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Chemical Elements in Mulch and Litterfall of Beech Ecosystems and Their Total Turnover

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Abstract. The beech communities on the territory of Bulgaria had been objects of regional, local as well as large scale national investigations aiming their classification, determination of their ecological characteristics, conservation status, habitats etc. They are included as objects of the intensive monitoring of forest ecosystems in Bulgaria also. The investigations of chemical content of the litter – fall in these forests were conducted until now. The novelty of the present research is investigation of these elements in the mulch and the ratio between the established quantities calculation. The main goal is the biological turnover special features characterization of the investigated elements which give us a chance to define the investigated ecosystems state and functioning. The indexes as litter – mulch and acropetal coefficients were used for this aim. The content of macroelements as N, Ca and K and microelements as Pb, Zn, Mn and Fe in soils, mulch and in different litter- fall fractions have been calculated. The investigation was carried out on three sample plots.

During the investigation was established that the soils are characterized with acid reaction, high content of Fe, N and Mn and low content of Ca and K. The concentration of Zn and Pb are high also.

The calculated average store of investigated elements in litter – fall is 81.312 kg.ha^{-1} and in the mulch - 314 kg.ha^{-1}. According to the acropetal coefficient N is accumulated mainly in the acorns, K – in the annual phytomass fractions and Ca – in the perennial fractions. The leaves and the acorns fraction accumulate Mn, and cupolas - Fe.

The litter – mulch coefficient vary from 1,6 (Mn) to 4,2 (Pb). The tendencies of Zn and Ca turnovers acceleration are discovered, while the turnover of more investigated elements is inhibited. The litter – mulch coefficient for Zn and Ca is 0,8 and 1,4 accordingly, i.e. corresponding to the intensive type of turnovers which is not typical for the broadleaved forest communities.

The determination of cause factors and the functioning of beech communities in the future have a great importance for the environment and the economy of the country.

Key words: Bulgaria, beech ecosystem, macro- and microelements, total turnover.

Introduction

The beech communities on the territory of the Petrohan experimental and educational forest enterprise (EEFE "Petrohan") and State hunting range "Vitinia" had been objects on regional, local (GARELKOV, 1967; PAVLOV, 1978; PAVLOV *et al.*, 2003) as well as large scale national investigations (PENEV *et al.*, 1969; TZONEV *et al.*, 2006 etc.) aiming their classification, determination of their ecological characteristics, conservation status, habitats etc. (DJANKOVA *et al.*, 2003; MIHOV *et al.*, 2008). They are included as object of the intensive

monitoring of forest ecosystems in Bulgaria (KOLAROV *et al*. (2002).

The investigations of some of the main functional characteristics as turnover of the chemical elements, quality and quantity of the litter-fall and the processes of decomposition in these forests were also a subject of many investigations in Bulgaria (KOCHEV & GORUNOVA, 1975; LALOVA, 1994; LYUBENOVA & ALEXANDROV, 1999; LYUBENOVA & DIMOVA, 2000; LYUBENOVA *et al*., 2002; MIHOV *et al*., 2008) as well as in abroad (SANTA REGINA & TARAZONA, 2001; KAVVADIAS *et al*., 2001; LEBRET *et al*., 2001 and others).

Investigations of the litter – fall chemical content in these forests have been conducted recently. The aim of present research is to characterize the biological turnover special features of the investigated elements and to define ecosystems status and the functioning rate. The novelty is investigation of these elements in the mulch and finding the ratio between the established quantities.

Material and methods

Object of investigation

The objects of investigation are beech communities in the region of West Balkan Mountains. Sample plot 1 (SP 1) is situated in a region of State hunting range "Vitinia". It is representative for the high stem beech forests. The territory belongs to the West Balkan Region of the temperate continental forest area (PAVLOV, (1995) and to the Europe broadleaves forest area (BONDEV, 1991). The investigated region gets into the Mountainous climatic district, West Balkan Mountain sub district, and characterizes with annual average precipitations (AP) around 900 mm and prevailing winds with south component (VELEV, 2002). The soils are *Cambisols*, CM (NINOV, 2002).

