STUDY ON THE MACRONUTRIENT CONTENT OF APPLE LEAVES IN AN ORGANIC APPLE ORCHARD

ALMALEVÉL MAKROELEMTARTALMÁNAK TANULMÁNYOZÁSA ÖKOLÓGIAI ALMAÜLTETVÉNYBEN

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ABSTRACT

Macronutrient contents of soil and apple leaves were investigated in an organic apple orchard in Eastern Hungary in 2002-2004. Soil samples were taken from 0-20 cm depth in April and October. The macronutrient content of leaves was measured on cvs. Jonagold, Mutsu, Idared, Red Elstar, Egri Piros, Reka, and Remo at six assessment dates (from April to September). The macronutrient contents of N, P, K, S, Ca and Mg were measured in both soil and leaf samples, then macronutrient ratios were calculated from the obtained results. The results showed that younger leaves contained more N and P than older ones. K and Ca contents of leaves decreased until July, then increased slightly, and decreased again. A continuous decrease of the S content of leaves was observed until August. The Mg content of leaves increased until June, then decreased in July and then increased again. Macronutrient values were dependent on cultivar. Calculated macronutrient ratios showed that the nutrient supply of soil was not optimal in the orchard.

KEY WORDS: apple, organic fruit production, soil and leaf analysis, macronutrients, N, P, K, Ca, Mg, dynamics of nutrient uptake

ÖSSZEFOGLALÓ

A talaj és az almalevelek makroelem-tartalmát vizsgáltuk egy kelet-magyarországi ökológiai almaültetvényben 2002 és 2004 között. Talajmintákat 2 alkalommal áprilisban és októberben vettünk 0-20 cm mélységből. Hét almafajta (Jonagold, Mutsu, Idared, Red Elstar, Egri Piros, Reka és Remo) levelének makroelem-tartalmát mértük összesen hat alkalommal áprilistól szeptemberig. Mind a talaj- mind a levélmintákban a N, P, K, S, Ca és Mg tartalmat mértük és az eredmények alapján a tápelem arányokat számítottuk. Az eredmények azt mutatták, hogy a fiatalabb levelekben több N és P található, mint az idősebb levelekben. A levelek K és Ca tartalma csökkent júliusig, majd enyhén nőtt és újra csökkent. Folyamatos S-tartalom csökkenés volt tapasztalható a levelekben a tenyészidőben, egészen augusztusig. A levelek Mg-tartalma nőtt júniusig, majd júliusban csökkent, azt követően pedig újra emelkedett. A makroelem-tartalom a fajtánként változó volt. A tápelem arányok értékei azt mutatták, hogy a talaj tápanyagellátása nem volt optimális az ültetvényben.

KULCSSZAVAK: alma, ökológia almatermesztés, talaj és levél analízis, makroelemek, N, P, K, Ca, Mg, tápanyagfelvételi dinamika

DETAILED ABSTRACT IN HUNGARIAN

Bár a magyarországi éghajlati viszonyok kitűnőek a gyümölcstermesztés és különösen az almatermesztés szempontjából, az utóbbi években csak néhány tanulmány vizsgálta a hazai almaültetvények tápanyagellátását. Ennél is kevesebb információ áll rendelkezésünkre az ökológiai almaültetvények talajának illetve a növények tápanyagtartalmával kapcsolatban. Jelen tanulmány célja volt, hogy meghatározza egy ökológiai almaültetvény talajának és leveleinek tápanyagtartalmát valamint, hogy megállapítsa a vizsgált tápelemek arányát.

A kísérletet a Debrecen-Pallagon elhelyezkedő 40 fajtából álló alma fajtagyűjteményben hajtottuk végre. Az ültetvény egyik felét az ökológiai gyümölcstermesztés szabályai szerint kezelik. Hét almafajtát (Jonagold, Mutsu, Idared, Red Elstar, Egri piros, Remo and Reka) választottunk ki vizsgálatainkhoz. A talajmintavételre a tenyészidőszak elején és végén, áprilisban és októberben került sor 2002-től 2004-ig. A levélmintákat is a fenti almafajtákról gyűjtöttük be. A levélminták gyűjtése havonta történt áprilistól szeptemberig 2002-től 2004-ig.

A N és P könnyen felvehető tápanyagformáinak vizsgálatához 0,01 M $CaCl_2$ oldószert, míg a talajok Ca és Mg tartalmának meghatározásához NH_4-acetát+ EDTA-t használtunk. A levelek makroelem tartalmát fotometriai, atomadszorpciós és atomemissziós módszerekkel határoztuk meg. Az elemtartalom meghatározása mellett, a legyakrabban használt tápelem arányokat (N/K, N/Ca, K/Mg, K/Ca and Ca/Mg) is kiszámítottuk a júliusi adatok hároméves átlagából.

