Soil & Environ. 25(2): 119-127, 2006

Diagnostic criteria of micronutrients for sweet orange

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Abstract

A field study was conducted on sweet orange (cultivar "Red Blood") orchard of a farmer at Shahbaz Garhi, Mardan to evaluate the effect of foliar spray of Zn, Mn and B on the fruit yield and leaf nutrient concentrations as well as to diagnose their critical levels. Zinc, Mn and B alone and in various combinations were applied as foliar spray in the form of sulfate salts and boric acid @ 0.4, 0.2 and 0.04 kg ha^{-1}, respectively dissolved in 400 liters of water. Leaf samples were analyzed for different micronutrients and fruit yield was recorded. Foliar sprays of Zn, Mn and B significantly increased fruit yield. Leaf concentrations of Zn and Mn were also increased with the foliar spray of the respective micronutrients but leaf B was not significantly influenced by B spray. Critical levels of Zn, Mn and B in leaves were found to be 22, 25 and 29 mg kg^{-1}, respectively. It may be concluded that the levels of leaf concentrations of Zn, Mn and B mentioned above serve as guide for the nutrient status of sweet orange trees. Trees require foliar application with the relevant micronutrient when its leaf concentration goes down the critical level.

Keywords: Sweat orange, Boron, Zn, Mn, foliar spray

Introduction

Citrus fruits play an important role in our daily nutritional requirements. It is one of the profitable crop commonly grown in Pakistan. In NWFP the total area under citrus (*Citrus sinensis* L.) crop during 2004-2005 was 4400 hectare with a total production of 36800 ton ha^{-1}. (Agric. Statistics of Pakistan, 2006). Most of the fruits are consumed as fresh, while some portion is used in the form of squashes, juices and drinks. Soil and crop surveys revealed that deficiency of Zn, B, Cu, Fe and Mn are appearing in citrus orchards and as such production and quality of citrus fruits are gradually declining. The deficiencies more common after NPK are those of Zn, B, Cu and Mn. It appears especially where citrus is grown on calcareous soils.

Most soils of NWFP are calcareous with high pH values and are deficient in micronutrients (Khattak and Parveen, 1988; Habib, 1990). On such soils, foliar application in the form of inorganic salts or chelates is a valuable tool in combating nutrient deficiencies (El-Fouly *et al*., 1988). Micronutrients are particularly required for deep rooted fruit trees because of lower quantities in the subsoils.

Curing micronutrient deficiencies through foliar application is a common practice in getting profitable yield and good quality fruit (Leyden, 1983; El-Shazly and Hennawy, 1983; Mamm *et al*., 1985; Waheed, 1992). Foliar application of Zn, Mn, Cu, Fe and B has advantages over soil application (Labanauskas *et al*., 1969; El-Kassas *et al*. 1987). The advantages include high effectiveness, rapid plant responses, convenience and elimination of toxicity symptoms brought about by excessive soil accumulation of such nutrients. Embleton *et al*. (1965) reported that correcting deficiency symptom of Zn and Mn alone did not increase the yield of lemon trees but yield was increased when levels of both the elements were increased simultaneously.

Accurate diagnosis is important for removing micronutrient deficiencies for getting profitable crop yield. The diagnostic criteria for sweet orange trees are non-existent especially under the prevailing local conditions. Keeping in view the importance of micronutrients and calcareous nature of the soils of NWFP, this study was undertaken to evaluate the micronutrient status of sweet orange trees with the objectives of developing critical micronutrient levels in plant tissue to be used for diagnostic purposes.

Materials and methods

This experiment was conducted on 16-year old trees of sweet oranges cultivar 'Blood Red' at Shahbaz Ghari, Mardan. Twenty-four trees of similar size and vigor, growing under similar conditions of soil fertility and irrigation were selected and each tree was tagged.

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Composite soil samples were collected at two depths (0-45 cm and 45-90 cm) from sites dug out at different crossings of four plants in the orchards. Soil samples of each depth were mixed to make a composite sample, air dried, crushed with wooden hammer, passed through 2 mm plastic sieve for determination of various physico-chemical characteristics.

