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# The Nutritional Status of some Horticultural Crops in Salalah Region, Sultanate of Oman

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**تقييم العناصر المغذية في بعض المحاصيل البستانية بمنطقة صلالة في سلطنة عمان**

الملخص: تم إجراء مسح حقلي غذائي بمنطقة صلالة بسلطنة عمان لتقييم الحالة الغذائية للمحاصيل المختلفة والتربة النامية عليها بتلك المنطقة. أوضحت نتائج تحليل العينات التي تم جمعها خصيصا لهذا الغرض أن أراضي تلك المنطقة تتصف بارتفاع الرقم الهيدروجيني، وكذلك محتواها من كربونات الكالسيوم الكلية، كما تتصف بنقص في محتواها من العناصر المغذية الصغرى. ولقد تسببت هذه الظروف غير المناسبة في التربة في نقص العناصر المغذية داخل أنسجة النبات. ولتصحيح هذا الوضع يجب استخدام السماد على أساس من اختبارات التربة وتحاليل النبات، ودراسة النظام الزراعي والإدارة الحقلية. كما أنه لا بد من أخذ استخدام العناصر المغذية الصغرى في الاعتبار لتحقيق التوازن الغذائي المنشود وزيادة المحصول .

ABSTRACT: A field survey has been conducted in Salalah region, Sultanate of Oman to evaluate the nutrient status of some horticultural crops and the respective soils. Soil and leaf samples were collected and analyzed. Soils were found to be characterized by high pH, high $CaCO_3$ content, low or very low micronutrient contents. The unfavorable conditions caused nutrient deficiencies within the plant tissues. To correct the situation, fertilizer use should be based on soil testing and plant analysis, as well as information on farming system and farm management. Use of micronutrient fertilizers should be considered as a part of the fertilizer regime.

Providing crops with their nutrient requirements is a prerequisite for producing high yields. It is evident that the nutrient limitation attributed to the real deficiency or factors influencing the nutrients availability leads to yield decreases (El-Fouly, 1983, El-Fouly, 1984; Mengel and Kirkby, 1987). On the other hand, integrated and balanced nutrient management is considered a key factor for crop production (El-Fouly *et al.*, 1987). Reaching the yield potential of a given crop was found to be highly dependent on the balanced nutrient ratios within the plant tissues (Fawzi *et al.*, 1996; Shaaban and Abou El-Nour, 1996).

Agriculture in the Sultanate of Oman is developing fast. The high population increase requires parallel increase in the cultivated area together with vertical increase in the crop production. The Government of Oman did and still does a great amount of work in the field of agriculture extension (Abdalla and Ali, 1983; Al-Zidgali *et al.*, 1989; El-Hag, 1990; MOAF, 1988, 1991). However, intensive research work is still needed on the soil nature and its nutrient contents, as well as the nutritional requirements for the cultivated crops (Cookson 1996).

The present work has been conducted within FAO activities and was aimed at studying the nutritional status of different horticultural crops in Salalah region with special emphasis on micronutrients in order to suggest the suitable remedies.

## Materials and Methods

A field survey was carried out in four districts (Hafa-Salalah-Dahariz and Augadain) in Salalah region to investigate the status of soil nutrients as well as the nutritional status of major horticultural crops.

INVESTIGATED CROPS: Banana, Papaya, Grapes, Chico, Mango, Lime, Mandarin, Orange, Pomelo, Pomegranate, Guava, Coconut, Tomatoes and Pepper.

FERTILIZERS USED: It was difficult to get accurate information about fertilizers used and their quantities, however, generally, nitrogen and phosphorus are used and in a very small scale, K and micronutrients. In vegetables and some fruit orchards specially citrus, and vegetables high amounts of organic manure are used. Pesticides, Mn, Zn and Cu were intensively used.

SAMPLING - SOIL: Representative soil samples were taken from the depths 0-25 cm and 25-50 cm. The samples were sun-dried, ground and sieved through a 2-mm sieve and prepared for extraction and analysis.

SAMPLING - PLANT: Leaf samples were taken from different plants. The samples were collected from the recommended parts of each crop (Chapman and Pratt 1978). Leaves were washed, dried at 70° C and then ground.

