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Study on the micronutrient content of soil and leaf of an organic apple orchard in Eastern Hungary

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Summary: The aim of our study was to investigate the relationship between micronutrient content of soil and leaf in an organic apple orchard. The experiment was carried out at the Experimental Site of the University of Debrecen, Centre of Agricultural Sciences at Pallag in an apple cultivar collection in Eastern Hungary in 2002–2004. The soil sampling was carried out twice per year, at the beginning and the end of the vegetation period in 2002, 2003 and 2004, respectively. The micronutrient content of leaf of seven apple cultivars (Jonagold, Mutsu, Idared, Red Elstar, Egri piros, Reka, Remo) was studied according to phenological phases of apple (April – September) to investigate the dynamism of plant nutrient uptake.

It was found that results of leaf analysis correlated with the obtained results of soil. According to the data of July, manganese and copper content of leaf is in the 'favourable' but zinc is the 'low' range of nutrient supply category. Moreover, there were significant differences in the micronutrient content of leaf among cultivars. From our results it is evident that more reliable data were obtained for fruit nutrition by determining of micronutrient content of soil and plant and calculate their ratios as well.

Key words: apple, organic fruit production, soil and leaf analysis, micronutrient uptake of apple cultivars

Introduction

Nowadays, the organic production form is regarded as the most favourable for sustainable and environmentally-friendly fruit production. While the ratio of organic production is above 2.1% in EU and United States, the ratio of it is approximately 0.5% in Hungary (*Kovács,* 2003). In the future, the organic production form is expected to be widely used in our country according to EU and Hungarian recommendations and assistances for restructuring the agrarian economy.

Furthermore, after the EU accession the Hungarian fruit growers have to face with health, environmental, and economic problems, regulations and intensive competition in the internal markets. Due to the oriented state subsidies growers are increasingly interested in organic farming system. The increasing interest can be explained by the benefits of this system. It has the potential to reduce some of the negative environmental effects of conventional agriculture (*Reganold* et al., 2001) and may offer market advantages over conventional production practices (*Granatstein & Dauer*, 2000; *Loureiro* et al., 2000).

Although more and more fruit growers have joined the organic farming system all over the world and the organic market has grown exponentially in Europe during the last ten years, only a few papers have been published in the last few years about the status of micronutrients of soil-plant system, especially about organic apple orchards examined by us.

Although a lot of studies have been published about the role, uptake and deficiency symptoms of manganese, copper and zinc in plant systems and limiting values of apple leaf of these micronutrients (*Bergmann & Neubert,* 1976; *Failla,* 1992; *Papp,* 2004), many questions still remain unanswered in organic production.

The question is that, whether using only the organic manures to nutrition is enough for proper fruit growing or not, where the soil of the orchard site is acidic, poor in clay, humus and nutrients. Furthermore, in Hungary, the applied nutrient dosages decreased dramatically in the last few years, mostly for economic reasons and due to the changing structure of the agricultural firms. The negative balance of nutrient status of soil is typical in Hungary (*Loch,* 2000). A further question is how this affects the micronutrient status of soil and leaf in orchards. These questions are very important in recent days because the quality requirements, mostly the consumer requirements increased at a higher rate during the last years in Hungary (*Racskó* et. al. 2005).

Material and method

Experimental site

The experiment was carried out at the Experimental Site of the University of Debrecen, Centre of Agricultural Sciences at Pallag in an apple cultivar collection. The orchard was established in the spring of 1997, grafted on M26 rootstocks at a spacing of 4 ×1.5 m. Cultivars were planted in plots. Each plot consisted of 7 trees per cultivar. Plots were placed in a randomised design with 3 replicates. The collection of 40 apple cultivars was divided into two parts. From the first year, one half of the orchard has been treated according to the Integrated Fruit Production guidelines, and the other half according to the Organic Fruit Production guidelines.

