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Monthly Monitoring of the Nutrient Status in Citrus Leaves as a Guide for Proper Fertilization

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الرصد الشهري لتركيز العناصر المغذية في أوراق الموالح كأساس لضبط عملية التسميد

الملخص : أجريت دراسة حقلية على مدار عامين متتاليين على خمسة أصناف من الموالح، مزروعة في تربة طينية بمنطقة قويسنا – محافظة المنوفية – مصر ، بغرض استخدام تركيز العناصر المغذية بالأوراق كأساس لضبط عملية تسميد الأشجار. أوضحت النتائج أن تركيز العناصر في التربة كانت ضمن المدى الكافي إلا أن صفات التربة غير الملائمة قد أثرت سلبا على توفر بعض العناصر للامتصاص. لقد كان تركيز العناصر في أوراق الأصناف الخمسة متشابهة إلا في القليل من الحالات. فمثلا كان تركيز النيتروجين في الأوراق في المدى الكافي، ولتوفير السماد وللحفاظ على البيئة من التلوث بالجرعات الزائدة يجب ألا تزيد كمية السماد عن ١٠٠ كجم للفدان ، مضافة على ثلاث دفعات في مارس و يونيو وسبتمبر . يجب إضافة الأسمدة الفوسفاتية لمثل هذه التربة الطينية في سبتمبر وعند الحاجة إلى جرعة أخرى فتضاف في شهر مايو . أما عند التسميد البوتاسي فإنه يوصى بمضاعفة الكمية التي يحتاجها المحصول وأن تقسم إلى دفعات عديدة. كما يجب الاهتمام بالتسميد بعنصر المغنيسيوم . أما بالنسبة للعناصر الصغرى فقد كانت عند مستويات كافية إلا أنه في مثل حالات هذه التربة يوصى باستخدام الأسمدة الحمضية وتعطى العناصر الصغرى على ثلاث دفعات رشا على الأوراق في سبتمبر ومارس ومايو . نظرا لأن متوسط تركيز العناصر المغذية بأوراق النموات الربيعية بن ٥ إلى ٧ أشهر كانت في حدود الكفاية ، وأن الأشجار قد أعطت أعلى إنتاج متوقع للمنطقة المزروعة بها، فإن المتوسطات الشهرية المتحصل عليها للعناصر – عدا النحاس– يمكن اعتبارها مثلى وتصلح للعمل بها كأساس لتعديل برنامج التسميد في أي من مراحل النمو .

ABSTRACT: A field study was conducted with five citrus cultivars grown in clay soil in Kewesna, Monufia, Egypt for two successive growing seasons. The study aimed at using nutrient concentrations in the leaves as a guide for proper fertilization. The study revealed that most of the nutrients in the soil were at adequate levels. However, there were unfavourable soil conditions that affected negatively nutrient availability. Nutrient concentrations in the leaves of the five cultivars were nearly the same, except for a few cases. Leaf nitrogen concentrations were at adequate levels. To minimize the usage of fertilizers, the quantity of N-fertilizer should not exceed 100 kg N per feddan, added as three doses in September, March and June. Phosphorus fertilizers should be added in September and when another dose is needed, it should be in May. For such a clay soil, nearly double the potassium requirement of the crop should be added as split application. More attention should be given to magnesium fertilization. Micronutrients concentrations were at adequate levels. However, under such soil conditions, fertilizers of acidic reactions are recommended and micronutrients should be supplied as foliar sprays in September, March and May. Adequate levels of the nutrients in the 5-7 months spring flush together with the high obtained yields suggest that the obtained levels of the nutrients (except copper) can be used as a basis to correct the fertilizer programmes at any growth stage.

The mineral content of plant materials differs markedly according to the genetically mediated nutrient uptake for each element (Mengel and Kirkby, 1987). Mineral concentrations also differ considerably among the plant organs (Shaaban, 1995). They are also very much dependent on the plant age (Smith, 1962) as well as the plant organ's age (Jungk, 1970). Availability of plant nutrients in the plant growing medium is another factor controlling the mineral content of the plant material. Application of adequate quantities of fertilizer at the proper time for a given crop is an important factor for adequate realization of the nutrient in the plant tissues. This in turn leads to a good crop yield.

