Stability of Norway spruce (*Picea abies* [L.] Karst.) stands in the Beskid Śląski and Beskid Żywiecki Mts. from the aspect of their nutrition status

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ABSTRACT: The aim of the present research was to determine the stability of spruce stands in the areas of threat to forest stability in the Beskid Śląski and Beskid Żywiecki Mts. in the light of their nutrition. In 2002 samples of soil and of one- and two-year-old spruce needles were taken from sample plots representing various degrees of the threat of disintegration to stands. The following factors were determined in soil: reaction, exchangeable acidity, content of exchangeable cations: Ca^{2+}, Mg^{2+}, K^{+} and Na^{+} and the total content of macroelements: C, N, S, Ca, Mg, K and Na. Very small amounts of alkaline cations were found in the sorptive complex, present also in the chemical composition of spruce needles where most of the elements under analysis were in the lower zone of the optimum range or below the threshold values. The results of chemical analyses of spruce needles indicate differences in their content in various needle ages and a disturbance of their proportions, particularly of N, S, K to Ca and Mg, in the stands under serious threat of disintegration. They document the upsetting of mineral economy in spruce, which in turn may influence a greater susceptibility of this species to stress factors.

Keywords: Norway spruce; soil; needles; macroelements; stability; Beskid Śląski Mts.; Beskid Żywiecki Mts.; Southern Poland

The forests of the Beskids Mts., belonging to the Regional Directorate of State Forests in Katowice (RDLP Katowice), are characterized by a high proportion of spruce, particularly in their western and southern parts, which is mainly found in monocultures, is often of unknown origin and grows at unsuitable sites. In the Beskid Żywiecki Mts., this species takes up from about 75% to about 95% (on average 85%) of the area of the state forests. The highest proportion of spruce (over 90%) is found in the forest districts Ujsoły, Węgierska Górka and Wisła (RDLP Katowice 1996). The proportion of this species in the species composition increases with altitude and for this reason it is so significant locally also in other administrative units. Moreover, at high altitudes there are fewer mixed spruce stands and especially fewer other multi-species stands.

Until the early 1970s, these spruce stands were considered relatively stable. However, a rapid increase in the air pollution has resulted in tree damage, site contamination and forest biocoenosis impoverishment, which has diminished the immunity of these forests (Barszcz 1990; Barszcz et al. 1994; Staszewski et al. 1996; Bytnerowicz et al. 1999; Zwoliński 2003; Małek et al. 2005). In this situation, other anthropogenic and natural factors, both biotic and abiotic, have intensified their activity synergistically, increasing the scale of damage. The aim of the present study is to determine the stability of spruce stands in the areas of threat to forest stability in the light of the assessment of their nutrition.

Research area

According to the nature and forest regionalization of Poland (Trampler et al. 1990), the area of the present research is located in Carpathian Region

VIII, Province 1 of the Beskid Śląski Mts. and Beskid Mały Mts. and partly in Province 4 of the Beskid Żywiecki Mts.

According to Romer's division (1949), the area of the present research lies in the zone of mountainous climate in the region of the Beskid Śląski Mts. and Beskid Zachodni Mts. According to Hess (1965), it is situated in the moderately cold climate with a yearly average temperature 4–6°C and precipitation 1,020–1,150 mm and cold climatic zones with average temperature 2–4°C and precipitation 1,150–1,350 mm (Wilczek 1995). Prevailing winds are south-western and western; in summer also north-western. These winds gain the highest speed between November and March and can cause great damage to stands. The spatial distribution of rain and snowfall in the Beskid Śląski Mts. and in the western part of the Beskid Żywiecki Mts. depends on the location of the extended part of this region with relation to rain-bearing winds from NW and SW, which is the cause of higher amounts of rain and snowfall than in the other parts of the Beskidy Mts. at the same altitudes (Kozłowska-Szczęsna et al. 1983). Abundant snowfall may cause damage due to deposition of snow and ice on tree branches, while rainfall brings in considerable amounts of industrial pollution (Małek et al. 2005). The research area also witnesses a periodical lack of rainfall, which may weaken the vitality of spruce and hinder its regeneration (Modrzyński 1998).