A full basal dose of 150 kg N ha^{-1} (1.7 kg urea tree^{-1}), 100 kg P_2O_5 ha^{-1} (3 kg super phosphate tree^{-1}) and 100 kg K_2O ha^{-1} (1 kg potassium sulphate tree^{-1}) was applied under the canopy of each tagged tree leaving 2 feet area around the trunk of tree and trees were then irrigated.

The arrangement of the treatments combination was 2 x 3 factors factorial in a randomized complete block design. Each treatment was replicated three times with one tree for each replicate. Three micronutrients (Zn, Mn and B) at a single rate alone and at different combinations in the form of zinc sulphate ($ZnSO_4$), manganese sulphate ($MnSO_4$) and boric acid (H_3BO_3) were applied at the following three stages:

i. Before flower initiation.
ii. At late bloom stage and
iii. When fruit was at plum size.

Preparation of Spray Solutions

The volume of water (2.14 L/tree) was estimated per tree by assuming the average volume of water required to wet completely the canopy of three trees. The spray solution was prepared on the basis of 1.75, 0.75 and 0.2 kg ha^{-1} $ZnSO_47H_2O$, $MnSO_43H_2O$ and H_3BO_3, respectively in 400 liters of water. Urea (3.4 kg ha^{-1} in 400 liters of water) and surf (0.1%) were applied along with treatments. The above nutrients on elemental basis were as 0.4, 0.2 and 0.04 kg ha^{-1} Zn, Mn and B respectively dissolved in 400 L of water. Detail of treatment combinations are given in Table 1.

Solution of all treatments contained urea at a concentration of 0.8% to activate mineral absorption and surf (detergent) as a wetting agent at a concentration of 0.1% for enhancing absorption through reducing contact angle between the liquid and leaf surface.

a) Zinc treatment consisted of 0.4 kg ha^{-1} Zn (elemental basis) from $ZnSO_4$ $7H_2O$, (23% Zn) in 400 L of water.
b) Manganese treatment consisted of 0.2 kg ha^{-1} Mn (elemental basis) in the form of $MnSO_4$ $3H_2O$, (26.8% Mn) in 400 L of water.
c) Boron treatment consisted of 0.04 kg ha^{-1} B (elemental basis) in the form of H_3BO_3, (18% B) in 400 L of water.

Table 1. Detail of micronutrients (Zn, Mn and B) doses and their combinations

Treatment	Treatments	Zn[a]	Mn[b]	B[c]
		kg ha^{-1} in 400 L of water		
T1	Zn_0 Mn_0 B_0	--	--	--
T2	Zn_1 Mn_0 B_0	0.40	--	--
T3	Zn_0 Mn_1 B_0	--	0.20	--
T4	Zn_0 Mn_0 B_1	--	--	0.04
T5	Zn_1 Mn_1 B_0	0.40	0.20	--
T6	Zn_1 Mn_0 B_1	0.40	--	0.04
T7	Zn_0 Mn_1 B_1	--	0.20	0.04
T8	Zn_1 Mn_1 B_1	0.40	0.20	0.04

Leaf Samples Collection

Leaf samples were collected from medium portion of tagged shoots before and after each foliar spray as recommended by Agrotech (1987). The canopy of the tree was divided into 4 quadrants and 20 leaves per tree from each treatment i.e. 5 leaves per quadrant were collected from spring cycle growth of 5-7 months old having approximately the same size from non-fruit bearing terminals three to six feet above the ground. Diseased and injured leaves were discarded. Standard values reported by Jones (1966) were used as leaf analysis guide for diagnosing nutrient status of mature Valencia orange trees.

Determination of Critical Levels of Nutrients

Attempts were made to determine the critical levels of Zn, Mn and B in citrus leaves using the data generated by Waheed (1992), Raza (1993) and data of the present work pooled together. The data of previous studies were also used in addition to this study in order to increase the number of observations for improving critical values of the micronutrients. Cate and Nelson (1965) graphical method was used using the concept of Relative yield. (Critical value is defined as the lowest amount of element in plants accompanying the maximum yield). The following steps were used for calculating critical values.

