Growth responses of a Norway spruce (*Picea abies* [L.] Karst.) small pole-stage stand in a region exhibiting extensive decline of allochthonous spruce forests to differentiated thinning

Igor Štefančík[1, 2], Slavomír Strmeň[1], Vilém Podrázský[2], Stanislav Vacek[2]

[1]National Forest Centre-Forest Research Institute in Zvolen, T. G. Masaryka 22, SK-960 92 Zvolen, Slovak Republic, e-mail: stefancik@nlcsk.org; strmen@nlcsk.org
[2]Faculty of Forestry and Wood Technology, Czech Agriculture University in Prague, Kamýcká 1176, CZ-165 21 Prague 6 – Suchdol, Czech Republic,
e-mail: podrazsky@fld.czu.cz; vacekstanislav@fld.czu.cz

Abstract
Štefančík, I., Strmeň, S., Podrázský, S., Vacek, S. 2012. Growth responses of a Norway spruce (*Picea abies* [L.] Karst.) small pole-stage stand in a region exhibiting extensive decline of allochthonous spruce forests to differentiated thinning. *Folia oecol.*, 39: 77–87.

The paper deals with assessment of the growth responses of a 26-year old Norway spruce (*Picea abies* [L.] Karst.) small pole-stage stand, situated in a region affected by mass dying of spruce monocultures, dependent on the different treatment intensity. The intervention was realized at a stand age of 22 years – in order to decrease its density to 1,600 and 1,100 individuals per hectare. Characteristics of quantitative production (number of trees, basal area, stand volume, diameter increment) were analysed and compared among the presented variants of treatment. The special attention was paid to the assessment of target trees (400 individuals per hectare). The results have confirmed correctness of heavy treatments in spruce forests of younger growth stages also for the regions showing mass decline and dying of spruce forests.

Key words
forest decline, forest structure, Norway spruce, stand stability, tending

Introduction

Decline and/or extensive dying of spruce monocultures (monocoenoses) are undoubtedly the most serious problem for forestry not only in Slovakia, but also in the Czech Republic (Hlásny et al., 2011; Kuneš et al., 2011; Mauer and Palátová, 2010; Vacek et al., 1999; Vacek and Lepš, 1987, 1991) and Poland (Magnuski et al., 2001; Skrzyszewski and Skrzyszewska, 2004). This phenomenon is supposed caused by the synergic effect of a complex of abiotic (wind, snow, rime, temperature and moisture extremes), biotic (insect, fungi) and physiological (dry stress, moisture deficit) harmful agents, including impacts of anthropogenic factors (air pollution), especially in the past (Vacek et al., 2007; Hlásny et al., 2010). Apart from these causes, the decisive fact is unfavourable health condition of allochtonous spruce forests, very probably caused by the ongoing climate change impact (Vacek and Matějka, 2010). Premature regeneration and/or reconstruction of damaged, declined and disintegrated spruce monocultures is mostly realized in order to address this serious problem (Pecháček et al., 2011; Novák et al., 2011; Remeš et al., 2004; Magnuski et al., 2001; Skrzyszewski and Skrzyszewska, 2004; Košulič, 2010). There still remains an open question: whether it is possible to influence the dying of spruce stands by tending at younger age.

Although tending of spruce stands meets multiple goals (Slodičák and Novák, 2007), the main focus is on strengthening the stand stability in order to get resistant against unfavourable harmful agents, and, at the same time, to serve the required forest functions. Very important is defining the stand age and intensity optimal for treatment of spruce stands. Most of the authors suggest that the tending in spruce forests (especially from natural regeneration) should start as soon and as intensively as possible (Mráček and Pařez, 1986; Slodičák and Novák, 2001; Chroust, 1997; Štefančík and Kamenský, 2009, 2011). However, the forest practice exhibits just the reverse approach,: interventions applied in the youngest growth stages are either very limited and delayed or not realized at all (Slodičák and Novák, 2007; Štefančík and Kamenský, 2011). In accordance with this fact, Slodičák and Novák (2007) stated, that delayed intervention realised in stands are very laborious and expensive also from the viewpoint of their economic effectiveness.

