Generalized Cu, Fe, Mn and Zn contents of the major soils of the world related to Citri- and Viticulture

Prepared for AKZO Nobel Chemicals

by

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CAUTION

The results of this study have been related to Citri- and Viticulture. Extrapolation to other cultures may not be valid.

CONTENTS

1. INTRODUCTION

At the request of AKZO Nobel Chemicals, Geelen Consultancy and the International Soil Reference and Information Centre (ISRIC) have prepared a generalized overview on the content of some selected micronutrients in soils world-wide, in relation to Citri- and Viticulture. The purpose was to identify regions where deficiencies occur or may be expected and where supplementing may be necessary. The results may serve AKZO Nobel Chemicals to better understand the market for their Dissolvine® micronutrient products and to forecast possible new markets.

Geelen Consultancy is a consulting company specializing in agricultural marketing and marketing research. ISRIC is a research and documentation centre, supported by the Dutch government and various international and UN agencies, which collects and disseminates knowledge on soils in the world for better understanding of our soil resources.

The micronutrients selected for this study, copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn) are important micronutrients, particularly for citrus and grape. Citrus is rated amongst the crops which are sensitive to deficiency in Fe, Mn, Zn and, to a lesser extent, Cu, while grape is recorded as often treated for Fe and Mn deficiency.

Availability of micronutrients to plants is a function of the amount present in the soil and the form in which they occur. Often they are rendered inaccessible because they occur in inorganic compounds or as part of stable humus complexes, or their solubility is hampered by the prevailing pH range of the soil. Micronutrient contents of soils given in the literature have to be interpreted with care as the figures depend much on the extractants used. For example, acid ammonium acetate extractable iron will give the iron complexed by organic compounds and which is not readily available to plants.

2. CROP REQUIREMENTS

To get insight in potential citrus- and grape-growing regions in the world and their soil conditions with respect to micronutrients, it is necessary to analyze first the agro-ecological and general soil requirements affecting the plant growth. Both citrus and grape are ranked amongst the tropical and subtropical crops. However, their demands differ climatologically, physically and chemically.

2.1. General environmental requirements for citrus fruits

Citrus fruits (*Citrus* spp) can stand light frost for short periods only. The susceptibility to frost depends on the stage of dormancy of the trees. Therefore they are cultivated only between 45°N and 35°S in altitudes ranging from 600 m in the subtropics to 2000 m in tropical regions (Purseglove, 1968). The optimum temperature range for growth lies between 23 and 30°C (Langdon, 1968) and a total amount of about 900-1200 mm of rainfall is required in order to cultivate citrus without irrigation (Purseglove, 1968; Rehm & Espig, 1991). The total growing period of citrus is between 240 and 365 days/year.

Citrus trees require deep, well drained and aerated, medium to coarse textured soils. Groundwater level should be below 130 cm, but preferably deeper (Landon, 1991). They have a low tolerance to short periods of waterlogging and a moderate tolerance to drought. Fine textures (associated with poor aeration and restricted water movement) adversely affect citrus production as well.

Chemically, citrus is moderately tolerant to acid soil conditions. The preferred pH range is between 5 and 7. Most citrus species have a low tolerance to soil salinity. Citrus trees have a high N and K demand.

Based on these data the regions north of the 45° parallel and south of the 35° parallel, as well as areas with shallow soils, soils subject to waterlogging and/or having a high groundwater level, and soils with a high clay content were not considered in this study on the micronutrient status for citrus. Some of these constraints may be alleviated by civil engineering measures, e.g. by lowering of the groundwater table. In the evaluation of the soils, however, this has not been taken into account.

2.2. General environmental requirements for grape

Grapes (*Vitus* spp) are grown from the temperate zone to the humid tropics (Rehm & Espig, 1991). During growth grapes are sensitive for frost, but during dormancy they are resistant down to -18°C (Langdon, 1968). The optimum temperature range for growth is 15-25°C. Minimum annual rainfall required is about 400 mm. Due to their extensive root system, with the bulk of the roots between 30 and 60 cm depth (Jacob & Uexküll, 1960), grapes extract water from a large volume of soil. The total growing period is 180-270 days/year.

Well drained, medium textured soils are preferred, but grapes also grow well on more finer textured soils and even on stony soils, as is shown, for example, in the Mosel region (Germany) and in Switzerland. Waterlogging is not tolerated and good aeration is a prerequisite.

Chemically, preferred pH range is close to neutrality (pH 6-7). Soils rich in humus and calcium are most suitable, but some varieties are sensitive to an excessive calcium content (Jacob & Uexküll, 1960). A little salinity is tolerated (up to 0.4% salts, calculated for dry soil) (Rehm & Espig, 1991).

Based on these data the regions north of the 50° parallel and south of the 50° parallel, as well as areas with soils subject to waterlogging and/or having a high groundwater level, and sandy soils have not been considered in the study on the micronutrient status for grape.

The regional restrictions outlined above are reflected in the list of citrus- and grape-producing countries shown in Table 1. This table also shows the area of citrus and grape which is fertilized (IFA/IFDC/FAO, 1992).