ANALYSIS - SOIL: Physical characteristics - Mechanical analysis was carried out using the hydrometer method, pH and E.C. values were measured in a water extract (1:2.5), calcium carbonate ($CaCO_3$ %) was determined using calcimeter method and organic matter (O.M. %) was determined using potassium dichromate method (Chapman and Pratt, 1978).

ANALYSIS - SOIL: Nutrient extraction - Phosphorus was extracted using sodium bicarbonate as described by Olsen *et al.* (1954). Potassium and magnesium were extracted using ammonium acetate and Fe, Mn, Zn and Cu were extracted using DTPA (Chapman and Pratt, 1978).

ANALYSIS - LEAVES: The plant material was wet digested using a mixture of perchloric : sulphuric: nitric acids (1: 1:8) (Chapman and Pratt, 1978).

NUTRIENT MEASUREMENTS: Nitrogen was determined in the dry plant material using Buaschi digestion and distillation unit. Phosphorus was photometrically determined using the molybdate-vanadate method according to Jackson (1973). Potassium, and calcium were measured in the extract using Eppendorf flamephotometer. Magnesium, iron, manganese, zinc and copper were determined using the Atomic absorption spectro-photometer PMQ3.

EVALUATION OF THE NUTRIENT STATUS: Values of soil analysis were evaluated according to Ankerman and

TABLE 1

***Physical characteristics of the soil of Salalah region.***

| Cultivated crop | pH | E.C. mmhos/cm | O.M. % | $CaCO_3$ % | Sand % | Silt % | Clay % | Texture |
|---|---|---|---|---|---|---|---|---|
| | | | **0-25 cm depth** | | | | | |
| Banana | 8.50* | 0.35 | 2.04 L | 39.00 ** | 50.0 | 31.3 | 19.0 | S.L. |
| Papaya | 8.58** | 1.92 | 1.72 L | 37.50 ** | 50.0 | 29.0 | 21.0 | S.L. |
| Grapes | 8.06* | 3.25 | 3.68 | 37.00 ** | 45.0 | 38.0 | 17.0 | S.L. |
| Lime | 8.76** | 0.24 | 1.14 L | 33.00 ** | 51.0 | 30.0 | 19.0 | S.L. |
| Other citrus | 8.04* | 4.22 | 1.40 L | 37.00 ** | 31.0 | 32.0 | 17.0 | S.L. |
| Coconut | 8.15* | 2.12 | 1.40 L | 31.00 ** | 63.0 | 22.0 | 15.0 | S.L. |
| Tomates | 8.61** | 1.51 | 1.40 L | 37.00 ** | 53.0 | 28.0 | 19.0 | S.L. |
| Pepper | 8.53** | 5.95* | 1.75 L | 37.00 ** | 53.0 | 28.0 | 19.0 | S.L. |
| Mean | 8.40* | 2.37 | 1.81 L | 36.06** | 52.0 | 30.0 | 19.0 | S.L. |
| SD (±) | 0.28 | 1.92 | 0.80 | 2.65 | 5.2 | 4.5 | 2.1 | |
| | | | **25-50 cm depth** | | | | | |
| Banana | 8.40* | 0.26 | 1.19 L | 38.00 ** | 56.4 | 23.3 | 20.3 | S.L. |
| Papaya | 8.75** | 0.53 | 0.70 vL | 37.00 ** | 55.0 | 23.0 | 22.0 | S.L. |
| Grapes | 8.43* | 1.44 | 0.98 vL | 36.00 ** | 53.0 | 30.0 | 17.0 | S.L. |
| Lime | 8.67** | 0.25 | 0.70 vL | 31.00 ** | 51.0 | 30.0 | 19.0 | S.L. |
| Other citrus | 8.78** | 0.17 | 0.35 vL | 33.00 ** | 51.0 | 26.0 | 23.0 | S.L. |
| Coconut | 8.61** | 0.30 | 0.70 vL | 30.00 * | 61.0 | 22.0 | 17.0 | S.L. |
| Tomates | 8.53** | 0.97 | 0.56 vL | 31.00 ** | 49.0 | 32.0 | 19.0 | S.L. |
| Pepper | 8.53** | 5.95* | 1.75 L | 37.00 ** | 53.0 | 28.0 | 19.0 | S.L. |
| Mean | 8.58** | 0.75 | 0.78 vL | 33.12 ** | 53.4 | 27.0 | 19.5 | S.L. |
| SD (±) | 0.14 | 0.87 | 0.27 | 3.44 | 3.89 | 3.9 | 2.2 | |

* = High; ** = Very high; L = Low; vL = Very low

Large (1974) while plant nutrient values were evaluated according to DeGeus (1973), Martin-Prevel *et al.* (1984) and Robinson (1986).

