

MACRO- AND MICROELEMENTS CONTENT IN SPRUCE NEEDLES (*Picea abies* (L.) K a r s t.) IN A REGION WITH BACKGROUND LEVELS OF AIR POLLUTION

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Abstract. Foliar element analysis as a criterion for environment assessment was carried out in spruce ecosystems, included in the Monitoring of Forest Ecosystems in Bulgaria. The content of macro- and microelements was measured using an original approach. The site where the representative sample should be collected was determined on the basis of data statistical analysis. The obtained values for macro- and microelements may serve as a background for the investigated region. The comparative assessment of the data was made by taking into consideration the accepted limits in ICP – Forests (ECE/UN).

Keywords: macro- and microelements, spruce needles, statistical analysis.

AIMS AND BACKGROUND

The state evaluation of forest plantation is based most often on indices such as yield, height, thickness, etc. Under conditions of a moderate air pollution these indices may not always be used for evaluation of the reaction of wood plants. The defoliation and the changes of leaves' colour are under observation within the frames of the International Cooperative Program (ICP) "Evaluation and Monitoring of Air Pollution on Forest Ecosystems" (ICP-Forests-ECE) (Economic Commission of Europe)^{1,2}. The reaction of wood species towards the environmental conditions is checked by changes in colour, dimension, duration of vitality, foliation density of the crowns, chlorosis, necrosis and other visible peculiarities^{1,4}.

The existing investigations, related to estimation of empirical dependencies of defoliation and colour change upon the environmental factors, consider the wood plants on the one hand as components of the forest ecosystems and on the other hand – as individual organisms. This means that the investigations have been carried out on regional and functional levels. The experimental models involve different number of variables. Most of them comprise data for the content of mineral nutrition elements⁵⁻⁷.

The aim of the present study is to determine the content of macro- and microelements in the needles of a common spruce (*Picea abies* (L.) K a r s t.) in an area with background pollution levels and to apply these data for comparison with other areas where the pollution is on a regional or local level.

EXPERIMENTAL

The investigated objects comprise three spruce ecosystems in the central part of Rodopi mountains, in the vicinity of the "Rozhen" background station. The age of the plantations is 44, 85 and 87 years, respectively. They are situated at 1350, 1490 and 1600 m a.s.l., on steep slopes, viewing to east and west.

The samples for determination of N, P, K, Ca, Mg, Na, Fe, Mn, Zn, Cu and Pb content in spruce leaves are taken as follows: for 1 and 2 years old needles; separately from the 1st to the 10th and combined from the 2nd to the 4th and from the 5th to 8th bifurcation of the central stem; separately for eastern (E), western (W), northern (N) and southern (S) view and combined N+E and S+W. The chemical analyses were performed by means of methods, applied for analysis of leaf samples in the ICP-Forests-ECE program⁸. The statistical evaluation of the data was carried out by means of Statistika 7 and ArcView 3.0 software.

RESULTS AND DISCUSSION

The analysis of the determined macro- and microelements content shows that the average values for N, Mg, Fe and Na in 1 and 2 years old needles vary insignificantly. The amounts of P and K do not differ very much. A slight increase was observed for 1 year old needles. Significant differences between the quantities of Ca and Mn were obtained for 1 and 2 years old needles. The data for 2 years old needles were higher (Table 1).

The investigated elements in 1 and 2 years old needles can be ordered corresponding to their quantities as follows:

1 year old – N > K > Ca > P > Mg > Mn > Fe > Na;

2 years old – N > Ca > K > P > Mn > Mg > Fe > Na.

The place for taking a representative sample was determined by evaluating the percentage participation of the obtained average values at different bifurcation points (Table 2). The analysis shows that by 1 year old needles the maximum percentage of N, P, K, Mg and Mn is obtained at the 3rd bifurcation and in the case of Ca and Zn – at the 6th. By 2 years old needles maximum percentage of K, Mg, Mn, Zn and Cu was obtained at the 6th bifurcation and for N, P, Fe and Na – at the 3rd one.

