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THE EFFECT OF ECOLOGICAL-SANITATION MEASURES ON LENGTH OF NEEDLES OF NORWAY SPRUCE (*Picea abies* K a r s t.) IN DISTRICT FOREST OF THE VILLAGE OF NÁLEPKOVO

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Abstract

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This paper is focused on statistical evaluation of prospective effects of ecological-sanitation measures (liming and fertilisation) on needle length of Norway spruce (*Picea abies* K a r s t.), which was planted 8 years ago on semipractice experimental plots in the neighbourhood of Nálepkovo (Slovenské rudohorie Mts). The plots were established on clearings, which appeared after calamity decayed secondary spruce forests.

Key words: sanitation measures, needle length, *Picea abies*

Actual state of dealt problems

Massive decaying of secondary spruce forests in the Western Carpathians, which started approximately in the half of 80's of the 20th century and has continued until now, attracted remarkable attention of scientists from forestry and ecological branches as well as from practice people. In addition to wide and complex studying of reasons of this calamity event we paid attention also to regeneration of stabile forests on studied pilot plots. An example of such attempts can be found in the District Forests of Nálepkovo (Slovenské rudohorie Mts), where secondary spruce forests created about 70% of the whole area with total extent 3 200 ha. These forests have remained here nearly for 300 years by artificial reforesting at the beginning and, afterwards, also by natural regeneration. In all the cases they were established at sites after fir-beech forests (*Abieti-Fagetum* K l i k a 1936, 1949), acidophilous beech forests (*Luzulo-Fagetum* H a r t m a n n 1953) or after fir forests (*Circaeo alpini-Abietetum* Š o m š á k 1982).

The reasons of massive dying of secondary spruce forests in the study area are dealt in other papers (Šomšák et al., 1995, 1997). We are allowed to say that besides synergic effects of several factors, such as secondary character of spruce forests, defects in annual precipitation pattern, clear-cutting, pests, fungi, global warming etc., catastrophic dying was for sure accelerated by imission loads from the soil cover. Soils are contaminated by emissions from local sources (smelters, iron and copper mills) and long-distance transmissions. Heavy metal pollutants accompanied by arsenic persisted in soils even after these sources of emission were cancelled. Soils are classified as Cambic Podzols (Juráni, 1997), which are strongly acid with pH(KCl) between 2.8 and 3.2.

When secondary spruce forests decayed two semipractice experimental plots were established in the District Forests of Nálepkovo with total area about 1 ha. Plots are approximately 1.5 km far away one from other. Pilot plot No. 1 (Surovec) is located in the altitude 800-890 m above see level and it is sloping (50%) to the east. On the other hand, plot No. 2 (Záhajnica) occurs 600–670 m above see level and it is oriented to the NW with an average slope up to 20%. Target trees aiming to establish stabile forest stands, i.e. *Fagus sylvatica*, *Abies alba*, together with amelioration trees, which are able to accumulate heavy metals, such as *Tilia cordata* and *Acer pseudoplatanus*, were planted in these experimental plots.

Due to significant dying touched all age stages of Norway spruce, forest management plans have not taken spruce artificial regeneration into account already for two decades. In spite of that Norway spruce was planted in both experimental plots. We can mention several reasons why, but the main argument was to check the effect of ecological-sanitation remedies common in forestry, such as liming by dolomite limestone and fertilisation by phosphate and boron fertilisers, on vitality and health conditions of young spruce plantations in this territory. We consider the effects of sanitation measures on length of needles to be one of indicators of biological spruce character.

Aim of the contribution

This paper is especially aimed to evaluate the effects of ecological-sanitation measures, i.e. liming by powdered dolomite limestone and application of phosphate and boron fertilisers, on length of needles in young spruce plantations observed on two semipractice experimental plots in the District Forests of Nálepkovo (Slovenské rudohorie Mts).

Description of sanitation measures

Sanitation measures include, as mentioned above, liming by powdered dolomite limestone with technical name DOLVAPVARINIT using dosage of 4 $t.ha^{-1}$, which was applied by hands in all the study area. Then it includes fertilisation by phosphate fertiliser called SILVAMIX (grit and tablets) and finally by solution of boron with technical name LAMAG-BOR and superphosphate.

Two rows of seedlings were treated by mulching canvas, which were impregnated by solution of calcium carbonate. These rows help us to clearly identify in the field the control site (blank) and sites where remedies were realised. The schedule of individual sanitation measures as well as dosages of applied substances are summarised by following Tables 1 and 2.

T a b l e 1. Experimental plot No. 1 (Surovec).