Orchards were not irrigated. In this paper we publish the results of organic orchard part only. Stable manure, 25 t ha^{-1} was applied to the soil in 2000 and 2002 in the organic orchard part.

Soil sampling

Soil samples were taken from each plot of the 7 apple cultivars (Jonagold, Mutsu, Idared, Red Elstar, Egri piros, Remo re and Reka re) in the organic orchard sections. Three samples were taken from each plot, one from the middle and one from both edges of the section by leaving 1 m at both sides. For the characterisation of the soil the most important soil parameters were determined. The samples were taken from the upper 0-20 cm layer of the soil by using manual soil sampling equipment, according to *MSZ-08 0202–77.* Sampling was performed at the beginning and the end of the vegetation period on April and October in 2002, 2003 and 2004, respectively.

Plant sampling

The above-mentioned seven cultivars were selected for the study. The selected cultivars are: resistant, current and traditional. Plant samples (leaf) were taken monthly, from April to September, during 2002-2004. Leaves were taken from all trees of each plot of the seven apple cultivars in the organic orchard sections according to *MI-08 0468-81.*

Laboratory examination of soil samples

The soil samples were dried outdoors in an airy place under air temperature in a 1–1.5 cm layer. Before grinding, samples were cleaned from plant remains and other possible dirt, and the soil was passed through a 2 mm screen, homogenized and stored in plastic boxes in dry place until the examination. Besides the main characteristics of soil the content of macro- and micronutrients were measured by using two kinds of methods. For establishing the content of easily soluble nutrient forms of N, P and K, 0.01 M $CaCl_2$ extractant was used, while for studying the available micronutrients content of soils NH_4-acetate+ EDTA (so called Lakanen-Erviö extractant) was used (*MSZ 20135:1999*).

Laboratory examination of plant samples

Pretreatments of *the plant samples* involve drying, grinding and washing. The samples were washed to remove dust and possible remains of pesticide, then first dried outdoors in an airy place under air temperature then in a well-ventilated drying oven at 40 C. Then the material was finely ground and homogenized.

The dried and ground samples should be stored in paper bags in a cool and dry place protected against direct sunlight.

For leaf analysis the samples were digested with cc. HNO_3 and H_2O_2 in heating block digestor, at 120 °C for 2 h. The amount of Mn, Cu and Zn was determined by using the atom adsorption method.

Results and discussion

Results of soil analysis

Whereas the conditions of uptake of micronutrients are not independent from the soil properties, macronutrient status and supply of soil, we determined these parameters of soil and interpreted here.

According to our results the orchard soil type was brown forest soil with alternating thin layers of clay substance "kovárvány". The type of soil is acidic sandy and poor in clay and humus (*Table 1*).

Table 1. Examined soil parameters (2002–2004, three-year average)

Soil type	Brown forest soil with „kovárvány"
Soil texture	Sand
K_A*	28
pH ($CaCl_2$)	5.13
Humus (%)	0.75
NO_3–N (0.01 M $CaCl_2$) (mg/kg)	1.00
NH_4^+–N (0.01 M $CaCl_2$) (mg/kg)	0.81
P (0.01 M $CaCl_2$) (mg/kg)	4.76
K (0.01 M $CaCl_2$) (mg/kg)	168
Mn (LE) (mg/kg)	62.3
Cu (LE) (mg/kg)	3.48
Zn (LE) (mg/kg)	1.78

*Plasticity index according to Arany

The content of available N forms in soil was very low according to type and properties of soil.

The nitrification processes were blocked by pH and the poor life conditions of microorganisms. In contrast with the results of N, the content of available K and P was high. The significant available K can be explained by the notable dosage of applied organic manure because it is considered as a major K source (*Table 2*).

