FOLIA OECOLOGICA – vol. 33, no. 2 (2006). ISSN 1336-5266

Contents of bioelements and energy equivalent in assimilatory organs of European chestnut (*Castanea sativa* Mill.)

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Abstract

Konôpková, J. 2006. Contents of bioelements and energy equivalent in assimilatory organs of European chestnut (*Castanea sativa* Mill.). *Folia oecol*., 33: 94–101.

The work evaluates the content of selected bioelements (Ca, Mg, K, P, Na, Fe, Mn, Zn, Cu) and energy amount in the assimilatory organs of various stand types of European chestnut (*Castanea sativa* Mill.). In assimilatory organs of the European chestnut were determined optimum contents of Ca, Mg, P and Zn. The content of Na, Fe and Cu was found slightly increased and Mn was high. Content of K was lower. Analysis of variance identified statistically very significant differences among all the analysed bioelements across several years and in various stand types. Energy values in leaves of European chestnut varied from 18.193 to 19.837 kJ g^{-1}. There were found high significant differences in energy contents among the stand types.

Key words

macroelements, microelements, energy equivalent, biomass, *Castanea sativa* Mill.

Introduction

Mineral nutrition is one of the main factors influencing growth and development of woody plants, and biomass creation as well. The interest in works oriented on assessment of bioelements content in assimilatory organs of woody plants, arisen in the fiftieth years of the last century, has not been interrupted up to the present. In our conditions was the topic documented with valuable data by Huzulák (1972) and Bublinec (1975, 1994). Supuka et al. (1991) studied bioelements content in woody plants in urban greenery. Study of biomass of woody plants belongs to the basic issues in assessment of their production and functional efficiency. Oszlányi (1988) monitored trends in weight of aboveground biomass development for *Fagus sylvatica* L. in the Small Carpathians Mts. The data about quantification and structure of phytomass in alien woody plants in Slovakia can be found in Tokár (1998, 1999, 2002) and Benčať (1989). Vreštiak (1988, 1991) evaluated leaf biomass in urban greenery in several model Slovak towns.

To reach more precise evaluation of organic matter quality in production-ecological studies, it is necessary to express the biomass size in units of energy (J), instead of dry weight, because equal amounts of different biological materials don't need have equal energy values (Duvigneaud, 1988). Knowledge of the energy values of organic materials is important when we examine the flow of energy through individual trophic levels of ecosystems, because it enables us more to provide objective comparison of production in forest ecosystems with other ecosystems, calculation of solar energy utilization, etc. Lieth (1968), Runge (1973) began with calculations of caloric values of biological materials and assessment of their ecological effectiveness in the seventies of the last century. Porcorossi (1989) elaborated a list of caloric values of biomass in stands of European chestnut in Italy. Núñez et al. (1997), Núñez-regueira et al. (2004) reported caloric values of woody plants (*Sorbus aucuparia* L., *Acer pseudoplatanus* L., *Taxus baccata* L., *Fagus sylvatica* L., *Quercus robur* L., *Castanea sativa* Mill.) that are typical for the temperate zone, forming broadleaved deciduous forests, in the region of Galicia in Spain. Biomass energy values of plants in Slovakia are reported by Oszlányi (1988), Vokoová (1987), Benčať (1994), Kováčová (1997), Kováčová et al. (1996a, b, 1999), Schieber and Kováčová (2003), and Konôpková and Tokár (1997, 2000).

The subject of this work is evaluation of bioelements content and energy values in assimilatory organs of European chestnut (*Castanea sativa* Mill.).

Material and methods

We determined contents of selected macrobiogenic elements (Ca, Mg, K, P), microbiogenic elements (Zn, Fe, Mn, Cu) and Na, from group of beneficial elements. The study material was sampled in stands of European chestnut, on permanent experimental plots – PEP II, PEP IV, PEP VIII and PEP X in Lefantovce, at two-month intervals, during the vegetation periods 1995–1997. The stand composition on the PEP is as follows:

- o PEP II – monoculture of *Castanea sativa* Mill. (100%)
- o PEP IV – mixed stand of *Castanea sativa* Mill. (80%) and *Quercus petraea* (Mattusch.) Liebl. (20%)
- o PEP VIII – mixed stand of *Castanea sativa* Mill. (60%) and *Tilia cordata* Mill. (40%)
- o PEP X – mixed stand of *Castanea sativa* Mill. (60%) and *Pinus sylvestris* L. (40%).

