Air pollution load and stand nutrition in the Forest District Jablunkov, part Nýdek

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ABSTRACT: Concentrations of air pollutants measured by passive samplers, atmospheric deposition to forest ecosystems, soil water chemistry, nutrient content in the soil and foliage were all measured within a study of the causes of forest decline in Nýdek Forest Range, Jablunkov Forest District (Silesian Beskids). Declining Norway spruce stands are situated in a region of historically high air pollution load, mainly from the Třinec and Ostrava agglomeration. Air pollution significantly decreased in the second half of the 1990s. Forest soils showing the insufficiency of main nutrients remain today as the main factor affecting the forest vitality. The situation in the soil is subsequently reflected in the nutrition level of the assimilation tissues. Simultaneous effects of other stressors (e.g. biotic, meteorological ones) can support a sudden worsening of the stand health and cause serious damage.

Keywords: deposition; stand nutrition; spruce decline; Silesian Beskids

Intensive development of industry in the 1960s and 1970s had a negative impact on forest ecosystems due to a high air pollution load, mainly of sulphur dioxide (Lomský et al. 2002; Hrdlička 1990). The region of the Silesian Beskids is situated in the direction of prevailing winds from Třinec and Ostrava agglomeration with heavy industry concentration. Air pollution decreased in the 1990s, when desulphurizing devices were applied by pollution producers, and also a great part of the industrial production was decreased. The state of the atmosphere was improved significantly during the 1990s (ČHMÚ 2001), however, long-term acidification in the soil is still an important cause of forest decline and decay. During the last 5 years, a slight increase in NO_2 and SO_2 has been recorded again, and especially it is pollution by dust particles (PM_{10}) that has increased. In the Moravia-Silesian Region, the most significant increase in PM_{10} and NO_2 in the Czech Republic was recorded (ČHMÚ 2006). It is clear that the present level of deposition in forest stands can have negative impacts on their vitality (Malek et al. 2006).

This is a problem in the whole Beskids region, including also their Polish and Slovak part. In the Polish part of the Silesian Beskids, low content of the basic elements, low pH, and mainly low content of calcium and magnesium were found. This affects the nutrition of needles where an acute insufficiency of Ca, Mg and P was recorded (Zwoliński 2003). Increased deposition of nitrogen and sulphur in forest ecosystems in the Silesian Beskids, and deficiency of magnesium and phosphorus in needles were also detected by Bytnerowicz et al. (1999). In Slovakia, similar problems were reported from the Kysuca and Orava region (Istoňa 1989). The decline, observed in the Jablunkov region, is different in many aspects from the current state in the Hercynian mountains in the Czech Republic (Krušné hory Mts., Jizerské hory Mts., Orlické hory Mts.). It gives to the Silesian Beskids region special consideration.

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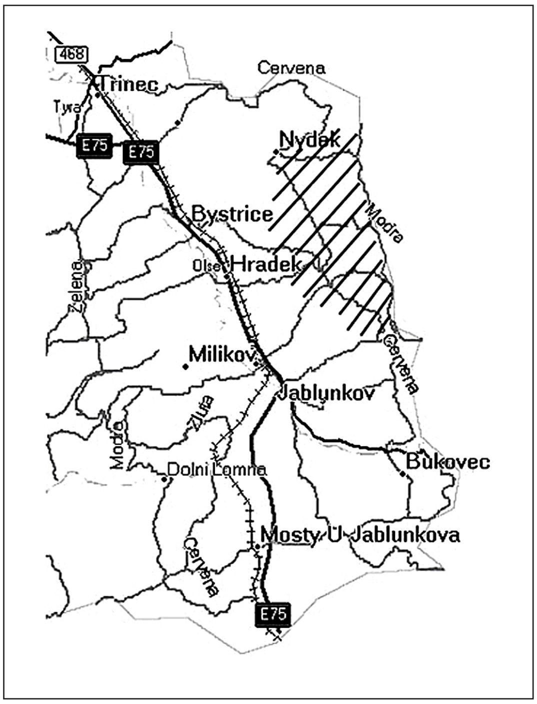

Fig. 1. The area of interest (shaded)

The paper presents the first results of the study aimed at complex causes of the decline of Norway spruce (*Picea abies* [L.] Karst.) stands in Jablunkov, with a focus on air pollution load, and the state of forest soil and nutrition of forest stands.