Artificial forestation		22.5.1996
Giving of mulching canvas		7.6.1996
Liming (DOLVAPVARINIT)	4 t/ha	8-9.7.1996
Fertilisation (cca 1/3 of the area):		
SILVAMIX MG grit	173 g/m^2	12.3.2002
SUPERPHOSPHATE	10 g/m^2	23.5.2002
LAMAGAR-BOR 5% solution	400 l of water/ha 0.88 kg	25.6.2002
		2.7.2002
SILVAMIX MG – tablets	173 g/m^2	17.4.2003
SUPERPHOSPHATE	10 g/m^2	9.6.2003

T a b l e 2. Experimental plot No. 2 (Záhajnica).

Artificial forestation		27.5.1996
Giving of mulching canvas		10.6.1996
Liming (DOLVAPVARINIT)	4 t/ha	10-11.7.1996
Fertilisation (cca 1/3 of the area):		
SILVAMIX MG grit	173 g/m^2	12.3.2002
SUPERPHOSPHATE	10 g/m^2	23.5.2002
LAMAGAR-BOR 5% solution	400 l of water/ha 0.88 kg	25.6.2002
		2.7.2002
SILVAMIX MG – tablets	173 g/m^2	16.4.2003
SUPERPHOSPHATE	10 g/m^2	9.6.2003

Chemical composition of applied fertilisers is presented by Tables 3 and 4.

T a b l e 3. Chemical composition of LAMAGAR-BOR.

% MgO	16
% B	0.4-1.2
PH	9.5-10.5

T a b l e 4. Chemical composition of SILVAMIX MG – grit and tablets.

Total nitrogen N (weight % N)	10
Content of water resistant N /WIN/ (weight % N)	4.6
Content of phosphates soluble in mineral acids only (weight % P_2O_5)	13
Content of phosphates soluble in neutral ammonium citrate (weight % P_2O_5)	9.5
Content of phosphates soluble in water (weight % P_2O_5)	3
Total potassium (weight % K_2O)	6.5
Content of potassium soluble in water (weight % K_2O)	4
Total magnesium (weight % MgO)	16

Methods

Samples of needles from 8 years old spruce seedlings were taken in the field in October, 2003. We picked up the needles from 3–5 years old branches of the third whorl from the top, from the same aspect and approximately from the same exposure. The number of analysed spruce individuals is as follows:

	Experimental plot Nor. 1 – Nor. of individuals	Experimental plot Nor. 2 - Nor. of individuals
Control site	5	8
Limed and non-fertilised site	5	8
Limed and fertilised site	4	4
Non-limed and fertilised site	4	4

An average set of 100 needles was chosen from each sampled spruce individual. The length was taken on millimetre paper and is determined in mm. The results are statistically evaluated by F-test (Fisher-Snedecor test) and two-sample t-test (Student test). The initial assumption supposes that both selections belong to the 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 according to Eq.1.

$$\text{Eq.1.} \quad F = \frac{S_1^2}{S_2^2} \, ,$$

where S1 and S2 are standard deviations and $S1^2 > S2^2$.

Eq. 2 was used for t-statistics if variances were equal, on the other hand, if they differ, Eq. 3 was consequently used. All calculations and graphs were done in EXCEL program.

$$\text{Eq. 2.} \quad t = \frac{X_1 - X_2}{\sqrt{\frac{S_p^2}{n_1} + \frac{S_p^2}{n_2}}} \, ,$$

where X1, X2 is average, Sp is standard deviation and n1, n2 is number of observations.

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

where X1, X2 is average, S1, S2 is standard deviation and n1, n2 is number of observations.

Results

Expected effects of mentioned ecological-sanitation measures on length of needles in 8 years old plantations of *Picea abies* are evaluated separately for both experimental plots.

Experimental plot No. 1 (Surovec)

Measured results were statistically analysed by F-test and t-test. F-test was used to check if two subsets have equal variances or not, what is a basic assumption for selection the most suitable method of t-test, i.e. two-sample t-test with equal variances or without. We tested so-called blank subset (needles obtained from site, which was non-limed and non-fertilised) against needles obtained from limed and fertilised site, limed and non-fertilised site and finally non-limed and fertilised site of the study area.

The cases, where the critical value (*t-critical (1)*) was higher than the *t-stat* value, show statistically insignificant differences between mean values at confidential level $\alpha = 0.05$. On the other hand, the mean values are significantly different if the critical value is less then the statistical value *t-stat* at the same confidential level. Achieved statistical results are summarised by Tables 5–7.

T a b l e 5. Two-sample t-test assuming different variances ($\alpha = 0.05$) – liming and fertilisation.