The problem of spruce stand tending effectiveness is topical also today, especially in relation to the so called "novel spruce forest decline", markedly manifested in Slovakia during the last decade (Hlásny et al., 2009), with spruce stands in the Kysuce and Orava regions most suffering from this damage (Hlásny and Sitková, 2010; Kulla and Sitková, 2010). In spruce stands affected seriously, the most frequent question is either it is possible to eliminate and/or reduce their disintegration by applying certain measures (tending) or premature cutting (artificial regeneration) is necessary. Answering this principal question requires to think about multiple factors and circumstances – natural, ecological, technological and economical. The damage degree, stand age and estimated time of its disintegration and/or survival are considered to be the crucial facts. In many cases when the assumed lifetime exceeds some limit, conversion of these spruce stands is realised.

The consistent, systematic and intensive stand tending at the youngest growth stages is supposed to be a possibility how to reduce and/or delay the current extensive disintegration of spruce monocultures (Štefančík and Kamenský, 2009, 2011).

In accordance the above-mentioned facts, the aim of our research discussed in this paper was to study how the growth reponses in a spruce small pole-stage spruce stand situated in a region affected by the mass dying of spruce stands were influenced by the treatment intensity.

Material and methods

The research was carried out on two experimental plots, established in a stand located in a model area situated in the Kysuce region, Slovakia. The basic mensurational stand characteristics are presented in Table 1.

The stand age on the experimental plots at their establishment in 2006 was 21 years. The area of each plot is 0.18 hectare. Two variants with different stand density and/or treatment intensity were investigated on both plots. In one part of the first plot (EP 1) we selected and marked 1,600 the most perspective spruce trees per hectare (Variant A). Similarly, in another part of this plot, (EP 1), there were selected 1,100 individuals per hectare (Variant B). Several other tree species (beech, fir and larch) were also chosen to maintain. All the other individuals were removed in order to investigate responses to the intervention applied. The EP 1 also includes a part without any treatment (control plot – marked as EP 1/0) with stand density 2,500 trees per hectare. The second experimental plot (EP 2) was segmented by the same way, at which 2,500 individuals per hectare were left for comparison as a control plot (EP 2/0).

The investigated stand originated from natural regeneration (the 2nd generation of allochthonous spruce monoculture), and later it was subjected to silvicultural measures. The experimental plots were established by applying a single silvicultural intervention with light intensity (cleaning), with the aim of sanitary selection.

The biometric measurements (in 2007 and 2011) comprised these characteristics: the total number of trees and the number of trees in the main stand, as well as the diameter at the breast height and the tree height. Consequently, the basic stand characteristics (basal area, stand volume) were calculated and converted to the values per hectare. On each plot, there were selected and marked 400 target (crop) trees per hectare, with crowns released from 90 to 100%, by a treatment in 2007. The calculation of the results was performed by standard methods for tending evaluation and production-silviculture relations (Štefančík, 1974). To find out the statistical significance of the differences, the single-factor analysis of variance (anova) was used.

Results and discussion

The tree species composition in terms of basal area (G) during the investigated period before and after intervention and 4 years after the treatment is presented in Table 2.

On the treated plots (EP I – Variant B and EP II – Variant A) is dicernible a mild increase in fir and beech proportion, which could be favourable for the desired decrease of spruce proportion and increase of share of other tree species (mainly fir and beech). It has been mainly influenced by intervention with positive selection – to prefer all admixed species, in order to increase their proportion and to decrease the spruce share. This has also been confirmed by typological proposals of the tree species composition (Hančinský, 1972), which presents, for the given forest type, spruce proportion of 25–40%, followed by fir 20–30%, beech 30–40% and valuable broadleaved species 5–10% with rare occurrence of larch. The latest models, which take into account altered site conditions, including climate change (Rizman et al., 2007), present spruce proportion of 5–45%, fir 5–25%, beech

Table 1. The basic mensurational characteristics of the given compartment on the model area for management-plan area (Forest management plan 2000–2009)

Compartment (part of a stand)	5299b
(Characteristic)	(PS: 3)
Area [ha]	4.78
Age [years]	15
Stocking	9
Exposure	SE
Inclination (in percentage)	40
Altitude a.s.l. [m]	780–800
Forest category	H (commercial)
Silvicultural system	V (high forest)
Rotation [years]	100
Management complex of forest types	511 (fertile fir beechwood)
Management complex of stand types	21
Management complex	55
Zone of air pollution	D
Forest type	5301–90%; 5302–10%
Tree species composition	
(in percentage)	Beech – 5
	Birch – 10
	Fir – 5
	Sycamore maple – 5
	Larch – 5
	Spruce – 70

5301 – Lowherb fir beechwood, low tier (*Asperula odorata, Oxalis acetosella, Senecio nemorensis, Prenanthes purpurea*).
5302 – Nitrophile lowherb fir beechwood, low tier (*Asperula odorata, Oxalis acetosella, Senecio nemorensis, Mercurialis perennis, Prenanthes purpurea*).