1. Relative % yield was calculated using the formula:

$$\text{Relative yield (\%)} = \frac{\text{Yield of check/treatment}}{\text{Maximum yield}} \times 100$$

   Nutrient concentration in citrus leaves was determined for all levels of applied nutrients.
2. The scattered diagram of Relative % yield (Y-axis) versus nutrient values in the leaves (X-axis) was plotted using Microsoft-Excel. Graph paper can also be used.
3. A pair of intersecting lines perpendicular to the axes as overlay was drawn using computer's *"Drawing"* menu bar of MS-word in such a way that the diagram was divided into four sectors (two positive and two negative) of roughly equal size. Upper right and lower left quadrants are positive while others are negative.
4. The intersecting overlay lines were moved about horizontally and vertically on the diagram in such a way to accomplish maximizing the number of points in the positive quadrants and minimizing in the negative sectors. The point where the vertical line crosses the X-axis was defined as the "critical level".
   i. Alternatively, a piece of clear plastic having half the dimension of the graph is cut out for use as an overlay. A pair of intersecting perpendicular lines is drawn on the overlay with marker in such a way that it is divided into four sectors as mentioned above.
   ii. The overlay is moved about horizontally and vertically on the graph, always with the two lines parallel to the two axes on the graph, until the number of points showing through the overlay in the two positive sectors is at maximum.
   iii. The position of the lines on the overlay with respect to the axes of the graph is transferred on the graph by making marks on the edges of the graph. The two intersecting lines are then drawn on the graph with pencil. The point where the vertical line crosses the X-axis is the "critical level".

Data Analysis

Treatments effect on the concentrations of micronutrients in the leaves and on the yield after spray was interpreted statistically. Treatment differences were evaluated by Duncan's Multiple Range test. All these tests were done with the help of micro-computer by using MSTAT-C package (Version 5.1).

Results and discussion

The soil under the orchard was medium in texture, alkaline in reaction, and calcareous in nature with low organic matter content. The extractable Zn, Mn and B contents of soil were deficient and that of Cu and Fe were adequate (Table 2) according to the standards reported by Soltanpour (1985).

Micronutrient (Zn, Mn, Fe, Cu and B) Concentrations in Leaves of Sweet Orange Trees before Foliar Spray

The data summarized in Table 3 show the concentrations of micronutrients (Zn, Mn, B, Cu and Fe) of sweet orange leaves before foliar spray of Zn, Mn and B. The data revealed that Zn concentration with a mean value of 13.2 mg kg^{-1} (<16 mg kg^{-1}) and standard deviation of 3.12 was found deficient, Manganese concentration with a mean value of 23.1 mg kg^{-1} (<24 mg kg^{-1}) and standard deviation of 1.7 was found low. Boron concentration with mean value of 51.3 mg kg^{-1} (>30 mg kg^{-1}) and standard deviation of 4.0 was found optimum. Iron, with a mean value of 173.3 mg kg^{-1} (>120 mg kg^{-1}) and standard deviation of 19.9 was found high. Copper with a mean value of 12.63 mg kg^{-1} (>5 mg kg^{-1}) and standard deviation 1.9 was found in the optimum range.

The above results showed that Zn was deficient in citrus leaves, Mn was low, B and Cu were optimum while Fe was high before foliar application of micronutrients. These were evaluated on the basis of criteria reported by Jones (1966).

Table 2. Properties of the soils of sweet orange orchard before treatments

Properties	Unit	Depth (cm) 0 – 45	Depth (cm) 45 – 90	Remarks
pH	--	7.87	7.79	Alkaline
Lime	%	10.00	9.38	Calcareous
Organic matter	%	0.42	0.35	Very low
Texture	--	Sandy loam	Sandy loam	Well drained soils
AB-extractable Zn	mg kg^{-1}	0.42	0.31	Deficient
AB-extractable Mn	mg kg^{-1}	1.50	1.00	Deficient
AB-extractable Cu	mg kg^{-1}	0.61	0.57	Adequate
AB-extractable Fe	mg kg^{-1}	10.98	12.30	Adequate
Hot water soluble B	mg kg^{-1}	0.10	0.28	Deficient

Table 3. Native concentration of micronutrients (Zn, Mn, Cu, Fe and B) in leaves of sweet orange trees before foliar spray of Zn, Mn and B