	Blank	Liming and fertilisation
Mean value	15.753	16.049
Variance	10.867	7.369
Nr. of observations	500	400
Hyp. difference of mean values	0	
Difference	897	
t-stat	1.476	
$P(T \leq t(1))$	0.070	t-stat < t-critical (1)
t – critical (1)	1.647	statistically non-significant difference between means
$P(T \leq t(2))$	0.140	
t – critical (2)	1.963	

Needles taken from limed and fertilised site have not statistically different mean value of their length compared to those taken from non-limed and non-fertilised sites. However we can notice slightly positive effect of liming and fertilisation on needle length.

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

	Blank	Fertilisation
Mean value	15.753	15.293
Variance	10.867	8.531
Nr. of observations	500	400
Hyp. difference of mean values	0	
Difference	889	
t-stat	2.213	
P(T ≤ t(1))	0.0136	t-stat > t-critical (1)
t – critical (1)	1.647	statistically significant difference between means
P(T ≤ t(2))	0.0271	
t – critical (2)	1.963	

We observed statistically significant difference in mean values and fertilisation negatively affects the length of needles.

T a b l e 7. Two-sample t-test assuming different variances ($\alpha = 0.05$) – liming.

	Blank	Liming
Mean value	15.753	14.805
Variance	10.867	8.421
Nr. of observations	500	
Hyp. difference of mean values	0	
Difference	982	
t-stat	4.827	
P(T ≤ t(1))	8.05E-07	t-stat > t-critical (1)
t – critical (1)	1.646	statistically significant difference between means
P(T ≤ t(2))	1.61E-06	
t – critical (2)	1.962	

The effect of liming is also negative as for the length of needles as proved by table 7, which shows statistically significant difference in mean values. Achieved results are plotted on Fig. 1.

Plotted results (Fig. 1) shows that the longest needles were taken from limed and fertilised site, where, however, the needles were only 0.4 mm longer than needles sampled at site non-limed and non-fertilised. Liming and fertilisation individually have negative effect on the length of needles on experimental plot No. 1 (Surovec).

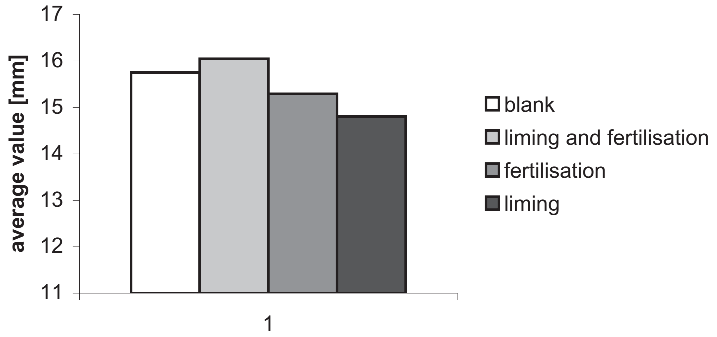

Fig. 1. Mean values of length of needles of Norway spruce (*Picea abies* K a r s t.) observed on experimental plot No. 1 (Surovec).

Experimental plot No. 2 (Záhajnica)

The method of evaluation is the same as it was used in previous experimental plot. The results of t-test are collected in Tables 8–10.

T a b l e 8. Two-sample t-test assuming different variances ($\alpha = 0.05$) – liming and fertilisation.

	Blank	Liming and fertilisation
Mean value	13.680	4.096
Variance	7.265	400
Nr. of observations	800	
Hyp. difference of mean values	0	
Difference	1020	
t-stat	9.564	
P(T ≤ t(1))	4.09E-21	t-stat > t-critical (1)
t – critical (1)	1.656	statistically significant difference between means
P(T ≤ t(2))	8.19E-21	
t – critical (2)	1.962	

Statistical t-test proved statistically significant difference between mean values of blank site (non-limed and non-fertilised) and limed-fertilised site. Liming together with fertilisation positively affect the length of spruce needles.

We observed strongly negative effect of liming itself on the length of needles. Mean values are statistically different as shown by Table 10.

T a b l e 9. Two-sample t-test assuming equal variances ($\alpha = 0.05$) – fertilisation.

	Blank	Fertilisation
Mean value	13.679	13.579
Variance	7.265	6.585
Nr. of observations	800	400
Hyp. difference of mean values	0	
Difference	1198	
t-stat	0.619	
P(T ≤ t(1))	0.268	t-stat < t-critical (1)
t – critical (1)	1.646	statistically non-significant difference between means
P(T ≤ t(2))	0.536	
t – critical (2)	1.962	

Fertilisation itself has not significant effect on the length of spruce needles. The difference in mean values is negligible.