Table 2. Tree species composition according to basal area (G)

Plot	Variant	Age [years]	Stand	Tree species in %			
				spruce	fir	larch	beech
EP I	A	22	Total	98.3	–	1.7	–
			Main	100	–	–	–
		26	Main	100	–	–	–
	B	22	Total	91.9	–	3.6	4.5
			Main	88.9	–	3.6	7.5
		26	Main	88.7	–	1.5	9.8
	0	22	Total	100	–	–	–
		26	Main	100	–	–	–
EP II	A	22	Total	88.5	4.7	3.9	2.9
			Main	87.6	5.4	3.6	3.4
		26	Main	89.2	6.4	–	4.4
	B	22	Total	93.8	–	6.2	–
			Main	94.7	–	5.3	–
		26	Main	100	–	–	–
	0	22	Total	94.6	–	1.7	3.7
		26	Main	94.3	–	1.7	4.0

Variant A → plot with 1,600 pcs ha^{-1} of spruce trees after the 1st intervention. Variant B → plot with 1,100 pcs ha^{-1} of spruce trees after the 1st intervention. Variant 0 → plot without intervention (control).

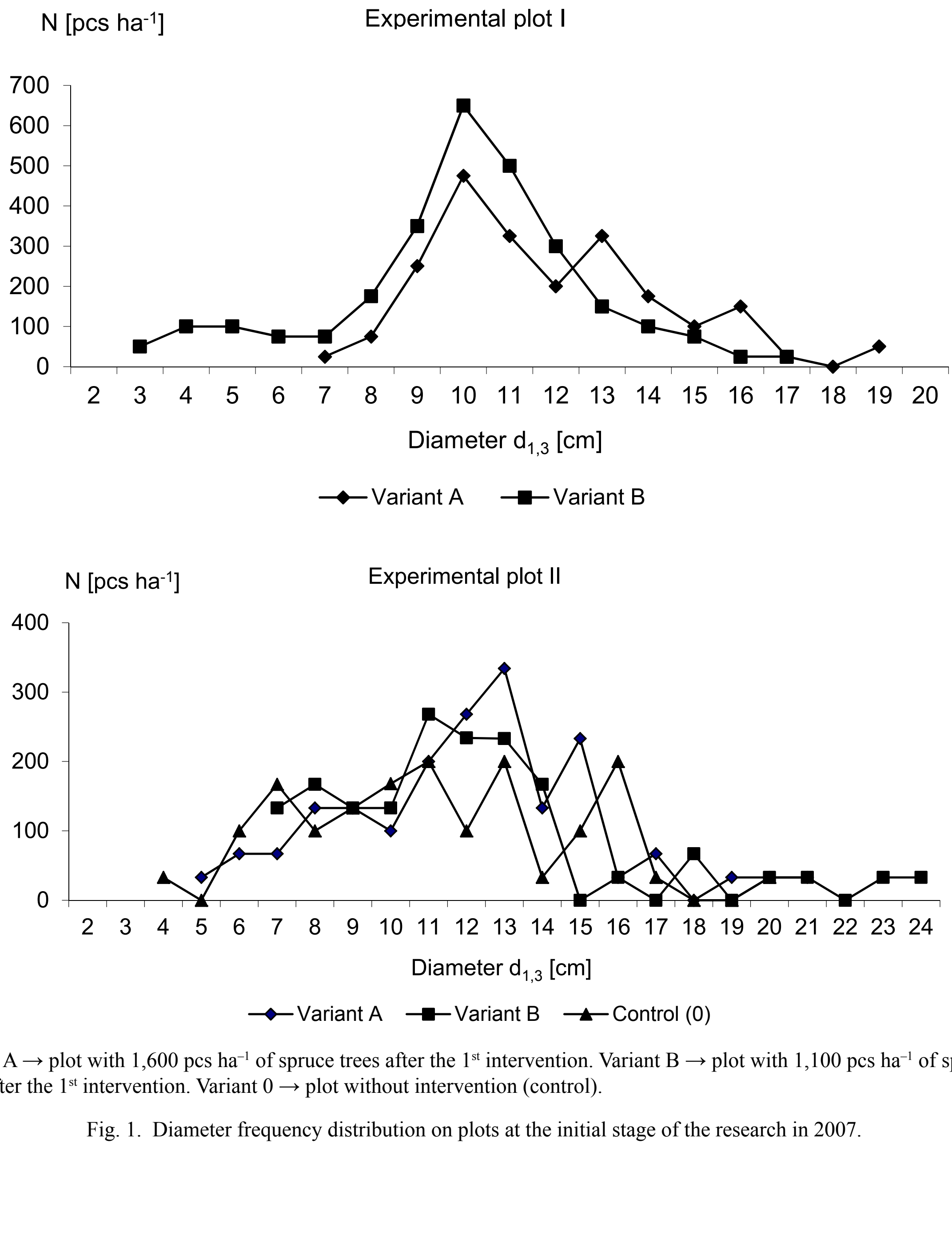
45–60% and valuable broadleaved species up to 10%. From this trend it is clear, the interventions planned in the future should interfere in favour of other species, especially beech and fir.