Sr. No.	Treatments Proposed	Nutrients concentrations in citrus leaves (oven dried basis) Zn	Mn	B	Cu	Fe
		mg kg^{-1}				
1	Zn_0 Mn_0 B_0	12.3	20.1	58.0	14.93	180.8
2	Zn_1 Mn_0 B_0	20.4	23.4	56.5	13.20	196.0
3	Zn_0 Mn_1 B_0	12.9	22.5	50.0	11.47	154.2
4	Zn_0 Mn_0 B_1	12.5	24.7	52.33	12.33	179.1
5	Zn_1 Mn_1 B_0	10.8	25.0	50.2	15.33	154.0
6	Zn_1 Mn_0 B_1	11.7	23.5	48.3	12.33	157.9
7	Zn_0 Mn_1 B_1	10.7	24.4	47.63	11.87	159.8
8	Zn_1 Mn_1 B_1	14.1	21.5	47.33	9.60	204.9
	x^-	13.2	23.1	51.3	12.63	173.3
	Sx^-	3.12	1.7	4.0	1.9	19.9
	Status	Deficient	Low	Optimum	Optimum	High

Effect of Foliar Application of Micronutrients on the Zn, Mn and B Concentrations in Leaves of Sweet Orange Trees

Effect of Zn

The data given in Table 4 revealed that foliar application of zinc on sweet orange trees significantly ($P < 0.01$) increased leaf zinc content as compared to leaves from trees not treated with zinc. Mean values of Zn in Table 4 showed that Zn concentration in citrus leaves was increased upto 80-95 mg kg^{-1} in all those treatments where Zn was applied along with Mn or B, while Zn application alone increased leaf Zn content beyond the optimum range i.e. 107.4 mg kg^{-1}. This increase in leaf Zn content was due to its maximum absorption from Zn source through foliage and less translocation to other parts of the plant. This suggestion is based on the findings of Mitra and Sadhu (1988). They reported high accumulation of Zn content in citrus leaves and less translocation even to younger leaves of Zn deficient plants.

It is concluded from the above results that Zn content in sweet orange leaves was increased upto the optimum range when it was applied along with Mn or B in foliar spray mixture, as compared to Zn spray alone. Similar findings were also reported by Nanaya *et al*. (1985). Mamm *et al*. (1985), on the other hand, found Zn more effective in increasing leaf Zn when applied alone.

Effect of Mn

The data in Table 4 revealed that foliar application of Mn to orange trees significantly ($P < 0.01$) increased leaf Mn content, as compared with trees not sprayed with Mn concentration. This increase in leaf Mn content was due to the better uptake of Mn ion by sweet orange leaves in the presence of urea (Labanauskas *et al*., 1969). The highest concentration of Mn i.e. 48.67 mg kg^{-1} was obtained where Mn was applied alone as compared to its combination with Zn or boron. Manganese combined with Zn or B in foliar spray mixture increased the Mn content in sprayed leaves but not to the same degree as Mn alone (Table 4). Similar results were also reported by El-Shazly and Hennawy (1983) and Razeto *et al*. (1986) who suggested that Mn combined with Zn or B foliar spray mixture was not as effective in increasing leaf Mn content as compared to Mn alone.

Table 4. Effect of foliar spray of Zn, Mn and B on their concentrations in leaves of sweet orange trees

No.	Treatments[a]			Zn	Mn	B
				---------------------- mg kg^{-1}	------------------------	
1.	Zn_0	Mn_0	B_0	19.73 B	20.73 B	39.10
2.	Zn_1	Mn_0	B_0	107.40 A	19.87 B	39.83
3.	Zn_0	Mn_1	B_0	16.46 B	48.67 A	40.00
4.	Zn_0	Mn_0	B_1	20.47 B	22.87 B	40.00
5.	Zn_1	Mn_1	B_0	95.13 A	44.00 A	36.53
6.	Zn_1	Mn_0	B_1	83.27 A	24.47 B	40.17
7.	Zn_0	Mn_1	B_1	28.80 B	44.13 A	43.90
8.	Zn_1	Mn_1	B_1	80.68 A	46.00 A	43.43
F. Value				**	**	NS
Main Effects[b]						
	Zn_0			21.36	34.1	40.85
	Zn_1			91.61	33.8	39.99
F. Value				**	NS	NS
	Mn_0			57.71	21.98	39.87
	Mn_1			55.26	45.70	40.96
F. Value				NS	**	NS
	B_0			59.68	33.31	38.86
	B_1			53.30	34.36	41.97
F. Value				NS	NS	NS
Interactions:						
Zn x Mn				NS	NS	NS
Zn x B				NS	NS	NS
Mn x B				NS	NS	NS
Zn x Mn x B				NS	NS	NS