T a b l e 10. Two-sample t-test assuming different variances ($\alpha = 0.05$) – liming.

	Blank	Liming
Mean value	13.679	11.856
Variance	7.265	3.510
Nr. of observations	800	800
Hyp. difference of mean values	0	
Difference	1425	
t-stat	15.709	
P(T ≤ t(1))	1.03E-51	t-stat > t-critical (1)
t – critical (1)	1.646	statistically significant difference between means
P(T ≤ t(2))	2.07E-51	
t – critical (2)	1.962	

Mean values of needle length measured on experimental plot No. 2 (Záhajnica) are presented also by Fig. 2.

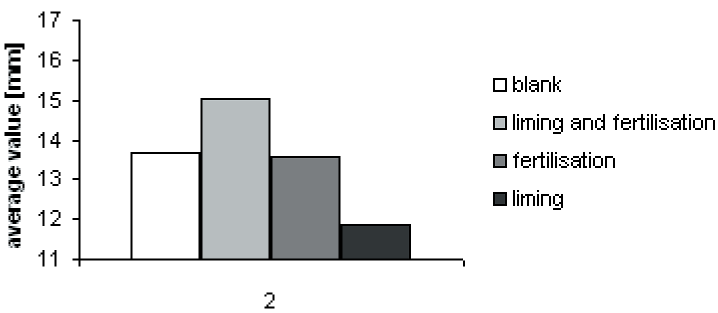

Fig. 2. Mean values of length of needles of Norway spruce (*Picea abies* K a r s t.) observed on experimental plot No. 2 (Záhajnica).

Positive effect of sanitation remedies was observed only in the case of liming together with fertilisation. Fertilisation had not significant effect on the length of spruce needles whereas liming affected it negatively.

Discussion and conclusion

Statistical and graphical presentation of effects of ecological-sanitation measures on the length of spruce needles, which were taken from 8 years old plantations, show the positive effect of combination of liming and fertilisation on both study experimental plots. Needles from plot No. 1 (Surovec) are approximately 0.29 mm longer at limed and fertilised site in comparison with control site and needles from plot No. 2 (Záhajnica) even 1.32 mm longer. The effect of liming itself was negative in both cases. Whereas the difference against control is less than 0.95 mm on the plot No.1 (Surovec), it is up to 1.85 mm on the plot No. 2 (Záhajnica).

However the total length of needles does not significantly differ from values, which are mentioned in literature sources. Not even in one of variants, i.e. control site, limed and fertilised site, non-limed and fertilised site, limed and non-fertilised site. It means that *Picea abies* K a r s t. has needles within the range as it use to have. Dostál (1950) estimates needle length within the ranger of 10–25 mm, Krüsmann (1978) between 10–20 mm. We obtained similar results where needle length is 15.23 mm in average on experimental plot No. 1 and 13.57 on experimental plot No. 2.

Based on complex evaluation of dealt effects of ecological-sanitation measures on the length of spruce needles we can say that only the combination of liming and fertilisation by phosphate and boron fertilisers has positive effect. However also this remedy has to be carefully weighted because this relatively expensive input (13 607 Sk/ha – Antoni, 2003) improved average length of needles only slightly.

Liming had negative effect in this study area despite dolomite limestone powder was hand applied evenly covering topsoil so it was easily reachable for the whole root system of Norway spruce. Phosphate and boron fertilisers were applied similarly. We are allowed to say that liming is not effective for improving needle length, similarly as it was not effective for total increment of tree volume (Helexová et al., 2006) and slimness coefficient of Norway spruce (Antoni, Žarnovičan, 2005) in the study area.

Translated by the authors

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Helexová A., Šomšák L., Žarnovičan H.: **Vplyv ekologicko-ozdravných opatrení na dĺžku ihlíc smreka** (Picea abies K a r s t.) **v lesoch obce Nálepkovo.**

V príspevku sa vyhodnocuje predpokladaný vplyv vápnenia dolomitickým prachovým vápencom a aplikácia fosforečnanových a bórových prípravkov na dĺžku ihlíc smreka obyčajného (*Picea abies* K a r s t.) v osem ročných kultúrach vysadených na trvalé pokusné plochy v lesoch obce Nálepkovo (Slovenské rudohorie).

Autori štatistickým vyhodnotením dokazujú, že jediným efektívnym zásahom na zvýšenie dĺžky ihlíc je kombinácia vápnenia a hnojenia. Samostatné hnojenie a samostatné vápnenie bolo neúčinné, naopak čisté vápnenie sa odrazilo na skrátení dĺžky ihlíc smreka.