MATERIAL AND METHODS

The area of interest is located in the Silesian Beskids in Jablunkov Forest District – Nýdek Forest Range (Fig. 1). Declining stands of Norway spruce (*Picea abies* [L.] Karst.) are located in the 4th –5th altitudinal zone (550–700 m above sea level). All age classes of this species are affected.

The level of air pollution is measured with passive dosimeters, a UK Gradko Ltd. product. Concentrations of NO_2, SO_2 and ground ozone (O_3) are measured. The filters are placed 1.5 m above the soil surface, in an open area, and close to the most damaged locality. They are changed in four-week intervals. The analysis of dosimeters and the calculation of concentrations are done by the producer.

The deposition of acidifying and eutrophicating substances, basic cations, fluorides and chlorides in forest and forest soil are monitored in the open area (bulk deposition) and under the canopy (throughfall). In the European beech (*Fagus sylvatica* L.) stand, stemflow is also measured. In the open area, two funnels 23.3 cm in diameter are used. There are three polyethylene gutters, 0.2 m wide and 2 m long, in the stand. To measure stemflow, two trees were selected and spiral-type stemflow collectors were installed on them. The captured precipitation is stored in containers that are placed in a covered soil pit, under the surface, in order to ensure stable temperature and prevent the growth of algae.

To collect gravitational water, polyethylene zero-tension lysimeters are used, placed under the humus horizon (LH) at the depth of 30 cm (L30), and in the European beech stand also at the depth of 50 cm (L50) of mineral soil. Two rectangular lysimeters 40 × 15 cm, are located at each depth.

Samples of deposition and soil solution have been collected since April 2006 in ten-day intervals. Quarterly samples are analyzed, pooled in proportion to the volume determined.

Pre-treatment and analyses are done in the Forestry and Game Management Research Institute (FGMRI) laboratory, using the Manual of ICP Forests Program (UNECE 2006) method.

The nutrition level of the Norway spruce stands was evaluated from the results of needle analyses. Samples to be analyzed were taken from five trees by the climbing method in a mature stand, and with the use of telescopic scissors from ten trees in young stands. Samples were taken in 2004–2006 from the upper third of the crown which is exposed to the sun. The mixed stand samples are analyzed, with the current-year needles and one year old needles being analyzed separately. The evaluation is based on results from 11 forest stands within the area of interest.

The nutrient content in the soil was determined in the upper humus layer (FH) and in the mineral soil (B) to a depth of 30 cm. A part of the samples was taken by the method when the upper part of the mineral horizon, which is enriched with humus, is taken separately (A). The mixed stand sample was analyzed. The mixed sample was composed of three spots in each stand.

Chemical analyses were done in the FGMRI laboratory. The amount of available nutrients was determined by the AAS method in 1 M of NH_4Cl solution, and a spectrometer was used to determine available phosphorus. The total element content in the soil was determined with an ICP-OES instrument in an *aqua regia* solution. Total C and N content was determined with a Leco CNS analyzer. Samples of plant material are decomposed in HNO_3 and H_2O_2 in the MDS-2000 microwave system, and the content of the elements is determined with an OES-ICP analyzer. A part of the results of the Central Institute for Supervising and Testing in Agriculture (ÚKZÚZ) Brno database was used.