Diameter structure

The diameter development of the investigated stands is characterized by the diameter frequency distribution (Fig.1 and Fig. 2), as well as by the values of mean diameter (d_g) presented in Table 3.

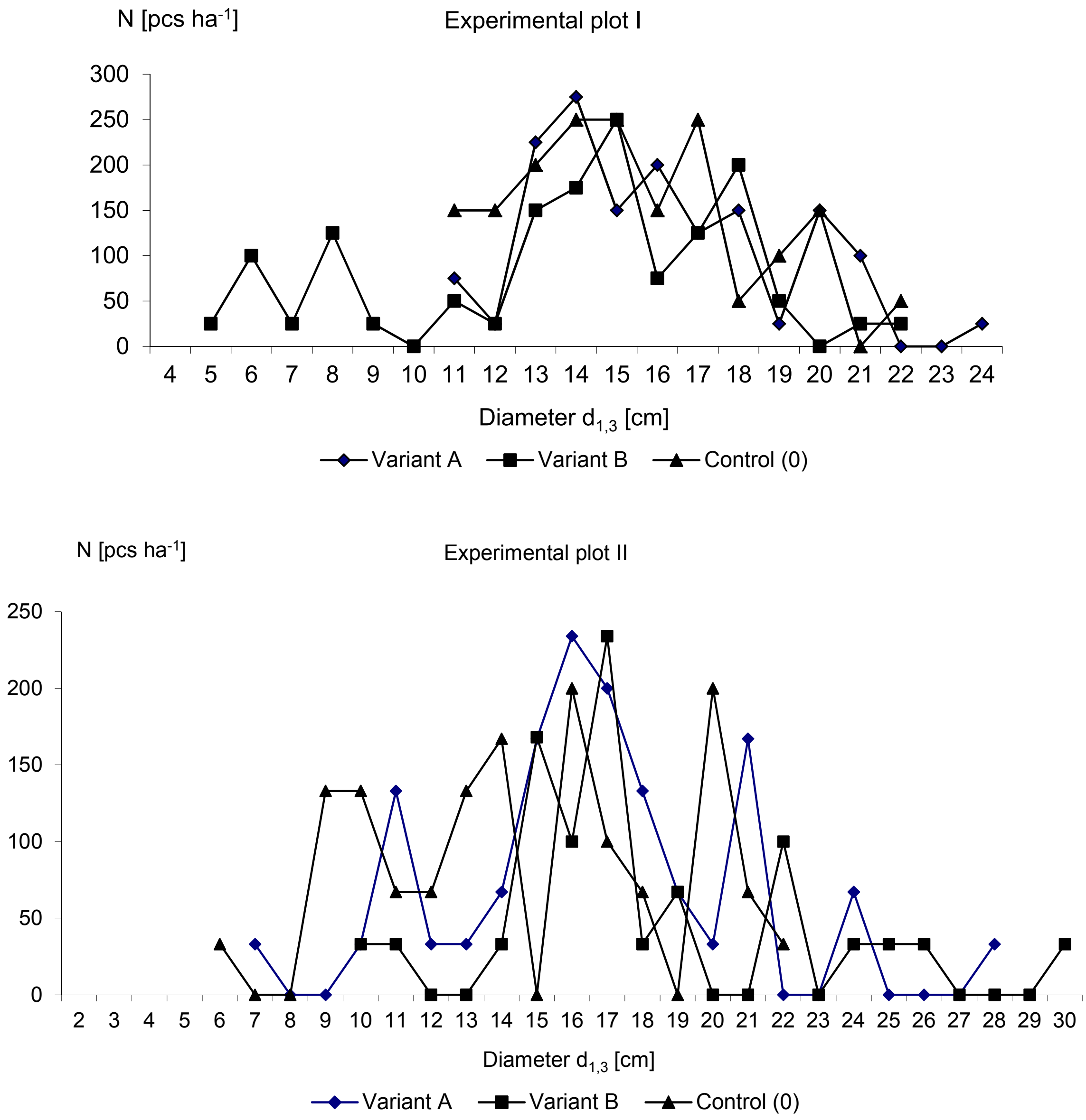
In the initial stage of the research, the course of curves of diameter frequency distribution was found somewhat different, the testing, however, of statistical significance of the d.b.h. differences in individual plots unveiled significant differences on the level $\alpha = 0.05$ only between the Variant A and Variant B on EP I. It is more or less symmetric distribution, as for frequency distribution. The highest values of mean d.b.h. were found for Variant A, on both experimental plots.