Fertilization practice of citrus trees which is wide spread in Egypt still depends on a farmer's knowledge and to a small scale on extension information services.

The literature contains only the norms of the different nutrient levels at a certain growth stage (mature leaves of the 5-7 months spring flush). Accordingly, this may be only used to formulate the next season fertilizer programmes. The objective of the present study is to define the nutrient levels in leaves of different citrus cultivars at different growth periods in order to recognize the proper fertilization times and use them as a guide to correct the fertilizer program at any growth stage.

Materials and Methods

The study was conducted in a citrus orchard at Kewesna, Monufia governorate, Egypt during two successive seasons. The orchard contained five different varieties of 20 year-old citrus trees, namely: Orange (*Citrus sinensis* var. Balady), Orange (*Citrus sinensis* var. Sukkary), Orange (*Citrus sinensis* var. Navel), Mandarin (*Citrus reticulata*) and Lime (*Citrus aurantifolia*).

The trees of different varieties were cultivated at 5 x 5 m distance (170 tree/fed) in a clay soil and received the following agricultural practices during the course of the study: **Fertilization** - (1) 20 m^3 cattle manure/fed. in November; (2) 200 Kg N/fed. as ammonium sulfate added in equal quantities in 4 doses in March, July, August and September; (3) 60 Kg P_2O_5/fed. as mono-calcium phosphate in 2 doses in March and October; (4) 150 Kg K_2O/fed. as potassium sulfate in 3 splits in October, March and May; (5) As micro nutrient fertilizers, the trees were sprayed three times in March, May and June using a compound containing 2.25% Fe-EDTA, 6.5% Zn-EDTA, 4.5% Mn-EDTA and 0.5% Cu-EDTA in concentrations of 1-1.5 g/l in the spray solution. **Other agricultural practices** - (1) The orchard was weeded three times yearly in March, July and September; (2) Irrigation was carried out as flood irrigation every 15 days from the beginning of March till the end of August. Then the irrigation period extended to 30 days during a 5 month rest period; (3) Pest control took place when needed. **Sampling: Soil samples** - They were taken from the zone of the root tips of the trees in November. At least five samples were randomly taken for each feddan. Soil samples were air dried and passed through a 2 mm sieve. **Plant samples** - plant leaves were collected from the fully mature leaves of spring flush in the second week of every month. The 2^{nd} and the 3^{rd} leaves from the fruitful branches of about 20 trees, 5-10 leaves from each, were randomly taken around the tree. The samples were washed with tap water, 0.01 N HCL and distilled water, respectively, then dried at 70°C and ground in a stainless steel mill. **Analysis: Soil physical characteristics** - Soil samples were analyzed for pH and electric conductivity (EC) using water extract (1:2.5) method, calcium carbonate ($CaCO_3$%): calcimeter method, organic matter (O.M.%): potassium dichromate method (Chapman and Pratt, 1978). **Nutrient extraction** - Phosphorus (P^{5+}) was extracted using sodium bicarbonate (Olsen *et al.*, 1954). Potassium (K^+) and Magnesium (Mg^{2+}) were extracted using ammonium acetate. Iron (Fe^{2+}), Manganese (Mn^{2+}), Zinc (Zn^{2+}) and Copper (Cu^{2+}) were extracted using DPTA (Chapman and Pratt, 1978). The plant material was digested using an acid mixture consisting of nitric, perchloric and sulfuric in the ratio of 8:1:1 (v/v), respectively (Chapman and Pratt, 1978). **Determinations and measurements** - Nitrogen (N) was determined in the dry plant material using a Buechi digestion and distillation apparatus. Phosphorus was photometrically determined using the molybdate-vanadate method according to Jackson (1973). Potassium was determined using flame photometer Eppendorf. Mg^{2+}, Fe^{2+}, Mn^{2+}, Zn^{2+} and Cu^{2+} were determined using the Atomic absorption spectro-photometer PMQ3. **Data analysis** - data of soil analysis were subjected to the NCSS - 5X computer program (Hintze, 1990) in order to calculate means, standard deviations (SD) and the possible correlations (r).