Table 1. **Land area (in 1000 ha) used for citrus fruits and grape per country** (between brackets the percentage of area fertilized)

Country	Citrus fruits		Grape	
Algeria (1986)	45	(100)	130	
Austria (1990)			54	(100)
Brazil (1989)	880	(100)	58	
Chile (1991)			59	
China (1990)	236	(100)	165	(100)
Cyprus (1990)	7	(100)		
Egypt (1991)	180	(100)		
Guatemala (1987)	1	(100)		
Hungary (1989)			111	(15)
Israel (1990)	34	(100)	4	(100)
Japan (1989)	130	(100)		
Jordan (1990)	7		11	
Republic of Korea (1989)	19	(100)		
Mexico (1990)	313	(59)	50	(100)
Morocco (1990)	72	(100)		
Nicaragua (1991)	14	(4)		
Panama (1991)	2	(43)		
Philippines (1990)	29			
Saudi Arabia (1986)	2	(100)	5	(100)
South Africa (1990)	41	(100)		
Spain (1990)	259	(100)	1,474	(80)
Turkey (1988)	513	(5)	590	(56)
Uruguay (1990)	21	(92)	12	(56)
Zimbabwe (1990)	12	(60)		
Total (× 1,000 ha)	2,817		2,723	

Source: IFA/IFDC/FAO (1992)

Note: No data are available for such important citrus- and grape-producing countries as Australia, France, Germany, Greece, Italy, Switzerland and the USA.

2.3. General micronutrient demand of citrus and grape

In the literature many ranges of optimal micronutrient content of soils are given. The values depend very much on the extracting method used. For example, Sillanpää (1990) gives the following deficiency and excess ranges which, however, are not crop-specific:

Micronutrient and method		Range of mg/l soil deficiency	excess
B	hot water extraction	< 0.3-0.5	> 3-5
Cu	AAAc-EDTA[a]	< 0.8-1.0	> 17-25
Fe	AAAc-EDTA	< 30-35	-
Mn	DTPA[b] + pH correction	< 2-4	> 150-200
Mn	AAAc-EDTA + pH correction	< 10-25	1300-2000
Mo	AAAc-EDTA + pH correction	<0.002-0.005	0.3-1.0
Zn	DTPA	< 0.4-0.6	> 10-20
Zn	AAAc-EDTA + pH correction	< 1.0-1.5	> 20-30

Source: Sillanpää (1990)

The removal of mineral elements in harvested fruit is a good indicator for the nutrient demand of crops. IFA (1992) gives the following figures for micronutrient uptake/removal by citrus and grape:

	Cu	Fe	Mn	Zn
Citrus (g/ton fresh fruit)	0.3-0.6	2.1-3.0	0.4-0.8	0.7-1.4
Grape (g/ha/year)[c]	64-910	292-1121	49-787	110-585

[a]AAAc-EDTA: acid ammonium acetate - ethylenediaminetetracetic acid

[b]DTPA: diethylene-triamine pentacetic acid

[c]Total annual uptake in stems, leaves and fruits for a yield of 7-25 ton/ha.

Obviously, these figures are hard to compare and it is even more difficult to relate them to critical plant available micronutrient levels in soils. De Geus (1967) reports that on soils with citrus trees containing 21 mg Cu per litre ("50 lb. CuO per acre to a depth of 6 inch") no copper is needed but that acid sandy soils having more than 63 mg Cu per litre ("150 lb. CuO per acre to a depth of 6 inch") are at a potentially dangerous copper level. Taking into account that about 7-17% of the total copper (as reported by De Geus) can be considered "plant-available" (Aubert & Pinta, 1977), the optimum range for Cu in the soil can be assumed to be 2-10 mg/l soil. This range can be related to the range in copper content in citrus fruit as reported by IFA when the latter figures are recalculated to the same unit, i.e. mg/l soil. The IFA figure for Cu uptake/removal in citrus, 0.3-0.6 g/ton fresh fruit, corresponds with a range of 0.001-0.009 mg/l soil, taking into account that citrus yields vary from 15 tons/ha for extensive cultures to 60 tons/ha for intensive cultures (IFA, 1992), and assuming that the bulk of the roots responsible for nutrient uptake occur over a depth of 40 cm (figure frequently used in Dutch horticulture; Dr. B.H. Jansen, pers. comm.). The obtained range is about 1200-1300 times lower than the optimum range obtained for Cu content of the soil. By lack of precise figures in the literature on optimum Cu, Fe. Mn and Zn content in the soil for citrus fruits, a ratio 1:1250 has been used to calculate a minimal range from the micronutrient content in fresh fruit. It is realized that this procedure assumes a similar behaviour of the micronutrients concerned and a similar uptake mechanism of the micronutrients by the plants, which may not be the case. However, no better procedure could be established to arrive at these ranges required for the interpretation of the available soil data.

The ranges (for citrus trees) thus obtained are: Cu 2-10 mg/l soil, Fe 10-55 mg/l soil, Mn 2-15 mg/l soil and Zn 4-25 mg/l soil. These figures, based on the removal of micronutrients, may be considered as the low to adequate ranges. The upper limits, i.e. the values by which the micronutrients start being toxic, can be much higher.