The data evaluated in this paper comes from three sources: (1) data from expert consultancy activities

Table 1. Deposition in Jablunkov FD in 2006 (kg/ha/year)

	pH	Ca	K	Mg	Na	F^-	Cl^-	NH_4^+	NO_3^-	$N(NH_4^+ + NO_3^-)$	SO_4^{2-}	$S\text{-}SO_4^{2-}$
Open field (bulk)	4.89	12.40	3.30	2.37	6.92	0.25	17.18	8.56	29.84	13.39	38.54	12.86
Throughfall spruce	4.66	18.34	20.79	3.93	9.36	0.99	23.46	14.62	54.58	21.51	61.46	20.52
Throughfall beech	5.91	17.84	31.08	4.39	11.01	0.45	18.41	8.34	35.14	13.87	44.12	14.73

of FGMRI in 2004 and 2005, (2) data obtained from the project supported by the Grant Agency of the Forests of the Czech Republic, state enterprise (3) data provided by the Central Institute for Supervising and Testing in Agriculture Brno from the investigation in 2004.

RESULTS AND DISCUSSION

In 2006, sulphur dioxide concentrations were very low; the highest four-week value was about 7 μg/m^3. The average four-week values of NO_2, with the highest measured concentration of 6.3 μg/m^3, do not pose any significant risk for the forest tree species. In contrast, the ozone concentrations were relatively high. The highest four-week average of 133 μg/m^3 was recorded in the period from July 21 to August 11, 2006. This value is comparable with the other heavily loaded regions of the Czech Republic such as the summit parts of the Jizerské hory Mts., Orlické hory Mts. or Krkonoše Mts. (Šrámek et al. 2007).

The values of atmospheric deposition and element concentrations in precipitation, as measured on the plot of Jablunkov Forest District, were compared with those of the twelve intensive monitoring plots in the whole Czech Republic during the identical period (V–XII 2006). The intensive monitoring plots are described in detail in Boháčová et al. (2007).

Higher precipitation concentrations were found for SO_4^{2-} in the open area (2.76 mg/l) and for F^- in the spruce stand (0.08 mg/l). The value of pH in precipitation water in the spruce stand (4.66) and in the open area (4.89) was the lowest of all the plots studied. SO_4^{2-} and NO_3^- deposition was also the highest in the open area (38.54 and 29.84 kg/ha/year, resp.) and in the beech stand (44.12 and 35.14 kg/ha/year, resp.). Cl^- deposition was the highest in the open area (17.18 kg/ha/year) and in the beech stand (18.41 kg/ha/year). The highest F^- deposition was measured under the spruce stand in Jablunkov FD; the deposition of SO_4^{2-}, NO_3^- and Cl^- was high, and the stand was among the spruce stands with deposition measurement where the load is the highest in the Czech Republic. Calculated deposition values (kg/ha/year) in Jablunkov FD are presented in Table 1.

Thanks to the interception of dry deposition in the spruce stand, the deposition of sulphur and nitrogen is nearly twice the value of deposition in the open area. In the beech stand, where stemflow was included in the total throughfall deposition, the increase due to dry deposition was not so significant.

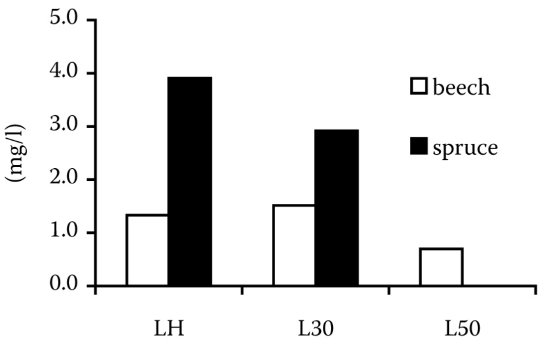

Fig. 2. Average calcium concentration in soil water
LH – under the humus horizon, L30 – at the depth of 30 cm of mineral soil, L50 – at the depth of 50 cm of mineral soil (in the European beech stand)