Sample plots 2 and 3 are situated in the region of the Petrohan experimental and educational forest enterprise. The area belongs to North Bulgarian climatic zone with temperate-continental climate. The average annual precipitations are between 700-1000 mm (VELEV, 2002). The soils are *Cambisols*, CM (NINOV, 2002). The region is slightly impacted by different forms of environmental pollution.

The investigated beech communities are related to associations *Festuco drymejae-Fagetum sylvaticae* and *Asperulo odoratae-Fagetum sylvaticae* (habitat *Asperulo-Fagetum* - 9130) in the region of Petrohan and association *Aremonio agrimonoidis-Fagetum sylvaticae* (habitat *Moesiacus beech forests*, 91W0) in the region of Vitinia (MIHOV *et al*., 2008).

Methods

The annual litter-fall was gathered with five 1 m^2 litter-catchers from each sample plot. The stores of mulch were calculated according methodical leads of Smolianinov (by LYUBENOVA, 2009).

Chemical analyses were made with samples (1 g) which are average for the respective phytomass fraction and the investigated communities. They have been dried to absolutely dry weight (85° C, 48 h) and grinded.

The soil samples were cleared from big roots, stones and other mixtures, dried, grinded and sift out through 2 mm sieve.

The pH was determined in soil suspense in relation soil: water - 1:2.5 (according to standards) using the potentiometric method (ISO 10390).

The total N was determined by Kjeldahl. The analytical determining of other elements was made on PERKIN-ELMER 310A spectrometer in the Institute of Biodiversity and Ecosystem Investigations after wet mineralization of samples according to the requirements of ISO 11466.

The ratio between the contents of investigated elements in the litter-fall fractions and between their contents in the mulch and litter-fall (acropetal and litter-mulch coefficient) were calculated (by LYUBENOVA, 2009).

Results and Discussion

Content of macro- and microelements in the soil and the mulch in studied communities

The content of macro- and microelements in soil and mulch of the beech communities are presented in Table 1. The soils are characterized with acid reaction, high

content of N, Fe and Mn and low content of Ca and K. The content of Zn and Pb is also high. The A/B ratio shows that the soils are the main reservoir of Pb and Fe, respectively about 200 and 82 times higher soil content of these elements than the mulch content. The soil content of Zn, Mn and N also is higher (respectively 5, 3 and 1,3 times) than the mulch content. The A/B ratio for Ca and K is the same.

According to the established average total amount (mg.kg^{-1} a.d.w.) of macroelements in the litter-fall the investigated fractions are arranged as follows: Acorns>Branches>Leaves>Cupolas (Table 2). According to the quantity proportions in the litter-fall the investigated elements are in the following order: N>Ca>K, i.e. N with 73.10^3 mg.kg^{-1} average sum was prevailing in the investigated fractions. The average content of N and K in the acorns, and of Ca – in the branches is biggest then the content of these elements in the other fractions (respectively 30.5.10^3, 4.1.10^3 and 7.5.10^3 mg.kg^{-1} a.d.w.).

The total sum of macroelements varies for the different investigated beech communities from 96.5.10^3 (I) to 110.9.10^3 mg.kg^{-1} a.d.w. (III). The sum of macroelements in the acorns and in the cupolas was more variable in comparison with the other fractions.

According to the calculated average sum of microelements (in mg.kg^{-1} a.d.w.) the investigated fractions are arranged as follows: Leaves > Acorns > Branches >Cupolas (Table 2).

According to the quantity proportions in the litter-fall the investigated microelements are in the following order: Mn>Fe>Zn>Pb, i.e. Mn with 2.1.10^3 mg.kg^{-1} average sum is prevailing in the investigated fractions. The contents of: Mn in the leaves (1.0.10^3 mg.kg^{-1} a.d.w.), Fe in the cupolas (0.6.10^3 mg.kg^{-1} a.d.w.) and Zn and Pb in the branches (0.05.10^3 and 1 mg.kg^{-1} a.d.w.) are biggest than the contents of these elements in the other fractions.

