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Application of Mg-fertilizers to prevent and to decrease Norway spruce yellowing

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ABSTRACT: Yellowing of the Norway spruce is a relatively common problem in many areas of the Czech Republic. In some of them, it is also connected with forest decline; it was studied in the Šumava (Bohemian Forest) Mts. and in the western part of the Krušné hory Mts. This unfavourable phenomenon is initiated by several ecological as well as anthropic processes, one of the most important being the imbalance of forest stand nutrition. Particular reasons lead to the deficiency of nutrients, especially of magnesium. Solution of this undesirable trend is the profound ecological analysis and cause-oriented treatments. Besides lowering the air pollutant input, fertilization with deficient nutrients is a successful treatment in the forest stand management in affected areas. In the areas of interest, the application of a relatively small amount of appropriate fertilizer (SILVAMIX Mg) led to considerable improvement in the defoliation dynamics and yellowing progress since the first years after use.

Keywords: air pollution impact; defoliation; spruce yellowing; nutrient deficiency; fertilization

The forest tree yellowing was recognized relatively late in the Czech Republic, due to a very intensive direct air pollution impact on forests. Great acute damage led to deterioration of the forest condition, to strong defoliation and even to dieback in some areas and covered more subtle appearance of chronic damage to the trees. After relatively high improvement of the air pollution situation since the 1990s, the chronic air pollution stress was manifested as more important, and so there appeared new mechanisms of forest damage. These tendencies in the forest dynamics were widely and thoroughly described in literature from Germany and Austria and restoration management was solved in research field as well as in practice. The "new type of forest decline, in these countries neuartige Waldschäden" was also described for the first time in the 1980s, which mainly consisted in soil base leaching (primarily magnesium) not only from forest soils but also extensively from the assimilatory organs. It led to base deficits, disorders in nutrient balance and to physiological damage of forest trees (Huettl 1985). This type of damage was observed in the Czech-Germany border areas such as Šumava Mts., Český les, Smrčina, later also in the Krušné Mts. and described and published in many articles. This type of damage has lately expanded to other air-pollution mountain areas and sometimes led to the forest deterioration. The nutrient disorders were observed not only on the spruce but also on the broadleaves such as a beech. The processes which led to nutrient losses from the forest ecosystems and nutrient imbal-

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ance of forest trees are at present considered as the main reason for forest damage and sometimes also decline, however the causes of the worsening condition of forests are many and differ at the different sites. Due to a small number of experimental plots founded to solve this problem, any new results are very important and a good source of knowledge of this process is crucial for efforts to find practically useful solutions for the forest condition improvement. The aim of this study is to present the results of experimental application of fertilizers in stands with marked spruce yellowing.

PROBLEM ANALYSIS

Forest tree yellowing has already been studied for a few decades (Bosch 1986; Hüttl 1985, 1987; Huettl, Zoettl 1993; Rehfues 1989; Ulrich 1986) mainly but not solely in spruce. The occurrence of this phenomenon is connected with indirect effects of air pollution situation. Aside from the direct influence of the anthropogenic air pollution components the forest tree environment is affected, especially forest soils. Acid deposition leads to soil changes, root system damage and nutrient imbalance. The most important impacts of soil acidification are as follows:

– base nutrient leaching from assimilatory organs of forest trees and also from the upper horizons of forest soils,
– activation of soil toxic components, mainly of forms of free aluminium, which leads to damage to roots and their re-movement to the upper soil horizons, so the possibility of drought damage is higher,
– high nitrogen deposition together with acidification can cause nutrient imbalance, especially for base nutrients such as magnesium (Materna 1986; Hüttl 1985; Huettl, Zoettl 1993).

It is necessary to emphasize that these facts were of less importance in the most damaged polluted areas in the past, and in the Krušné hory Mts. area and northern mountains direct damage by the high air pollutant concentrations prevailed. Indirect damage caused mainly by the soil affection can occur mainly in these conditions:

– in the areas with relatively low air pollutant concentrations but relatively high acid deposition,
– in the regions with poor soils with low content of basic nutrients, magnesium primarily,
– in the case of relatively vital forest stands of medium or higher age, with prevailing latent or chronic damage

These conditions are fulfilled in two main areas of the Czech Republic – Šumava and W Krušné hory Mts., the forest yellowing occurs there on a large scale and leads to management problems.