The figures derived from IFA are in fair agreement with the values given by Sillanpää (1990) i.e. Cu 1-17 mg/l soil, Fe >35 mg/l soil, Mn 4-150 mg/l soil and Zn 0.6-10 mg/l soil, except for Fe, while for Zn the range shows a shift to lower contents. This may be due to the extraction methodology on which these figures are based. For example, DTPA-extracted

Zn gives the range of 0.6-10 mg/l soil, while AAAc-EDTA-extractable Zn with pH correction gives a range of 1.5-20 mg/l soil.

In conclusion, the following ranges and evaluative levels of micronutrient content ("classes") have been adopted for Citriculture:

	RANGE	CLASSES			
		Deficient	Low	Adequate	High
			(values in mg/l)		
Cu	2-10	<2	2-5	5-10	>10
Fe	>35	<35	35-75	75-200	>200
Mn	5-150	<5	5-15	15-50	>50
Zn	1-10	<1	1-2	2-5	>5

For Viticulture the values given by IFA (1992) represent total annual micronutrient uptake in the entire vegetative production (stems, leaves and fruit) and can therefore be more easily related to a minimal required content of plant available micronutrient in the soil for optimal growth. Recalculation of the IFA figures to the units used in this report (mg/l soil) gives the following ranges in uptake, assuming that the bulk of the roots responsible for nutrient uptake occur over a depth of 30 cm (Jacob & Uexküll, 1960): Cu 0.02-0.30 mg/l soil, Fe 0.10-0.35 mg/l soil, Mn 0.02-0.25 mg/l soil and Zn 0.04-0.20 mg/l soil. To relate these figures to micronutrient contents as measured in soil extracts, a correlation factor has to be established. In this case boron was used as both average B-uptake by grape (0.01-0.08 mg/l soil) (IFA, 1992) and the optimal range in hot water extractable B (1-3 ppm or about 1.5-4.5 mg/l soil; De Geus, 1967) for grape is known. Again, it is realized that this procedure assumes a similar behaviour of the micronutrients concerned and a similar uptake mechanism of the micronutrients by the plants, which may not be the case. However, since no better procedure could be established to arrive at the ranges required for the interpretation of the available soil data, this approach was used to get an approximate correlation.

Comparing the boron figures one comes close to a 1:100 ratio. Introducing this ratio in the IFA micronutrient uptake values, the following ranges and evaluative levels of micronutrient content ("classes") have been adopted for Viticulture:

	RANGE	CLASSES			
		Deficient	Low	Adequate	High
		(values in mg/l)			
Cu	2-25	<2	2-5	5-25	>25
Fe	10-30	<10	10-30	30-100	>100
Mn	1-25	<1	1-5	5-25	>25
Zn	2-15	<2	2-5	5-15	>15

The ranges come close to the general ranges given by Sillanpää (1990). However, Fe and Mn values seem rather low. As no better figures could be obtained the derived ranges for Fe and Mn have been tentatively retained.

3. EVALUATION OF AVAILABLE SOIL DATA

A global study on micronutrient content (Sillanpää, 1982) has been taken as basis for the study on the copper, iron, manganese and zinc status of soils. In this study micronutrient levels have been analyzed for 30 countries and the average micronutrient values are related to the major soil groupings as established by FAO-Unesco (1974). The methods used for the analysis[d] of these micronutrients are: Cu AAAc-EDTA + organic C correction, Fe AAAc-EDTA, Mn DTPA + pH correction, and Zn DTPA. The results of this study are summarized in Table 2 and Table 3.

These data have been evaluated against the classes established in the previous section. The interpretation, indicating if a certain soil type is deficient in Cu, Fe, Mn or Zn, or has a ***low***, ***adequate*** or ***high*** supply in these nutrients, is subsequently combined in groups of soils in which the micronutrients are either ***deficient*** or ***low***, or both. These two classes are considered of importance as these soils will show under cultivation either deficiencies immediately or in the near future, or require immediate maintenance fertilization. The result of this grouping is shown in Table 4, which shows seven ***deficiency/low content*** classes for Citriculture and four ***deficiency/low content*** classes for Viticulture. The ratings shown in Table 4 have been computerized to generate two potential micronutrient deficiency maps for Citri- and Viticulture, using the WISE soil data base linked to GIS (Batjes & Bridges, 1994).

The results indicate that copper and zinc are in scarce supply in a number of soils. On the other hand, the figures given for iron and manganese seem to indicate that no shortages of these micronutrients can be expected. This impression is only seemingly true because the Fe values given by Sillanpää are obtained using the AAAc-EDTA extraction method buffered at a pH of 4.65. Mn figures were obtained using the DTPA extraction at a pH 7.3. As both citrus and grape favour a higher pH (see pages 2 and 3), plant-available Fe will be much less than indicated because its solubility in the soil decreases with increasing pH (see Figure 1). This is especially important for grape which requires a significant amount of calcium for optimum growth. This may already be present in the soil, as the climates in which grape is

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[d]For abbreviations used see footnotes [a] and [b], p. 5.

grown favour accumulation of calcium carbonate in the soil, or is supplied, usually as calcium hydroxide or (dolomitic) limestone. These amendments bring the soil pH close to neutrality in which case iron is rendered largely unavailable.