STATISTICAL ANALYSIS: The obtained data were subjected to NCSS-5X computer programme (Hintze, 1990) in order to calculate means and standard deviations (SD).

**Results and Discussion**

SOIL PHYSICAL CHARACTERISTICS: Data in Table (1) shows that Salalah region soils are characterized by high to very high pH values which lead to low availability of micronutrients (Page 1962; El-Fouly 1983 and Cookson 1996). On the other hand, high $CaCO_3$ content of the soil causes decreases in the availability of Fe, Mn and Zn (Cottenie and Kiekens 1974). Moreover, such sandy loam texture of the soil together with low organic matter content, allowed leaching of the mobile elements in the soil solution (Shuman 1979).

Soil "available" Nutrients - Soil nutrient contents (Table 2) were found to be a reflection of the unfavorable physical conditions.

MACRONUTRIENTS: In most cases, phosphorus content of the surface layer was higher than normal probably as a result of adding of phosphate fertilizers. Potassium content was very low in the surface layer, but sufficient and even high in some cases as with coconut and tomatoes in the subsurface layer. Magnesium content was adequate in all cases and calcium values were found to range between sufficient, low or very low. K/Mg ratio is very much in favour of Mg in the surface layer. However, soils of citrus, coconut and tomatoes were characterized by relatively high K content in both surface and subsurface layers.

MICRONUTRIENTS: Iron and manganese contents were very low in both soil layers. Zinc and copper contents were generally low or very low. However very few locations contained adequate Zn concentrations. Here again, soils of citrus, coconut and tomatoes showed relatively higher Zn content than other soils, which might be attributed to the organic manure used. Under such cases, low yields are expected, unless a balanced and integrated nutrient management is used.Nutrient Status of the plant leaves.

MACRONUTRIENTS (TABLE 3): Nitrogen is deficient in the plant leaves of almost all crops with some few exceptions, which can directly lead to great losses in

TABLE 2

*Macro and micronutrients available contents of the soil.*

| | Macronutrients (mg/100g soil) | | | | Micronutrients (ppm) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Crop | P | K | Mg | Ca | Fe | Mn | Zn | Cu | K/Mg |
| | | | | | 0-25 cm depth | | | | |
| Banana | 3.63* | 5.30 vL | 75.3 | 19.9 vL | 3.67 vL | 2.76 vL | 1.20 L | 1.13 | 0.07 |
| Papaya | 2.70 | 5.50 vL | 77.9 | 98.0 | 4.85 vL | 3.30 vL | 1.55 L | 0.90 | 0.07 |
| Grapes | 3.80* | 18.40 L | 93.6 | 179.0* | 2.90 vL | 4.30 vL | 0.40 vL | 2.60 | 0.19 |
| Lime | 3.10* | 11.00 vL | 59.8 | 17.1 vL | 3.40 vL | 3.20 vL | 0.80 L | 1.20 | 0.18 |
| Other citrus | 2.60 | 4.90 vL | 73.7 | 93.8 | 2.40 vL | 5.60 L | 2.00 | 0.80 L | 0.07 |
| Coconut | 3.30* | 6.00 vL | 74.9 | 59.7 L | 2.10 vL | 3.20 vL | 1.60 | 0.60 L | 0.08 |
| Tomatoes | 2.60 | 12.30 L | 53.7 | 76.7 L | 1.60 vL | 4.30 vL | 2.60 | 1.00 | 0.23 |
| Pepper | 1.40 | 4.90 vL | 113.0 | 264.0* | 5.80 L | 2.80 vL | 0.50 L | 0.20 vL | 0.04 |
| Mean | 2.89* | 8.53 vL | 77.7 | 101.0 | 3.35 vL | 3.68 vL | 1.33 L | 1.05 | 0.11 |
| SD (±) | 0.75 | 4.92 | 18.6 | 83.3 | 1.42 | 0.97 | 0.76 | 0.70 L | |
| | | | | | 25-50 cm depth | | | | |
| Banana | 1.76 | 6.53 vL | 60.4 | 15.6 vL | 3.60 vL | 2.20 vL | 0.60 L | 1.00 | 0.11 |
| Papaya | 1.40 | 19.90 | 55.3 | 38.3 vL | 3.60 vL | 2.30 vL | 0.40 vL | 0.80 L | 0.36 |
| Grapes | 2.50 | 11.00 vL | 63.4 | 59.7 L | 2.60 vL | 4.00 vL | 1.30 L | 0.60 L | 0.17 |
| Lime | 1.80 | 8.60 vL | 52.5 | 25.6 vL | 4.00 vL | 2.50 vL | 0.20 vL | 1.00 | 0.16 |
| Other citrus | 0.90 L | 29.40 | 44.7 | 12.8 vL | 4.00 vL | 2.10 vL | 0.90 L | 0.40 vL | 0.66 |
| Coconut | 1.20 | 46.60* | 65.2 | 17.1 vL | 2.40 vL | 1.40 vL | 0.30 vL | 0.40 vL | 0.71 |
| Tomatoes | 2.00 | 34.30* | 62.6 | 59.7 L | 5.80 L | 6.10 L | 4.30 | 1.00 | 0.55 |
| Pepper | 3.10 | 17.20 | 70.0 | 128.0 | 2.90 vL | 2.80 vL | 0.80 L | 0.20 vL | 0.24 |
| Mean | 1.83 | 22.80 | 59.2 | 44.6 L | 3.61 vL | 2.98 vL | 1.10 L | 0.67 L | 0.37 |
| SD (±) | 0.71 | 15.50 | 8.0 | 38.6 | 1.07 | 1.41 | 1.34 | 0.32 | |