PEP Lefantovce belong to the oak forest vegetation tier, management set HS 25 (nutritive beech oak-woods), management set of forest types HSLT 111 (nutritive hornbeam oak-woods), group of forest types SLT Carpineto-Quercetum (CQ), LT 1308 (production vetch hornbeam oak-wood). The site is situated at 230 m above sea level, with mean annual precipitation of 560 mm, and mean annual temperature of 9.7 °C. The soil type is brown soil, the stand age in 1995 was 32 years.

Average leave samples were taken from 3 sample trees (from each PEP), from the central third of shoots (annual shoot) on crown surface, in the lower part of the crown. The samples were dried, homogenised and processed by wet ashing. In the obtained mineralised material, we determined amounts of Ca, Mg, K, Na, Fe, Zn, Mn, Cu by the method of atomic absorption spectrophotometry; P concentration was measured spectrophotometrically. We calculated the average concentrations of individual elements in mg g^{-1} of dry matter from three parallel experimentally obtained values, then the average values of bioelement contents for individual years, and for the whole studied period (Konôpková, 2003).

The samples of plant material, in which we assessed the content of biogenic elements, were also used for assessment of energy values. Energy values (= combustion heat) given in kJ g^{-1} dry matter, ash inclusive, were measured in a water calorimeter, following the method suggested by Jakrlová (1987).

We subjected the obtained results to statistical evaluation by the multi-way analysis of variance and the Tukey's test.

Results and discussion

Content of bioelements in assimilatory organs

The analysis of plant assimilatory organs and assessment of their nutrition state allow us to provide an early diagnostics of damage to stands, before the damage symptoms can be identified visually.

We assessed the nutrition state of European chestnut during the years of observation on the basis of average annual values of the assessed nutrients. We confronted these values with the values reported in literature (Bergmann, 1988; Procházka et al., 1998; Fecenko and Ložek, 2000). We evaluated the level of mineral nutrition on the individual experimental plots on the basis of average values of bioelements contents for the whole three-year period (Tables 1–2).

The content of Ca in assimilatory organs of European chestnut varied from 17.63 to 21.36 mg g^{-1}. Magnesium varied from 3.29 to 4.00 mg g^{-1}. In the course of the experiment was kept the content of K within the range of 9.40 to 11.85 mg g^{-1}. Phosphorus reached the values from 1.97 to 2.59 mg g^{-1}, and Na from 0.071 to 0.076 mg g^{-1}. Fe was present in an amount of 0.128–0.161 mg g^{-1}. The values of Zn varied from 0.044 to 0.050 mg g^{-1}, and Mn from 1.826 to 2.066 mg g^{-1} dry matter. The content of Cu varied from 0.023 to 0.027 mg g^{-1} dry matter. The optimum contents of Ca, Mg, P and Zn found in assimilatory organs of European chestnut were compared with the data published in literature. The content of Na, Fe and Cu was slightly increased, and content of Mn was high. Most of the assessed values of K were lower or low, near the lower limit of optimum.

Table 1. Contents of macroelements in assimilatory organs of *Castanea sativa* Mill. on individual experimental plots

Experimental plot	Ca	Mg	K	P
	(mg g^{-1})± SE			
PEP II.	18.50±0.439 a	4.00±0.246 a	10.60±0.535 ab	2.59±0.163 b
PEP IV.	18.01±0.411 a	3.78±0.202 ab	9.40±0.488 a	2.39±0.138 b
PEP VIII.	21.39±0.459 b	3.56±0.134 ab	11.85±0.691 b	2.48±0.133 b
PEP X.	17.63±0.596 a	3.29±0.185 b	10.63±0.516 ab	1.97±0.141 a

Table 2. Contents of microelements and Na in assimilatory organs of *Castanea sativa* Mill. on individual experimental plots

Experimental plot	Ca	Mg	K	P
	(mg g^{-1})± SE			
PEP II.	18.50±0.439 a	4.00±0.246 a	10.60±0.535 ab	2.59±0.163 b
PEP IV.	18.01±0.411 a	3.78±0.202 ab	9.40±0.488 a	2.39±0.138b
PEP VIII.	21.39±0.459 b	3.56±0.134 ab	11.85±0.691 b	2.48±0.133 b
PEP X.	17.63±0.596 a	3.29±0.185 b	10.63±0.516 ab	1.97±0.141 a