After the intervention, purposed for reducing the density of the main stand to 1,600 (Variant A) and 1,100 (Variant B) spruce trees per hectare, the changes were found only on EP II where the mean d.b.h. was found the highest in Variant B. The mentioned trend was the same also 4 years after treatment. The diameter fre-



Variant A → plot with 1,600 pcs ha^{-1} of spruce trees after the 1st intervention. Variant B → plot with 1,100 pcs ha^{-1} of spruce trees after the 1st intervention. Variant 0 → plot without intervention (control).

Fig. 1. Diameter frequency distribution on plots at the initial stage of the research in 2007.



Variant A → plot with 1,600 pcs ha^{-1} of spruce trees after the 1st intervention. Variant B → plot with 1,100 pcs ha^{-1} of spruce trees after the 1st intervention. Variant 0 → plot without intervention (control).

Fig. 2. Diameter frequency distribution on investigated plots in 2011 (4 years after intervention).

quency distribution (Fig. 2) remained symmetric on the treated plots.

Our results are similar to the values published by Chroust (1997), recorded on the experimental object "Sedloňov", with two cleaning variants peformed on a 12-year-old stand. On the plots treated by heavy intervention, the number of trees of 1,750 individuals per hectare was registered at the stand age of 22 years, with the mean diameter (d_g) of 11.90 cm. At the stand age of 26 years, it was 1,610 pcs ha^{-1} and (d_g) 14.5 cm. During the first years after the treatment, a slightly higher increase in the mean diameter was found in the thickets treated by heavy intervention, what was found true in our investigated plots. Four years after the treatment, the mean diameter increased mostly in Variant B (on both plots): by 36.0% on EP I and by 35.3% on EP II. Consequently, in Variant A it was only 28.4% and 31.0%.

Height structure

The height structure of the investigated plots was expressed by the relative number in the growth (tree) classes (Table 4). The proportion of trees in the crown level of the stand (1st + 2nd growth class) and the suppressed level of the stand (3rd to 5th growth class) is very important from the silvicultural point of view. Since the data from the first measurement are not available, only the results 4 years after the intervention are presented.

The differences in the height structure (proportion of the crown level and the suppressed one) among the plots and/or variants were well discernible. The highest proportion of crown level was found on EP I, for Variant A (86.9%), and the lowest for Variant B (56.9%). This result is logical, because the more intensive intervention, aimed at decreasing the number of trees to 1,100 individuals per hectare, required to remove more trees from the crown level of the stand. The opposite was found on EP II, where the proportion of the crown level was the highest for Variant B (1,100 pcs ha^{-1}), reaching 82.2%. This may follow from lower number of trees on EP II (in comparison to EP I), where mostly co-dominant trees remained in the stand after intervention. Significant role represents also shifts in height, very frequent and distinctive in Variant with stronger intervention, also confirmed by the values of mean height (Table 3) at the age of 26 years, i.e. 4 years after the treatment. This has also been confirmed by statistical testing significance of the differences (at level α = 0.05) in the mean height between the variants (Table 3).

The height values were found higher in comparison with those presented by Chroust (1997): 8.6 m and 11.0 m, obtained in the Experimental object Sedloňov, on a plot treated by heavy intervention at the stand age of 22 and 26 years. They are more similar to the values found on the treated plot Machov I, being 13.6 cm at the age of 24 years, and the plot Zaječiny, with the values on treated plots 13.6 cm, 14.4 cm and 15.2 cm.