Az eredmények azt mutatták, hogy a fiatalabb levelekben több N és P található, mint az idősebb levelekben. A levelek K és Ca tartalma csökkent júliusig, majd enyhén nőtt és újra csökkent. Folyamatos S-tartalom csökkenés volt tapasztalható a levelekben a tenyészidőben, egészen augusztusig. A levelek Mg-tartalma nőtt júniusig, majd júliusban csökkent, azt követően pedig újra emelkedett. A makroelem-tartalom a fajtánként változó volt. Az eredmények igazolták azt is, hogy a tápelem arányok sokkal jobban jellemzik a növénytáplálás zavarait, mint a tápelemtartalom konkrét értékei. Az eredmények alapján hangsúlyozni kell hogy az ökológiai almaültetvények helyes növénytáplálását a talaj és a növényanalízis együttes eredményeire kell alapozni.

INTRODUCTION

Although the Hungarian climate conditions are excellent for fruit growing, and especially for apple growing, for the last few years, only a few scientific studies have investigated the nutrient supply of Hungarian apple orchards [6, 7, 8, 20, 21, 22]. Even less information is available about the nutrient content of plants and soils of organic apple orchards.

Changes in fertilization applied (dosage, ratio of nutrient) in the last few years verify the importance of investigating nutrients [12]. The lack of fertilization or the improper ratio of nutrients results in a disharmony in nutrient supply and in a negative balance of the nutrient status of the soil. These changes have disadvantageous effects on yield, quality and storability. Furthermore, the quality requirements are higher than in the past and are continuously increasing [12, 17, 18].

The study on nutrient management is a must, especially nowadays – with respect to the processes and new trends in fruit growing like sustainable and environmentally-friendly production which become the major principles of today's fruit growing [2, 9, 10].

In organic production, only organic manures can be applied and no artificial fertilizers are permitted [1]. Moreover, in the plant protection of organic orchards, only copper- and sulphur-based and natural products can be applied [3, 9]. However, very little information is available about the soils and plant nutrition status and organic apple orchards [5, 25].

The aim of the present study was to determine the nutrient contents of the soils and apple leaves of an organic apple orchard, to investigate the dynamic of uptake of macroelements and to establish the nutrient supply level of investigated elements.

MATERIAL AND METHODS

Experimental site

The experiment was carried out at Debrecen-Pallag in an apple cultivar collection. The orchard was established in the spring of 1997, using M26 rootstocks at a spacing of 4 x 1.5 m. Cultivars were planted in plots. Each plot consisted of 7 trees per cultivar. Plots were placed in a randomised block design with 4 replicates. The collection of 40 apple cultivars was divided into two parts. From the first year, 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 [1].

The orchard soil type was brown forest soil with alternating thin layers of clay substance "kovárvány". The type of soil is acidic sandy soil, poor in clay, nutrients and humus (Table 1). Orchards were not irrigated. In this paper, we publish the results of the organic orchard part only. Stable manure, 25 t ha^{-1} was applied to the soil in 2000 and 2002 in the organic orchard part.

Table 1. Main soil parameters of the examined area
1. táblázat. A vizsgált terület főbb talajtulajdonságai

Soil type	Brown forest soil with „kovárvány"
Soil texture	Sand
*K_A	28
pH ($CaCl_2$)	5.13
**y_1	8.16
Salt (%)	0.002
Humus (%)	0.75
P (0.01 M $CaCl_2$) (mg/kg)	4.76
K (0.01 M $CaCl_2$) (mg/kg)	168

*Plasticity index according to Arany
** Hydrolytic acidity

Soil sampling

Soil samples were taken from each plot of the seven selected apple cultivars (Jonagold, Mutsu, Idared, Red Elstar, Egri piros, Remo and Reka) from the organic orchard. Three samples were taken from each plot, one from the middle and one from both edges of the plots 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 a manual soil sampling equipment, according to the Hungarian sampling guidelines [15]. Sampling was performed at the beginning and at the end of the vegetation period in April and October in 2002, 2003 and 2004, respectively.

Plant sampling

The above-mentioned seven cultivars were also selected for leaf sampling from the organic orchard. Leaf samples were taken monthly, from April to September, during 2002-2004. Leaves were collected from all trees of each plot of the seven apple cultivars in the organic orchard sections according to the Hungarian sampling guidelines [14].