Results and Discussion

SOIL PHYSICAL AND CHEMICAL CHARACTERISTICS: PHYSICAL CHARACTERISTICS - The orchard soil physical characteristics, where the five citrus varieties were grown, are shown in Table 1. The mean soil pH is 8.44. Under such high pH values, availability of a number of the nutrients such as phosphate, Mn^{2+}, Zn^{2+}, Cu^{2+} and Fe^{2+} is depressed (Lucas and Davis, 1961). Salt content expressed as electric conductivity (EC) is low enough that it has no apparent effect on nutrient availability (Szabolics, 1971). The table also illustrates that the $CaCO_3$ content of the orchard soil is at a medium level which is expected to have no effect on the nutrient availability (Ankerman and Large, 1974). The soil has a relatively low organic matter content (an average of 1.35 ± 0.16). Unless more organic matter is added, a poor buffering capacity as well as less availability of nutrients are expected to occur in the root medium (Ankerman and Large, 1974). However, the exchange capacity of the soil could be increased with a clay content of 35-45%. It is worth mentioning that the negative correlation between clay content and EC is of beneficial effect on growth.

TABLE 1

Physical characteristics of the soil on which the citrus varieties were grown

Citrus variety	pH	EC[1] DS/m	$CaCO_3$ %	OM[2] %	Clay %
Orange (Balady)	8.5	0.27	2.55	1.38	35
Orange (Sukkary)	8.5	0.37	2.1	1.6	45
Orange (Navel)	8.6	0.28	1.75	1.16	43
Mandarin	8.1	0.36	2.46	1.35	41
Lime	8.5	0.37	3.25	1.28	43
SD	0.19	0.05	0.56	0.16	3.8
r with clay content	NS	-0.40*	--	--	1.0

* $P<0.05$
[1] Electric conductivity
[2] Organic matter

TABLE 2

Macro- and micro-nutrients content of the soil

Citrus variety	P^{5+}	K^+	Mg^{2+}	Fe^{2+}	Mn^{2+}	Zn^{2+}	Cu^{2+}
	mg/100 g soil			ppm			
Orange (Balady)	3.50	36.80	113.80	45.40	16.20	1.30	4.50
Orange (Sukkary)	4.60	23.60	228.80	32.10	19.80	2.10	3.60
Orange (Navel)	2.50	27.0	190.60	39.0	17.40	1.35	3.25
Mandarin	2.80	32.60	109.10	42.40	14.20	1.70	4.90
Lime	2.50	20.50	99.40	40.80	13.0	1.91	4.0
SD	0.89	6.60	57.70	4.97	2.67	0.34	0.66
r with clay content	-0.18	-0.55*	0.51*	-0.61*	0.19	-0.30	-0.50

* $P<0.05$

Thus the adsorption of the detrimental cations such as Na and Mg on the surface of the clay minerals can limit their harmful effect on the roots as well as their antagonism with other nutrients.

CHEMICAL CHARACTERISTICS: **Macro elements** - Table 2 contains the average values of the major macro and micro element concentrations in the soil samples.

Because of the rapidly changeable status of soil nitrogen due to nitrification, denitrification, ammonification, fixation, leaching, etc., soil nitrogen assays were found to be of no value.

Available P-content ranged between 2.5-4.6 with an average of 3.18 mg/100 g soil. According to Walker and Syers (1976), this concentration is enough for a good growth and yield. Moreover 60 Kg P_2O_5/fed were added to improve the P-content of the root medium. In such soil with high clay content, phosphate mobility is rather low, so that P-fertilizer is scarcely leached into the deeper soil layers and in this case, P-loss will be minor. However, phosphate fixation under high pH conditions can limit P-availability to some extent.

Extracted potassium levels seem to be adequate (Ankerman and Large, 1974). In addition, 150 Kg K_2O/fed. was added during the growing season to compensate the K^+ fixation in the soil, especially those soils of high clay content (Arifin *et al.*, 1973). This was true for the samples under study, where a significant SD for K was found between samples according to their variation in clay content. Moreover, a relatively high negative correlation (r) was also found between clay content of the soil and K-content of leaves.

According to Draycott and Durrant (1971), the extractable Mg of the soil in the present study is very high. However, Mg^{2+} uptake by plants can be restricted by the high levels of K^+, Ca^{2+} and NH_4^+ in the root medium (Mengel and Kirkby, 1987).

