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Diagnosis and Remedy of Malnutritional Leaf Yellowing of Citrus in Najran, Saudi Arabia

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Abstract. Severe zinc and mild managanese deficiencies were recognized in citrus trees in Najran area, Saudi Arabia. These were corrected by foliar spray of the two elements at the rate of 2 g/l each of Zn and Mn chelates regularly once a year. After two consecutive sprays, zinc deficiency symptom was recovered. Further diagnostic studies revealed that apart from potassium and boron, which were in the high range, other macro and micro-nutrient elements were in the optimum range. Mild boron toxicity symptoms were also observed in some sensitive citrus varieties. Nitrogen, however, was required to be applied regularly to compensate for the soil's low nitrogen content.

Introduction

The Najran oasis, located at 17° 42′ N Lat. and 43° 23′ E Long. in the south western region of Saudi Arabia, covers an area of approximately 20,000 ha. Because of the suitability of its soil, water and climatic conditions, the oasis has been earmarked by the government for citrus growing. Until now, approximately 600,000 citrus trees of different cultivars have been established with an annual increment of about 150,000 budded trees.

Some nutritional problems related to citrus leaf yellowing have been diagnosed in Najran [1,2]. The alkaline and calcareous soils of Najran are likely to be deficient in their content of nutrients particularly in one or more of the micronutrients. This has been reported to be a problem in other parts of Saudi Arabia and elsewhere [3-7]. There are several diagnostic methods used to assess mineral deficiency and/or excess in crops such as soil test, leaf and irigation water analyses [8-17]. Leaf analysis, however, seems to be the best method in identifying the need for fertilizer application to

tree crops [18;19, p 382-392]. Since no systematic studies on citrus nutrition were performed in this area, it was of prime importance to identify the nutritional disorders in citrus trees in Najran and to establish the best methods of correcting mineral deficiencies in order to produce healthy citrus trees.

Materials and Methods

In september, 1987, 22 leaf samples (5-7 months old, 3rd mature leaf from non-fruiting shoots)- 11 from apparently healthy and 11 from chlorotic citrus trees (4 years old) were collected at random from the variety-root stock trial in the National Centre for Horticultural Research and Development, Najran. These leaf samples were dried for 48hr at 65°C, then ground in a Willy Mill to pass a 20 mesh screen, and digested by wet ashing and were analyzed for iron, zinc, manganese, copper and boron.

Since citrus trees were showing visual deficiency symptoms, probably, zinc and/or manganese, chelating compounds 2g Zn-EDTA (14% Zn) + 2g Mn-EDTA (10% Mn) + 7g Urea- 0.01% surfactant per litre were sprayed twice with an interval of 15 days according to Embleton *et al.*, [20, p. 122-172] over the foliage spray in May, 1988. Zinc Sulphate (2 g/l) alone with urea (7 g/1) was, however, applied as foliar spray in March, 1988 with little effect on the trees showing severe zinc deficiency symptoms.

In September, 1988 sixteen leaf samples covering four cultivated citrus variety-rootstock combinations namely, Olinda Valencia / Carrizo, Clementine / Carrizo, Frost March / Carrizo and Allen Eureka / Macrophylla, each of 5 years age were collected and analyzed for N, P, K, Ca, Mg, Fe, Zn, Mn, Cu and B. Sixteen composite soil samples taken from under tree areas (0-20 cm), corresponding to the trees samples, were also collected simultaneously and most of the macro- and micro nutrient elements were extracted by using the methods of Soltanpour and Schwab [21]. Nitrogen was determined by micro- Kjeldahl's method. Other nutrients were determined by using an atomic absorption spectro- photometer and a flame photo-meter as outlined by Isaac and Kerber [22]. The orchard soil is classified as belonging to the Typic Torriorthent Subgroup under the Entisol order of the U.S. Soil Taxonomy system. The main characteristics of the soil under investigation were loamy sand with 6% clay, 0.65% organic matter and 2.8% $CaCO_3$ and its pH, electrical conductivity (dS m^{-1}), saturation percentage (%) and cation exchange capacity (meq/100g) were 8.0, 4.3, 20.3 and 9.4, respectively [23].

The area has a mean maximum temperature ranging from 23°C in January to 36°C in July while the mean minimum temperature ranges from 6°C to 20°C. Relative humidity ranges from 37% to 46% during winter and from 13% to 19% during summer.