* = High  ** = Very high  L = Low  vL = Very low

TABLE 3

***Nutrient concentrations in the leaves of the studied plants.***

| Crop | Macronutrients (% of D.M) | | | | | Micronutrients (ppm) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | P | K | Mg | Ca | Fe | Mn | Zn | Cu |
| Banana | 2.38* ±0.70 | 0.29 ±0.13 | 2.44* ±0.50 | 0.49 ±0.10 | 1.82 ±0.49 | 136.5 ±55.9 | 143.0 ±67.7 | 20.4** ±5.3 | 6.1 ±2.2 |
| Papaya | 3.74 ±1.18 | 0.59 ±0.23 | 2.13* ±0.60 | 0.59 ±0.09 | 1.73 ±0.36 | 238.3 ±71.6 | 69.3 ±24.9 | 26.6 ±5.1 | 7.8 ±2.8 |
| Grapes | 2.36* ±0.21 | 0.28 ±0.03 | 1.13* ±0.43 | 0.36 ±0.05 | 2.13 ±1.18 | 126.7 ±57.7 | 85.5 ±72.2 | 21.7** ±10.6 | 73.2 ±26.2 |
| Chico | 1.16* ±0.13 | 0.19 ±0.04 | 1.53* ±0.59 | 0.28 ±0.03 | 1.28 ±0.08 | 73.6 ±17.2 | 38.0 ±7.54 | 6.3* ±1.5 | 4.8 ± 0.0 |
| Mango | 1.07 ±0.18 | 0.20 ±0.02 | 0.70 ±0.42 | 0.39 ±0.06 | 3.12 ±0.60 | 102.0 ±13.2 | 74.0 ±16.7 | 15.7* ±3.5 | 5.9* ±2.0 |
| Lime | 2.06* ±0.51 | 0.26 ±0.04 | 2.04 ±0.65 | 0.29 ±0.03 | 2.96 ±0.34 | 84.5 ±18.2 | 23.3* ±8.70 | 16.2* ±2.8 | 2.1* ±0.5 |
| Mandarine | 2.42 | 0.24 | 1.87 | 0.03* | 3.63 | 69.0 | 21.0* | 9.0* | 4.8* |
| Orange | 2.72 | 0.31 | 1.36 | 0.33 | 2.87* | 114.5 | 40.0 | 16.0* | 8.6 |
| Pomolo | 2.07* | 0.22 | 1.95 | 0.03* | 2.63* | 81.0 | 49.0 | 49.0 | 7.7 |
| Pomegranate | 1.42* | 0.36 | 1.79 | 0.41 | 1.20* | 96.0 | 32.0 | 16.0* | 8.6 |
| Guava | 2.76 | 0.26 | 1.74 | 0.26 | 1.25 | 113.0 | 117.0 | 24.0 | 15.5 |
| Coconut | 1.41* ±0.16 | 0.22 ±0.07 | 0.62* ±0.0 | 0.49 ±0.0 | 0.65* ±0.21 | 154.0 ±0.7 | 36.0 ±5.65 | 14.0** ±2.8 | 4.3 * ±0.7 |
| Tomatoes | 3.18* | 0.34* | 1.95 | 0.29* | 2.47 | 354.0 | 160.0 | 71.0 | 22.5 |
| Pepper | 3.48 | 0.35 | 3.48 | 0.70 | 2.20 | 145.0 | 117.5 | 39.0 | 26.6 |