Micro elements - In general, the soluble Fe - content is extremely low compared to the total content of the soil. According to Lindsay (1974), the extractable Fe^{2+} level of the present soil samples is considered high (Table 2). However, under high pH conditions (between 7.4-8.5), Fe - hydroxides are formed and the solubility levels are low (Lindsay and Schwab, 1982).

Extractable Mn^{2+} was also of a higher level than that required by most crops (Hamdy, 1986), but the uptake of the element can be depressed by high levels of Fe^{2+}, Cu^{2+} and Zn^{2+} (Geering *et al.*, 1969). On the other hand, Mn^{2+} tends to form Mn - organic matter complexes under high pH conditions which render it less available (Page, 1962).

Citrus trees are known to be very sensitive to Zn^{2+} deficiency. According to Hodgson *et al.* (1966), extractable Zn^{2+} of the soil under study is adequate for good growth. However, due to the high pH, Zn^{2+} can be adsorbed on the clay minerals or organic matter as Zn^{2+}, $ZnOH^+$ or $ZnCl^+$. Availability can also be reduced by flooding due to formation of Zn-carbonates and Zn - sulphides under anaerobic conditions (Yoshida *et al.*, 1971). Highly available phosphate is well known to depress Zn^{2+} uptake. High levels of organic matter may also restrict Zn^{2+} availability (Lucas and Knezek, 1972).

Most soils contain adequate levels of available copper. Using DTPA as an extraction agent, a concentration of 0.2 ppm can be considered as the critical level for the element (Follett and Lindsay, 1970). On the other hand, recent use of Cu - containing pesticides may increase excessively the copper content of the soil thus rendering it toxic for the crops (Shaaban *et al.*, 1995).

NUTRIENT CONCENTRATIONS IN THE PLANT LEAVES, MACRONUTRIENTS: NITROGEN - Nitrogen concentration in the leaves followed the same behaviour in the five cultivars under study and ranged between 2-4% (on dry matter basis) (Figure 1). During most of the year i.e. from June-March, the concentrations were adequate (2-3%) (Reuter and Robinson, 1986). However, concentrations greater than 3.5% were detected in April, May and July. In such trees, nitrogen should be added only according to the removal requirement by the expected fruit yield in order to save fertilizers and keep a clean environment. A 15-20 tons/fed average expected yield requires around 80-100 Kg N (Jan G. de Geus, 1973). Accordingly, half of the added nitrogen units is suggested to be enough (i.e. 100 Kg N/fed.) as acidic fertilizer (useful at high pH conditions) and should be applied in three doses: just before the nutrient peaks (i.e. in September to keep a proper level in the tree tissues during the winter season; in March to meet properly the requirements of the new spring flush; and in June to meet the requirements of fruit quality. Since the highest peak of the nutrient was detected in April, a greater N-dose should be applied in March.

PHOSPHORUS - Phosporus determined P-concentrations in the mature leaves of spring flush ranged between 0.1-0.25% (Figure 1) which are adequate (Reuter and Robinson, 1986), while in winter, they reach more than 0.4%.

Phosphate fertilizers were reported to be added preferably in spring to meet the new sprout's growth requirements (Prausse, 1968). However, from the obtained results, it appeared that the plant's accumulate phosphorus in winter (the highest peak in November - December) to be assimilated later. In the clay soil under study, leaching is minimum, and one dose of P-fertilization should be added (if necessary) in September as a complimentary dose to the P-content of the soil. If another dose is required, it should be added in May.

POTASSIUM - Potassium concentrations in the leaves ranged between 0.4-1.3% (Figure 1) with an adequate range in the fully mature leaves of the 5-7 months old spring flush (<0.7%) (Reuter and Robinson, 1986). K^+ concentrations in the leaves are expected to be negatively affected by the high clay content of the soil (Arifin *et al.*, 1973). Under such conditions, the quantities of K - fertilizer can be very high. Furthermore, deep application is recommended (Budig, 1970). Under similar conditions, Budig found that the surface layer is rich in available K^+, but the deeper layers (40-60 cm) were depleted. Use of K - sulphate is generally suitable under high pH conditions and results in higher carbohydrate production and translocation (Edelbauer, 1977). Therefore, double quantity, required by any given cultivar in the form of K-sulphate, is recommended to be added as a split application in the root zone of the plants.