Table 1. Macro- and microelements' content in spruce needle (mg/kg)

	Valid N	Mean	Median	Minimum	Maximum	Std.dev.	Std. err.	% varia- tion of std. err. depending on x
N-1 year old	54	14100.00	14300.00	10300.00	17400.00	1200.00	200.00	1.14
N-2 years old	53	13700.00	13900.00	9900.00	16200.00	1800.00	200.00	1.76
P-1 year old	54	1901.20	1920.00	850.00	2330.00	241.63	32.88	1.73
P-2 years old	53	1442.74	1420.00	1125.00	2060.00	178.03	24.45	1.69
K-1 year old	54	5693.52	5700.00	2300.00	8450.00	1575.64	214.42	3.77
K-2 years old	53	4748.11	4700.00	1850.00	11500.00	1759.53	241.69	5.09
Ca-1 year old	54	4186.11	4350.00	1550.00	7550.00	1316.13	179.10	4.28
Ca-2 years old	53	7577.36	7600.00	3950.00	14350.00	2313.60	317.80	4.19
Mg-1 year old	54	1144.63	1150.00	110.00	1850.00	274.98	37.42	3.27
Mg-2 years old	53	1134.91	1050.00	700.00	2200.00	322.79	44.34	3.91
Fe-1 year old	54	90.60	64.50	6.50	524.00	81.35	11.07	12.22
Fe-2 years old	53	94.58	74.00	45.50	394.00	59.59	8.19	8.65
Mn-1 year old	54	735.19	725.00	300.00	1400.00	211.83	28.83	3.92
Mn-2 years old	53	1203.77	1300.00	450.00	1800.00	354.62	48.71	4.05
Na-1 year old	54	18.56	13.75	7.00	56.50	12.16	1.65	8.92
Na-2 years old	53	18.92	15.00	7.00	65.00	12.69	1.74	9.21
Cu-1 year old	54	3.89	3.50	0.50	11.00	1.94	0.26	6.78
Cu-2 years old	53	2.78	3.00	0.50	9.00	1.69	0.23	8.33
Zn-1 year old	54	35.27	36.25	18.50	46.00	6.78	0.92	2.62
Zn-2 years old	53	33.42	31.50	15.50	54.50	11.04	1.52	4.54

The ratio between the mineral nutrition elements in leaves was also determined (Table 3). The analysis of distribution of the cumulative frequency of ratios between elements shows that the medians for 1 and 2 years old needles differ for N/P, N/Ca, K/Ca and Ca/Mg. The differences for N/Mg and K/Mg are insignificant. The most data, included in the database, used for median determination, are shifted to the minimum values. The N/Mg-ratio is an exception – about 60% of the results are distributed over a wider range and shifted to the maximum values.

Table 2. Limits of variation of the amount of macro- and microelements in spruce needles (*Picea abies* (L.) K a r s t.) and their participation (%) in the stem bifurcation

N		P		K		Ca		Mg											
1 year old	2 years old	1 year old	2 years old	1 year old	2 years old	1 year old	2 years old	1 year old	2 years old										
%																			
limits of variation \pm std. err. around the means																			
1.400-1.430		1.345-1.395		1870-1930		1420-1470		5500-5900											
								4000-4400											
								7350-7950											
								1110-1180											
								1090-1175											
whirls (in % share)																			
I	12.5	I	-	I	-	I	20.0	I	16.7	I	-	I	-	I	-	I	-	I	-
II	-	II	-	II	14.3	II	14.3	II	20.0	II	-	II	-	II	-	II	9.1	II	-
III	25.0	III	50.0	III	28.6	III	28.6	III	40.0	III	16.7	III	16.7	III	20.0	III	27.3	III	-
IV	12.5	IV	25.0	IV	-	IV	-	IV	-	IV	16.7	IV	-	IV	-	IV	-	IV	-
V	12.5	V	-	V	-	V	14.3	V	-	V	-	V	-	V	-	V	-	V	9.1
VI	12.5	VI	-	VI	14.3	VI	14.3	VI	20.0	VI	50.0	VI	50.0	VI	-	VI	27.3	VI	100.0
VII	-	VII	-	VII	14.3	VII	28.6	VII	-	VII	-	VII	-	VII	20.0	VII	18.2	VII	-
VIII	-	VIII	-	VIII	14.3	VIII	-	VIII	-	VIII	-	VIII	-	VIII	-	VIII	-	VIII	-
IX	12.5	IX	25.0	IX	-	IX	-	IX	-	IX	33.3	IX	20.0	IX	20.0	IX	-	IX	-
X	12.5	X	-	X	14.3	X	-	X	-	X	-	X	40.0	X	9.1	X	-	X	-