The Beskid Śląski and Żywiecki Mts. are formed of the Godula nappe. Its constituent types of rock

Table 1. Characteristics of sample plots in the Beskid Śląski and Żywiecki Mts.

Plot No.	Forest District	Compartment	Division	Altitude (m a.s.l.)	Species composition	Age	Degree of damage to spruce crown	Type and subtype of soil
RS-1 (mixed stable stands)								
II	Ustroń	Brenna	111f	900	6NS, 3EB, 1SF	130	0.87	BRk
XVII	Węgierska Górka	Lipowa	117f	1,020	8EB, 2NS, s SM	150	0.89	BRk
XXI	Jeleśnia	Jeleśnia	180f	1,170	NS, s EB	190	0.97	BRk
RS-2 (stable stands – pure spruce stands)								
XIV	Bielsko	Szczyrk	148k	1,200	NS	110	0.69	BRk sł.b
XXII	Ujsoły	Ujsoły	17a	1,180	NS	150	1.13	BRk sł.b
RTH (stands under relative threat)								
I	Ustroń	Brenna	111a	900	NS	130	1.38	BRk
III	Ustroń	Brenna	112g	900	NS	130	1.35	BR sł.b
IV	Ustroń	Brenna	112h	900	NS	130	1.37	BRk sł.b
XVIII	Węgierska Górka	Lipowa	118b	1,020	NS	110	1.48	BRk sł.b
XX	Jeleśnia	Jeleśnia	212d	1,180	NS, s EB	120	1.39	BRk sł.b
XXIII	Ujsoły	Ujsoły	2a	1,150	NS	80	1.47	BRk sil.b
STH (stands under serious threat)								
VIII	Wisła	Wisła	142c	1,075	NS	100	1.93	BRk sil.b
IX	Bielsko	Szczyrk	149i	1,125	NS	100	1.71	BRk sil.b
XV	Węgierska Górka	Lipowa	117b	1,200	NS	80	1.84	BRk sil.b
XVI	Węgierska Górka	Lipowa	117b	1,200	NS	80	1.89	BRk sil.b

BRk – brown soil, k – acid, sł.b – light podzolization, sil.b – high podzolization; NS – Norway spruce, EB – European beech, SF – silver fir, SM – sycamore maple, s – single

(Maciaszek et al. 2000) are quartz-silicate and carbonate-silicate. At high altitudes, the most important base of soil is the quartz-silicate series, consisting of conglomerates and coarse-grain types of sandstones (mainly the Magura and Istebna ones), which produce sandy or sand-clayey acid rock mantle – the base of podzolic soils. This series is typical of coniferous sites. The rock mantle of these deposits is rather stony. At high altitudes, especially on mountain tops and ridges, the rock mantle is coarse-stony. The water conditions, especially on tops and ridges and on steep southern slopes, are worse for demanding spruce and its saplings (Modrzyński 1998) than the conditions on the mantle rock of marl-silicate deposits. The latter create more favourable water conditions for plants, especially in areas with small slope reduction; and they form a substrate for various types of brown soils. Under homogeneous spruce forests, they have been variously degraded or have become podzolic (Maciaszek et al. 2000).