Šumava Mts. region

The Šumava Mts. region represents a typical area with forest tree yellowing because of the high ecosystem susceptibility to environment acidification: nutrient poor soils without higher base content, relatively vital forest stands, and low pollutant concentrations in the air. On the contrary, e.g. studies of the IFER documented considerably high acid deposition, comparable with regions with higher direct air pollution impact. Yellowing phenomena in former Military Forest Area in this region were common in the last decades, especially in the former Horní Planá Forest Enterprise territory since the mid-1980s. Yellowing occurs very often in younger (pole-stage) stands, in the further stage of higher age the problems are less pronounced. As an example it is possible to show results from the Forest District Borová Lada, the nutrient state of the yellowing forest stands as documented by Hřebek (1997) (Table 1).

Table 1. Nutrient content in assimilatory organs of young spruce stands in the Forest District Borová Lada (Hřebek 1997) and Forest District Cikháj (unpubl.)

Nutrient (%)	Limit	Borová Lada District (2 years old spruce needles)		Cikháj District (1 year old spruce needles)	
		green	yellowing	green	yellowing
N	1.30			1.51	1.27
P	0.12			0.16	0.17
K	0.40	0.27	0.45	0.61	0.62
Ca	0.20	0.29	0.21	0.22	0.03
Mg	0.07	0.08	0.04	0.050	0.015

The yellowing trees show a significantly lower and deficient content of magnesium and sometimes a lower content of calcium, and on the other hand higher contents of nutrients such as iron and manganese, for which the higher content in the soil solution is connected with acidification. As the main reason for tree yellowing it is possible to determine the magnesium deficiency, caused by the natural conditions with lower level of this nutrient in the parent rock and also the progressing anthropogenic acidification. This is typical of the Šumava Mts. and the Český les Mts. areas. Another example in Table 1 is from Cikháj (Czech-Moravian upland). Foliar samples from the yellowing trees show a much lower (0.03%) calcium and also (0.015%) magnesium content, the amount of which is in the rate of high deficit (1/7 and 1/5 of the deficient limit content). So in any case (in particular areas and stands) the reasons for the tree yellowing could be different. Extreme climatic conditions, nutrient poor parent rock, organic soils (Histosols, peats) lead to the low degree of the biochemical nutrient cycles, so the amount of nutrients is relatively low with high intensity of recycling. In the conditions of commercial forests, in cutting cycles, there appear markedly increased variations and discrepancies between nutrient content in soils and tree demand. These effects appear mainly at the lower age of stands when the growth is relatively fast and biomass increases significantly. In the old stands, the balance occurs between tree layer demand and nutrient release by the humus mineralization and weathering. This balance could be disturbed again by the high acidification or the silvicultural intervention.

Krušné hory Mts. region

Similar dynamics of forest stands is observed in a geographically neighbouring region, in the western Krušné hory Mts., former Forest Enterprises Horní Blatná, Kraslice and Kladská. A large damaged area appeared there in spring 1999, demonstrated as yellowing of older Norway spruce needles progressing into their drying up and premature leaf shedding (Lomský et al. 2000). Colour changes and forest decline dynamics resembled fully the situation in Germany and Austria 15 years ago. Foliage damage was very often irreversible resulting sometimes in lethal tree defoliation. This unfavorable situation was initiated by long lasting acid deposition, direct air pollution effects, soil degradation and acidification of its upper layers. Chemical analyses detected the deficit of nitrogen, calcium and especially magnesium. Temporarily there are experimental plots of the Forest and Game Management Research Institute Jíloviště-Strnady and Faculty of Forestry and Environment Czech University of Agriculture in Prague with research aimed at liming and fertilizer application.

EXPERIMENT WITH FERTILIZERS ON THE YELLOWING PLOTS IN THE ŠUMAVA MTS.

Methods

Two pairs of permanent research plots (PRP) were established for the study of fertilization effects in summer 1998. Research plots are located in the Stožec Forest District area in zones II of the National Park Šumava (plot U kanálu – 920 m a.s.l., beech-spruce vegetation altitudinal zone, forest type 7O1, stand age 44 and plot Stožec – 1,230 m a.s.l., spruce vegetation altitudinal zone, forest type 8K7, stand age 107). On both localities there were established two adjacent plots with control and fertilized variant. Fertilizer application was carried out in summer 2000, manually, at an amount of 100 kg of nitrogen per hectare in the form of SILVAMIX Mg fertilizer. Plot area is 50 × 50 m, yellowing and defoliation are observed every year in the autumn and an ocular estimation method is used for this purpose, in 5% defoliation and yellowing classes (Vacek, Mayová 2000).