* = Significant at 5%, ** = Significant at 1% level of probability.

Effect of B

Foliar application of boron to sweet orange trees did not significantly increase leaf boron content as compared to trees not sprayed with B concentration (Table 4). This effect was due to high mobilization of boron content from sprayed leaves to the fruit. These results are in agreement with the findings of Khalil and Thompson (1960). They found that mid season sprays of boron substantially increased the boron content of the fruits, but had little effect on the boron level of the leaves. The highest content of B i.e. 43.90 mg kg^{-1} was obtained by the combined effects of Mn and B as compared to B alone which was followed by 43.40 mg kg^{-1} with the application of B+Zn+Mn combination (Table 4). In terms of the main effects Zn application significantly increased leaf Zn content but could not significantly affected leaf Mn and B. Manganese application significantly increased leaf Mn but did not affect Zn and B. Boron application did not affect leaf Zn, Mn and B. Interaction among Zn, and B was non-significant (Table 4).

a) The subscript 0 trees received no spray of the element indicated. Values associated with subscript 1 are the mean values of 0.4 kg Zn, 0.2 kg Mn and 0.04 kg B ha^{-1} in 400 L of water for the element indicated.
b) Each value is a mean of 12 individual determinations.

Effect of Micronutrients on Yield of Sweet Orange

Foliar application of Zn, Mn and B on sweet orange trees increased significantly the fruit yield as compared to trees not sprayed with these nutrients (Table 5). Zinc and Mn alone caused a yield increase of 49.79 % and 30.87 % respectively as compared to yield obtained from trees not sprayed with these nutrients. The yield increases

Table 5. Concentration of Zn, Mn and B in citrus leaves with relative yield

Treatments	Nutrient concentrations			Yield			Relative yield		
	R1	R2	R3	R1	R2	R3	R1	R2	R3
	---------mg kg^{-1}---------			---------kg $tree^{-1}$---------			----------- % ------------		
***Waheed (1992)**									
Zn_0	15.0	17.8	18.0	50.0	47.5	45.0	45.9	43.6	41.3
Zn_1	56.4	58.2	50.8	50.5	51.5	52.0	46.3	47.2	47.7
Mn_0	19.8	22.0	25.0	50.0	47.5	45.0	45.8	43.5	41.3
Mn_1	35.2	53.8	36.6	45.5	42.5	40.0	41.7	38.9	36.7
****Raza (1993)**									
Zn_0	31.7	24.0	36.5	80.0	60.0	49.0	73.3	55.0	44.9
Zn_1	98.9	75.3	87.8	50.0	74.0	109.0	45.9	100.0	57.8
Mn_0	26.4	26.3	51.6	80.0	60.0	49.0	73.4	55.0	44.9
Mn_1	62.2	70.1	65.3	109.0	82.0	76.0	100.0	75.0	69.7
B_0	20.5	29.0	21.9	80.0	60.0	49.0	88.8	66.6	54.4
B_1	24.0	23.6	24.2	62.0	81.0	49.0	68.8	90.0	54.4
****Hafeez present thesis (1993)**									
Zn_0	14.8	17.0	27.4	70.0	70.0	71.0	64.2	64.2	65.1
Zn_1	136.0	67.8	107.4	105.0	106.0	105.0	96.3	97.2	96.3
Mn_0	17.2	27.6	17.4	70.0	70.0	71.0	64.2	64.2	65.1
Mn_1	53.2	53.8	39.0	91.0	92.0	93.0	83.4	84.4	85.3
B_0	39.1	36.5	41.7	70.0	70.0	71.0	77.7	77.7	78.8
B_1	43.3	37.6	40.3	87.0	90.0	90.0	96.6	100.0	100.0

were due to significant increases in leaf Zn, Mn and B concentrations, which in turn induced more flowering and minimized fruit let drop in sweet orange trees. These results are in agreement with those of Gracia *et al*. (1984). They reported that fruit let drop decreased as leaf Zn and Mn content increased.