If tentatively a decrease of 50% in plant-available Fe is accepted compared to the Fe values given by Sillanpää because of the prevailing higher soil pH under citrus and grape cultures, Kastanozems and Xerosols may be considered deficient in Fe for citrus while Acrisols, Andosols, Chernozems, Ferralsols, Nitosols and Yermosols may be considered to be in short supply. For grape, which seems to have a lower demand in iron compared to citrus (10-30 mg Fe/l soil versus > 35 mg Fe/l soil) the values given by Sillanpää suggest lower nutrient stress compared to citrus. However, it should be borne in mind that soils under vineyards usually have a higher soil pH and therefore render iron even less available. Thus, low contents in Fe or even deficiencies may be expected in a number of soils, particularly Kastanozems, Nitosols, Yermosols and Xerosols.

The manganese determinations were carried out at a pH higher than favoured by the crops. As Mn becomes more available at lower pH, the values given by Sillanpää may be used to as indicative for the Mn status of the soils.

Figure 1. Soil pH and relative availability of plant nutrients and activity of soil microflora (the wider the band, the greater the availability/activity) (*Source:* FAO, 1984)

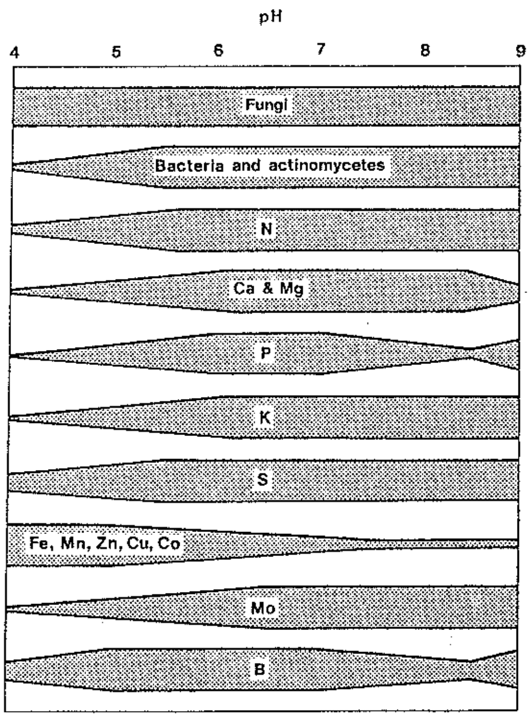

Table 2. Average micronutrient content of soils in relation to Citriculture

Average Cu, Fe, Mn and Zn content of FAO major soil groupings
(compiled from literature data)

Major Soil Grouping	Micronutrients Cu	Fe	Mn	Zn	Deficient	Low	Adequate	High
	mg/l							
Optimal	2-10	>35	5-150	1-10				
Acrisols (n=73)	2.7	140	75	2.0		Cu	Fe Zn	Mn
Andosols (n=8)	5.0	110	82	2.5			Cu Fe Zn	Mn
Arenosols (n=22)	2.8	250	75	9.9		Cu		Fe Mn Zn
Cambisols (n=246)	4.9	260	32	2.3		Cu	Mn Zn	Fe
Chernozems (n=48)	4.3	120	23	2.1		Cu	Fe Mn Zn	
Ferralsols (n=127)	3.5	130	80	2.3		Cu	Fe Zn	Mn
Fluvisols (n=470)	8.1	170	12	1.3		Mn Zn	Cu Fe	
Kastanozems (n=64)	4.8	61	15	0.7	Zn	Cu Fe	Mn	
Luvisols (n=217)	7.4	230	29	3.1			Cu Mn Zn	Fe
Nitosols (n=106)	2.0	82	82	1.1		Cu Zn	Fe	Mn
Phaeozems (n=307)	3.3	180	42	2.0		Cu	Fe Mn Zn	
Podzols (n=27)	2.5	360	37	9.8		Cu	Mn	Fe Zn
Regosols (n=42)	5.3	150	23	2.0			Cu Fe Mn Zn	
Yermosols (n=92)	5.9	91	8	0.5	Zn	Mn	Cu Fe	
Xerosols (n=101)	5.2	71	9	0.6	Zn	Fe Mn	Cu	

Other soils

Gleysols	: not considered, too wet under natural conditions
Halosols	: not considered, too wet and sodium-toxic under natural conditions
Histosols	: not considered, too wet under natural conditions
Lithosols	: not suitable, too shallow
Planosols	: not considered, too wet under natural conditions
Rendzinas	: not suitable, too shallow
Vertisols	: not suitable, too clayey and poorly aerated

Evaluation

	Deficient	Low	Adequate	High
	(values in mg/l)			
Cu	<2	2-5	5-10	>10
Fe	<35	35-75	75-200	>200
Mn	<5	5-15	15-50	>50
Zn	<1	1-2	2-5	>5

Table 3. Average micronutrient content of soils in relation to Viticulture

Average Cu, Fe, Mn and Zn content of FAO major soil groupings
(compiled from literature data)