Mean values followed by the same letters (a)–(d) are not significantly different at the 0.01 level of significance (Tukey's multiple range rest).
PEP – permanent experimental plots (for the symbols see Material and methods)

Table 3. Mutual ratio K/Mg

Experimental plot^{-1}	Woody plant	Year of sampling	K/Mg
PEP II.	*Castanea sativa* Mill.	1995	1.53
		1996	2.75
		1997	4.80
		$\bar{x}$	3.03
PEP IV.	*Castanea sativa* Mill.	1995	1.98
		1996	2.77
		1997	3.01
		$\bar{x}$	2.59
PEP IV.	*Quercus petraea* (Mattusch.) Liebl.	1995	2.68
		1996	3.32
		1997	4.62
		$\bar{x}$	3.54
PEP VIII.	*Castanea sativa* Mill.	1995	2.56
		1996	3.65
		1997	4.08
		$\bar{x}$	3.43
PEP VIII.	*Tillia cordata* Mill.	1995	1.89
		1996	3.49
		1997	5.57
		$\bar{x}$	3.65
PEP X.	*Castanea sativa* Mill.	1995	2.41
		1996	3.20
		1997	4.73
		$\bar{x}$	3.44
PEP X.	*Pinus sylvestris* L.	1995	1.83
		1996	2.45
		1997	3.03
		$\bar{x}$	2.44

x – average value for three years period, PEP – permanent experimental plots (for the symbols see Material and methods).

Bergmann (1988) reported that also values of K/Mg < 3 suggest an insufficient storage of K; in 1995, such values were found on all studied PEP, and on PEP II. and PEP IV. (Table 3) also in 1996.

Gallardo et al. (1998) studied contents of bioelements in 25-year old stands of European chestnut in the mountain range Siera de Gata (central part of western Spain). The authors report following amounts of macronutrients in leaves: Ca – 5.0; Mg – 3.0; K – 4.3; P – 1.9; in mg g^{-1} dry matter and micronutrients Fe – 74; Zn – 27; Mn – 919; Cu – 14 and Na – 408; in mg kg^{-1} dry matter. Compared with these results, we have found higher concentrations of bioelements, with exception of Na and Mn in all stand types of European chestnut.

Analysis of variance (ANOVA) showed statistically high significant differences among values of all the assessed elements in the individual years (Tables 4–5).

The results of Tukey's test also confirmed statistically high significant differences among the tested values of Ca, Mg, K, P, and Mn (Tables 1–2) on individual experimental plots. Differences in average values of macro and microelements between individual years and between experimental plots are to a considerable extent caused by meteorological factors as well as by different values of exchangeable soil reaction (pH/KCl). For evaluation of climatic conditions during the studied years, we used the data assembled by the Agrometeorological station of the University of Agriculture (Konôpková, 2003). The average annual temperature was 10.1 °C in 1995; 9.0 °C in 1996 and 9.6 °C in 1997. From the measured values it follows that, concerning the precipitation, the year 1995 was normal (580.4 mm), 1996 was extraordinary wet (680.7 mm), and 1997 was normal (495 mm) again. Exchangeable soil reaction (pH/KCl) reached the following values: PEP II. – 3.96; PEP IV. – 3.81; PEP VIII. – 3.80 and PEP X. – 3.86; indicating strong acid soil reaction.

Works of Santa Regina and Salazar (2005) and Santa Regina et al. (2005) also mention dependence between mineral nutrition and biomass production. The authors found significant differences in amount of humus cover in dependence on the stand age, and they suggested that the changes in nutrient utilization coefficient might depend on the type of stand. PORTELA (2000) and PORTELA and LOUZADA (2005) studied the relation between nutrient content in health state of *Castanea sativa* Mill., and they observed that calcium reduced the ink disease of chestnut trees (*Phytophthora cambivora* (Petri) Buism., *Ph. Cinnamoni* Rands.). During the study of malignant influence of canker (*Cryphonectria parasitica* (Murr.) Barr.), there were detected significant differences in nutrient concentrations between the healthy stands and the stands affected by the disease.