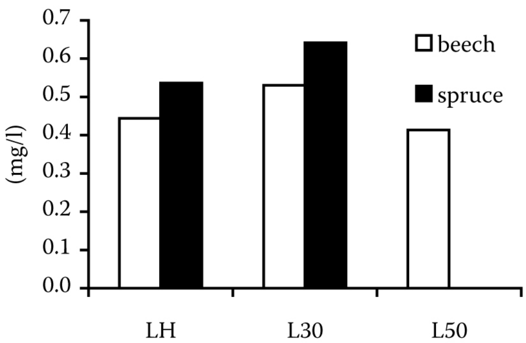

Fig. 3. Average magnesium concentration in soil water
LH – under the humus horizon, L30 – at the depth of 30 cm of mineral soil, L50 – at the depth of 50 cm of mineral soil (in the European beech stand)

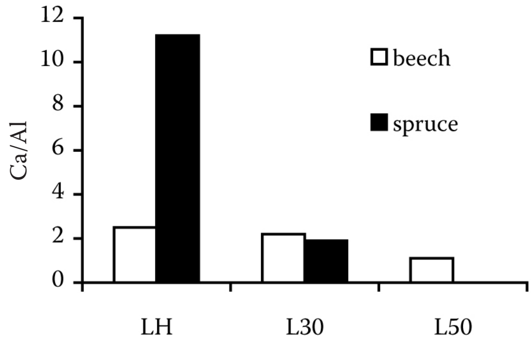

Fig. 4. Ca/Al molar ratio in soil water
LH – under the humus horizon, L30 – at the depth of 30 cm of mineral soil, L50 – at the depth of 50 cm of mineral soil (in the European beech stand)

Nutrient contents in soil water were studied in strongly damaged Norway spruce stand and in neighbouring European beech stand. Higher Ca concentrations were measured (Fig. 2) in samples taken under the Norway spruce, which also corresponds to the performed soil analyses. In the humus layer of the two stands, the amounts of Ca were comparable, however, the total amount of this element was higher in the spruce stand due to a thicker humus layer. In mineral soil 0–40 cm, the amount of available Ca was double under spruce, as compared to beech. Also, the concentration of Ca, as measured in soil water samples taken at the depth of 30 cm, corresponds to that. In Mg amounts, a similar trend like in Ca can be observed (Fig. 3); the difference between the two stands, however, is not so significant. In soil water in the Norway spruce stand, higher N concentrations were also found. In both species, ammonium compounds are prevailing over nitrates. For K, there was no significant difference in the soil water under the humus layer. At 30 cm, higher concentrations were measured in the Norway spruce stand.

The soil water pH under damaged Norway spruce was only 4.14 under the humus layer and 4.42 under beech. At 30 cm, the situation is balanced; the pH of gravitational water under spruce is 4.36 and 4.39 under beech. The molar ratio Ca/Al, in contrast, is much higher under the humus layer of the spruce stand than under beech (Fig. 4), which is affected by the characteristics of the humus layer. In both stands, the molar ratio Ca/Al up to 30 cm is above 1.0, which is the threshold for damage of fine roots. However, considering that both localities are on relatively fertile Dystric Cambisols, the values are very low.

The soils in the investigated region are mostly very acid ($pH_{(KCl)}$ in the interval 3–4), and in some stands they are moderately acid, or, on the contrary, very strongly acid. In the majority of the cases available phosphorus is the distinctly deficient element (< 20 mg/kg) in most mineral samples taken. However, its total pool in the soil is not critical. Calcium contents in most mineral samples are also very low (< 140 mg/kg) or low (140–350 m/kg). In contrast to phosphorus, the total amount of Ca in the soil is also very low. Its possible increase above the deficiency limit due to the weathering of minerals or changes in chemical valence is negligible and the trees need to concentrate on the Ca supply in the humus layer. Also, the amounts of magnesium available in mineral horizons are often very low (< 20 mg/kg) or low (20–40 mg/kg). The total Mg content is sufficient, therefore just as in the case of phosphorus, there is a potential to increase it by weathering or by changes in chemical valence in the case of pH change.