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 a dry place until the examination. Samples from the organic part were analyzed by using two kinds of methods. For studying the easily soluble and available nutrient forms of N and P 0.01 M $CaCl_2$ extractant was used, while for studying the Ca, Mg and micronutrient contents of soils NH_4-acetate+ EDTA was used [11]. Only the main parameters of the soil of the organic orchard part were published in this paper (Table 1).

Laboratory examination of plant samples

Pre-treatments 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 were stored in paper bags in a cool and dry place protected against direct sunlight.

Leaf samples were digested with cc. HNO_3 and H_2O_2 in a heating block digestor, at 120 °C for 2 h for determining P and K content.

The N and S content of leaves was determined from the ground and homogenized samples directly using the dry combustion method [16]. Content of P was determined with photometry. The amount of Ca and Mg was determined by using the atom adsorption method, while the content of K by using the atom emission method.

Besides the element content, the ratio of the different elements was also determined according to Papp & Tamási [19] and Füleky [4]. The most frequently used ratios (N/K, N/Ca, K/Mg, K/Ca and Ca/Mg) were calculated from the three-year mean data of July.

RESULTS AND DISCUSSION

Nitrogen content of leaves

The results on the intensity and dynamics of N-uptake (Table 2) were in agreement with those of earlier studies and corresponded to the phenological phases of apple [19, 23, 24]. Younger leaves contain more N than elder due to the effective N uptake of young leaves. The changing of N content of leaves is remarkable from April to July. After July, this change was not so expressed but the reduction was continuous. The relationship between soil and leaf analysis is not so strong as in other plants, especially in grains. So, although the humus content of the soil is very low, the N content of leaves is in the range of the optimum category and is satisfactory during the whole examined period [17, 18]. There is a significant difference in the N content of leaves between cv. Jonagold and cv. Egri piros, but this effect is not explicitly obvious due to the inhomogenity of the soil of the examined area.

Phosphorus content of leaves

The dynamics of P-uptake corresponded to the phenological phases of apple (Table 3). The phosphorus was found to be in higher quantity at the first sampling in all cultivars. Changing of values was the greatest between the sampling of April and May. In June, the P content of leaves reduced to 0.21 and did not change considerably.

Table 2. N content of leaves of seven apple cultivars (2002-2004, three-year mean)
2. táblázat. Hét almafajta levelének N-tartalma (2002-2004, 3 éves átlagadat)

	N (% dry matter)					
	April	**May**	**June**	**July**	**Aug**	**Sept**
Jonagold	3.11	3.08	2.51	2.28	2.13	2.00
Mutsu	3.58	3.12	2.52	2.31	2.19	2.07
Idared	3.54	3.09	2.55	2.19	2.12	2.01
Red Elstar	3.41	3.1	2.51	2.28	2.22	2.16
Egri Piros	3.91	3.17	2.59	2.29	2.2	2.10
Reka	3.38	3.09	2.51	2.26	2.12	1.96
Remo	3.58	3.16	2.49	2.03	2.11	1.91
Mean	**3.50**	**3.12**	**2.53**	**2.24**	**2.16**	**2.03**
SD	**0.24**	**0.04**	**0.03**	**0.10**	**0.05**	**0.08**
LSD 5%	**0.18**	**0.03**	**0.02**	**0.07**	**0.03**	**0.06**

Table 3. P content of leaves of seven apple cultivars (2002-2004, three-year mean)
3. táblázat. Hét almafajta levelének P-tartalma (2002-2004, 3 éves átlagadat)

	P (% dry matter)					
	April	**May**	**June**	**July**	**Aug**	**Sept**
Jonagold	0.41	0.23	0.21	0.19	0.18	0.18
Mutsu	0.42	0.27	0.21	0.21	0.18	0.19
Idared	0.38	0.25	0.21	0.19	0.18	0.18
Red Elstar	0.43	0.29	0.21	0.20	0.20	0.15
Egri Piros	0.40	0.23	0.22	0.21	0.19	0.22
Reka	0.39	0.23	0.23	0.21	0.18	0.19
Remo	0.45	0.23	0.21	0.20	0.18	0.19
Mean	**0.41**	**0.25**	**0.21**	**0.20**	**0.19**	**0.19**
SD	**0.02**	**0.03**	**0.01**	**0.01**	**0.01**	**0.02**
LSD 5%	**0.02**	**0.02**	**0.01**	**0.00**	**0.01**	**0.01**