* = deficient ** = Low ± = Standard deviations between different locations

yields. Indirectly, nitrogen deficiency may negatively affect the absorption of micronutrients (El-Fouly *et al.*, 1990). Phosphorus concentrations were nearly sufficient in all studied locations being more or less in the same levels, which reflect the adequate concentrations in the soil. Potassium was found to be deficient in about 50% of the crops which is an expected result due to its deficiency in the soil in particular in the surface layer. Deficient Mg concentrations were detected in some crops, in spite of the adequacy in soil. In other cases, sufficient concentrations were measured in the leaves, in spite of its low or very low levels detected in the soil solution.

MICRONUTRIENTS: Mn was sufficient in most cases. Only lime and mandarin, were deficient. Zn showed a similar trend, while copper deficiency was found in mango, lime, mandarin and coconut. It is very interesting to note that crops which are normally treated with fungicides like grapes, tomatoes and pepper showed very high (rather toxic) concentrations of Cu, Zn and Mn, probably due to using pesticides containing these elements.

In spite of the severe deficiency symptoms found in most crops, Fe was found in adequate and high concentrations. It should be noted that especially in case of Fe, leaf concentrations of total Fe are not corresponding to the biologically active iron. Plants absorb high Fe-quantities from the soil, but a great portion is biologically inactive (Mengl and Bueble, 1983; Zeiter and Ghalayini, 1994), which results in chlorosis.

VISUAL SYMPTOMS: In most studied locations, banana showed K and micronutrient deficiency symptoms. The same case was found with grapes where Fe and Zn deficiency symptoms were observed. Papaya showed K, Fe and Zn deficiency symptoms, while only a deficient level was detected by analysis. On chico, only the symptoms of Fe deficiency were observed but N, K and Zn concentrations were under the critical levels. Mango showed deficiency symptoms of Fe and Zn, while the leaf analysis showed Zn and Cu deficiencies. Citrus trees including lime developed deficiency symptoms of Fe, Zn and Mn. Zinc deficient levels were found to be the most common in these crops and in some cases Mn, Mg , Ca and N. Coconut showed deficiency symptoms of K and Zn but the analysis showed that there are N, K, Ca and Cu deficiency. Tomatoes showed also Fe and Zn deficiency symptoms, while leaf analysis showed only that N, P and Mg are deficient.

NUTRIENT RATIOS: Inadequate and imbalanced macro and micronutrients contents create the imbalanced ratios of nutrients within the plant tissues. Figure 1 shows comparison between the ratios of the nutrient concentrations actually present in the leaves and those of the a critical values cited from literature. It is worthy to mention that the highest ratio was found with N/Fe and the least in N/K and K/Mg. Deviations of the present values from the critical ones are expected to cause disturbance of the physiological behavior in the plant tissues, which lead to low yields. The figure clearly illustrates that N/K ratio in the leaves of different studied plants is always less than the critical one. The same trend was found with N/K and K/Mg in most of the cases. In the mean time, the ratios P/Mn and P/Zn were more or less above the critical ratios. Similar picture was reported by Fawzi *et al.*, (1996) with mango. They found that when the nutrient ratios were imbalanced, low yields were obtained. Shaaban and Abou El-Nour (1996) found also that certain