The total sum of microelements varies for the different investigated beech communities from 3.1.10^3 (III) to 4.4.10^3 mg.kg^{-1} a.d.w. (I). The microelements content varying in the litter – fall fractions of studied communities is better expressed in comparison with this of macroelements.

The average stores of investigated macro- and microelements in the litter - fall are 81.312 kg.ha^{-1} (Table 3) and in the mulch – 170.314 kg.ha^{-1} (Table 1).

Table. 1. Average storage of macro- and microelements in soil and mulch

Elements	Soil, kg.ha^{-1} (A)	Mulch, kg.ha^{-1} (B)	A/B
Ph	4.2	-	-
N	145.350	108.940	1,33
Ca	0.260	28.421	0,01
K	0.240	27.004	0,01
Pb	0.790	0.004	197,50
Zn	0.960	0.171	5,61
Mn	11.040	3.576	3,09
Fe	179.300	2.198	81,57

According to the established average total amount (mg.kg^{-1} a.d.w.) of macroelements in the litter-fall the investigated fractions are arranged as follows: Acorns>Branches>Leaves>Cupolas (Table 2). According to the quantity proportions in the litter-fall the investigated elements are in the following order: N>Ca>K, i.e. N with 73.10^3 mg.kg^{-1} average sum was prevailing in the investigated fractions. The average content of N and K in the acorns, and of Ca – in the branches is biggest then the content of these elements in the other fractions (respectively 30.5.10^3, 4.1.10^3 and 7.5.10^3 mg.kg^{-1} a.d.w.).

The total sum of macroelements varies for the different investigated beech communities from 96.5.10^3 (I) to 110.9.10^3 mg.kg^{-1} a.d.w. (III). The sum of macroelements in the acorns and in the cupolas was more variable in comparison with the other fractions.

According to the calculated average sum of microelements (in mg.kg^{-1} a.d.w.) the investigated fractions are arranged as follows: Leaves > Acorns > Branches >Cupolas (Table 2).

According to the quantity proportions in the litter-fall the investigated microelements are in the following order: Mn>Fe>Zn>Pb,

i.e. Mn with $2.1.10^3$ mg.kg^{-1} average sum is prevailing in the investigated fractions. The contents of: Mn in the leaves ($1.0.10^3$ mg.kg^{-1} a.d.w.), Fe in the cupolas ($0.6.10^3$ mg.kg^{-1} a.d.w.) and Zn and Pb in the branches ($0.05.10^3$ and 1 mg.kg^{-1} a.d.w.) are biggest than the contents of these elements in the other fractions.

The total sum of microelements varies for the different investigated beech communities from $3.1.10^3$ (III) to $4.4.10^3$ mg.kg^{-1} a.d.w. (I). The microelements content varying in the litter – fall fractions of studied communities is better expressed in comparison with this of macroelements.

The average stores of investigated macro- and microelements in the litter - fall are 81.312 kg.ha^{-1} (Table 3) and in the mulch – 170.314 kg.ha^{-1} (Table 1).

Table 2. Content of macro- and microelements (mg.kg^{-1} a.d.w.) in the litter – fall fractions