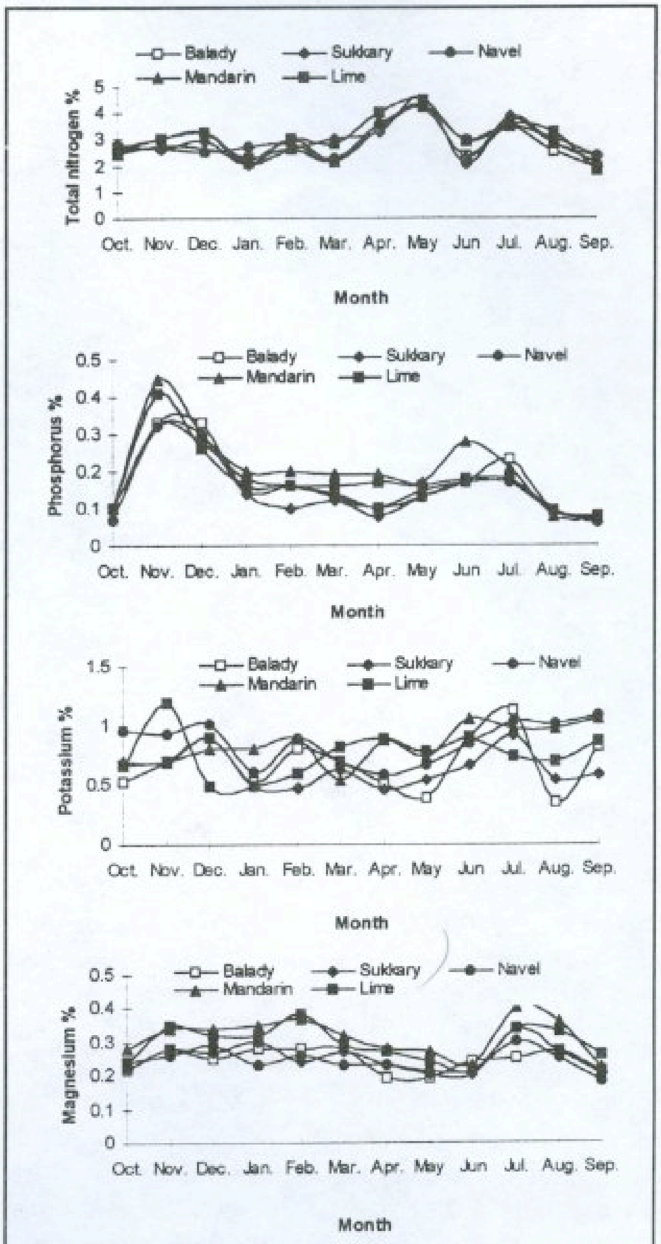

Figure 1. Monthly concentrations of macronutrients in the leaves of different citrus cultivars

MAGNESIUM - Leaf magnesium concentrations ranged between 0.2-0.4%. Magnesium concentration curves for the five cultivars (Figure 1) followed nearly the same pattern. Peaks were observed during winter (November-February) and summer (July-August). As the magnesium added to the soil is impure, addition of pure Mg^{2+} fertilizers becomes more important. The high levels of cations such as NH_4^+, K^+, Ca^{2+} can restrict Mg^{2+} uptake. Therefore, addition of Mg-sulfate during February and June is important to meet the high demand of citrus trees for Mg^{2+} in such periods.

MICRONUTRIENTS - Figure 2 illustrates the micronutrient concentrations in the leaves of citrus trees throughout the year. Fe-concentrations followed the same pattern except with lime in November. Regarding the other four cultivars, Fe-concentration peaked in November to reach about 1000-1500 ppm. This may be due to the addition of ammonium-sulphate and potassium-sulphate fertilizers in October which fosters greater availability of micronutrient, or it could be normal peaks specific for orange and mandarin. The figure also revealed that Mn^{2+} and Zn^{2+} concentrations have followed more or less the same trend with all citrus cultivars under study. Concentrations of both elements were adequate. Unless the trees have been sprayed three times with micronutrient fertilizers containing Fe^{2+}, Mn^{2+}, Zn^{2+} and Cu^{2+}, micronutrient deficiency ought to occur especially under high pH and clay content of the soil.