Table 4. K content of leaves of seven apple cultivars (2002-2004, three-year mean)
4. táblázat. Hét almafajta levelének K-tartalma (2002-2004, 3 éves átlagadat)

	K (% dry matter)					
	April	**May**	**June**	**July**	**Aug**	**Sept**
Jonagold	1.60	1.70	1.32	1.01	1.31	0.97
Mutsu	1.86	1.89	1.47	1.16	1.32	1.08
Idared	1.55	1.68	1.33	1.09	1.17	1.01
Red Elstar	1.83	1.89	1.58	1.25	1.43	1.23
Egri Piros	1.81	1.94	1.62	1.47	1.72	1.44
Reka	1.57	1.56	1.14	0.89	1.16	1.08
Remo	1.63	1.59	1.24	1.10	1.28	0.93
Mean	**1.69**	**1.75**	**1.39**	**1.14**	**1.34**	**1.11**
SD	**0.14**	**0.15**	**0.18**	**0.19**	**0.19**	**0.18**
LSD 5%	**0.10**	**0.11**	**0.13**	**0.14**	**0.14**	**0.13**

The nutrient supply level of the different elements in apple leaves is determined based on the data of July all over the world [4]. Based on the measurements conducted in July (mid-3rd / July 15-30), the P content of leaves was satisfactory during the whole examined vegetation period. The results of soil analysis corresponded to the data of leaf analysis.

Potassium content of leaves

In this study, the dynamics of K uptake and K content of leaves in an organic apple orchards (Table 4) showed similar tendency as reported by earlier studies [18, 19]. According to our measurements, the K content of apple leaves decreases continuously until July, after that it slightly increases, then decreases again. This tendency is typical of K and agrees with earlier observations [19]. Based on the data of July, the K content ranges between 0.89 and 1.47, the average being 1.14. These values are in the "low" K supply category [17]. Furthermore, there were also significant differences in the K content among cultivars which is in agreement with earlier findings that the N and K contents of leaves are widely variable among cultivars [4, 19].

Sulphur content of leaves

A continuous decrease was observed in the sulphur content of apple leaves until August then the reduction was not considerable (Table 5). The change in the S content of leaves shows similar tendency to phosphorus. Similarly to the results of N, the S content of leaves shows significant differences among the certain cultivars (Jonagold and Mutsu vs. Remo). This may be due to the strong correlation between the uptake and role of nitrogen and sulphur in plants.

Calcium content of leaves

The change in the Ca content is different from that of the above nutrients (Table 6). It is due to the special uptake of Ca. The Ca content of leaves increases continuously until July, after that it decreases, then increases again until the end of the examined period. Based on our measurements, the Ca content is satisfactory and is in the low range of the optimal Ca supply category. Based on the results of July, significant differences were observed among certain cultivars. The greatest difference was measured between cv. Jonagold and cv. Egri Piros.

Magnesium content of leaves

The Mg content of leaves increases continuously until June, it decreases in July, then increases again (Table 7). In August and September, it does not change notably. The Mg content of leaves is above the optimal range of Mg supply in July. It can not be explained by the results of the soil analysis and the applied nutrient management. However, it is widely known that the good P supply level of the soil helps the uptake of Mg [12, 13].

Ratio of macronutrients

The ratio of N/K varied from 1.56 to 2.54 depending on the cultivar (Table 8). The obtained means (2.01) were high compared to the optimal value (1.5). Our results point out that the nutrient supply of the examined soil was not optimal. There was a disharmony in the available nutrient supply of soil. The ratio of N/Ca varied from 1.29 to 1.95 also depending on the cultivar. The mean value (1.56) was near the optimal value (1.5). The ratio of K/Ca varied from 0.57 to 1.11. The mean value (0.79) was near the optimal value (0.87). The ratio of K/Mg varied between wide ranges (2.18 to 3.19). The obtained

Table 5. S content of leaves of seven apple cultivars (2002-2004, three-year mean)
5. táblázat. Hét almafajta levelének S-tartalma (2002-2004, 3 éves átlagadat)

	S (% dry matter)					
	April	**May**	**June**	**July**	**Aug**	**Sept**
Jonagold	0.28	0.25	0.23	0.22	0.20	0.19
Mutsu	0.30	0.26	0.23	0.22	0.21	0.19
Idared	0.30	0.25	0.24	0.21	0.20	0.19
Red Elstar	0.33	0.28	0.24	0.21	0.19	0.19
Egri Piros	0.34	0.29	0.25	0.20	0.18	0.17
Reka	0.32	0.29	0.24	0.20	0.19	0.19
Remo	0.29	0.26	0.24	0.19	0.18	0.18
Mean	**0.31**	**0.27**	**0.24**	**0.21**	**0.19**	**0.19**
SD	**0.02**	**0.02**	**0.01**	**0.01**	**0.01**	**0.01**
LSD 5%	**0.02**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**

