THE EFFECT OF SANITATION MEASURES ON TREE VOLUME IN YOUNG PLANTATIONS OF SPRUCE (*Picea abies* (L.) K a r s t.) IN FORESTS OF THE VILLAGE OF NÁLEPKOVO

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Abstract

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This paper deals with effects of liming by dolomite powder and fertilisation by phosphate fertilizers on building up the tree volume in young (8 years old) plantations of *Picea abies* (L.) K a r s t. in forests of the village of Nálepkovo (Slovenské rudohorie Mts). The results are based on two semipractice experimental plots, which are situated nearly at the same site conditions. Following especially the effect of liming, we observed that studied measures lead to significantly different results in tree volume and therefore we do not propose liming as a universal sanitation measure for diseased forest stands.

Key words: forestry sanitation measures, tree volume, young individuals of *Picea abies* (L.) K a r s t.

Current state of dealt problems in the study area

Since year 1995 the members of the Department of Soil Science at Faculty of Natural Science Comenius University in Bratislava cooperating with the Forest District of Nálepkovo and the Village hall of Nálepkovo have observed the results of massive decaying of secondary spruce forests. At the beginning we focused especially on validation of several hypotheses related to reasons of forest decaying of spruce. After we had studied natural values of dealt forest ecosystems (soil typology, plant sociology, biodiversity, microbial processes, primary production, soil chemistry, pollutant loads etc.) we adopted an opinion that despite synergic effects of several factors (secondary character of spruce forests, defects in annual precipitation pattern, global warming, insect pests, fungi etc.) the catastrophic forest decaying had been accelerated by imission loads of local sources (Rudňany, Krompachy, Slaná) as well as sources of long-distance transmissions, namely from the Ostrava-Katowice area. Many pollutants persist in soils and partially evoked an extreme effect of reactive aluminium on soil environment as well as toxic situation for widespread secondary spruce forests (Dlapa et al., 1997).

The second phase of the study was focused on some proposals aiming to establish stable forest ecosystems. The basic research realized in wider neighborhood and studies of fragments of natural forests in the target area (Šomšák, 1973, 1979, 1982; Šimurdová, 2001 etc.) proved that various communities of fir-beech forests (namely *Abieto-Fagetum* K l i k a 1936, *Poo-chaixii-Fagetum* Š o m š á k 1979, *Luzulo-Fagetum* H a r t m a n n 1953, *Circaeo alpinae-Abietetum* Š o m š á k 1982) had been prevailing coenoses before spruce forest were established 200–300 years ago.

Two semipractice experimental permanent plots with the area approximately 1 ha were established in 1996 in the district forests of the village of Nálepkovo. They were established at sites of calamity decayed secondary spruce stands with aim to test several possibilities of artificial forest regeneration there. Their detailed site conditions were published by Antoni (1997). Both experimental plots occur on acid geological substrate (gemerids) as well as on acid soils (Cambic Podzols – Juráni, 1997) at the altitude 630–690 m and 800–870 m above see level. The shortest straight distance between experimental plots is approximately 1.5 km. Soils have different textural composition and different aspect (NW, E).

It is very important to mention that soils of dealt plots are highly affected by immission loads, similarly to soils in the whole neighbourhood. They are especially SO_2 and NO_2, which input soil environment after dissolution in rainfall and increase soil acidity, what is closely accompanied by decreased availability of Ca^{2+}, K^+ and Mg^{2+} for plants. It is also important to take into account increased aluminium activity, which prevents nutrient input into plant roots. Catabolic effect of organic matter, which is the source of organic forms of N, P, S and other nutrients, is inhibited in acid soils. For example amonification (release of ammonium from soil organic matter) and nitrification (transformation of ammonium ions into nitrates) occur only between narrow pH spectrums. The study area, including experimental plots, is highly affected by mercury loads from previous ore mills located in the neighbourhoods. The problem is that mercury preserves in soils in various compounds, which differ in their character. Lead and cadmium also belong to elements with similar effects as mercury although their contents do not overlap indication levels. Arsenic, which is phytotoxic, seems to be an element accompanying mercury. It gets over indication level “B“ in the study area. As for toxicity nickel and cobalt are of lover importance there.

In 1996 target trees (*Abies alba* M i l l.*, Fagus sylvatica* L.) and, following the experiences from other localities, also amelioration trees (*Tilia cordata* M i l l.*, Acer pseudoplatanus* L.) were planted on experimental permanent plots. We assumed perfect hyper-accumulation properties of *Tilia cordata* M i l l., i.e. taking heavy metals away from soil and accumulating them in wooden parts of trees (Šomšák et al., 2000).