Concerning copper, concentrations were adequate (5-20 ppm as shown in Figure 2) (Reuter and Robinson, 1986). Two peaks were observed (November-December and March-April) with less severity in lime. This may be due to the accumulation of Cu^{2+} because of the higher uptake in October and/or the application of Cu - containing pesticides during the two periods.

It is worthy to mention that the values of plant analysis in the literature are based only on the determinations of nutrient concentrations for a specific growth stage (fully matured leaves of 5-7 months spring sprouts) (Reuter and Robinson, 1986; Benton *et al.*, 1991). Thus, the nutrient concentrations determined in the other growth stages cannot be evaluated on the basis of the values of the above mentioned stage. Hence, the fertilizer program cannot be corrected in advance or the determinations may be only useful to formulate the program of the next growth season. Since the values of nutrients predicted for the 5-7 month spring sprouts are in the desirable ranges found in the literature, the concentration curves of the nutrients throughout the year could be considered as optimum for each nutrient (except copper). In this way, sampling can be carried out in any growth stage to correct the fertilizer program in the suitable times.

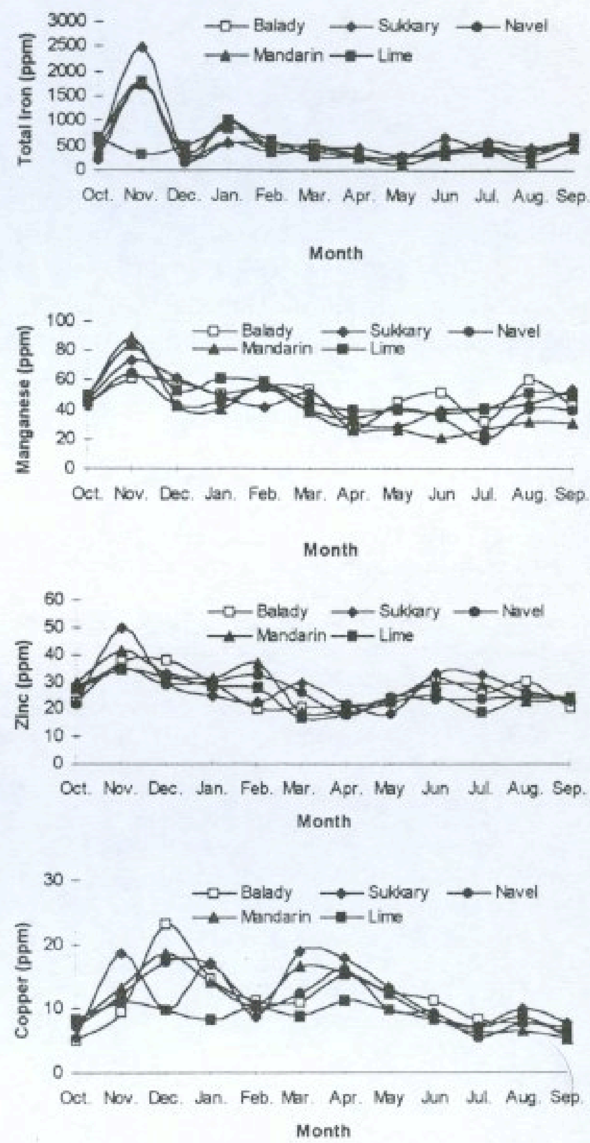

Figure 2. Monthly concentrations of micronutrients in the leaves of different citrus cultivars

Conclusions

From the present work, the following can be concluded: (1) N-fertilization for citrus trees grown in clay soil containing moderate organic matter should not exceed 100 Kg N/fed. divided into 3 doses (September, March and June). The split of March should be greater in quantity than the others to meet the requirements of the new growth. In this way, it could save fertilizers and keep the environment clean. (2) P-fertilization should be added in September and if there is another dose, it should be in May. (3) K-fertilization should take into consideration the ratio of clay content. In the case of high clay content, at least double the quantity of the tree requirement should be added as several doses in the root zone to ensure a continuous K-supply. (4) Because of the purity of fertilizers, magnesium fertilizers should be added at least two times (i.e.

September-October and May). (5) Under the high pH conditions of the soil, micronutrient fertilizers should be added as foliar application at least three times i.e. in September, March and June.

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