Fe		Mn		Na		Zn		Cu											
1 year old	2 years old	1 year old	2 years old	1 year old	2 years old	1 year old	2 years old	1 year old	2 years old										
%																			
limits of variation \pm std. err. around the means																			
74.7-82.1		141.5-155.6		158.4-165.5		268.7-289.0		18.7-24.6											
								23.6-26.2											
								35.7-37.7											
								40.7-44.1											
								4.10-4.52											
								2.92-3.31											
whirls (in % share)																			
I	-	I	-	I	-	I	-	I	-	I	-	I	-	I	-	I	-	I	7.7
II	-	II	-	II	-	II	14.3	II	-	II	11.1	II	-	II	-	II	-	II	-
III	-	III	54.5	III	50.0	III	16.7	III	14.3	III	30.0	III	22.2	III	-	III	-	III	15.4
IV	-	IV	-	IV	-	IV	16.7	IV	28.6	IV	10.0	IV	11.1	IV	20.0	IV	-	IV	-
V	33.3	V	-	V	-	V	-	V	-	V	10.0	V	-	V	20.0	V	-	V	7.7
VI	-	VI	27.3	VI	25.0	VI	50.0	VI	-	VI	20.0	VI	33.3	VI	20.0	VI	-	VI	38.5
VII	33.3	VII	18.2	VII	-	VII	-	VII	14.3	VII	-	VII	-	VII	20.0	VII	-	VII	7.7
VIII	-	VIII	-	VIII	-	VIII	16.7	VIII	-	VIII	10.0	VIII	11.1	VIII	-	VIII	-	VIII	-
IX	-	IX	-	IX	25.0	IX	-	IX	14.3	IX	10.0	IX	11.1	IX	20.0	IX	-	IX	15.4
X	33.3	X	-	X	-	X	-	X	14.3	X	10.0	X	-	X	-	X	-	X	7.7

Table 3. Average values of ratios between elements for 1 and 2 years old spruce needles

N/P		N/K		N/Ca		N/Mg		K/Ca		K/Mg		Ca/Mg	
1 year old	2 years old	1 year old	2 years old	1 year old	2 years old	1 year old	2 years old	1 year old	2 years old	1 year old	2 years old	1 year old	2 years old
7.61	9.61	2.72	3.22	3.78	1.93	15.11	12.69	1.46	0.64	6.21	4.32	4.30	6.82