It can be seen that 62.3 mg/kg LE soluble Mn was measured in the soil (*Table 2*). The high content of Mn can be

Table 2. The nutrient supply ability* of applied organic manure dosage

Years	N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)
2002	37.5	37.5	75
2003	25	17.5	37.5
2004	–	–	–

*The nutrient supply ability of organic manure was estimated by *Sarkadi,* 1975

explained on the one hand by the soil properties (poor content of clay and acidic soil pH) and on the other hand by the notable dosage of applied organic manure. Our findings pointed out that the available content of Mn may be notable using organic guideline where the soil are prone to acidity.

The Cu displayed medium, while the Zn showed low content in the examined soil according to the soil properties (low content of humus, acidic soil pH and value of K_A, etc.) (*Molnáros & Gráczol,* 2000). Furthermore, the low Zn content of soil is explained by the measured high P content.

Results of leaf analysis

The content of manganese, copper and zinc as micronutrients was measured in apple leaves monthly, from April to September, in 2002–2004.

The three-year data on Mn content of apple leaves are included in *Table 3*.

A continuous increase was registered in the manganese content of apple leaves till June. At the end of intensive shoot growing period (mid-July) the Mn content of leaves dropped slightly, then it increased again from August to September.

According to our measurements, the Mn content of leaves was in the 'favourable' range of nutrient supply category (*Failla,* 1992; *Papp,* 2004). It corresponds to the above mentioned results of soil analysis.

Based on the data of July, it seems that there is a significant difference of Mn content of leaves among cultivars, especially group of cultivars. Significantly (P=0.05) higher Mn content of leaves was measured in cv. 'Red Elstar', cv. 'Egri piros' and cv. 'Reka' than in cv. 'Jonagold', cv. 'Idared' and cv. 'Remo'. The found Mn value of cv. 'Mutsu' was between these groups.

The copper content of leaves of cultivars was also examined in 2002–2004 the findings are shown in *Table 4*.

The dynamics of Cu-uptake corresponded with the phenological phases of apple. The changing of Cu content of leaves is the most remarkable from April to May, when the reduction of Cu content of leaves was more than 50%. It can be explained by the dilution effect which is caused by the difference between the growth of plant mass and intensity of Cu-uptake. The Cu content of leaves showed a small increase from July to September.

The changing of Cu content of leaves is very similar to observed N content of leaves. It confirms the earlier observations that there is a strong correlation between nitrogen and copper uptake of plants and the role of copper in nitrogen metabolism.

According to the data of July, the Cu content of leaves is in the 'favourable' range of nutrient supply category (*Failla,* 1992; *Papp,* 2004). It can be explained by the measured Cu content of soil. On the other hand, the observed sufficient Cu-uptake can be explained by the used, mostly copper

Table 3. Mn content of leaves of seven apple cultivars (2002–2004, three-year average)

	Mn (mg/kg)					
	April	**May**	**June**	**July**	**Aug**	**Sept**
Jonagold	50.77	60.33	68.67	66.97	73.37	80.27
Mutsu	63.75	55.18	69.87	71.17	82.37	84.45
Idared	65.11	72.70	69.38	60.39	71.94	77.01
Red elstar	69.07	79.42	84.05	81.55	87.07	97.55
Egri piros	58.98	82.95	86.43	82.90	90.45	105.63
Reka	54.53	73.63	93.33	83.23	90.23	91.20
Remo	49.25	60.73	68.08	65.63	73.60	79.92
Mean	**58.78**	**69.28**	**77.12**	**73.12**	**81.29**	**88.00**
St. deviation	**7.57**	**10.58**	**10.51**	**9.39**	**8.24**	**10.57**
LSD5%	**5.61**	**7.84**	**7.79**	**6.95**	**6.11**	**7.83**

Table 4. Cu content of leaves of seven apple cultivars (2002-2004, three-year average)