MATERIAL AND METHODS

Detailed investigations were carried out on the authors' own permanent sample plots, set up in homogeneous spruce stands with the taper of 0.6–0.7 and with different degrees of disintegration threat as well as in monocultures where disintegration was already complete. According to the degree of degradation threat, the following groups of sample plots were distinguished:

- RS – relatively stable stands (RS-1 – mixed stands with spruce – plots No. II, XVII and XXI; – RS-2 – pure spruce stands – plots No. XIV and XXII with the degree of crown damage within 0.69 and 1.13), probably of native origin, growing there for many generations;
- RTH – stands relatively threatened with degradation (plots No. I, III, IV, XVIII, XX, and XXIII with the degree of crown damage within 1.35–1.48), spruce monocultures in the first generation;
- STH – stands seriously threatened with degradation (plots No. VIII, IX and XV, with the degree of crown damage within 1.71–1.93), consisting of spruce monocultures in the second generation, with occasional occurrence of beech, mountain ash and sycamore. The degree of crown damage was established on each plot from three average trees cut according to: changes in the length, shape and colour of needles, number of needles per shoot and number of needle ages and defoliation, changes in tree vitality, height increment and canopy shape. The administrative divisions and the characteristics of site and stand conditions of these sample plots are presented in Table 1.

In September 2002, mixed soil samples were taken for chemical analysis from each plot, from the distinguished horizons (from 5 subplots). One- and two-year-old needles were collected from the 7th verticil of mature spruce trees of Kraft's class II.

Air-dried soil samples were passed through a sieve with the mesh diameter of 2 mm in order to determine:

- the reaction, using the potentiometric method in H_2O and in 1M KCl; (H) – exchangeable acidity in 1M $HCOONH_4$; (S_H) – the content of exchangeable cations: Ca^{2+}, Mg^{2+}, K^+ and Na^+ – by means of the ASA method, using 1M NH_4Ac as an extract. The sum of exchangeable cations (T_H), sorptive capacity (V_H) and the proportion of alkaline cations were also calculated;
- the total content of C, N, S (by means of LECO CNS-2000) and of Ca, Mg, K and Na by the ASA method in organic soil layers – after wet mineralization in a mixture of the acids HNO_3 and $HClO_4$ at a 1:4 ratio and in mineral soil layers – after wet mineralization in 60% $HClO_4$.

The total content of the same elements as in soil samples was determined in spruce needles after their drying at the temperature of 60°C, their grinding and wet mineralization in a mixture of the acids HNO_3 and $HClO_4$ at a 1:4 ratio.

The results were processed in the Statistica 6.0 program (Łomnicki 2002; Rutkowska, Socha 2003). Comparing the average values of the mean concentrations of elements in four groups of spruce stands, i.e. RS-1, RS-2, RTH and STH and between plots, the following tools were used: Student's *t*-test and in the case of the absence of normal distribution Mann-Whitney *U*-test with a statistically significant reaction of an analyzed feature at the significance level $\alpha = 0.05$.

RESULTS AND DISCUSSION

Assessment of the degree of threat to spruce stands and of soil degradation

The analysis of soils on the sample plots showed that under the stands of the RS-1 plot there are acid brown soils, relatively the richest in Mg content (similarly like the soils of the RS-2 group), with relatively small deformation shown e.g. by a thinner layer of humus than under the remaining stands, sometimes by a disappearance of the AB horizon and by the occurrence of indistinct AE horizon. Under the stands of the RS-2 subgroup there are acid brown slightly podzolic soils

Table 2. Average values of reaction and sorptive properties of soils in sample plot groups in the Beskid Śląski and Żywiecki Mts.

Plot groups	Horizon	pH		H	Na	K	Ca	Mg	S_H	T_H	V_H
		H_2O	KCl	(me/100g)							(%)
RS-1	AB, AE	3.68	2.96	30.82	0.11	0.17	0.66	0.26	1.12	31.94	3.67
	Bbr	4.23	3.72	17.64	0.09	0.07	1.32	0.11	0.70	18.34	4.00
	BfeC	4.40	4.13	12.93	0.06	0.04	1.36	0.06	0.51	13.44	3.78
RS-2	AE	3.72	2.89	22.09	0.12	0.17	0.71	0.23	1.08	23.17	5.08
	Bhfe	3.95	3.26	26.50	0.08	0.13	0.64	0.13	0.88	27.38	3.38
	BfeC	4.39	4.01	17.60	0.09	0.13	0.69	0.07	0.65	18.24	3.69
RTH	AB, AE	3.63	3.00	22.63	0.09	0.10	0.94	0.26	1.24	23.88	5.14
	BbrBfe, Bbr	4.04	3.34	17.85	0.09	0.06	1.48	0.10	0.68	18.53	3.96
	BfeC, BC	4.30	3.53	11.60	0.06	0.05	1.13	0.09	0.68	12.28	5.75
STH	AEes	3.54	2.91	26.76	0.09	0.24	0.58	0.21	1.12	27.88	4.00
	BfeBbr	3.86	3.16	24.00	0.13	0.17	0.41	0.10	0.80	24.80	3.25
	BfeC	3.99	3.54	16.88	0.09	0.13	0.44	0.07	0.73	17.60	4.51