Development of quantitative production

The development of stand characteristics before and after the intervention is presented in Table 3. At establishment of the plots, the highest initial number of trees (N) was found on EP I, representing 2,750 pcs ha^{-1} and the lowest on control plot (EP II). We can see that on EP I (Variant A) was reached the final number N 1,600 of individuals per hectare, but for Variant B it exceeded 425 trees – as a consequence of a higher beech proportion (Table 1). Consequently, it was almost the same in comparison with the planned reduction of stand density on EP II.

The stand density found on the discussed plots is in accordance with the long-term research results on spruce stands (mainly in Bohemia). Many authors (Mráček and Pařez, 1986; Slodičák, 1987; Chroust, 1997, Slodičák and Novák, 2007) recommend heavy reduction of N to 1,600 trees per hectare and less, especially in spruce stands cultivated in areas endangered by snow break, what is also the case of the investi-

Table 3. Development of stand characteristics

Plot/Variant	Stand	Age [year]	N [pcs ha^{-1}]	G [m^3 ha^{-1}]	V_{7b} [m^3 ha^{-1}]	Mean diameter $d_{1,3}$ [cm]	Mean height [m]
EP I	Total	22	2,175	25.277	121.250	11.91^{a}	10.22^{a}
Variant A	Main	22	1,600	20.474	82.075	12.52^{a}	10.52^{a}
	Main	26	1,525	31.986	247.025	16.07^{a}	15.26^{a}
EP I	Total	22	2,750	23.415	99.800	10.06^{b}	9.39^{b}
Variant B	Main	22	1,525	13.930	60.675	10.26^{b}	9.65^{b}
	Main	26	1,450	24.055	149.400	13.95^{bc}	12.05^{b}
Control (0)	Main	26	1,750	33.725	224.200	15.39^{ac}	13.05^{c}
EP II	Total	22	1,900	24.097	109.767	12.26^{a}	9.11^{a}
Variant A	Main	22	1,600	21.595	100.767	12.69^{a}	9.33^{a}
	Main	26	1,433	32.933	219.000	16.63^{ab}	12.8^{a}
EP II	Total	22	1,700	21.433	104.433	12.22^{a}	9.93^{a}
Variant B	Main	22	1,133	17.205	88.033	13.38^{a}	10.46^{b}
	Main	26	933	25.448	183.300	18.10^{a}	14.31^{b}
Control (0)	Total	22	1,600	17.560	80.000	11.28^{a}	9.30^{a}
	Main	26	1,400	25.771	181.867	14.74^{bc}	13.18^{ab}

N, number of trees; G, basal area; V_{7b},volume of the timber to the top of 7 cm.
The values with the same letter are not significantly different on the level α = 0.05.
Variant A → plot with 1,600 pcs ha^{-1} of spruce trees after the 1st intervention. Variant B → plot with 1,100 pcs ha^{-1} of spruce trees after the 1st intervention. Variant 0 → plot without intervention (control).

Table 4. Relative number according to the growth classes

Plot/Variant	Stand	Age	Growth class				
		[year]	1	2	3	4	5
EP I /A	Main	26	32.8	54.1	13.1	–	–
EP I /B			12.1	44.8	36.2	5.2	1.7
EP I /0			28.6	37.1	31.4	2.9	–
EP II /A	Main	26	32.6	39.5	20.9	7.0	–
EP II /B			28.6	53.6	14.3	3.5	–
EP II /0			23.8	33.3	23.8	16.7	2.4

Variant A → plot with 1,600 pcs ha^{-1} of spruce trees after the 1^{st} intervention.
Variant B → plot with 1,100 pcs ha^{-1} of spruce trees after the 1^{st} intervention.
Variant 0 → plot without intervention (control).

gated plots. Mráček and Pařez (1986) informed that a decrease of N to 2,600-1,600 trees already by the first cleaning during the period of closer canopy formation is characterized by many advantages, mainly by a very favourable effect on static stability. The mentioned authors also stated that a decrease to 1,600 individuals and less is especially important in areas endangered by snow, comprising in Slovakia localities situated at about 800–850 m a.s.l., i.e. plots assessed by this paper.