	Cu (mg/kg)					
	April	**May**	**June**	**July**	**Aug**	**Sept**
Jonagold	16.87	12.33	8.27	7.40	6.43	6.80
Mutsu	25.67	7.27	8.30	7.75	7.35	8.45
Idared	28.51	10.09	6.98	7.18	6.77	7.74
Red elstar	14.22	9.22	7.55	6.25	6.38	7.92
Egri piros	27.87	8.18	9.32	6.41	6.93	6.67
Reka	16.40	11.77	10.55	7.90	9.30	8.13
Remo	20.30	8.37	6.76	5.26	7.00	5.54
Mean	**21.40**	**9.60**	**8.25**	**6.88**	**7.17**	**7.32**
St. deviation	**5.90**	**1.89**	**1.34**	**0.95**	**1.00**	**1.09**
LSD5%	**4.37**	**1.40**	**0.99**	**0.70**	**0.74**	**0.81**

Table 5. Zn content of leaves of seven apple cultivars (2002–2004, three-year average)

	Zn (mg/kg)					
	April	**May**	**June**	**July**	**Aug**	**Sept**
Jonagold	16.87	12.33	8.27	7.40	6.43	6.80
Jonagold	24.38	21.92	20.16	24.25	25.34	19.60
Mutsu	26.38	23.94	21.13	23.78	24.09	24.54
Idared	24.72	21.54	21.01	22.04	21.09	21.14
Red elstar	29.91	24.69	20.37	22.51	21.86	20.96
Egri piros	23.53	24.13	20.77	21.26	21.78	22.14
Reka	22.67	21.09	24.07	23.92	32.52	32.17
Remo	25.29	22.92	23.66	24.87	24.18	29.26
Mean	**25.27**	**22.89**	**21.60**	**23.23**	**24.41**	**24.26**
St.deviation	**2.37**	**1.41**	**1.59**	**1.31**	**3.90**	**4.74**
LSD5%	**1.75**	**1.04**	**1.18**	**0.97**	**2.89**	**3.51**

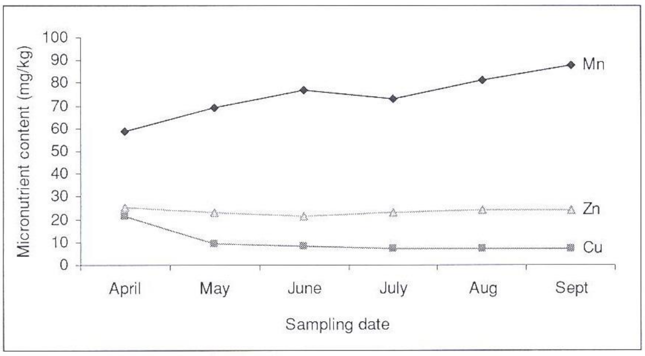

Figure 1 Contents of micronutrients of apple leaves during examined vegetation period (2002–2004)

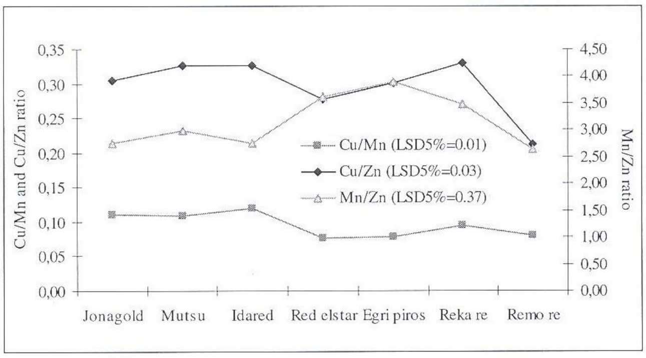

Figure 2 Ratios of microelements of apple leaves

containing plant protection products which have a beneficial effect on the Cu-supply of plant.

From the obtained data of July, it can be concluded that the Cu content of leaves showed significant differences (P=0.05) among cultivars, demonstrated in the case of Mn. A significantly higher Cu content was observed in cv. 'Reka re', cv. 'Jonagold', cv. 'Idared'and cv. 'Mutsu' than in cv. 'Red Elstar', cv. 'Egri piros'. The lowest Cu content was measured in cv. 'Remo'.