SH – sum of content of exchangeable cations: Ca^{2+}, Mg^{2+}, K^+, Na^+; T_H – sum of exchangeable cations; V_H – sorptive capacity

with symptoms of the washing out of the humus layer. Under the stands which are slightly threatened with degradation (RTH) there are acid brown soils as well, but leached to a lesser extent than in the next group because of a short period of the spruce activity (in the first generation). Under the spruce stands strongly threatened with disintegration (STH), there are acid brown strongly podzolic soils (hence the presence of the AEes and BfeBbr horizons), whose transformation – considering the further activity of spruce (in its next generation) – may lead to the occurrence of proper podzolic soils. Similar processes in this region were described by Maciaszek et al. (2000). The intensification of podzolization processes under spruce stands was also reported by Schmidt-Vogt (1986, 1989). According to the authors mentioned above, these processes are related to the transformation of organic deposition towards humus and to lowering the reaction and leaching of easily accessible calcium, magnesium and potassium out of the surface layers of soil (Tables 2 and 3).

The analyzed soils are shallow at high altitudes and moderately deep at lower altitudes, mostly medium-skeletal in their organic-mineral layers, and strongly or very strongly skeletal (stony) in deeper layers. In their granulometric composition these are mostly medium and light clays and sometimes heavy and light clayey sands.

As concerns the reaction, the analyzed soils (Table 2) can be described as strongly acid, generally without large differences between the particular groups of plots. It must be noted that the pH of these soils does not reach the optimum range for spruce but is closer to the lowest values. It results from the acid reaction of the organic deposition of spruce and from an increased process of retaining the acid precipitation in the tree crowns of this species and, as a consequence, from washing out aluminium and alkaline cations, which lowers the reaction and is particularly unfavourable in poor soil conditions (Małek 2004; Małek et al. 2005). This fact may be proved by a low level of alkaline cations and a small degree of saturation of the sorptive complex with them (Table 2), smaller than the values quoted by Maciaszek et al. (2000) for the lower forest zone in the Beskid Żywiecki Mts.

The degree of degradation of the analyzed soils and disturbance in the normal distribution of elements may also be revealed by the total content of potassium and magnesium, increasing when deeper into the profiles (while the exchangeable form of magnesium diminishes), and rapidly decreasing content of calcium (Tables 2 and 3). A similar distribution of the forms of magnesium and a low content of calcium, especially in the deeper layers of the profiles of brown soils in the Bieszczady Mts., were observed by Woźniak (1996). The data indicate that in the soils under stands of the groups RTH and STH the amounts of these elements are lower by about 20–25% than under stable stands (RS).

The content of sulphur in the organic layers of soils at the analyzed altitudes is higher in both regions than previously reported by Barszcz (1990) in the lower forest zone of the Beskid Śląski Mts. This proves a greater load of sulphur in forests at high altitudes, despite a considerable general decrease of its presence in the atmosphere in recent years.

Table 3. Average values of total concentrations of selected elements in soils of sample plot groups in the Beskid Śląski and Żywiecki Mts.