Macroelements						Microelements					
Plot/ Fraction	**Leaves**	**Branches**	**Acorns**	**Cupolas**	**Sum**	**Plot/ Fraction**	**Leaves**	**Branches**	**Acorns**	**Cupolas**	**Sum**
I						**I**					
N	13440.0	15520.0	28700.0	10670.0	**68330.0**	**Pb**	0.3	2.1	0.8	0.7	**3.9**
Ca	5299.3	6080.4	3966.4	1345.3	**16691.4**	**Zn**	23.2	75.0	15.9	9.8	**123.9**
K	2703.9	1834.0	3903.2	3065.9	**11507.0**	**Mn**	1310.3	516.5	698.3	164.0	**2689.1**
						Fe	162.3	372.4	282.5	756.0	**1573.2**
Sum	**21443.2**	**23434.4**	**36569.7**	**15081.2**	**96528.4**	**Sum**	**1496.1**	**966.0**	**997.6**	**930.5**	**4390.2**
II						**II**					
N	16210.0	14830.0	27900.0	16210.0	**75150.0**	**Pb**	0.2	0.2	0.6	0.7	**1.7**
Ca	4102.6	6488.1	2181.3	1377.3	**14149.3**	**Zn**	24.1	44.3	30.3	10.5	**109.2**
K	2922.1	1793.0	4574.9	3886.9	**89299.3**	**Mn**	1176.0	388.4	245.3	116.5	**1926.1**
						Fe	336.0	252.3	200.0	604.1	**1392.3**
Sum	**23234.7**	**23111.1**	**34656.2**	**21474.2**	**102476.2**	**Sum**	**1536.3**	**685.2**	**476.2**	**731.7**	**3429.4**
III						**III**					
N	12750.0	16490.0	34900.0	11360.0	**75500.0**	**Pb**	0.8	0.7	0.3	0.7	**2.5**
Ca	9037.6	9991.7	2530.4	1734.4	**23294.1**	**Zn**	23.4	42.9	15.6	11.2	**93.1**
K	2733.9	1909.4	3725.7	3734.8	**12103.7**	**Mn**	656.0	192.2	896.0	69.0	**1813.2**
						Fe	148.0	552.6	68.0	452.1	**1220.7**
Sum	**24521.5**	**28391.1**	**41156.1**	**16829.2**	**110897.8**	**Sum**	**828.2**	**788.4**	**979.9**	**532.9**	**3129.4**
Average						**Average**					
N	14133.3	15613.3	30500.0	12746.7	**72993.3**	**Pb**	0.4	1.0	0.6	0.7	**2.7**
Ca	6146.5	7520.1	2892.7	1485.6	**18044.9**	**Zn**	23.6	54.1	20.6	10.5	**108.8**
K	2786.6	1845.5	4067.9	3562.5	**12262.6**	**Mn**	1047.4	365.7	613.2	116.5	**2142.8**
						Fe	215.4	392.4	183.5	604.1	**1395.4**
Sum	**23066.5**	**24978.9**	**37460.6**	**17794.8**	**103300.8**	**Sum**	**1286.9**	**813.2**	**817.9**	**731.7**	**3649.7**

Table 3. Average stores of investigated elements in litter-fall, kg.ha^{-1}

Elements	Leaves	Branches	Acorns	Cupolas	Total	%
N	28.200	6.516	6.867	5.420	47.003	57.81
Ca	16.200	3.021	0.523	0.727	20.471	25.18
K	7.441	0.780	0.861	1.648	10.730	13.20
Pb	0.001	0.000	0.000	0.000	0.001	0.001
Zn	0.044	0.149	0.004	0.005	0.202	0.25
Mn	1.878	0.158	0.140	0.037	2.213	2.72
Fe	0.305	0.133	0.026	0.228	0.692	0.85
Total	54.069	10.757	8.421	8.065	81.312	100.00
%	66.50	13.23	10.36	9.92	100.00	

The percent participation of elements in litter-fall stores is shown on Fig. 1 and is preserved in the established stores of mulch. The distribution of the investigated elements in separate fractions is shown on Fig. 2. The content in the leaves fraction is the highest one – 66,50%, while in the other fractions it varies between 10 and 13%.