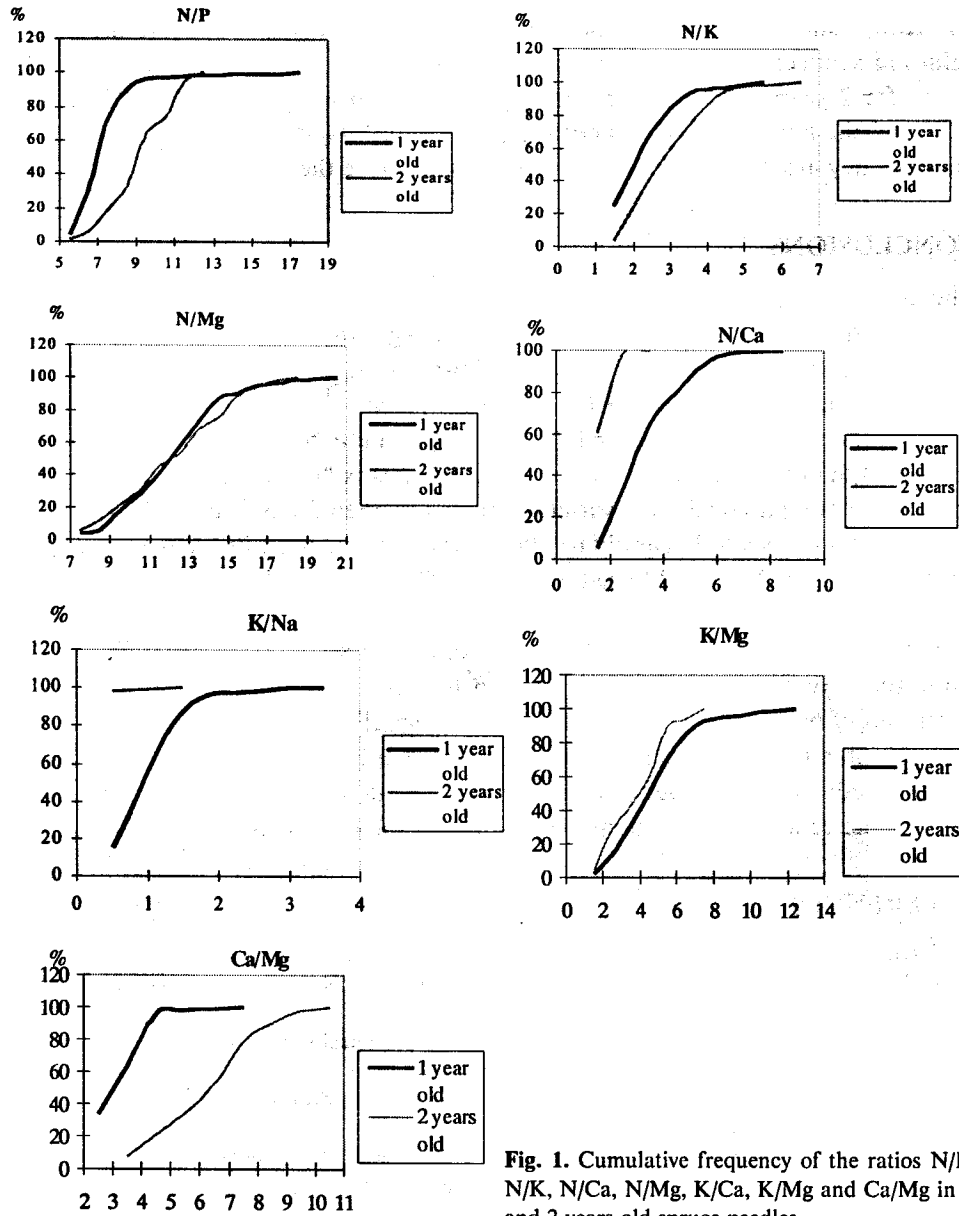


Fig. 1. Cumulative frequency of the ratios N/P, N/K, N/Ca, N/Mg, K/Ca, K/Mg and Ca/Mg in 1 and 2 years old spruce needles

The values obtained were compared using 3 ranges accepted in ICP-Forests-ECE for basic nutrient elements, the ratios between them⁸ and limit values, published in France⁵:

– for 1 and 2 years old needles all ratios are balanced according to the criteria of ICP-Forests-ECE⁸;

– for 1 year old needles the ratios N/Ca, K/Ca, Ca/Mg are balanced; N/P, N/Ca and K/Ca ratios are within and above the insufficiency limits; N/K, N/Mg and K/Mg ratios are above the optimum value (“excessive”), according to the limit values in France;

– for 2 years old needles all ratios are balanced according to ICP-Forests-ECE and the limit values in France – the ratios N/P, N/Mg and K/Mg. Closer to insufficiency are N/Ca and K/Ca, and Ca/Mg is above the optimum⁵.

CONCLUSIONS

The content of N, P, Ca, Mg, Fe, Mn, Na, Cu and Zn was established for the common spruce (*P. abies*) in an area with background levels of pollution. The quantitative order of the elements is as follows:

1 year old – N > K > Ca > P > Mg > Fe > Na;

2 years old – N > Ca > K > P > Mn > Mg > Fe > Na.

The quantity of Ca in the 2 years old needles is “excessive”, i.e. above the optimum if compared with the variation limits accepted for ICP-Forest-ECE. P is at the optimum level in 1 year old needles. The quantities of Fe in 1 and 2 years old needles and K in 2 years old needles are “insufficient” – at the lower limit.

The bifurcation of branches and the age of needles for taking of representative samples are established. 1 year old needles are suitable for analysis of P and K, while the 2 years old needles can be used for analysis of Ca, Fe and Mn. The quantities of N, Na, Cu, Mg and Zn are almost equal in 1 and 2 years old needles.

The obtained values may be applied for evaluation of mineral elements content in needle-shaped leaves of a common spruce in areas with regional and impact influence levels and stations where a background monitoring is applied.

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