The nutrition of the spruce stands in the investigated region was found not to be optimal. Mg is the

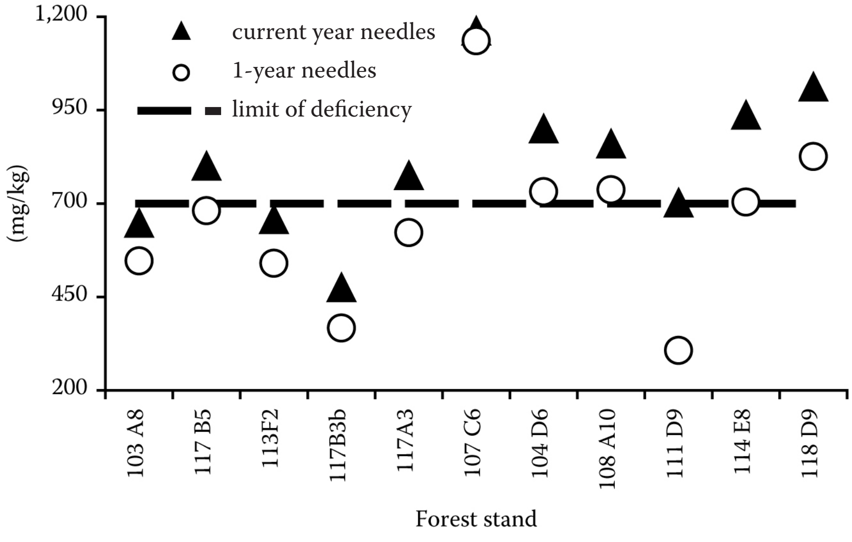

Fig. 5. Magnesium content in the samples of spruce needles

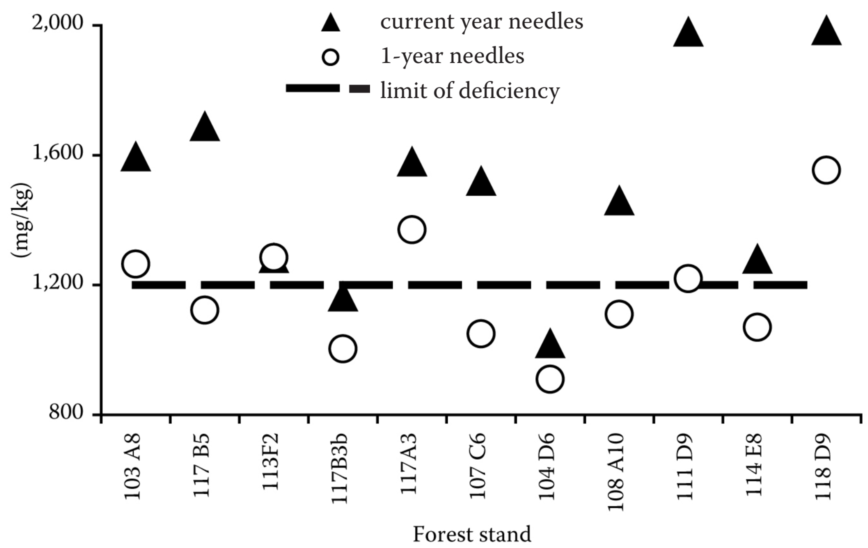

Fig. 6. Phosphorus content in the samples of spruce needles

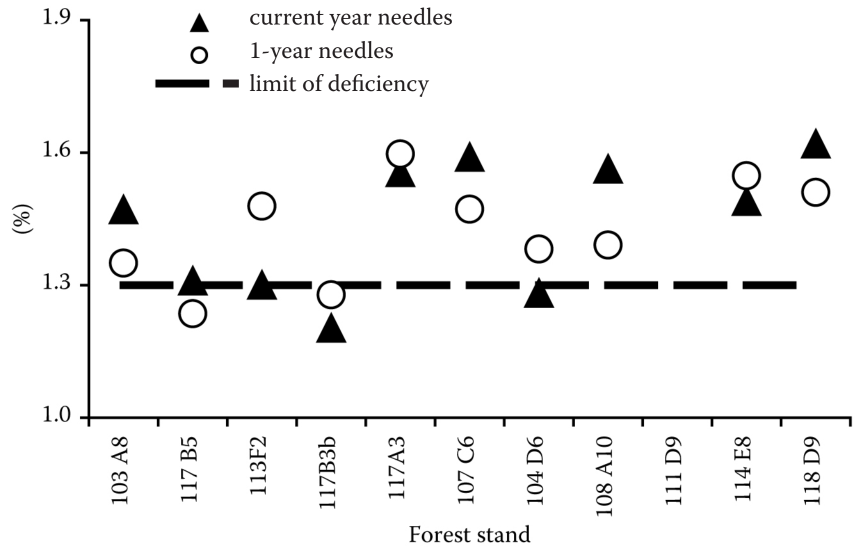

Fig. 7. Nitrogen content in the samples of spruce needles

most deficient element in the spruce needles. In the samples taken in 2006 and 2005, most samples were below the deficiency limit (700 mg/kg). In one year old needles, the amounts are lower than in the current years, which is typical. However, with the exclusion of the most damaged locality of stand 117B3b, they are not critical – under 400 mg/kg (Fig. 5).

Phosphorus is another deficient nutrient. In many cases, moderately insufficient amounts of this element were recorded (< 1,200 mg/kg), at least in one year old needles, and in several cases in both needle year classes (Fig. 6). Nitrogen deficiency can be considered only moderate (Fig. 7).

Average sulphur amounts in the current year needles were 1,091 mg/kg, and 1,126 mg/kg in one year old needles. The highest value measured, 1,429 mg/kg, confirms a moderately increased load, however, it does not correspond to the stand damage. The situation is similar for fluorine, with an average content in needles of 2.20 mg/kg. Only one sample was above the moderate load limit of 3.0 mg/kg. The average chlorine content in needles was 582 mg/kg; the moderate load limit (700 mg/kg) was exceeded only scarcely.

CONCLUSIONS

The state of forest stands in Nýdek District is unstable due to the long-term load of forest soils and air pollution stress. After the pollutant concentrations in the air decreased, the main factor affecting the forest stands is the state of forest soils which shows the insufficiency of the main nutrients available, and sometimes in the total amount as well. The situation in the soil is reflected in the nutrition level of the assimilation tissues of trees. The simultaneous effect of other stressors (e.g. biotic, meteorological ones) can support sudden deterioration of the health state and cause serious damage.