Despite forest management plans have not taken into account an artificial spruce regeneration for two last decenniums due to spruce decaying, we planted spruce seedlings on our experimental plots anyway. Spruce tree is considered to be industrially, economically and historically very important tree in this locality. On the other hand, we aimed to check sanitation measures realised by forestry practice.

Spruce, similarly to other target and amelioration trees, was planted in bio-groups at the area 20x75 m (= 850 individuals) and divided into subgroups with respect to the sanitation measures (limed, non-limed, fertilised, non-fertilised and their combinations).

Characteristic of sanitation measures

All the impacts related to sanitation measures are presented by Fig.1 (Table). It is essential to say that liming and fertilization were hand-applied all over the area.

Plot No. 1. Surovec (523 A)		
Spruce plantation		25.05.1996
Giving of mulching canvas		07.06.1996
Liming (DOLVAPVARINIT)	4 [t.ha^{-1}]	08.–09.07.1996
Fertilization 1/3 of the area:		
SILVAMIX MG grit	173 [g.m^{-2}]	12.03.2002
SUPERFOSFÁT	10 [g.m^{-2}]	23.05.2002
LAMAG-BOR 5% solution	400 l water/ha 0.88 [kg]	25.06.2002
SILVAMIX MG tablets	173 [g.m^{-2}]	17.04.2003
SUPERFOSFÁT	10 [g.m^{-2}]	09.06.2003
Plot No. 2. Záhajnica (220 A)		
Spruce plantation		27.05.1996
Giving of mulching canvas		10.06.1996
Liming (DOLVAPVARINIT)	4 [t.ha^{-1}]	10.–11.07.1996
Fertilization 1/3 of the area:		
SILVAMIX MG grit	173 [g.m^{-2}]	12.03.2002
SUPERFOSFÁT	10 g.m^{-2}]	23.05.2002
LAMAG-BOR 5% solution	400 l water/ha 0.88 [kg]	25.06.2002
SILVAMIX MG tablets	173 [g.m^{-2}]	16.04.2003
SUPERFOSFÁT	10 [g.m^{-2}]	09.06.2003

Fig.1. Temporal and quantitative schedule of liming and fertilization on experimental plots.

Chemical composition of used fertilizers:

1. DOLVAPVARINIT
   CaO+MgO – min 48%
   MgO – min 7%
   Granularity: >1.00 mm – 0%
   >0.315 mm – max 20.00%
2. LAMAG-BOR
   MgO 16%
   B 0.4–1.2%
   pH 9.5–10.5
3. SILVAMIX MG – grit and tablets:

Total nitrogen (in weight% N)	10.0
Water soluble nitrogen (in weight% N)	4.6
Phosphates soluble only in mineral acids (in weight% P_2O_5)	13.0
Phosphates soluble in neutral ammonium oxalate (in weight% P_2O_5)	9.5
Phosphates soluble in water (in weight% P_2O_5)	3.0
Total potassium (in weight% K_2O)	6.5
Total potassium soluble in water (in weight% K_2O)	4.0
Total magnesium (in weight% MgO)	16.0

As the figure shows, there were given mulching canvas in two rows around the seedlings, which were impregnated by dolomite limestone and under which 5 g of SUPERFOSFAT was applied in addition to liming and fertilization.

Aims of contribution

The primary aim of this contribution is to evaluate the effects of forest sanitation measures realized in young stands in various time periods on tree stocks of 8 years old spruce (*Picea abies*) on permanent experimental plots.

Methods

Sanitation measures described in Fig. 1 were applied on all tree species planted on experimental permanent plots. This paper however deals only with *Picea abies*, which has been the most frequent tree before decaying of forest ecosystems (approximately 70% from 3200 ha of forests).

Field database focusing tree stocks was completed by measuring the spruce height using 5 m high lath and the thickness diameter at 1.30 m height from the surface by millimetre nonius. For estimation of tree volume the equation by Petráš, Pajtík (1991) was used:

$$V\ [m^3] = b1(d + 1)^{b2}.h^{b3},$$

where h = height [m], b1 = 4.013841, b2 = 1.821861, b3 = 1.132062, (b1–b3 = constants of regression), d = diameter at 1.3 m height [cm].