Plot groups	Horizon	S	C	N	C/N	Na	K	Ca	Mg
		(%)				(%)			
RS-1	O	0.180	38.93	1.606	24	0.008	0.188	0.171	0.098
	AB, AE	0.055	7.52	0.413	18	0.015	0.465	0.015	0.236
	Bbr	0.034	3.33	0.195	17	0.011	0.506	0.007	0.332
	BfeC	0.031	2.93	0.159	18	0.010	0.697	0.006	0.501
RS-2	O	0.185	43.40	1.669	26	0.006	0.129	0.186	0.066
	AE	0.043	5.93	0.357	17	0.021	0.649	0.014	0.282
	Bhfe	0.039	5.24	0.292	18	0.024	0.729	0.011	0.323
	BfeC	0.029	2.68	0.142	19	0.026	0.903	0.012	0.501
RTH	O	0.182	38.69	1.610	24	0.007	0.139	0.216	0.081
	AB, AE	0.040	6.25	0.311	20	0.008	0.325	0.013	0.193
	BbrBfe, Bbr	0.029	4.31	0.209	21	0.010	0.378	0.008	0.269
	BfeC, BC	0.020	2.56	0.133	19	0.009	0.431	0.012	0.342
STH	O	0.198	41.42	1.706	24	0.013	0.182	0.173	0.078
	AEes	0.046	6.82	0.384	18	0.026	0.709	0.017	0.207
	BfeBbr	0.034	4.94	0.277	17	0.027	0.819	0.017	0.288
	BfeC	0.031	3.03	0.176	17	0.028	0.898	0.010	0.338

Chemical composition of spruce needles

According to Cape et al. (1990) and Arndt et al. (1987) the content of nitrogen in tree needles was deficient and according to Zöttl (1990) it was moderately deficient while the content of sulphur was approaching the optimum (Cape et al. 1990). In the light of the data presented by Arndt et al. (1987) and Zöttl (1990), the content of potassium in needles was normal; when compared to the data of Cape et al. (1990), it was slightly deficient. In the conditions of potassium deficiency, height and diameter growth of trees is suppressed, the root system develops poorly and only partial tissue lignification takes place (Table 4).

According to the standards set by Cape et al. (1990), the content of calcium in the second year of needles in all the analyzed groups of stands is on the decrease for the growth of trees and, in the first year also in the group of stands strongly threatened with disintegration (STH). However, according to the threshold values given by Arndt et al. (1987) and Zöttl (1990), the content of this element is normal except spruce needles in STH stands which grow at extreme high altitudes. In the light of the threshold values (Cape et al. 1990), magnesium in tree needles was on the decrease only in the group of stands which were seriously threatened with disintegration (RTH). A considerable, statistically significant decrease in the content of calcium and magnesium as compared with the other groups of elements under analysis was noted only in one-year-old needles of spruce which was highly threatened with disintegration (STH) (Table 4). The deficiency of Ca and Mg in spruce needles in the research area results from too a small content of these elements in soil (cf. Tables 2 and 3). According to Heinsdorf et al. (1988), in the case of calcium and magnesium deficiency in needles, there may occur damage to spruce stands in higher mountain locations. As revealed by research conducted in spruce stands in the uplands of Central Germany (Roberts et al. 1989), the deficit of magnesium and calcium is influenced by their leaching from soil by acid rains and their intake with wood. This phenomenon has recently been more and more intensive, especially together with the accompanying increase in the deposition of nitrogen, and particularly of ions NH_4^+ (Małek 2004; Małek et al. 2005). Moreover, an increase in the magnesium deficiency may be stimulated by water shortage and by weaker development of the root system (Roberts et al. 1989).

Research of various authors (Nihlgard 1989; Ranger et al. 1992; Małek 2002) indicates that the deficiency of nutrients may also influence their translocation from older needles to younger ones. But it was confirmed only for calcium in the area under present research.