* Zn_0 and Mn_0 are check plots and Zn_1 and Mn_1 means 0.50 and 0.19 kg ha^{-1} of the respective element dissolved in 400 L of water.

** Zn_0, Mn_0 and B_0 are check plots and Zn_1, Mn_1 and B_1 means 0.40, 0.20 and 0.04 kg ha^{-1} of the respective element dissolved in 400 L of water.

Boron showed 5.82 % increase in yield as compared to trees not treated with B. Our results are in line with the findings of Chiu and Chang (1986) who reported 3-15 % increase in fruit yield following B application. Although B alone could not gave satisfactory results as compared to Zn and Mn, but yield was increased from 89 to 95 kg $tree^{-1}$ when it was applied in combination with Zn in foliar spray mixture. This may be attributed to the cumulative effect of both Zn and B in reducing heavy drop of young fruits and increased fruit set. These results are in agreement with those of Sato (1962).

Critical Levels of Zn, Mn and B in Citrus Leaves

Critical levels of nutrients in citrus leaves were determined by plotting the Relative % yield against nutrient concentrations in leaves. Critical levels of Zn, Mn and B were thus obtained to be 22, 25 and 29 mg kg^{-1} respectively (Fig. 1, 2 and 3).

The values of Mn and B were closer to the value reported by Jones (1966) and IPI (1976), whereas the value of Zn was little lower from those reported by Jones (1966). They reported critical values of Zn, Mn and B as 24, 24 and 30 mg kg^{-1} respectively. The reasons for this variation may be due to limited data or may be due to different soil and climatic conditions and/or varietal differences.