Yellowing has already been observed for a long time in this area, not reaching the critical extent nor progressing into forest decline. In the German as well as Austrian part of this mountain range, many successful fertilization experiments were established to prevent and reduce Norway spruce yellowing and defoliation. The so-called "new type of forest decline" was described there since the 1980s and several treatment types were tested as counteraction.

Results

Results of experiments are documented in Table 2. There are obvious feature trends since the first years of the experiment: at the more extreme site (8th vegetation altitudinal zone, both fertilized and control plots), the defoliation was slightly higher. During the experiment, the values did not change very much, in 2002 a more notable decrease of foliation (13–19%) caused by bark beetle was observed. From the beginning the foliation state was worse on the fertilized plot and this tendency was apparent during the whole experimental period. Fertilizers thus did not influence assimilatory organ losses.

Table 2. Foliation and yellowing of spruce on the studied plots in the Forest District Stožec territory in 1998–2003 (%)

	1998		1999		2000		2001		2002		2003	
	F	Y	F	Y	F	Y	F	Y	F	Y	F	Y
7* Fertilization	80	13.0	86	9.2	82	6.5	84	9.2	71 a	1.6 a	69	1
7* Control	78	14.6	85	13.3	81	15.7	81	15.2	61 c	14.2 b	61	19
8* Fertilization	74	17.5	72	16.4	72	15.5	73	9.4	66 c	6.9 c	71	5
8* Control	76	15.0	76	14.0	75	18.8	75	17.0	71 c	19.1 d	73	21

Different indexes indicate statistically significant differences; 7* – 7th vegetation altitudinal zone, 8* – 8th vegetation altitudinal zone, F – foliation, Y – yellowing

Table 3. Foliation and yellowing (%) of Norway spruce on plots BL1 – BL6 in the Forest District Horní Blatná, Krušné hory Mts. in 2001–2003

Identification	Variant	2001		2002		2003	
		foliation	yellowing	foliation	yellowing	foliation	yellowing
BL 1	fertilization	68	24	71	18	75	17
BL 2	control	59	22	70	22	76	18
BL 3	fertilization	66	25	69	26	69	22
BL 4	control	61	28	67	28	73	22
BL5	fertilization	66	19	70	21	68	18
BL 6	control	73	18	73	18	78	14

A reverse trend was shown on the plot at the lower altitude, in the 7th vegetation altitudinal zone. Increased defoliation was also observed there during 2002, but the situation was better on the fertilized plot. So the ameliorative effect was more pronounced there also from the foliation aspect. From the beginning defoliation on these two plots was slightly higher on the control plot, but not significantly. Defoliation increase was observed during the period of study, being lower, compared to the higher altitudes at present – bark beetle is the main reason.

The second evaluated factor was assimilatory organ yellowing. Its occurrence was dependent on the stand conditions, higher occurrence was on the upper plots in the 8th vegetation altitudinal zone, due to higher climatic and possibly also air pollution stress. During the experimental period, the situation worsened and emphasized these trends. Fertilizers had a significant (differences 50–80%) effect on this factor. Already since 2000, few months after fertilization, the effect was marked and differences between fertilized and control plots appeared. In 2002 the occurrence of yellowing was significantly lower, more than 50%, on the fertilized plots and statistically significant. On the lower plots, the fertilizer effect was even more observable. On the fertilized plot the occurrence of yellowing almost disappeared, on the control plots its occurrence was equable during the experimental period.

Plots will be monitored in the future too, because the ameliorative effect will probably persist. Other components of forest ecosystems should also be evaluated, such as plant communities, upper soil organic layers and so on.

Similar plots were later established in the Krušné hory Mts. in the Horní Blatná region, but it is still very soon for significant results (Table 3).

CONCLUSIONS

Short-time effects of the fertilizers supplying deficient magnesium to soils appeared as positive.

They significantly decreased the occurrence of the assimilatory organ yellowing and also improved the foliation state, at least in less extreme site conditions. In the areas where intensive management and silviculture are expected, this nutrient supplement can improve the poor nutrient status of soils and trees and play a positive role in the spruce stand stability and health state improvement. The exception should be the first zones of national parks and small protected areas.