Major Soil Grouping	Micronutrients Cu (mg/l)	Fe	Mn	Zn	Deficient	Low	Adequate	High
Requirement, based on nutrient removal	2-25	10-30	1-25	2-15				
Acrisols (n=73)	2.7	140	75	2.0		Cu Zn		Fe Mn
Andosols (n=8)	5.0	110	82	2.5		Zn	Cu	Fe Mn
Cambisols (n=246)	4.9	260	32	2.3		Cu Zn		Fe Mn
Chernozems (n=48)	4.3	120	23	2.1		Cu Zn		Fe Mn
Ferralsols (n=127)	3.5	130	80	2.3		Cu Zn		Fe Mn
Fluvisols (n=470)	8.1	170	12	1.3	Zn		Cu Mn	Fe
Kastanozems (n=64)	4.8	61	15	0.7	Zn	Cu	Mn Fe	
Lithosols (n=23)	4.3	68	10	0.5	Zn	Cu	Mn Fe	
Luvisols (n=217)	7.4	230	29	3.1		Zn	Cu	Fe Mn
Nitosols (n=106)	2.0	82	82	1.1	Zn	Cu	Fe	Mn
Phaeozems (n=307)	3.3	180	42	2.0		Cu Zn		Fe Mn
Regosols (n=42)	5.3	150	23	2.0		Zn	Cu Mn	Fe
Rendzinas (n=48)	3.8	91	18	1.2	Zn	Cu	Mn	Fe
Vertisols (n=135)	7.0	130	17	0.8	Zn		Cu Mn	Fe
Yermosols (n=92)	5.9	91	8	0.5	Zn		Cu Mn Fe	
Xerosols (n=101)	5.2	71	9	0.6	Zn		Cu Mn Fe	

Other soils

Arenosols : not considered, too coarse textured
Gleysols : not considered, too wet under natural conditions
Halosols : not considered, too wet and sodium-toxic under natural conditions
Histosols : not considered, too wet under natural conditions
Planosols : not considered, too wet under natural conditions
Podzols : not considered, too coarse textured

Evaluation

	Deficient	Low (values in mg/l)	Adequate	High
Cu	<2	2-5	5-25	>25
Fe	<10	10-30	30-100	>100
Mn	<1	1-5	5-25	>25
Zn	<2	2-5	5-15	>15

Table 4. Micronutrient content groupings of the soils of the world.

Citriculture (between 45°N and 35°S)			Viticulture (between 50°N and 50°S)		
1	Zn deficient/ Fe Mn low	Xerosols	1	Zn deficient	Fluvisols Vertisols Yermosols Xerosols
2	Zn deficient/ Cu Fe low	Kastanozems	2	Zn deficient/ Cu low	Kastanozems Lithosols Nitosols Rendzinas
3	Zn deficient/ Mn low	Yermosols	3	Zn low	Andosols Luvisols Regosols
4	Cu low	Acrisols Arenosols Cambisols Chernozems Ferralsols Phaeozems Podzols	4	Cu Zn low	Acrisols Cambisols Chernozems Ferralsols Phaeozems
5	Mn Zn low	Fluvisols			
6	Cu Zn low	Nitosols			
7	None low	Andosols Luvisols Regosols			

4. CONCLUSIONS

The present study is merely indicative to which extent micronutrient imbalances may be expected in certain soils. The geographical linkage made to the occurrence of soils in the world is very generalized as within the scope of the study it was not possible to provide more detail. Considerable regional differences may therefore exist between similarly named soils.

4.1. Regional micronutrient status related to Citriculture.

4.1.1. The Americas

Large regions in the USA and Southern America (Brazil, Venezuela and the Amazon regions of Colombia, Ecuador and Peru), as well as some parts of Cental America (Southern Mexico, Honduras, Nicaragua) are in short supply of copper. However, significant regional differences exist. The mean value for copper measured on samples from Brazil is 16.0 mg/l soil, for Peru 5.6 mg/l and for Mexico 3.9 mg/l. It should be noted in this respect that the geographical distribution of the samples plays an important role. All samples from Brazil originated from the region south of Sao Paolo, and can therefore not be considered representative for the whole of Brazil.

The Midwest region of the USA, particularly the region east of the Rocky Mountains, large parts of Mexico and Paraguay and Northern Argentina seem to have low copper, iron and zinc status. Mean values recorded for Mexico are 3.9, 49 and 0.1 mg/l soil respectively, while those for Argentina are 3.2, 207 and 2.0 mg/l soil.

Northern Chile and large parts of the arid regions in the Western USA may be considered zinc deficient and low in manganese supply.

Finally, soils in California and in Northern Florida seem to have an adequate supply of micronutrients. However, iron availability (and to a lesser extent manganese) may be a problem as soils tend to have a pH of about 7.

