAROSHEVSKY, 1969). However, in spite of this abundance, Fe is frequently a limiting nutrient in crop production as a result of many complex interactions involving the plant and its environment: very low solubility of Fe (III) oxides (LINDSAY, 1979), redox relationships (SCHWAB & LINDSAY, 1983), chelation (LINDSAY, 1984) and nutrient interactions (LINDSAY *et al.*, 1963). The formation of stable Fe organic complexes which are soluble in soil solutions, thereby increasing the availability of Fe to plants, has been a popular theory, yet we know virtually nothing about the organic ligands in soil solutions (UREN, 1984).

As with iron, Mn is widely distributed in Nature. One reason for its wide distribution in different types of rocks is its similar ionic size to Mg and Ca, enabling it to replace the two elements in silicate structures (STAHLBERG *et al.*, 1976). As with the other micronutrients, there is no universal method for determining available Mn in soils that can accurately predict plant response to this element. Several chelating agents have become more popular, especially DTPA as used in the method of LINDSAY & NORVELL (1978). Unlike Fe, in soils high in organic matter, most of the Mn retention is in an unavailable form attributed to organic matter complexation, particularly to humic acids (MANDAL & MITRA, 1982).

MATERIAL AND METHODS. — The different types of soils studied were described in a previous report (FERNANDEZ FALCON *et al.*, 1992).

Samples were taken from the topsoils of most of the agricultural zones of Tenerife (357 samples). No samples were taken from tropical crops (banana and avocado) because they receive a heavy fertilization including micronutrients.

Analytical techniques. — The extraction methods used in this study are those employed by FAO/Unesco (SILLANPÄÄ, 1982). AAA_c-EDTA was used as the extractant of iron, and DTPA as the extractant of manganese.

The analytical techniques performed in the present work have been described in a previuos paper (FERNANDEZ-FALCON *et al.*, 1992).

To obtain background information on factors affecting the micronutrient contents, a number of additional analytical data of the soils (from the same sampling) were used (BORGES PEREZ & GUTIERREZ JEREZ, unpublished data). These data include sand, silt and clay content, cation exchange capacity (CEC), pH, electrical conducivity (EC), $CaCO_3$ and organic matter content (O.M.). We shall discuss only those parameters which are relevant.

RESULTS AND DISCUSSION. — Data study has been performed considering, on the one hand, the totality of sampled soils of the island, and on the other, two well differentiated zones (north and south) as well as soil characteristics such as climate.

Table 1 shows the mean contents and extreme values of available Fe and Mn in the Tenerife soils taken as a whole as well

TABLE 1. — Mean values of available Fe and Mn (mg L^{-1}) in the soils of Tenerife islands.

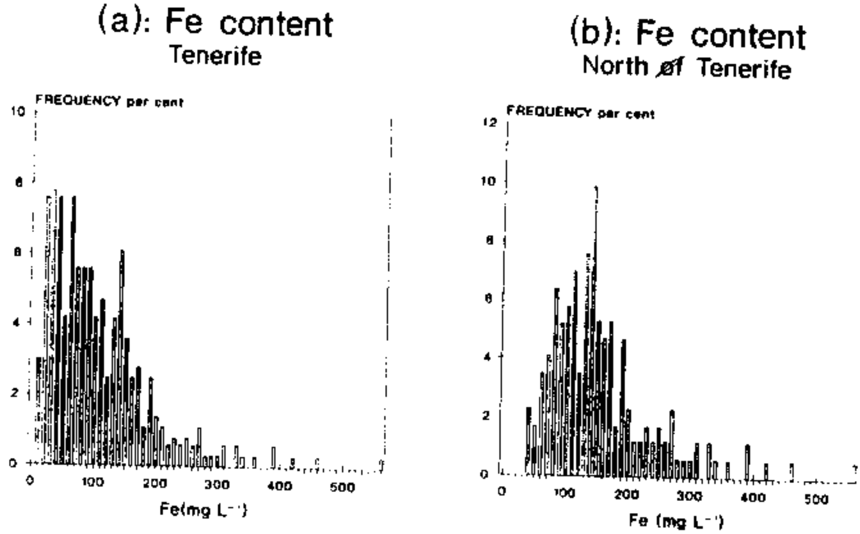
	Mean	S.D.	Minimum	Maximum	n
			IRON		
Tenerife	110.4	± 80.9	11.7	560.0	357
North	159.5	± 83.9	40.3	560.0	171
South	65.1	± 42.9	11.7	216.0	186
			MANGANESE		
Tenerife	67.1	± 76.3	1.8	457.5	357
North	92.8	± 92.9	2.1	457.5	171
South	43.5	±45.8	1.8	238.5	186

as those corresponding to the northern and southern zones.