Measurements were taken in four parallels and each of them was evaluated individually:

- non-limed and non-fertilised part (blank)
- limed and fertilised
- non-limed and fertilised
- limed and non-fertilised part.

We used *t*-test statistics for evaluation of two selections. The initial assumption supposes that both selections belong to a basic set with normal distribution. Despite our data show a deviation from the normal distribution (following the histograms of variables), this method is relatively robust and test results are not highly biased (Lepš, 1996). Afterwards we checked by *F*-test if both subsets have the same standard deviation pattern. All the procedure is summarised as follows:

1st step: *F*-test using the formula of eq. (1)

$$F = \frac{S_1^2}{S_2^2}, \tag{1}$$

where S_1 and S_2 are standard deviations and $S_1^2 > S_2^2$

2nd step: t-test statistics according to eq. (2) and eq. (3)

$$t = \frac{X_1 - X_2}{\sqrt{\frac{S_p^2}{n_1} + \frac{S_p^2}{n_2}}}, \tag{2}$$

if variances are equal,

where X_1, X_2 is average, S_p is standard deviation and n_1, n_2 is number of observations.

$$t = \frac{X_1 - X_2}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}}, \tag{3}$$

if variances are different.

All calculation were realized in EXCEL program.

Results

Experimental plot No. 1 (Surovec, altitude 800-870 m, aspect: E, Cambic Podzols)

The results of *F*-test and *t*-test statistics of tree volume obtained from experimental plot No. 1 are summarized in following Tables (1–3).

T a b l e 1. Two-sample *t*-test assuming equal variances (α = 0.05) – liming + fertilization

Sanitation measure	No input	Liming + Fertilization
Average value	197.795E-05	186.067E-05
Variance	1.6268E-06	1.10752E-06
No. of observations	68	68
Hyp. difference of mean values	0	
Difference	132	
t-stat	0.58484284	
P(T ≤ t(1))	0.27981843	t-stat < t-critical (1)
t-critical (1)	1-65630354	statistically non-significant difference between means
P(T ≤ t(2))	0.55963686	
t-critical (2)	1.97782356	

Statistical difference of means was not significant and it is evident, that the effect of liming together with fertilisation has no effect on tree volume.

T a b l e 2. Two-sample *t*-test assuming equal variances (α = 0.05) – fertilization

Sanitation measure	No input	Fertilization
Average value	197.795E-05	278.020E-05
Variance	1.626E-06	2.23747E-06
No. of observations	68	72
Hyp. difference of mean values	0	
Difference	138	
t-stat	3.40534075	t-stat > t-critical (1)
P(T ≤ t(1))	0.00043285	
t-critical (1)	1.65597157	statistically significant difference between means
P(T ≤ t(2))	0.0008657	
t-critical (2)	1.97730515	

These two sets have significantly different means. Fertilization has positive effects on tree volume.

T a b l e 3. Two-sample *t*-test assuming unequal variances (α = 0.05) – liming

Sanitation measure	No input	Liming
Average value	197.795E-05	154.855E-05
Variance	1.62676E-06	1.05957E-06
No. of observations	68	61
Hyp. difference of mean values	0	
t-stat	2.113116504	
P(T ≤ t(1))	0.018281694	t-stat > t-critical (1)
t-critical (1)	1.657035682	statistically significant difference between means
P(T ≤ t(2))	0.036563389	
t-critical (2)	1.978969522	

Two sets have significantly different mean values in the case of liming. Liming has negative effect on tree volume in our pilot plots.

Results gathered from the pilot experimental plot No. 1 (Surovec) are graphically plotted in Fig. 2.

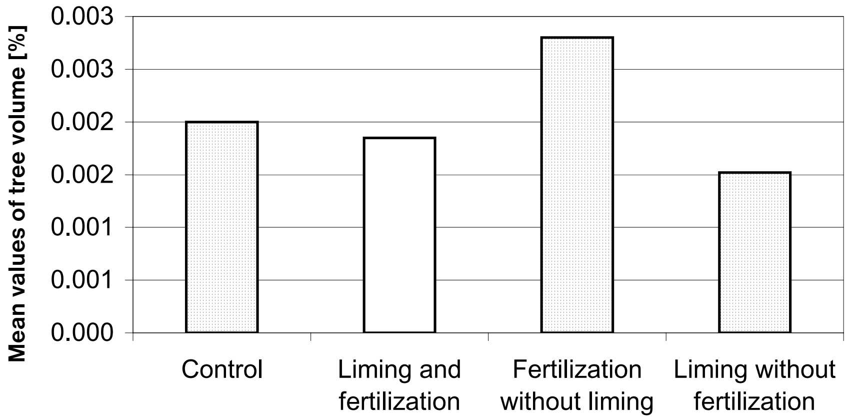

Fig. 2. A comparison of mean values of tree volume in spruce tree plantation (Surovec).