The irrigation water obtained from nearby boreholes contained an average 830 $\mu g\ g^{-1}$ total soluble salts including 180 $\mu g\ g^{-1}$ Ca, 38 $\mu g\ g^{-1}$ Mg, 54 $\mu g\ g^{-2}$ Na, 6.8 $\mu g\ g^{-1}$ K, 0.4 $\mu g\ g^{-1}$ B, 150 $\mu g\ g^{-1}$ Cl^-, 143 $\mu g\ g^{-1}$ SO_4^{-1} 270 $\mu g\ g^{-1}$ HCO_3^- 34 $\mu g\ g^{-1}$ NO_3^- and 2.0 $\mu g\ g^{-1}$ PO_4^{-3}. Irrigation water was practised through a trickle system every day at a rate of about 150 litres per tree.

Urea fertilizer (46% N) at the rate of 1.0 kg N/tree was applied through irrigation water in three doses: 50% in Feburuary, 25% in May and 25% in August. Triple super phosphate at the rate of 400 g/tree was applied in November, 1987 together with 20 kg/tree of dry decomposed organic manure.

Results

The micronutrients contents of the citrus leaves collected randomly are presented (Table 1). The data clearly indicate that there was severe zinc deficiency in citrus, the mean leaf content being only 6.7 $\mu g\ g^{-1}$ Zn. Manganese concentration in leaves was in the low range (22 $\mu g\ g^{-1}$ Mn), while iron (82 $\mu g\ g^{-1}$ Fe) and copper (9.1 $\mu g\ g^{-1}$ Cu) were in the sufficient range, and B (188.5 $\mu g\ g^{-1}$ B) was in the high range [18].

Table 1. Micronutrient concentration ($\mu g\ g^{-1}$) of citrus leaves (September, 1987)

Leaf (dry weight basis)	Fe	Zn	Cu	Mn	B
Apparently healthy	73.0b	7.9a	8.6a	24.0a	132.0b
Apparently chlorotic	91.0a	5.5b	9.6a	20.0a	245.0a
Mean	82.0	6.7	9.1	22.0	188.5

Means within each column followed by the same letter do not differ significantly at $P \leq 0.05$ according to Duncan's Multiple range test.

Table 2 shows the values of 10 elements in leaf samples collected after N, P, Zn and Mn fertilizer applications. Means of the values were N (2.44%), P (0.17%), Ca (3.05%), Mg (0.30%), Fe (71.4 $\mu g\ g^{-1}$), Zn (44.2 $\mu g\ g^{-1}$), Mn (37.5 $\mu g\ g^{-1}$ and Cu (6.73 $\mu g\ g^{-1}$) were all in the optimum range while K (1.34%) and B (273.35 $\mu g\ g^{-1}$) contents were in the high and excess range respectively.

Table 2. Macro and micro nutrient conentration of citrus leaves (September, 1988) after corrective sprays

Variety/ Rootstock	N	P	K	Ca	Mg	Fe	Zn	Cu	Mn	B
	(%)					($\mu g\ g^{-1}$)				
Olinda/ valenicia carrizo	2.43b	0.18b	1.32	2.74	0.27b	43.5c	40.5	5.7b	35.3	295.3a
Clementine/ carrizo	2.64a	0.21a	1.31	3.04	0.26b	63.5b	47.5	6.1b	37.5	308.8a
Red blush/ citrumelo	2.34b	0.18b	1.40	2.88	0.38a	53.3bc	45.0	7.3a	41.0	221.3b
Allen eureka/ macrophylla	2.37b	0.13c	1.34	3.54	0.28b	125.0a	43.9	7.8a	36.0	168.0b
Mean	2.44	0.17	1.34	3.05	0.30	71.3	44.2	6.73	37.44	248.35
SE+	0.055	0.010	.NS	NS	0.017	3.812	NS	0.269	NS	14.748

Means within each column followed by the same letter do not differ significantly at $P \leq 0.05$ according to Duncan's multiple range test.

The leaf N, P, K, Mg, Fe, Cu, Zn, Mn and B levels were found significantly different among the varieties while there were no significantly different for K, Ca, Zn and Mn (Table 2). Clementine trees on Carrizo rootstock accumulated the highest level of N and P while Red Blush grapefruit had the highest Mg. Micronutrient rootstock analyses (Table 2) showed that Allen Eureka on Macrophylla accumulated the highest concentration of Fe and Cu but lowest concentration of boron while Clementine/Carrizo had the highest Zn and B contents.

The available amounts of most of the macro-nutrient and micronutrient elements in soil corresponding to different citrus varieties are presented in Table 3. The organic matter content of the soil was very low (0.65%) and inadequate to supply enough nitrogen to plants [24,25]. Available phosphorous and potassium values were quite high (54.3 $\mu g\ g^{-1}$ P and 391.0 $\mu g\ g^{-1}$ K). Fe and Zn levels (3.82 $\mu g\ g^{-1}$ and 1.58 $\mu g\ g^{-1}$, respectively) were in the deficient or close to critical range [21]. Manganese were 3.43 $\mu g\ g^{-1}$. Boron level in the saturation extract also seemed to be very high (1.94 $\mu g\ g^{-1}$ B) and probably was toxic to citrus plants [26].