Therefore, in relation with the above-mentioned facts, the values of slenderness quotient are especially significant (not presented in Table). More favourable values were found on EP II (0.819 for Variant B and 0.789 for Variant A) than on EP I with 0.970 for Variant A) and 0.915 for Variant B), what indicates a good static stability of these stands. It is evident that the intervention was found resulting in decreasing slenderness quotient (except for EP I, Variant). This was caused "numerically" – as a consequence of removing thinner and lower trees. The goal of the mentioned intervention was to decrease stand density to the desired number of trees. Due to the short period after the intervention, the stand did not manifest much effect. As for the absolute values of slenderness quotient, they are comparable to those published by Chroust (1997), investigating a stand aged of 26 years in the experimental object Sedloňov (plot with heavy treatment), with the values of 0.756 in the original stand, followed by 0.801 on plot subjected to light treatment and 1.023 on the control plot.

Similar values, ranging from 0.830 to 0.890, were also found on treated plots in the experimental object Zaječiny at a stand age of 24 years. Consequently, Mráček and Pařez (1986), as well as Slodičák and Novák (2007) ascertained similar values, 0.850–0.880 after 40-year tending in numerous experiments carried out in spruce forests in the past.

For the other stand parameters (basal area – G and timber to the top of 7 cm o.b. – V_{7b}), at the initial stage of the research, we obtained the highest values on both plots in Variant A (1,600 pcs ha^{-1}) and the lowest (Variant B – 1,100 pcs ha^{-1}) on the control plot. The situation had not been changed even 4 years after the intervention; on EP I, however, we found the highest values of G on control plot (with the highest N), while on EP II (for almost the same N) it was by 27.8% more at Variant A than on control plot. Comparisons of G and V_{7b} in term of growth index values, always showed markedly higher values in Variant A than in Variant B. It may be explained by the fact that the stand with only sanitary selection applied in the past, the responses to heavy intervention by intense height increment and/or also diameter increment were shifter later. This has been confirmed by our results presented in the section discussing the height increment, when on EP I after 4 years it was 45.1% (Variant A) and 24.9% (Variant B), while on EP II it was 37.2% and 36.8%, respectively. The same results were also published by Slodičák (1987) who observed that the diameter increment decreased, as a rule, in spruce stands older than 15 years, contrarily to the height increment, that culminated or even increased. Consequently, the slenderness quotient exhibited an increasing trend, what was also confirmed on the investigated plots.

Similarly, the mean annual basal area increment (i_G) was also found higher on both plots in Variant A (1,600 pcs ha^{-1}) in comparison with Variant B (1,100 pcs ha^{-1}). On EP I it was 2.878 and 2.531 m^2 ha^{-1} $year^{-1}$; on EP II 2.061 m^2 ha^{-1} $year^{-1}$. The mentioned values are comparable to those obtained by Chroust (1997), ranging from 2.70 to 2.93 m^2 ha^{-1} $year^{-1}$, at age of 24 years on the treated plots in the experimental object Zaječiny.

Development of target (crop) trees

Development of target trees (TT), representing qualitative production in commercial forests are illustrated in Table 5. TT are especially important for static stability, therefore silviculturists primarily focus their efforts on these trees. In spruce stands, 400 TT per hectare are usually selected (Mráček and Pařez, 1986; Slodičák and Novák, 2007). It is not always possible to find and select the required number of TT, as they do need not meet the relevant criteria. For example, Slodičák and Novák (2007) presented only 360–380 TT per hectare on the IUFRO series Vítkov 13. The quantitative parameters (basal area, timber to the top of 7 cm o.b., mean diameter and height) in the initial stage of the research, exhibited the highest values for the same number of TT (400 pcs ha^{-1}) on plots EP I (Variant A – 1,600 pcs ha^{-1}) and EP II (Variant B – 1,100 pcs ha^{-1}) and the lowest values on the control plot.

The same tendency was recorded in years after the intervention. As for G and V_{7b}, the highest percentage of increase was found on EP I (Variant A) and the lowest on EP II (Variant B). The proportion of TT expressed by the percentage out of the main stand was found out always higher in the variant with lower stand density (Variant B) than in the denser stand (Variant A), which gives evidence for advantage of heavier treatment.

The mentioned results have also been confirmed with the values of the mean annual diameter increment – i_d (Table 6). They were always higher on the plot treated by stronger intervention (Variant B) compared to the lighter (Variant A), the differences, however, were neither high, nor statistically significant. The same trend was also ascertained by comparing i_d only for trees belonging to the crown level of the stand (1st and 2nd tree class), except for EP I where the differences between the variants were found out significant ($\alpha = 0.05$).