Achieved results presented by Fig. 2 show that the highest tree volume was sampled at that site of the experimental plot, which was only fertilized and not limed. It means that the fertilization alone had positive effect and, on the other hand, liming showed negative effect on stocks of tree volume. Liming combined with fertilization showed no significant effect compared to the control plot (blank).

Experimental plot No. 2 (Záhajnica, altitude 630–690 m, aspect: NW, Cambic Podzols)

The results of *F*-test and *t*-test statistics of tree volume collected from experimental plot No. 2 are summarized in Tables 4–6.

T a b l e 4. Two-sample *t*-test assuming equal variances ($\alpha = 0.05$) - liming + fertilization

Sanitation measure	No impact	Liming + Fertilizations
Average value	170.035E-05	251.768E-05
Variance	1.90339E-06	3.41631E-06
No. of observations	58	71
Hyp. difference of mean values	0	
t-stat	2.872966168	
P(T ≤ t(1))	0.002386701	t-stat > t-critical (1)
t-critical (1)	1.657035682	statistically significant difference between means
P(T ≤ t(2))	0.004773403	
t-critical (2)	1.978969522	

The results show that liming together with fertilization has positive effect on volume of trees.

T a b l e 5. Two-sample *t*-test assuming equal variances ($\alpha = 0.05$) – fertilization

Sanitation measure	No impact	Fertilization
Average value	170.035E-05	195.390E-05
Variance	1.90339E-06	1.70768E-06
No. of observations	58	67
Hyp. difference of mean values	1.79837E-06	
Difference	123	
t-stat	1.05492798	
P(T ≤ t(1))	0.146930531	t-stat < t-critical (1)
t-critical (1)	1.657335815	statistically non-significant difference between means
P(T ≤ t(2))	0.293861061	
t-critical (2)	1.979437911	

We can prove slightly positive effect of fertilization on tree volume; however, it is not statistically significant.

T a b l e 6. Two-sample *t*-test assuming equal variances ($\alpha = 0.05$) – Liming

Sanitation measure	No impact	Liming
Average value	170.035E-05	261.506E-05
Variance	1.90339E-06	2.59584E-06
No. of observations	58	65
Hyp. difference of mean values	0	
Difference	121	
t-stat	3.361433641	t-stat > t-critical (1)
P(T ≤ t(1))	0.000519105	
t-critical (1)	1.657544999	statistically significant difference between means
P(T ≤ t(2))	0.00103821	
t-critical (2)	1.979765329	

Liming alone has strongly positive effect on production of wood stocks.

The results from the pilot plot No. 2 (Záhajnica) are summarized by Fig. 3.

It is evident that liming alone, but also liming combined with fertilization has strongly positive effect compared to the control plot (not-limed, not-fertilized). Isolated effect of fertilization on stocks of tree volume of spruce plantations was not statistically significant despite the stocks of tree slightly increased in comparison with the blank plot.

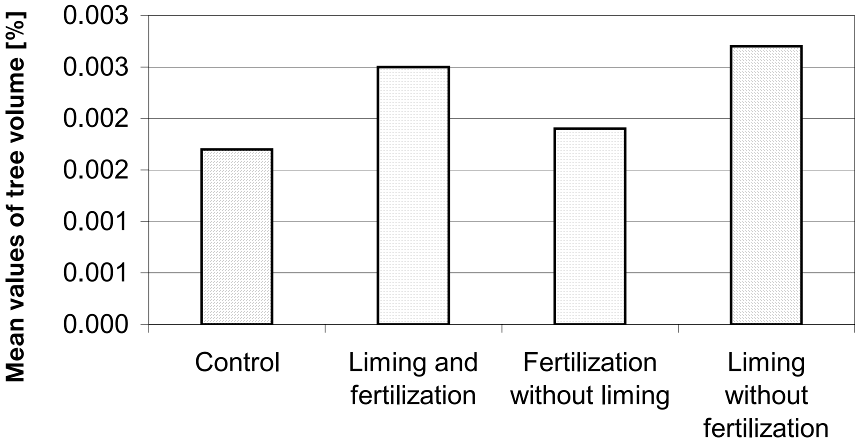

Fig. 3. A comparison of mean values of tree volume in spruce tree plantation (Záhajnica).