Table 6. Ca content of leaves of seven apple cultivars (2002-2004, three-year mean)
5. táblázat. Hét almafajta levelének Ca-tartalma (2002-2004, 3 éves átlagadat)

	Ca (% dry matter)					
	April	**May**	**June**	**July**	**Aug**	**Sept**
Jonagold	0.72	1.08	1.90	1.77	1.99	2.59
Mutsu	0.77	1.27	1.78	1.53	2.04	2.65
Idared	0.76	1.18	1.78	1.66	1.95	2.06
Red Elstar	0.71	1.11	1.48	1.26	1.84	1.92
Egri Piros	0.66	1.20	1.61	1.33	1.83	2.30
Reka	0.38	0.81	1.69	1.16	1.72	1.71
Remo	0.60	1.07	1.62	1.54	2.04	2.15
Mean	**0.66**	**1.10**	**1.69**	**1.46**	**1.92**	**2.20**
SD	**0.14**	**0.15**	**0.14**	**0.22**	**0.12**	**0.34**
LSD 5%	**0.10**	**0.11**	**0.10**	**0.16**	**0.09**	**0.25**

Table 7. Mg content of leaves of seven apple cultivars (2002-2004, three-year mean)
5. táblázat. Hét almafajta levelének Mg-tartalma (2002-2004, 3 éves átlagadat)

	Mg (% dry matter)					
	April	**May**	**June**	**July**	**Aug**	**Sept**
Jonagold	0.29	0.36	0.55	0.46	0.50	0.50
Mutsu	0.30	0.43	0.53	0.42	0.47	0.50
Idared	0.33	0.37	0.43	0.37	0.42	0.38
Red Elstar	0.31	0.40	0.49	0.40	0.43	0.44
Egri Piros	0.37	0.47	0.54	0.46	0.50	0.55
Reka	0.24	0.36	0.47	0.35	0.48	0.35
Remo	0.29	0.37	0.45	0.39	0.43	0.41
Mean	**0.30**	**0.39**	**0.50**	**0.41**	**0.46**	**0.45**
SD	**0.04**	**0.04**	**0.05**	**0.04**	**0.03**	**0.07**
LSD 5%	**0.03**	**0.03**	**0.03**	**0.03**	**0.02**	**0.05**

Table 8. Ratios of different nutrients of seven apple cultivars
8. táblázat. Hét almafajta különböző tápanyagformáinak arányai

	N/K	**N/Ca**	**K/Ca**	**K/Mg**	**Ca/Mg**
Jonagold	2.27	1.29	0.57	2.18	3.84
Mutsu	1.99	1.51	0.76	2.80	3.69
Idared	2.02	1.32	0.65	2.94	4.49
Red Elstar	1.83	1.81	0.99	3.11	3.13
Egri Piros	1.56	1.73	1.11	3.19	2.87
Reka	2.54	1.95	0.77	2.58	3.36
Remo	1.85	1.32	0.71	2.82	3.96
Mean	**2.01**	**1.56**	**0.79**	**2.80**	**3.62**
SD	**0.32**	**0.27**	**0.19**	**0.34**	**0.55**
LSD 5%	**0.24**	**0.20**	**0.14**	**0.25**	**0.40**

mean (2.8) falls short of the optimal value (3.9-6.0) due to the above-mentioned high Mg content of leaves. The obtained N/K and K/Mg values can be explained by the deficiency of K supply. The ratio of Ca/Mg varied between 2.87 to 4.49. The obtained average (3.62) can be explained by the above-mentioned tendencies. According to the literature data, the optimal value is 4.55 [4].

Our results showed that nutrient ratios indicated the disharmonies of plant nutrition better than concrete nutrient contents. Results also demonstrated that the applied fertilization management sustains a relatively good nutrient supply level in the organic orchard. But there was a disharmony in the supply of available nutrients in the soil due to the heterogenous conditions of the soil regarding uptake of different macronutrients. Results might be explained by the properties of soil, the applied dosage of manure and the processes of soil (e.g. ion-antagonism, blocked nitrification). Results also suggested that the proper plant nutrition must be based on the results of both soil and plant analyses.

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