Iron. — There are few references concerning deficient Fe levels in the soil for plants when this element is extracted by AAAc-EDTA as used in the present report and employed by FAO/Unesco (SILLANPÄÄ, 1982). Therefore, our data has been compared with the results presented by this Organization and concerning a micronutrients study performed in soils of many countries growing wheat and maize plants.

If we consider the totality of sampled soils from the island, the mean content of available Fe was 110.4 mg L^{-1} (Table 1) ranging from 11.7 to 560.0 mg L^{-1}. The obtained mean value was about a third lower than that reported by FAO/Unesco (165.8 mg L^{-1}). When the diagram of frequency distribution (in percentage) for Fe concentrations is observed (Fig. 1a), we can see that 10.64% of Tenerife soils present Fe contents below 30 mg L^{-1}, a level considered as critical by FAO/Unesco (SILLANPÄÄ, 1982).

As well as the results obtained for Cu (FERNANDEZ-FALCON *et al.*, 1992), the study by zones shows that the levels detected in the northern soils (mean value: 159.5, mg L^{-1}, max: 560 mg L^{-1}, min.: 40.3 mg L^{-1}) are significantly higher (at 1% level) than those from the south (mean value: 65.1 mg L^{-1}, max.: 216.0 mg L^{-1}, min.: 11.7 mg L^{-1}). It is clearly observed that none on the northern soils (Fig. 1b) are Fe deficient, while those from the sourthern zone (Fig. 1c) show this characteristic in 20.43% of soil sam-



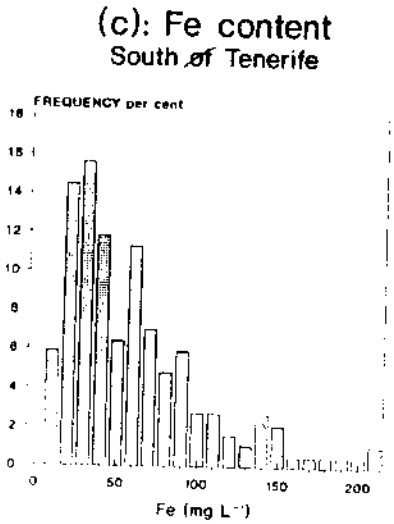


FIG. 1 — Frequency distributions (in percentage) of AAAc-EDTA extractable iron in the soil in: (a) Tenerife samples, (b) North Tenerife samples and (c) South Tenerife samples.

ples. In addition, a high percentage of southern soils (62.9%) present available Fe levels ranging from 30 to 100 mg L^{-1}, while most northern samples (55.54%) have higher contents (between 100 to 200 mg L^{-1}). Fe values higher than 200 mg L^{-1} are found in 21.07% of northern soils, while the southern zone only shows 1.62% of soils with these values.

TABLE 2. — Equations and correlation coefficients (r) for regressions of AAAc-EDTA extractable Fe in the soil on various soil factors.

Location	y	x	n	Regression	r
Tenerife	Fe	pH	357	$\log y = 2.55 - 0.10\, x$	-0.402***
Tenerife	Fe	O.M.	357	$\log y = 1.67 + 0.78 \log x - 0.3 (\log x)^2$	0.523***
Tenerife	Fe	CEC	357	$\log y = 2.22 - 0.008\, x$	-0.248***
Tenerife	Fe	EC	357	$\log y = 1.87 - 0.19 \log x$	-0.200***
Tenerife	Fe	Sand	357	$\log y = 2.18 - 0.005\, x$	-0.272***
Tenerife	Fe	Silt	357	$\log y = -0.002 + 2.57 \log x - 0.8 (\log x)^2$	0.304***
Tenerife	Fe	Clay	357	$\log y = 1.78 + 0.006\, x$	0.235***