Table 3. Available nutrients and of the soil samples taken from under various citrus cultivar/rootstock combinations

Variety/ Rootstock	P	K	Fe	Zn	Cu	Mn	B
				($\mu g\, g^{-1}$)			
Olinda valencia/ carrizo	47	316b	3.42b	2.19	0.37	3.20	2.07
Clementine/ carrizo	67	299b	4.55a	2.00	0.34	3.64	1.97
Red Blush/ citrumelo	57	506a	3.59b	0.99	0.27	3.46	1.90
Allen eureka/ macrophylla	46	443ab	3.70b	1.15	0.34	3.41	1.83
Mean	54.3	391	3.82	1.58	0.33	3.43	1.94
SE	NS	47.89	0.24	NS	NS	NS	NS

Means within each column followed by the same letter do not difer significantly at $P \leq 0.05$ according to Duncan's multiple range test.

Discussion

According to Embleton *et al.*, [27], mineral nutritional deficiency symptoms of orange leaves such as "mottle leaf" or "frenching" are caused when zinc level goes below 16 $\mu g\, g^{-1}$ and with lemons when its level decreases below 10 $\mu g\, g^{-1}$. Before 1988, almost all oranges and mandarins in the Najran area showed zinc deficiency symptoms [2] with zinc content in leaf being below 10 $\mu g\, g^{-1}$ (Table 1). All leaf samples of either healthy or chlorotic trees were classified as deficient in zinc. This may confirm the zinc deficiency in all types of citrus in the area. Calcareous soils having low organic matter, pH higher than 7.0, leached sandy soils and newly levelled, were reported to be deficient in Zn [18 pp. 90-128].

These conditions, at least partially, appear to exist in the soils of the present study and could be responsible for the observed Zn deficiency of citrus. Embleton *et al.*, [27] stated that leaf manganese concentration should be more than 25 $\mu g\, g^{-1}$ to be in the "sufficient" range. This means that the manganese content of citrus leaf samples (22 $\mu g\, g^{-1}$) were near the critical level. Two sprays of zinc and managanese were, therefore, performed in May, 1988 to correct the deficiency of zinc and manganese.

Copper and iron were found in the 'sufficent' range according to Embleton *et al.*, [20]. Data in Tables 1 and 2 suggest that despite high soil pH values and $CaCO_3$ contents, none of the citrus varieties were deficient in Cu and Fe. Fuehring [29] demonstrated that Cu is much less liable to be deficient in calcareous soils than Zn. Although the extractable Fe was generally low in the soils (Table 3) no citrus variety was found deficient in leaf Fe for the time being. Leaf B was in the high range in all the samples according to Chapman [30], the symptoms of born toxicity are very prominent in grape fruit though it is considered as a mediocre boron accumulator. He indicated that amounts over 200 $\mu g\ g^{-1}$ in dry leaf of grapefruit are often associated with symptoms of boron axcess. The high boron in the citrus groves were also related to high salinity of the soil under tree samples, the average EC of saturation extract being 7.25 dS m^{-1} [31]. The boron toxicity symptoms in citrus was diminished by regular yearly leaching of the citrus groves and by applying elevated N supply to the trees [32].

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تشخيص ومعالجة سوء التغذية واصفرار الأوراق على الحمضيات بمنطقة نجران في المملكة العربية السعودية

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ملخص البحث. شوهد نقص حاد للزنك ومعتدل للمنجنيز على أشجار الحمضيات في منطقة نجران بالمملكة العربية السعودية. تمت معالجة هذا النقص برش الأوراق بهذين العنصرين بمعدل ٢ جم/لتر من كل عنصر كل عام بشكل منتظم على صورة مركب مخلبي، اختفت أعراض نقص الزنك بعد رشتين متتاليتين، أشارت دراسات التشخيص التي تمت على أن محتوى العناصر الغذائية الكبرى والصغرى للنبات في المستوى المناسب ما عدا البوتاسيوم والبورون فقد كان تركيزهما عاليًا. كما لوحظ ظهور أعراض سمية ليست عالية للبورون على الأصناف الحساسة من الحمضيات. وقد وجد أيضًا أنه يجب إضافة عنصر النيتروجين بشكل منتظم في الأراضي المنخفضة في محتواها من النيتروجين.