4.1.2. The Mediterranean region

Spain, the central parts of Italy, former Yugoslavia and Western Turkey appear to have low supplies of copper. However, it should be noted that soils in Italy show to have high contents of copper (mean value of 11.3 mg/l soil). The majority of the samples with high Cu contents from this country originate from the northern Appenine region (Bologna, Modena, Florence, Arezzo, Perugia and Ascoli). Contrary to the impression given by the global main micronutrient deficiencies map for Citriculture, deficiency of Cu seems unlikely in Italy. In addition it must be noted that although no iron shortage has shown up on this map, the mean soil pH in Italy is 7.0 with a standard deviation of 0.7. In this range of pH Fe is rendered almost unavailable and a regular supply of iron may be expected to be needed.

Central parts of Turkey, Lebanon and adjacent regions of Syria and Israel, and some parts along the coast of Northern Africa (viz. Libya, Algeria and Morocco) seem to have low iron, manganese and zinc values. Mean figures for these elements recorded for Turkey, Lebanon and Syria are 110, 98 and 87 mg Fe/l soil, 20, 18 and 15 mg Mn/l soil, and 0.6, 0.9 and 1.2 mg Zn/l soil, respectively.

Many soils in Northern Africa, mainly the sandy ones, appear to be zinc deficient and low in manganese. Soils in Greece and large parts of the Balkan seem to have no shortages. For example, Hungarian soil samples show mean Cu, Fe, Mn and Zn values of 5.4, 151, 39 and 1.2 mg/l soil, respectively. Unfortunately, no data are available for Greece.

4.1.3. Sub-Saharan Africa

A considerable part of Western Africa (Southern Ghana and Ivory Coast, Liberia, Sierra Leone and Guinea), the Sahelian Region (Niger, Norther Nigeria and Cameroon, and Chad) and Ethiopia show low copper contents. Mean Cu data reported for Ghana are 1.9 mg/l soil, for Sierra Leone 1.1 mg Cu/l soil, while the mean Nigerian value is 1.9 mg Cu/l soil. Moreover, it is recorded that in Nigeria the great majority of the low Cu values originate from the Eastern States. For Ethiopia the mean Cu value is considerably higher, 4.6 mg Cu/l soil, but still within the low range for Citriculture.

The remainder of Western Africa and the Sahelian Region, with the exception if Northern Ethiopia and Southern Sudan show no severe deficiencies. In the latter two regions iron, manganese and zinc are in low supply. Samples from Ethiopia give values of 214, 87 and 3.6 mg/l soil, respectively.

Central and Eastern Africa mainly show soils low in copper, except for Eastern Kenya, Southern Tanzania, Eastern Zambia (the Luangwa Valley) and Zimbabwe, and parts of Malawi. Mean copper contents for samples from Tanzania and Zambia are 4.8 and 2.4 mg/l soil, respectively. However, it should be borne in mind that locally soils may have high copper contents, due to copper ore present in the subsoil. Data from soils near Lumumbashi, Shaba Province, Southern Zaire, which is located in the copper ore belt, give 15 mg Cu/l soil (Sillanpää, 1990), while other soils from Zaire show contents ranging from 0.6-1.9 mg Cu/l soil. Eastern Zaire shows besides low contents in copper also low values for zinc.

Large parts of Southern Africa show low contents in Fe, Mn and Zn. These are mainly the sandy soils in the Kalahari Region (Namibia, Botswana and Western South Africa). Low copper content soils also occur, mainly in Zimbabwe and Central South Africa (the Karroo). Eastern South Africa and Mozambique do not seem to have major shortages of Cu, Fe, Mn and Zn.

The eastern and central parts of Madagascar can be expected to be low in copper, as in most cases of deeply weathered tropical soils, which prevail in these parts of the island.

4.1.4. Middle East

Soils that may be suitable for Citriculture in this region mainly suffer from zinc deficiency and low contents in manganese. Moreover, taking into account that the Middle East region is largely arid, most soils will contain calcium carbonate and, consequently, will be low in plant-available iron. Locally also Cu shortages may be expected. The Euphrates and Tigris river valleys low in iron, manganese and zinc. Iraq reports mean values for Fe, Mn and Zn of 112, 9.2 and 0.3 mg/l soil, respectively, on samples mainly originating from these regions.

4.1.5. South Asia

Generally, Indian soils appear to have sufficient supply in the micronutrients considered, except from the region north of New Delhi. About 2/3rd of the samples analyzed by Sillanpää (1982) come from this region and the mean values reported for India, i.e. 4.3 mg Cu/l soil, 165 mg Fe/l soil, 15 mg Mn/l soil and 0.8 mg Zn/l soil, reflect the micronutrient status of these areas. This is in line with the expected low contents in Fe, Mn and Zn indicated in the border region of India and Pakistan. Along the coasts of India scattered areas occur in which soils are likely to have low contents in copper and zinc.

Those regions in Nepal which are climatologically suitable for citrus (for example the Terai Region) generally are low in copper. This is contrary to the conclusion of Sillanpää (1982), whose samples show an average content of 6.9 mg Cu/l soil. This discrepancy is probably caused by the fact that most of the Nepalese samples analyzed originate from the

Himalayan foothill regions and not from the Nepalese lowlands.