(***): Significant at $P = 0.001$

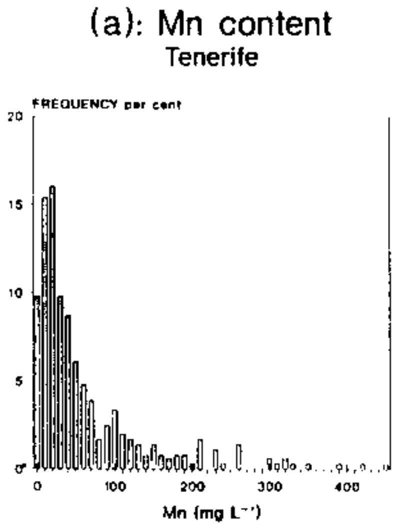
The soils from the south with deficient levels in available Fe present higher significant values of pH, CEC and sand content (at 1% level), and lower significant values for organic matter and clay contents (at 1% level) than the remainder of the southern soils. Evidently, some of these parameter influence Fe availability to the plants.

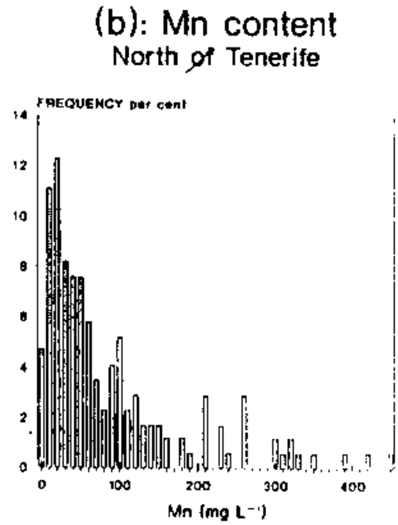
In Table 2, the correlation coefficients and regression equations found between available Fe in the island soils and some parameters studied in this report are shown. The known negative correlation between soil pH and Fe contents, frequently found in the bibliography (SILLANPÄÄ, 1982; SAKAL *et al.*, 1988; DOLUI *et al.*, 1988) is observed. The available Fe concentrations are also negatively influenced (at 0.1%) by CEC, EC and sand percentage, while organic matter, silt and clay contents are positively correlated (at 0.1%). Similar correlations for organic matter (SILLANPÄÄ, 1982; GEIGER & LOEPPERT, 1986; SAKAL *et al.*, 1988; ORTEGA *et al.*, 1988) and for clay contents (SILLANPÄÄ, 1982; ORTEGA *et al.*, 1988) have been reported.

From these data we can deduce that the soils from the northern zone do not seem to present Fe deficiency problems. A high percentage of southern soils are Fe deficient (20.43%) or potentially deficient (15.96%) because they show AAAc-EDTA-extractable Fe below 40 mg L^{-1}.

Manganese. — The mean content of available Mn found in the sampled soils of the whole island was 67.1 mg L^{-1}, about twice that reported by FAO/Unesco (34.7 mg L^{-1}), showing a great variability (s.d.: ±76.3), with values ranging from 1.8 to 457.5 mg L^{-1}. When the diagram of frequency distribution for this element is analyzed, we can observe that most (84.3%) of Tenerife soils (Fig. 2a) show available Mn levels considered as acceptable for plants (between 5 to 140 mg L^{-1}, according to SILLANPÄÄ, 1982). Only 0.28% of the soils are below 2 mg L^{-1} and 2.52% of them are in the range 2-5 mg L^{-1}, respectively considered as deficient and marginal levels (SILLANPÄÄ, 1982; BANSAL *et al.*, 1987).

The study by zones shows the same tendency observed above for Fe. Thus, the northern soils present very much higher contents (mean value: 92.8 mg L^{-1}, max.: 457.5 mg L^{-1}, min.: 2.1 mg L^{-1}) than the southern ones (mean value: 43.5 mg L^{-1}, max.: 238.5