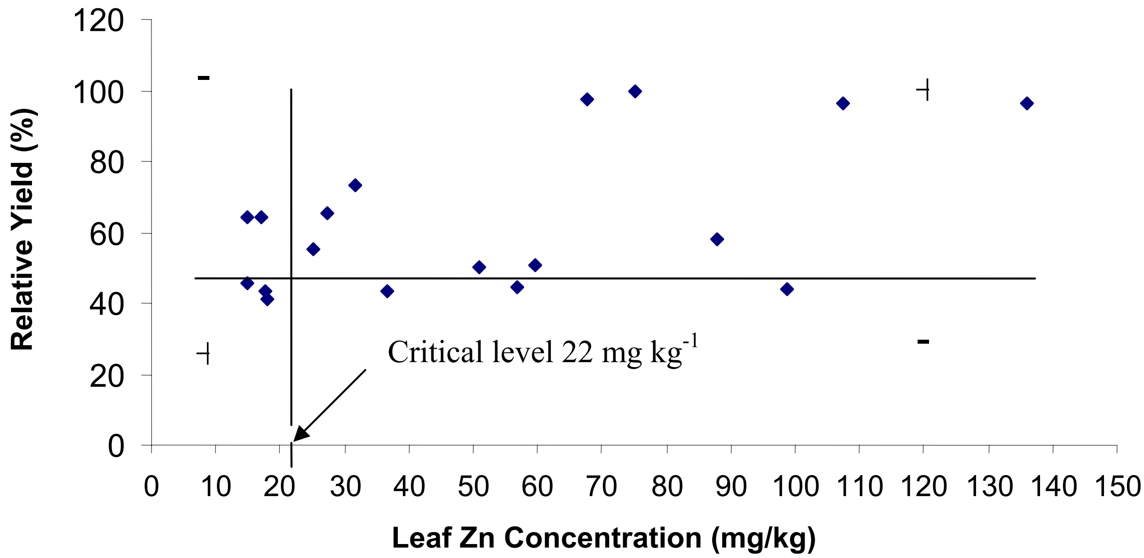

Fig. 1. Relation between Leaf Zinc and Relative Yield of Sweet Orange

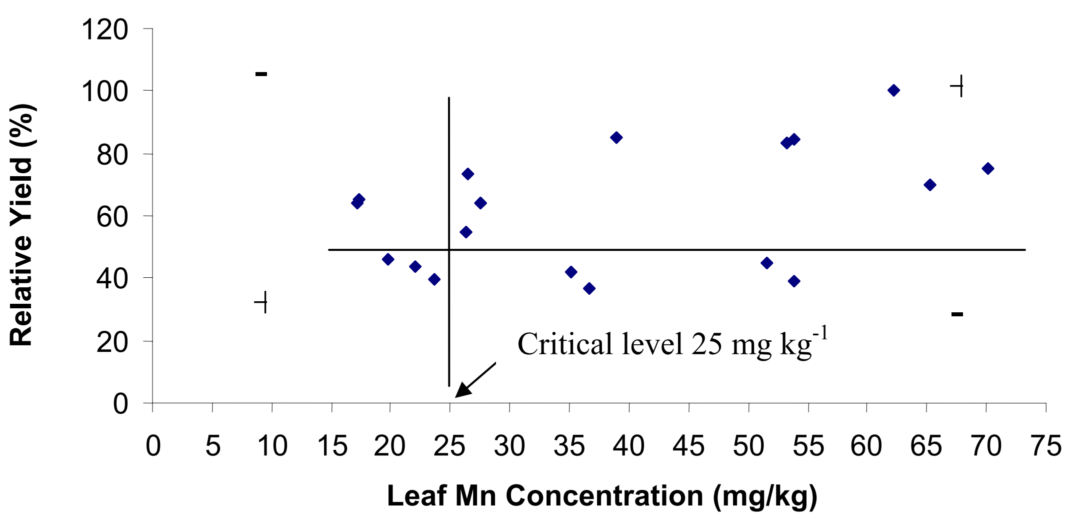

Fig. 2. Relation between Leaf Manganese and Relative yield of Sweet Orange

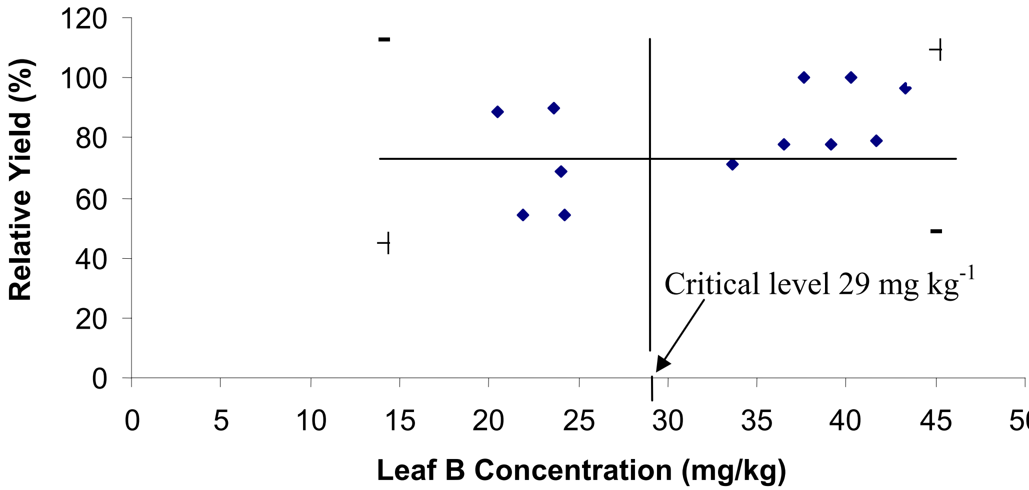

Fig. 3. Relation between Leaf Boron and Relative yield of Sweet Orange

Conclusion

It may be concluded that the critical levels of Zn, Mn and B in the sweet orange leaves are 22, 25 and 29 mg kg^{-1} respectively and these can be used as a guide for diagnosing micro-nutrient deficiencies in sweet orange trees. Trees require necessary foliar application with the relevant micronutrient when its leaf concentration goes down the critical level.

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