The average values of energy equivalent of the assimilatory organs of *Castanea sativa* Mill. on the experimental plots in the studied period (1995–1997) ranged from 18.193 kJ g^{-1} to 19.838 kJ g^{-1} (Fig. 1). We compared the obtained results with the values given by JAKRLOVÁ (1989).

Interesting is also comparison with dry matter energy values in other wood species reported by OSZLÁNYI (1988): *Pinus sylvestris* L. 20.27 kJ g^{-1}, *Picea excelsa* Link. 19.94 kJ g^{-1}, and *Fagus sylvatica* L. 19.42 kJ g^{-1}. VOOKOVÁ (1987) found in leaves of *Ligustrum vulgare* L. an energy content of 20.37 kJ g^{-1}. KOVÁČOVÁ (1997), KOVÁČOVÁ et al. (1995, 1996, 1999) studied production and energy equivalent of aboveground phytomass at various development stages in a population of *Carex pilosa* Scop. The authors found the maximum average energy value of biomass in the juvenile population of *Carex pilosa* in June (18.107 J g^{-1}) and minimum one in August (17.884 J g^{-1}).

On the obtained results, we can see that there were not considerable differences between the studied years, unlike among the different types of European chestnut stands. This has also been confirmed by the results of variance analysis. The differences between the repetitions of individual analyses were not statistically significant (Table 6).

The results of Tukey's test showed statistically high significant differences in energy values of assimilatory organs in European chestnut on PEP II. and PEP IV., PEP II. and PEP X., PEP IV. and PEP VIII., PEP IV. and PEP X., PEP VIII. and PEP X.

The obtained results show on an example of different stand types of European chestnut that in case they are not fertilised, the level of mineral nutrition is influenced by stand type (quality of the litterfall) and thinning methods (quantity of litterfall). The appropriateness of a given European chestnut stand type can be assessed based on the content of nutrients and energy values reflecting its phytomass production. The obtained results show that the most suitable type of stand is the mixed stand of European chestnut and small-leaved linden (PEP VIII.).

Acknowledgement

This study was financed by the grant No. 2/5013/98 of the Slovak Grant Agency VEGA.

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Table 4. ANOVA of contents of macroelements in assimilatory organs of *Castanea sativa* Mill.

Source of variation	d.f.	Ca			Mg			K			P		
		Mean square	F-ratio	P level	Mean square	F-ratio	P level	Mean square	F-ratio	P level	Mean square	F-ratio	P level
A: Year	2	26.462	7.772 **	0.001	36.529	112.492 **	0.000	27.928	5.088 **	0.008	13.760	100.215 **	0.000
B: Plot	3	77.291	22.700 **	0.000	2.475	7.623 **	0.000	27.190	4.954 **	0.003	1.969	14.340 **	0.000
C: Repetition	2	0.896	0.263	0.769	0.191	0.590	0.557	1.338	0.244	0.784	0.006	0.042	0.959
Residual	98	3.405			0.325			5.489			0.137		

**significant at P = 0.01

Table 5. ANOVA of contents of microelements and Na in assimilatory organs of *Castanea sativa* Mill.

Source of variation		Na			Fe			Zn			Mn			Cu		
	d.f.	Mean square	F-ratio	P level	Mean square	F-ratio	P level	Mean square	F-ratio	P level	Mean square	F-ratio	P level	Mean square	F-ratio	P level
A: Year	2	0.020	56.968 **	0.000	0.027	11.220 **	0.000	0.007	78.894 **	0.000	1.190	19.043 **	0.000	$8.235.10^{-4}$	14.320 **	0.000
B: Plot	3	$1.768.10^{-4}$	0.505 **	0.680	0.003	1.163 **	0.328	$2.071.10^{-4}$	2.384 **	0.074	0.300	4.810 **	0.004	$8.873.10^{-5}$	1.543	0.208
C: Repetition	2	$1.300.10^{-5}$	0.037	0.964	$1.200.10^{-5}$	0.005	0.995	$7.400.10^{-6}$	0.085	0.919	0.014	0.2150	0.807	$1.837.10^{-5}$	0.319	0.727
Residual	98	$3.503.10^{-4}$		0.002				$8.684.10^{-5}$			0.062			$5.750.10^{-5}$		