Yellowing of forest tree species, especially of Norway spruce, was observed in the Czech Republic for several decades, but its importance as a forest health state problem has increased in the last period only. The application of deficient nutrients was approved as a suitable intervention in this case, liming is also checked up as a less specific intervention for the soil nutrient state and soil chemistry restoration. From the short-time aspect, fertilization appeared as more efficient, but for the long-time effects other amelioration treatments could be more appropriate, e.g. biological amelioration, regeneration of soil biochemical cycles by liming. For the maximization of ameliorative effects and for the reduction of negative effects, it is necessary to respect these fundamentals:

– fertilizing or liming interventions should be carried out in relatively vital forest stands with soil protective vegetation cover,
– stands could be damaged, but this damage should not be lethal,
– accurate preliminary preparation is necessary, analyses of forest tree nutrient status and detailed soil condition are necessary,
– standard methods and comparable evaluation procedures for the evaluation of soil condition and foliar nutrition are available.

Application basics for fertilizers could be recommended:

– Actual nutrient deficiency detected by foliar analyses (and from visual effects on assimilatory organs) could be eliminated by foliar or fast-acting fertilizers, with high, fast and short-time effects;
– In the case of less pronounced and deeper-rooted problems with unbalanced or deficient nutrient status, slow-release fertilizers are recommended. For example SILVAMIX fertilizers were tested in this case, and their effects appeared as sufficient and long lasting;
– Another possibility of long lasting amelioration is forest soil revitalization by changes of stand species, age and spatial structure, liming application (or another carbonate calcium + magnesium fertilizers with the exception of podzolic soils, histosols, and soils with high organic matter content);
– Ameliorative effects decrease with increasing (climatic, ecological) extremity of the stands because the tree growth is thus limited by other factors.

With these fundamentals the ameliorative effect would be high and fast without very negative side-effects for the forest ecosystems, and financial costs would be used effectively.

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Aplikace Mg-hnojiv jako prevence a eliminace žloutnutí smrku ztepilého

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ABSTRAKT: Takzvané žloutnutí smrku představuje poměrně závažný a častý problém na mnoha územích České republiky. V některých oblastech vede až k hynutí porostů, hlouběji bylo studováno například na Šumavě a v západní části Krušných hor. Tento jev je iniciován řadou ekologických i antropicky podmíněných faktorů, jedněmi z nejdůležitějších jsou pak poruchy výživy lesních porostů. Různé příčiny vedou k nedostatečné výživě – v první řadě hořčíkem. Řešením tohoto problému je analýza stavu a aplikace cílených vhodných melioračních zásahů. Kromě bezpodmínečného snížení kyselé depozice představuje vhodné opatření přihnojení deficitními živinami. V zájmovém území vedla aplikace poměrně malého množství vhodného hnojiva (SILVAMIX Mg) ke značnému zlepšení stavu olistění a především k radikálnímu snížení žloutnutí u smrku od prvních let od aplikace.

Klíčová slova: vliv imisí; defoliace; žloutnutí smrku; deficit ve výživě; hnojení

V posledních letech nabývá na významu chronické poškození především smrkových porostů, tzv. žloutnutí smrku. Představuje poměrně závažný a hojně se vyskytující problém na mnoha územích České republiky. V některých oblastech vede až k hynutí porostů, hlouběji jsme žloutnutí studovali např. na Šumavě a v západní části Krušných hor. Příčinou je celý soubor antropických faktorů, zesílených nepříznivými přírodními podmínkami. Jednou z nejdůležitějším příčin pak jsou poruchy výživy lesních porostů, v první řadě deficit hořčíku. Tabulka 1 dokládá příklady nevyvážené výživy mladých lesních porostů na Šumavě a na Českomoravské vrchovině, v každém z těchto případů je v minimu jiný makroelement.

Vliv přihnojení hnojivem s obsahem hořčíku v oblasti Šumavy byl sledován na dvou dvojicích trvalých výzkumných ploch, každé o velikosti 50 × 50 m na LS Stožec, ve II. zóně Národního parku Šumava. Hnojivo (SILVAMIX Mg) bylo aplikováno ročně v roce 2000 v množství 100 kg N/ha. První z těchto ploch nesla označení U kanálu (920 m n. m., LT 7O1, věk 44 let), druhá Stožec (1 230 m n. m., LT 8K7, věk 107 let). V tab. 2 jsou uvedeny výsledky sledování výskytu žloutnutí a defoliace v letech 1998–2003. Přihnojení výrazně snížilo defoliaci a takřka eliminovalo žloutnutí, a to v krátkém období. Pomalá účinnost hnojiva SILVAMIX se projevuje zesilováním účinku v letech po aplikaci hnojiva. Výsledky experimentálního hnojení byly výrazně menší v extrémnějších stanovištních podmínkách. Pro srovnání jsou uvedeny příklady s minimální účinnosti podobného přihnojení v oblasti Krušných hor (tab. 3).

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