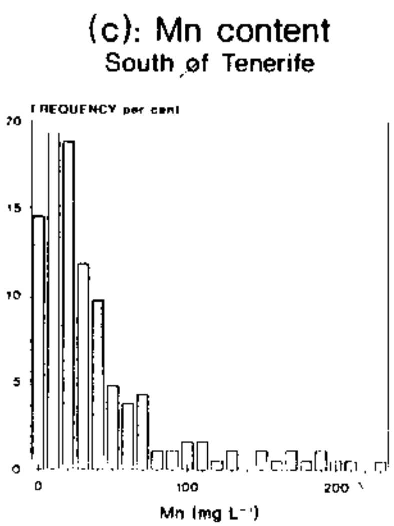


FIG. 2 — Frequency distributions (in percentage) of DTPA extractable manganese in the soil in: (a) Tenerife samples, (b) North Tenerife samples and (c) South Tenerife samples.

mg L^{-1}, min.: 1.8 mg L^{-1}), at a significance level of 1%. The northern zone (Fig. 2b) did not contain deficient values of available Mn in any soils, as happened with Fe, and only 0.58% of them showed marginal concentrations. The southern soils (Fig. 2c) present deficient (0.5% of samples) and marginal (4.29% of samples) values in available Mn. On the other hand, the north shows

TABLE 3. — Equations and correlation coefficients (r) for regressions of DTPA extractable Mn in the soil on various soil factors.

Location	y	x	n	Regression	r
Tenerife	Mn	pH	357	$\log y = 0.38 + 0.62\,x - 0.06\,x^2$	-0.616***
Tenerife	Mn	CEC	357	$\log y = 3.24 - 1.09 \log x$	-0.272***
Tenerife	Mn	$CaCO_3$	357	$\log y = 1.64 - 3.41\,x + 3.67\,x^2$	-0.303***
Tenerife	Mn	Sand	357	$\log y = 2.08 - 0.01\,x$	-0.366***
Tenerife	Mn	Clay	357	$\log y = 1.18 + 0.01\,x$	0.457***
Tenerife North	Mn	O.M.	171	$\log y = 2.04 - 0.05\,x$	-0.434***

(***): Significant at $P = 0.001$

available Mn values considered as excessive (>140 mg L^{-1}) in 20.5% of its soils while the south only present a percentage of 5.96%.

Table 3 shows the coefficients and regression equations between available Mn and various parameters of Tenerife soils. As occurred with Fe, pH significantly and negatively affected (at 0.1% level) available Mn contents according to many authors (SILLANPÄÄ, 1982; ADRIANO, 1986; SAKAL *et al.*, 1988; NISKANEN, 1989). In a similar way, CEC, $CaCO_3$ and sand percentage of the soils negatively affect (at 0.1% level) available Mn. contents. The influence of CEC and $CaCO_3$ has been reported by FAO/Unesco (SILLANPÄÄ, 1982). On the other hand, the presence of available Mn in Tenerife soils are only positively affected (at 0.1% level) by the clay content. Similar tendencies have been reported by SHUMAN (1979), SILLANPÄÄ (1982) and ORTEGA *et al.*, (1988).

Although O.M. percentages did not affect the available Mn levels in the island soils, when the study was carried out with data from the north a negative correlation was observed (r= 0.434, at the 0.1% significant level), as reported by PAVANASASIVAM (1973) and MANDAL & MITRA (1982). The O.M. contents of this zone are higher (mean value: 57.2 g Kg^{-1}) than those from the south (mean value: 21.9 g Kg^{-1}). PAGE (1962) indicates that most of Mn retention in an unavailable form was attributed to complexing with O.M., particularly with humic acids. The study carried out by FAO/Unesco showed that available Mn increased according to the increase of O.M. an then, at high levels of this parameter, it began to decrease.

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SUMMARY. — Available Fe and Mn contents and the influence of some soil properties on the availability of these micronutrients for crops were studied in most of the agricultural zones of the island of Tenerife (Canary Islands).

The mean Fe content was 110.4 mg L^{-1} (AAAC-EDTA extractable Fe), about a third lower than that reported by FAO for other regions. 10.64% of the soils presented Fe values below the considered critical level (30 mg L^{-1}). The mean Mn content was 67.1 mg L^{-1} (DTPA extractable Mn), almost twice that reported at international level by FAO. Only 0.28% of the soils showed values below 2 mg L^{-1} and 2.52% of these were in the range of 2-5 mg L^{-1}, respectively considered as deficient and marginal levels. The study by zones (north and south) shows that the northern soils presented mean Fe and Mn contents sensibly higher than the southern ones. Different correlations between some soil parameters and the studied micronutrients were observed.

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