**significant at P = 0.01

Table 6. ANOVA – energy equivalent

Source of variation	d.f.	Mean square	F-ratio	P-level
A: Year	2	0.461	1.628	0.2016
B: Plot	3	15.437	54.490**	0.0000
C: Repetition	2	0.193	0.681	0.5086
Residual	98	0.283		

**significant at P = 0.01

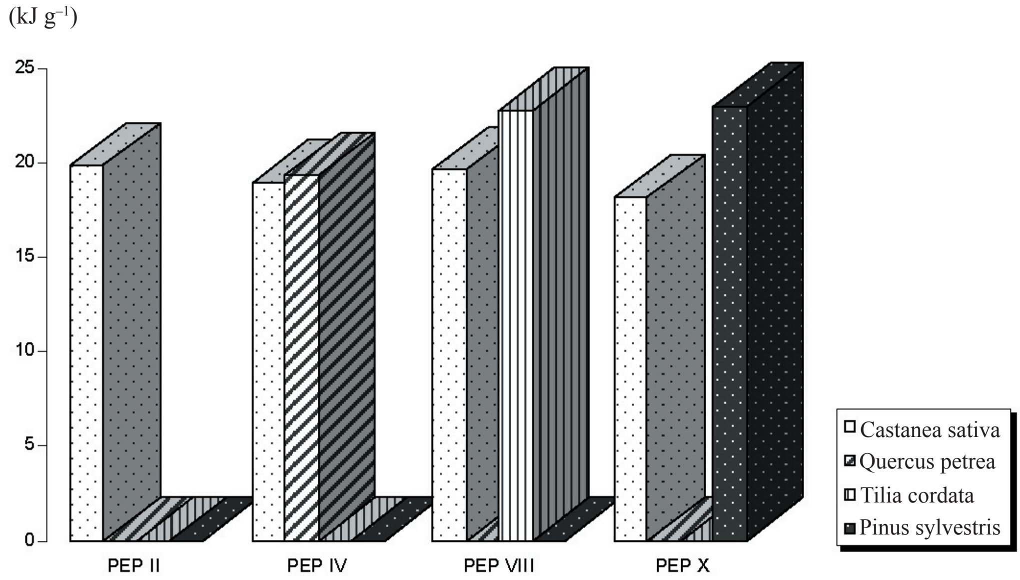

Fig. 1. Average values of energy equivalent on experimental plots

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Obsah bioelementov a energetický ekvivalent v asimilačných orgánoch gaštana jedlého (*Castanea sativa* Mill.)

Súhrn

Minerálna výživa je jedným z hlavných faktorov ovplyvňujúcich rast a vývoj rastlín a v konečnom dôsledku tvorbu rastlinnej hmoty. Primeraný rast drevín a zdravá listová zeleň svedčia o harmonickej výžive. Naopak, disproporcie vo výžive sa prejavujú špecifickými príznakmi, ktoré možno do určitej miery identifikovať podľa vizuálnych symptómov. Analýzami asimilačných orgánov a zistením stavu výživy je však možné signalizovať poškodenie porastov skôr, ako sa tieto symptómy vizuálne prejavia. Preto jedným z cieľov práce bolo zhodnotenie obsahu bioelementov v asimilačných orgánoch porastov gaštana jedlého (*Castanea sativa* Mill.), počas obdobia vegetácie rokov 1995 až 1997.V asimilačných orgánoch gaštana jedlého bol v porovnaní s literárnymi údajmi optimálny obsah Ca, Mg, P a Zn. Obsah Na, Fe a Cu bol mierne zvýšený a obsah Mn vysoký. Väčšina stanovených hodnôt K bola nižšia, alebo blízka spodnej hranici optima. Analýza variancie poukázala na štatisticky vysoko preukazné rozdiely medzi hodnotami všetkých stanovovaných prvkov v asimilačných orgánoch gaštana jedlého, v jednotlivých rokoch a výsledky Tukeyovho testu potvrdili, že obsahy Ca, Mg, K, P a Mn stanovené na jednotlivých experimentálnych plochách sú tiež štatisticky vysoko preukazné. Na vyjadrenie produkcie biomasy sme použili energetický ekvivalent ako kvantitatívne vyšší porovnávací ukazovateľ. Energetické hodnoty asimilačných orgánov porastov *Castanea sativa* Mill. mali hodnoty od 18,193 do 19,838 kJ g^{-1} sušiny.