4.1.6. Southeast Asia

Almost all soils from this region seem to be low in copper. Cross-checking it against actual values appears difficult since data are only available for Thailand, Korea and the Philippines. The mean values for these countries for the micronutrients concerned are: Cu 6.3, 3.8 and 13.4 mg/l soil, Fe 140, 177 and 273 mg/l soil, Mn 53, 39 and 45 mg/l soil and Zn 1.6, 6.8 and 3.3 mg/l soil, respectively. The high copper values for the Philippines can be largely explained by the fact that the soils are mostly from volcanic origin, which generally have higher Cu contents. The Thai samples represent Rendzinas, Vertisols (both of which are not suitable for citrus) and Acrisols and come mainly from the Central Plain which suffers from waterlogging for some period of the year. Thus, these figures cannot be considered representative for the main upland soils in Southeast Asia. The set of soils analyzed from Korea is probably the most representative as it includes Cambisols (37%), Acrisols (21%) and Luvisols (12%), the more dominant groups of soils in this part of the world.

4.1.7. Australia

Low contents in iron, manganese and zinc may be expected in many soils from Southern Australia. In Western Australia zinc deficiency may occur, while low contents of copper and manganese can be expected. No data are available to cross-check the interpretation made on basis of the occurring types of soils.

4.2. Regional micronutrient status related to Viticulture.

4.2.1. The Americas

Most soils in this region appear to be low in copper and zinc. This concerns the USA east of the Rocky Mountains, parts of Central America and large areas in South america, particularly Brazil, Venezuela, Colombia, Ecuador, Peru, Uruguay and Chile. Zinc deficiencies may be expected in the Midwest of the USA, Northern Mexico, Bolivia, Paraguay and large parts of Argentine. Average values reported for some of these countries are for Cu: 3.2 mg/l soil in Argentine, 17.5 mg/l soil in Brazil, 4.2 mg/l soil in Peru and 3.9 mg/l soil in Mexico, and for Zn 2.0 mg/l soil in Argentine, 3.8 mg/l soil in Brazil, 1.4

mg/l soil in Ecuador and 1.2 mg/l soil in both Peru and Mexico. All of these figures, except the Cu value for Brazil fall in the deficiency or low content range for both elements. In the more drier parts of the USA and Mexico also Fe shortages may be expected due to the high pH of the soils in these regions. The traditional vine-growing regions of California and Chile generally show only a low content in zinc, while in Argentine zinc deficiency seems to be more common.

4.2.2. Europe and the Mediterranean region

Most countries show up as having low contents of copper and zinc. Soils in the Alps appear to have zinc deficiency associated with a low content in copper. In Greece and in some parts of the Balkan, notably Hungary soils are low in zinc only. Zinc deficiencies show up in Central Turkey, in the Near East and in large parts of Northern Africa, sometimes associated with low contents in copper.

An exception to what is shown on the map may be Italy. In general, Italian soils contain amongst the highest levels of copper recorded in the world, on average 11.3 mg Cu/l soil. For other countries of this region mean Cu values are 5.2 mg/l soil in Hungary, 7.2 mg/l soil in Malta, 5.3 mg/l soil in Turkey, 6.0 mg/l soil in Lebanon and 4.5 mg/l soil in Syria. Zinc values for the respective countries are: 1.0 mg/l soil in Hungary, 2.3 mg/l soil in Italy, 10.3 mg/l soil for Malta, 0.4 mg/l soil for Turkey, 0.9 mg/l soil in Lebanon and 1.2 mg/l soil in Syria. The extreme high values for Malta cannot be explained.

In the entire Mediterranean region soil pH is such that plant-available iron is hardly present, despite possible high levels of AAAc-EDTA extractable iron. Average soil pH in the various countries is 7.0 in Hungary and Italy, 7.5 in Malta, 7.9 in Turkey, 7.4 in Lebanon and 7.7 in Syria. Consequently, shortage in iron may be expected in many soils of this region.

North African countries (Morocco, Algeria, Tunisia, Libya and Egypt) as well as Israel and Jordan are generally zinc deficient, or have only low contents in copper and zinc. For Egypt, for example, reported average Zn content is 1.3 mg/l soil.

4.2.3. Sub-Saharan Africa

Soils in Sub-Saharan Africa are generally low in zinc or both copper and zinc. Zinc deficiency may be expected in Southwestern Africa (Angola, Namibia, Botswana and South Africa), as well as in parts of Eastern Africa (Ethiopia, Sudan, Uganda and Kenya). Low contents in copper and/or zinc are shown for Western Africa and large parts of Eastern Africa. Sillanpää (1982) gives the following mean copper and zinc values for several countries: Cu 3.3 mg/l soil in Ethiopia, 1.9 mg/l soil in Ghana, 3.3 mg/l soil in Malawi, 1.9 mg/l soil in Nigeria, 1.1 mg/l soil in Sierra Leone, 4.6 mg/l soil in Tanzania and 2.4 mg/l soil in Zambia, and for Zn 4.9 mg/l soil in Ethiopia, 1.1 mg/l soil in Ghana, 1.6 mg/l soil in Malawi, 3.3 mg/l soil in Nigeria, 1.5 mg/l soil in Sierra Leone, 1.6 mg/l soil in Tanzania and 0.9 mg/l soil in Zambia. The averages of the soil pH in Sub-Saharan Africa are lower than in the Mediterranean Region. Consequently, availability of iron to the plant will not pose a serious problem. Average pH recorded are 5.6 in Ethiopia, 5.9 in Ghana, 5.4 in Malawi, 5.6 in Nigeria, 4.9 in Sierra Leone, 6.3 in Tanzania and 5.0 in Zambia. However, it should be borne in mind that the pH range preferred for grape is between 6 and 7 so that with the prevailing soil pH in Sub-Saharan Africa other nutrient imbalances, notably shortage of calcium, can be expected.