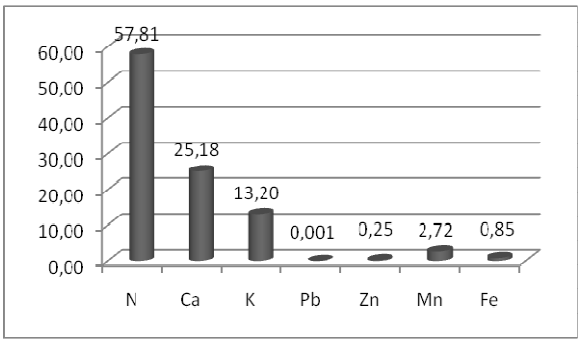

Fig. 1. Average participation of investigated elements in the litter - fall (%)

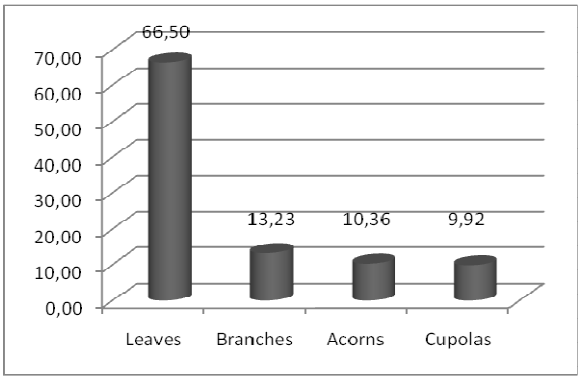

Fig.2. Average fraction distribution of investigated elements in the litter - fall (%)

The obtained results in this investigation are comparable with other investigations for Bulgarian beech forests.

Acropetal and litter-mulch coefficient

According to the acropetal coefficient N is accumulated mainly in the acorns, K – in the annual phytomass fractions and Ca – in the perennial fractions (Table 4). The leaves and the acorns accumulate Mn, and the cupolas - Fe. The investigated micro-elements have higher quantities in the perennial fractions as a whole.

Table 4. Acropetal and Litter-mulch coefficients

Elements/ Fractions	Acropetal coefficient			Litter-mulch coefficient
	Leaves	Acorns	Cupolas	
N	0.9	2.0	0.8	2,3
Ca	0.8	0.4	0.2	1,4
K	1.5	2.2	1.9	2,5
Pb	0.4	0.6	0.7	4,2
Zn	0.4	0.4	0.2	0,8
Mn	2.9	1.7	0.3	1,6
Fe	0.5	0.5	1.5	3,2

The turnover of the more investigated elements is inhibited. The litter – mulch coefficient vary from 1.6 (Mn) to 4.2 (Pb). The tendencies of accelerating of Zn and Ca turnover are established. The litter – mulch coefficients are 0.8 and 1.4 accordingly, i.e. corresponding to the intensive type of turnovers which are not typical for the broadleaved forest communities. The prevailing element is N followed by Ca and K.

Conclusions

The soils of the investigated beech communities are assessed as slight to average stored with nutrients. The content of Zn, Cu and Pb is below the level of maximum admissible concentrations for these elements in soils. The soil is the main reservoir of Pb and Fe while the mulch – of Ca and K. The soil content of Zn, Mn and N is also higher than the content in mulch.

The average stores of investigated elements in litter – fall are 81.312 kg.ha^{-1} and in mulch – 170.314 kg.ha^{-1}.

The acorn fraction is the richest with nitrogen, the annual fractions - with K and the perennial fractions – with Ca. The leaves and acorns accumulate Mn, and the cupolas - Fe. The biggest quantities of investigated microelements are measured in the leaves fraction.

According to the established capacity the biological turnover of investigated beech communities corresponds to the category of the average capacity turnovers (0,26 - 0,8 t.ha-^{1}) (LYUBENOVA, 2009).

According to the established chemistry the turnover belongs to the group of Na-Ca

turnovers with average mineral capacity which is characteristic for the average productive broadleaved forests (class of calcium-sub boreal turnovers) (LARCHER, 1978; LYUBENOVA, 2009). The prevailing of Ca over N in the phytomass is typical for this type of turnovers. For the investigated communities the N content prevailing have been observed and deviation of turnover to nitrogen - subtropical class of turnovers.

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