A comparison of effects of sanitary measures on tree volume in both semi-practice experimental plots

Table 7. Summary comparison table

Sanitary measure	Plot No. 1 (Surovec)	Plot No. 2 (Záhajnica)
Liming and fertilization	negative effect	highly positive effect
Fertilization without liming	highly positive effect	slightly positive effect
Liming without fertilization	highly negative effect	highly positive effect

The comparison Table No. 7 shows that the effects of sanitation measures on stocks of tree volume are nearly diametrically different in both experimental plots. It is especially true for liming. Whereas the volume of tree decreased on the experimental plot No. 1 (Surovec), it increased on the pilot plot No. 2 (Záhajnica) after liming. Similar different results are obtained in parts where trees were limed and fertilized. We observed a slight decrease in tree volume contrary to the control on the plot No. 1 whereas the tree volume highly increased on the plot No. 2. Fertilization without liming, especially fertilization by SILVAMIX, seems to have slightly positive effect despite it is not statistically significant. However we are not allowed to generalize the effect of fertilization, especially because the application of SILVAMAX was done only two years ago.

Results and discussion

It is not possible to generalize the effects of sanitation measures, mainly liming, on building up the stocks of tree volume in young spruce monocultures (8 years old) planted on calamity cleared secondary spruce forests in the district forests of the village of Nálepkovo. Despite both semipractice experimental plots occur on the same geological substrate and, in fact, also on the same soil types (Cambic Podzols), the results were diametrically different. We can assume that these different results can be evoked by different volume of stones in soil profiles. Whereas the volume of stones varies around 60% in B-horizons on experimental plot No. 1 (Surovec), Cambisols on the plot No. 2 (Záhajnica) contain only approximately 25% of stones. The differences can also be caused by different slope, which reaches up to 50% on the plot No. 1 (Surovec) whereas it is only 20% on the pilot plot No. 2 (Záhajnica). We can assume that longer leverage of rain water on moderately inclined slopes increases the solubility of dolomite limestone. The destiny of rain water related to the slope can have an effect also on dislocation of pollutants in soil and its horizons in this imission loaded region.

Based on achieved results, however, we are not allowed to prove the positive effect of sanitation measures, especially liming, despite liming was hand-done and dolomite powder was applied directly to each individual of planted spruce.

In addition to measuring of effects of sanitation measures on tree volume we also observed their effects on length of spruce needles, their colour, abnormalities in growing terminals and a degree of pest impacts, especially by *Sacchiphanes viridis* and *Gnaphalodes strobilobus*. The results are not published in this paper but they also showed that liming and fertilization had different effects in two semipractice experimental plots.

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Helexová A., Šomšák L., Antoni J., Kromka M., Kollár J.: **Vplyv ozdravných opatrení na tvorbu drevnej hmoty kultúr smreka obyčajného** (*Piecea abies* (L.) K a r s t.) **v lesoch Nálepkova.**

V práci vyhodnocujeme vplyv lesníckou praxou používaných ozdravných opatrení, ako je vápnenie pôd jemným dolomitickým vápencom (4 $t.ha^{-1}$), aplikácia fosforečných a iných hnojív na tvorbu drevnej hmoty 8 ročných kultúr *Picea abies* (L.) K a r s t. Tieto kultúry boli vysadené na trvalé poloprevádzkové pokusné plochy, založené na stanovištiach po kalamitne uhynutých sekundárnych smrečinách. Skúmaná oblasť leží v nadmorských výškach 600–900 m n.m. v centrálnej časti Slovenského rudohoria (lesy obce Nálepkovo) na kyslých kambizemiach. Oblasť v minulosti intenzívne ovplyvňovali lokálne, ale i diaľkové imisie. Z polutantov, ktoré v pôde ostali, sú najvýraznejšie toxické zlúčeniny ortuti (Hg) s vysokým doprovodným množstvom As.

Vplyv vápnenia a hnojenia vyhodnocujeme na dvoch paralelných plochách. I napriek takmer rovnakým stanovištným podmienkam obidvoch plôch vyšli diametrálne odlišné rozdiely, najmä vplyv vápnenia. Zhodné sú mierne pozitívne zvýšenia objemu drevnej hmoty po aplikácii fosforečných hnojív. Vápnenie ako univerzálny ozdravný zásah v lesníctve preto neodporúčame.