4.2.4. Middle East

Large parts of the Middle East, notably Saudi Arabia, Yemen, Oman, Iraq and Iran, appear as zinc deficient. Only along the northern coast of the Persian Golf soils seem to be somewhat better supplied and show up as having a low zinc content. Mean average content for zinc in soils of Iraq amounts to only 0.3 mg/l soil, while the Cu content is low, 4.7 mg/l soil.

Iron shortage may also be expected in this region as the soil pH is fairly high. For Iraq, for example, mean soil pH is 7.8.

4.2.5. Inner Asia

The soils of the former Soviet Union in Inner Asia appear to be zinc deficient, while some of them at the same time also show low contents in copper. However, no data are available from this region to cross-check the results of the interpretations.

4.2.6. South Asia

Soils in Pakistan and the central part of India appear to zinc deficient. Soil samples from Pakistan have an average Zn content of 0.6 mg/l soil, while those in India have, on the average, 0.9 mg/l soil. Also copper is generally low in both countries, on the average 4.4 mg/l soil. As soil pH is rather high, mean average values for Pakistan and India are 7.7 and

7.6, respectively, iron shortages may be expected in these countries. Nepal is dominantly deficient in zinc (average value is 0.8 mg/l soil) while copper content appears to be adequate (5.7 mg/l soil). Average soil pH is lower than in Pakistan and India with a mean value of 6.2. Less iron shortage may therefore be expected than in the other two countries. Finally, the soils of Sri Lanka appear on the map as having a low content in zinc. However, a cross-check against actual data shows that the soils are both low in copper and zinc, 3.9 and 3.8 mg/l soil, respectively.

4.2.7. Southeast and East Asia

Low contents in copper and zinc seem to be the main constraints in the soils of this region. This is corroborated by actual data from Korea, Philippines and Thailand which show an average amount in Cu of 3.0, 13.4 and 6.3 mg/l soil, respectively, and a mean content in Zn of 1.7, 3.3 and 1.6 mg/l soil. Only the copper content in Philippine soils is much higher, which may be attributed to the volcanic character of the islands. Japan is expected to have low zinc contents. Also here, copper may be in sufficient supply because of the volcanic nature of the islands.

The pH of the soils is such that shortage in iron will not occur frequently. The mean pH of the soils for the countries mentioned is 5.6 for Korea, 6.0 for the Philippines and 6.8 for Thailand.

It must be noted that the northeastern part of China, although it is shown on the map, is not suitable for Viticulture because of the severe winters with minimum temperatures often reaching -30°C and lower.

4.2.8. Australia and New Zealand

A large part of Australia in the East, South and West may be zinc deficient, while more central parts appear to be low in zinc. The tropical part of Australia as well as the eastern coast are generally low in copper and zinc. However, no data are available to cross-check the interpretation.

New Zealand soils appear generally to be low in zinc on the northern island, and low in copper and zinc on the southern island. The mean values recorded for both elements are 12.0 mg Cu/l soil and 3.0 mg Zn/l soil. The somewhat higher copper content may be attributed to the inclusion of sample material from Tonga and Rarotonga in the analyzed material from New Zealand. These samples appeared to have very high Cu contents (>30 mg Cu/l soil), thus disturbing the average of the New Zealand samples (Sillanpää, 1982).

4.3. Concluding remarks

The interpretation of the available data suggest that - from soils point-of-view - interesting markets may be found for **Cu- and Zn-chelate** fertilizers in Central and South America, in Southern Africa, the Mediterranean Region and the Middle East, Southeast Asia, and South Australia, and, to a lesser extent in South Asia and the remainder of Sub-Saharan Africa and Australia. **Fe- and Mn-chelates** may be in high demand in the Mediterranean and Middle East regions, in the western parts of the USA and in Mexico, in Southern Asia and in Australia because of the prevailing high soil pH, which renders both elements almost not available to the plants.

5. RECOMMENDATIONS

The following recommendations may be made:

1. The present study is very generalized and merely indicative to which extent micronutrient imbalances may be expected in certain parts of the world. Thus, the results may have only some validity on a global scale. ***It is therefore necessary that the major regions, identified in this report as possible interesting markets for Cu-, Fe-, Mn-chelates, are studied in more detail to get a better insight in the actual needs for these products.***

2. ***It may be worthwhile, once areas or regions are more definitively defined, to study as well the need for these chelate products for other crops which are important in the selected regions. For example, rice in Southeast Asia or wheat and maize in the Americas and Sub-Saharan Africa may be taken into account.***

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