The measurements of air pollution and needle analyses did not show a direct impact of air pollution. Only ozone values increased, but they were not above the values measured in other regions of the Czech Republic where no similar damage to forest stands was observed. The acid deposition and nitrogen deposition are still very high. The characteristics of the soil solution show (with respect to the originally suitable state) a significant level of disturbance of the soil environment.

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Imisní zatížení a výživa lesních porostů na LS Jablunkov, revír Nýdek

ABSTRAKT: V rámci analýzy a studia komplexu příčin chřadnutí smrkových porostů v oblasti revíru Nýdek na LS Jablunkov jsme měřili koncentrace škodlivin v ovzduší pomocí pasivních dozimetrů, depozice do lesních porostů, chemismus půdní vody, obsah živin v půdě a v asimilačním aparátu dřevin. Zkoumané chřadnoucí porosty jsou v oblasti s historicky silnou imisní zátěží zejména z třinecké a ostravské aglomerace. Po snížení tlaku škodlivin v ovzduší ve druhé polovině devadesátých let 20. století zůstává hlavním faktorem ovlivňujícím současné lesní porosty stav lesních půd, ve kterých se projevuje nedostatek důležitých živin v přístupné formě a někdy i v celkovém obsahu. Situace v půdě se následně promítá do úrovně výživy asimilačního aparátu dřevin. Spolupůsobení dalších stresorů (biotických a meteorologických) může přispět k náhlému zhoršení zdravotního stavu porostů a způsobit jejich vážné poškození.

Klíčová slova: depozice; výživa porostů; chřadnutí smrku; Slezské Beskydy

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