Besides manganese and copper content of leaves, zinc content was also measured in 2002–2004 the findings are shown in *Table 5*.

The Zn content of apple leaves displayed the lowest variation in the examined three-year average. Its amount decreased toward June and then it began to increase. The degree of change in Zn content was not remarkable in most cultivars between August and September.

Obtained monthly data are in harmony with the interim change of nutrient demand of apple trees (*Szűcs,* 2000).

Based on the data of July, the Zn content of leaves is in the 'low' range of nutrient supply category (*Failla,* 1992; *Papp,* 2004). Our data on zinc content corresponded with the results of soil analysis. As we mentioned above, the examined soil was poor in available Zn which was caused by the soil type, the soil conditions and the excess P content.

According to data of July, the Zn content of apple leaves varied between 21.26 and 24.87 mg/kg. Obtained Zn data showed similar tendency as the results of Cu.

Significantly higher Zn content was measured in cv. 'Mutsu', cv. 'Jonagold', cv. 'Reka' and cv. 'Remo' than in cv. 'Egri piros', cv. 'Idared' and cv. 'Red Elstar'.

Above-mentioned leaf analytical results are shown in *Figure 1.*

The data of figure were calculated from the obtained results of different cultivars to demonstrate the relationship between sampling date and micronutrient content.

In the science of plant nutrition, calculation of ratios of macroelements has been widely used to identify nutritional interactions and disharmonies of nutrient supply.

Similarly to this method, the microelement ratios were calculated from results because our assumption is that these ratios can provide a better indication of nutritional status than conventional sufficiency range approaches. It has been suggested that the use of these ratios minimizes the effects of dilution or concentration due to dry matter and age factors and better evaluates possible nutritional interactions.

Ratios of investigated microelements are shown in *Figure 2*. Results are calculated from the data of July of three-year mean.

From our results the Cu:Zn:Mn ratio was approximately 1:3:8 which is in accordance with literature data (*Bergmann & Neubert,* 1976; *Failla,* 1992; *Loch,* 2000; *Papp,* 2004).

From *Figure 2*, it is clear that the lowest ratios were found in cv. 'Remo'. It can be explained by the low Cu and Mn content of this cultivar. High Cu/Zn and Mn/Zn ratios were found in cv. 'Idared' due to the low Mn content of this cultivar.

It is notable that the Mn/Zn ratio varied between the widest margins of calculated ratios.

From our results it can be generally stated that the micronutrient ratios are in correlation with the cultivars. It means that between similar circumstances the uptake and content of micronutrient differs from each other according to cultivars.

It was found that creating of ratios of micronutrients is best viewed as a supplement to sufficiency range diagnoses which provides additional information to identify relative deficiency or excess.

Our soil and plant analytical results can be summarized as follows:

- Our data on microelement content showed that the soil of the examined organic orchard contained a satisfactory amount of manganese and copper to plant nutrition. But it was found that the zinc content of the examined soil was low. Results can be explained by the values characteristic to sandy soil type of low humus, clay content, pH value and high P content.
- Dynamism of uptake of examined micronutrients correlated well with the obtained results of soil.
- According to our measurements, we suppose that there is significant difference in micronutrient content of leaves among examined cultivars.
- The tendencies observed are similar to each other in connection with different micronutrients. Mostly the same variety showed higher Cu and Zn content of leaves but the result of Mn was different from those obtained for Cu and Zn.
- We propose that further examinations should be performed to find out the relationship between the nutrition management and nutrient uptake of different cultivars.
- From our results, it is evident that the proper plant nutrition must be based on the results of soil and plant analysis too.
- We found that the interactions among trace elements and their effects on plant growth are studied better in this way than by determining the absolute values of micro-elements. Furthermore, the nutrient conditions and processes of soil can be examined more specifically.

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