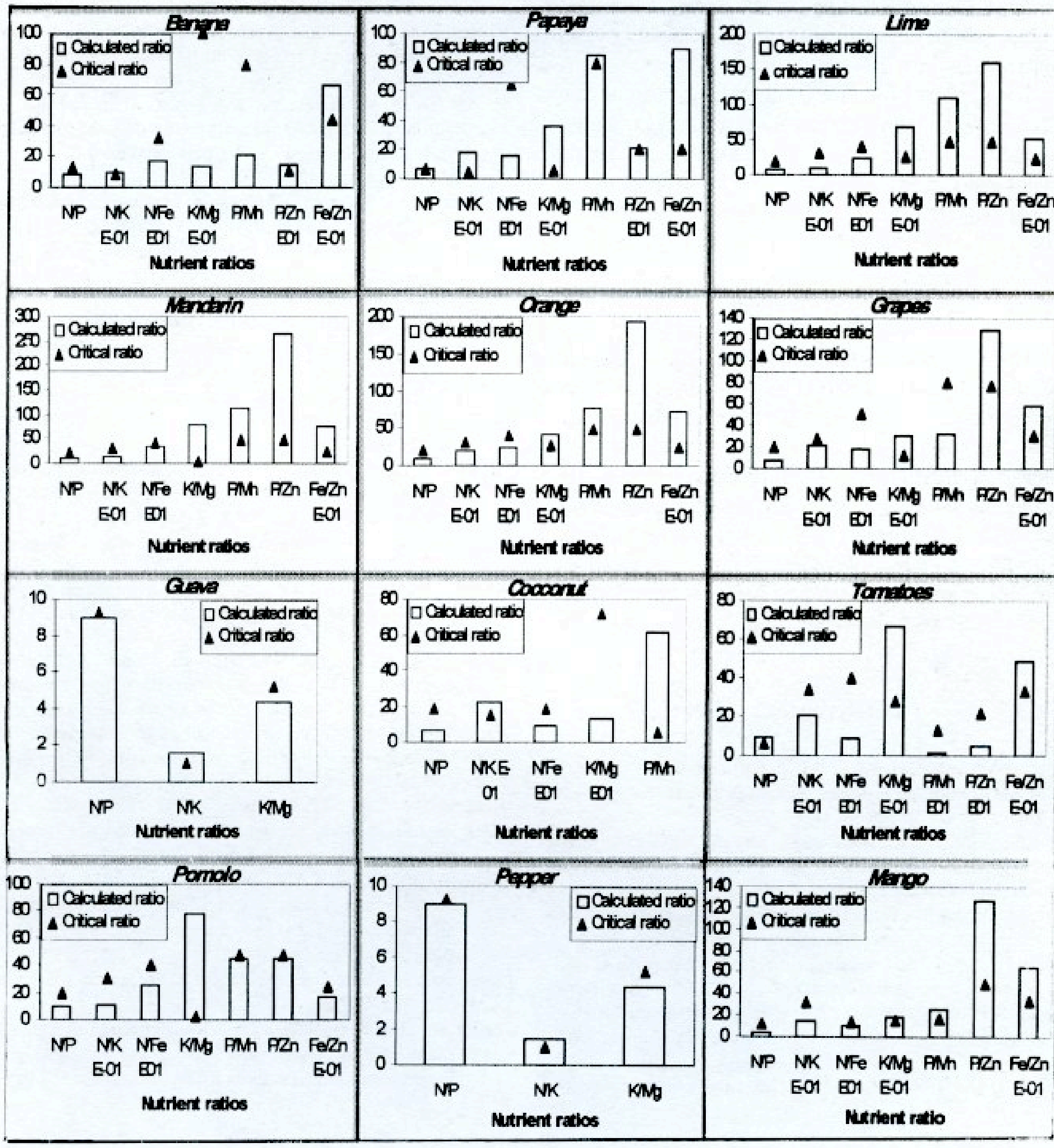


**Figure 1.** Calculated nutrient ratios in the leaves of the studied crops compared to the critical ratios (based on critical nutrient levels).

nutrient ratios are required to obtain high berseem yield and the increase or the decrease of these ratios result in low yields.

## Conclusions

From this work, it can be concluded that there is a nutrient disturbance in the horticultural crops examined in Salalah region, Sultanate of Oman. Micronutrient deficiencies are very obvious. Very severe unfavorable soil conditions such as high pH values and $CaCO_3$ content, which negatively affect the uptake of elements especially micronutrients, are present. Sub-optimal fertilizer use creates a nutrient imbalance within the plant tissues which leads to yield decreases.

To correct this situation, plants should be supplied with the suitable specific fertilizers in quality and quantity and according to the results of soil testing and plant analysis, information on both farming system and farm management. Micronutrient fertilizers should also be included in the nutrient management regime.

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