Table 4. Average values of total concentrations of selected elements in spruce needles on sample plots in the Beskid Śląski and Żywiecki Mts. (bold: statistically significant at a level α = 0.05 – STH to any other stands)

Plot groups	N	S	K	Ca	Mg	S:Ca	S:M	N:Ca	N:M	K:Ca	K:M
	(%)										
One-year-old needles											
RS-1	1.254	0.138	0.681	0.320	0.065	0.34	1.66	3.92	19.25	1.51	7.38
RS-2	1.229	0.103	0.390	0.300	0.058	0.34	1.76	4.09	21.11	1.30	6.70
RTH	1.234	0.120	0.520	0.324	0.067	0.37	1.80	3.81	18.50	1.61	7.80
STH	1.167	0.102	0.497	**0.241**	**0.040**	**0.42**	**2.57**	**4.84**	**29.52**	**2.06**	**12.57**
Two-years-old needles											
RS-1	1.326	0.116	0.684	0.205	0.064	0.57	1.83	6.47	20.83	3.33	10.74
RS-2	1.332	0.094	0.388	0.195	0.069	0.48	1.35	6.82	19.28	1.99	5.62
RTH	1.429	0.121	0.580	0.253	0.085	0.48	1.42	5.64	16.81	2.29	6.82
STH	1.250	0.108	0.460	0.187	0.062	0.58	1.73	6.70	20.04	2.46	7.37

For the proper nutritional status of trees, the ratios of the particular nutrients are also important. On the basis of the parameters proposed by Cape et al. (1990), it can generally be stated that in one-year-old spruce needles in the research area the ratios of S:Ca and K:Ca are disturbed in the STH stand group while in two-years-old spruce needles the ratios S:Ca and N:Ca are disturbed in all the stand groups under analysis and in most cases also K:Ca. In the ratios S:Ca and S:Mg in one-year-old spruce needles the disturbance becomes more profound with an increase in the degree of the threat of disintegration to stands. The greatest statistically significant disturbances of the relations of S, N and K to Ca and Mg were noted in one-year-old spruce needles in the stands which are highly threatened with disintegration (STH) (Table 4).

SUMMARIZATION AND CONCLUSIONS

The degree of threat to spruce stands and the degree of degradation of their sites depends on the origin, species composition, period of the influence of spruce on soil as well as on the negative influence of various synergistically interacting natural and anthropogenic factors which lead to their disintegration in different time periods, particularly at high altitudes.

In acid brown soils, where the spruce stands under analysis grow, the process of podzolization is taking place towards the formation of podzolic soils, intensifying with the susceptibility of these stands to disintegration and taking place along with the negative impact of industrial air pollution. It is visible in very small amounts of alkaline cations in the sorptive complex of soils, which in turn is reflected in the chemical composition of spruce needles where most of the analyzed elements are in the lower zone of the optimum range or below the threshold values. Despite a considerable decrease in the emission of sulphur to the atmosphere in recent years, the soils of the research area show a higher degree of its presence in forests at high altitudes than in the lower forest zone.

Differences in the content of macroelements in the ages of needles under analysis indicate unfavourable changes of their ratios which document disturbances in mineral economy in spruce growing in the area in question. In the case of the ratios S:Ca and S:Mg in one-year-old spruce needles, the disturbance becomes more profound with an increase in the degree of the threat of disintegration to stands. Disturbances of the relations of N and K to Ca and Mg also occur in the stands which are highly threatened with disintegration (STH). Hence, it is necessary to undertake the revitalization of sites in order to improve the growth conditions of spruce and to maintain its presence at higher altitudes in the Beskid Śląski and Żywiecki Mts.

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References

ARNDT U., NOBEL W., SCHWEIZER B., 1987. Bioindikatoren Möglichkeiten, Grenzen und neue Erkenntnisse. Stuttgart, Ulmer Verlag.

BARSZCZ J., SZUJECKI A.,1990. Siarka i metale ciężkie w glebach i roślinach Lasów Beskidu Śląskiego. In: Ocena zasobów leśnych w ekosystemach zagrożonych. Semin. Naukowe w Jedlni k/Radomia, 22–23 January 1989. Warszawa, Wydawnictwo SGGW-AR, Prace CPBP, *14*: 7–31.

BARSZCZ J., KOZAK J., WIDACKI W., 1994. The forest degradation in the Silesian Beskid Mountains (Karpaty Mountains), Poland. In: Proceedings GIS 94 The Worlds Premier Symposium on GIS for Natural Resources, Environmental and Land Information Management, Volume 2, February 21–24, 1994. Vancouver, Polaris Conference Inc.: 895–900.

BYTNEROWICZ A., GODZIK S., POTH M., ANDERSON I., SZDZUJ J., TOBIAS C., MACKO S., KUBIESA P., STASZEWSKI T., FENN M., 1999. Chemical composition of air, soil and vegetation in forests of the Silesian Beskid Mountains, Poland. Water, Air, and Soil Pollution, *116*: 141–150.

CAPE J.N., FREER-SMITH P.H., PATERSON I.S., PARKINSON J.A., WOLFENDEN J., 1990. The nutritional status of *Picea abies* (L.) Karst. across Europe and implications for forest decline. Trees, *4*: 211–224.

HEINSDORF D., KRAUSS H.H., HIPPELI P., 1988. Ernährungs- und bodenkundliche Untersuchungen in Fichtenbeständen des mittleren ThüringerWalds unter Berücksichtigung der in den letzten Jahren aufgetretenen Umweltbelastungen. Beiträge für die Forstwirtschaft, *24*: 74–85.

HESS M., 1965. Piętra klimatyczne w polskich Karpatach Zachodnich. Zeszyty Naukowe Uniwersytetu Jagiellońskiego, *140*, Prace Geograficzne: 11.

KOZŁOWSKA-SZCZĘSNA T., KRAWCZYK B., BŁAŻEJCZYK K., 1983. Warunki bioklimatyczne południowego obrzeża Górnośląskiego Okręgu Przemysłowego. Geografia, *7*: 7–67.

ŁOMNICKI A., 2002. Wprowadzenie do statystyki dla przyrodników. Warszawa, PWN.

MACIASZEK W., GRUBA P., JANUSZEK K., LASOTA J., WANIC T., ZWYDAK M., 2000. Degradacja i regradacja gleb pod wpływem gospodarki leśnej na terenie Żywiecczyzny. Krakow, Wydawnictwo AR w Krakowie.

MAŁEK S., 2002. The importance of litterfall and needle nutrients in circulation of elements and sustaining long-term productivity – example from different age classes of Istebna spruce stands in the Potok Dupnianski catchment. Southern Poland, Reports in Ecology and Environmental Engineering, *1*: 124–130.

MAŁEK S., 2004. Effect of the age of spruce stands on the balance of elements in the Potok Dupniański catchment. Dendrobiology, *51*: 65–70.

MAŁEK S., MARTINSON L., SVERDRUP H., 2005. Modelling future soil chemistry at a highly polluted forest site at Istebna in Southern Poland using the "SAFE" model. Environmental Pollution, *137*: 568–573.

MODRZYŃSKI J., 1998. Zarys ekologii świerka. In: Biologia świerka pospolitego. Poznań, PAN, Instytut Ddendrologii, Bogucki Wydawnictwo Naukowe: 303–359.

NIHLGARD B., 1989. Nutrient and structural dynamics of conifer needles in south Sweden 1985–1987. Meddelanden Norsk Institut Skogforskning, *42*: 157–165.

RANGER J., CUIRIN G., BOUCHON J., COLIN M., GELHAYE D., MOHAMED AHMED D., 1992. Biomasse et mineralomasse d'une plantation d'epicéa commun (*Picea abies* Karst.) de forte production dans les Vosges (France). Annales des Sciences Forestières, *49*: 651–668.

RDLP Katowice, 1996. Lasy i gospodarka. SAWIART.

ROBERTS T.M., SKEFFINGTON R.A., BLANK L.W., 1989. Causes of spruce decline in Europe. Forestry (London), *62*: 179–222.

ROMER E., 1949. Regiony klimatyczne Polski. Prace Wrocławskiego Towarystwa Naukowego, Seria B: 16.

RUTKOWSKA L., SOCHA J., 2003. Statystyczna analiza danych z wykorzystaniem programu Statistica. Mpis. Zakład Dendrometrii. Krakow, Wydział Leśny, AR w Krakowie.

SCHMIDT-VOGT H., 1986. Die Fichte. B II/1: Wachstum, Züchtung, Boden, Umwelt, Holz. Hamburg und Berlin, Paul Parey. (In Czech)

SCHMIDT-VOGT H., 1989. Die Fichte. B II/2 – Krankheiten, Schäden, Fichtensterben. Hamburg und Berlin, Paul Parey.

STASZEWSKI T., GODZIK S., SZDZUJ J., 1996. Monitoring spruce stands in Brenna and Salmopol pass in the Polish part of the Beskids. In: Zpravodaj Beskydy Vliv imisí na lesy a lesní hospodářství Beskyd. Brno, MZLU, *8*: 13–18. (In Czech)

TRAMPLER T., KLICZKOWSKA A., DMYTERKO E., SIERPIŃSKA A., 1990. Regionalizacja przyrodniczo-leśna na podstawach ekologiczno-fitosocjologicznych. Warszawa, PWRiL.

WILCZEK Z., 1995. Zespoły leśne Beskidu Śląskiego i zachodniej części Beskidu Żywieckiego. Katowice, Wydawnictwo Uniwersytetu Śląskiego.

WOŹNIAK L., 1996. Biogenne pierwiastki metaliczne i niektóre toksyczne metale ciężkie w glebach i roślinach Bieszczadów. Zeszyty Naukowe AR w Krakowie, Rozprawy Habilitacyjne, Nr. 216.

Zasady Hodowli Lasu, 2003. OR-W LP w Bedoniu.

ZÖTTL H.W., 1990. Ernährung und Düngung der Fichte. Forstwissenschaftliches Centralblatt, *109*: 130–137.

ZWOLIŃSKI J., 2003. Ocena zagrożenia lasów świerkowych w Beskidzie Śląskim przez zanieczyszczenia powietrza atmosferycznego. Prace Instytutu Badawczego Leśnictwa, Seria A, *1*: 53–68.

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Stabilita porostů smrku (*Picea abies* [L.] Karst.) v oblasti Beskid Śląski a Beskid Żywiecki z hlediska jejich minerální výživy

ABSTRAKT: Cílem současného výzkumu je vyhodnotit stabilitu smrkových porostů v poškozovaných oblastech Beskid Śląski a Beskid Żywiecki z hlediska jejich výživy. V roce 2002 byly odebrány vzorky půdy a prvního a druhého ročníku jehličí na plochách reprezentujících různé stupně poškození. U půdních vzorků byla stanovena jejich kyselost, výměnná acidita, obsahy výměnných prvků: Ca^{2+}, Mg^{2+}, K^{+}, Na^{+} a celkový obsah makroprvků: C, N, S, Ca, Mg, K, Na. V sorpčním komplexu byly zjištěny velmi nízké obsahy bazických kationtů. To platilo i pro chemické složení jehličí, kde se většina analyzovaných prvků pohybovala buď ve spodním rozsahu optimálního stavu, nebo pod hranicí deficience. Výsledky ukázaly odlišné obsahy prvků v různě starých jehlicích a u silně poškozených porostů také narušení vzájemného poměru prvků – zejména N, S a K – vzhledem k Ca a Mg. Výsledky dokládají narušení rovnováhy minerální výživy porostů, což může následně ovlivňovat jejich vyšší citlivost k ostatním stresovým faktorům.

Klíčová slova: smrk ztepilý; půda; jehlice; makroprvky; stabilita; Beskid Śląski; Beskid Żywiecki; jižní Polsko

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