Analysis of silvicultural treatment

The heaviest intervention was realized on EP I (Variant B), with an intensity (out of number of trees) of 44.5%, followed by EP II (Variant B) with intensity 33.4%. Contrariwise, the lowest intensity of the intervention was applied in Variant A (EP I – 26.4% and EP II 15.8). The same trend hold in the thinning intensity according to the basal area (Fig. 3).

We may suggest that both variants of treatment favourably influenced stand development, especially its static stability, considered to be crucial in this growth stage. From the plot treated by heavier intervention (Variant B), mostly suppressed trees were removed from the lower stand layer, but less interventions were realized in the crown level of the stand in comparison with Variant A (stand with higher density). Slodičák and Novák (2007) concluded from their own experiments that heavy intervention in the suppressed level of the stand was completely able to eliminate snow damage 15 years after the intervention. This fact is in accordance with our results obtained on experimental plots in the Kysuce region, with a single snow-broken individual found four years after the treatment.

Conclusions

There were studied growth responses of a 26-year old spruce stand located in an allochthonous site in the Kysuce region, four years after an intervention with diversified intensity, manifested by changes in the stand diameter and height structure. Due to the short period, there have hitherto been registered only little changes in quantitative parameters and slenderness values. More intensive intervention resulted in a favourable diameter increment in the target (crop) trees in comparison with lower thinning intensity. The interventions in stands

Table 5. Development of target (crop) trees

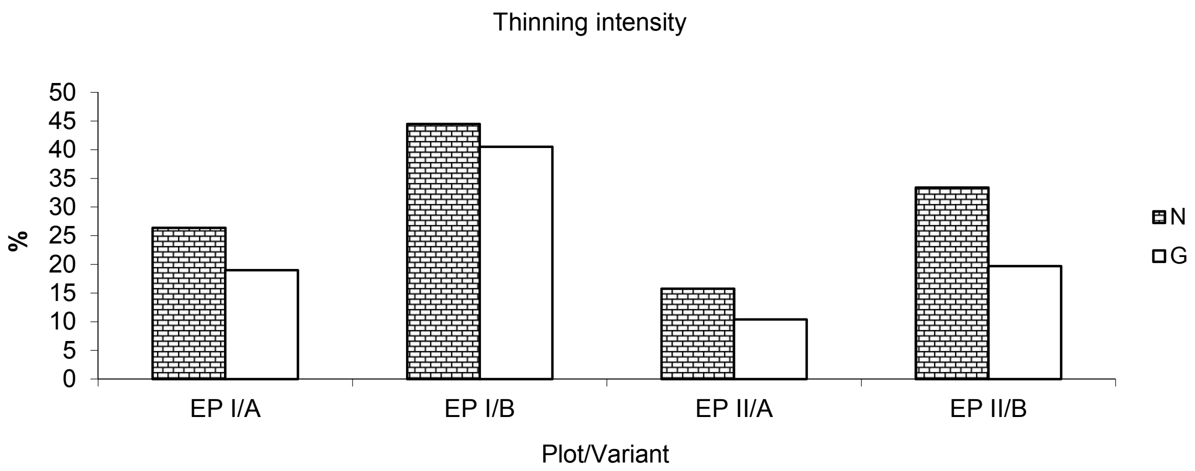
Plot/Variant	Age	N	G		V_{7b}		Mean	
				% out of		% out of	diameter $d_{1,3}$	height
	[y.]	[pcs ha^{-1}]	[m^2 ha^{-1}]	main stand	[m^3 ha^{-1}]	main stand	[cm]	[m]
EP I /A	22	400	6.508	31.8	34.575	42.1	14.22	10.99
	26	400	11.241	35.1	90.575	36.7	18.71	16.34
EP I /B	22	400	4.535	32.6	20.500	33.8	11.95	10.74
	26	400	9.215	38.3	61.550	41.2	16.97	13.97
EP II /A	22	400	8.239	38.2	42.267	41.9	15.88	10.45
	26	400	13.528	41.1	96.933	44.3	20.44	14.30
EP II /B	22	400	8.867	51.5	49.767	56.5	16.26	11.34
	26	400	14.327	56.3	106.667	58.2	20.90	15.25
Control (0)	22	367	6.025	34.3	31.133	38.9	14.28	10.60
	26	367	10.611	41.2	81.133	44.6	19.05	14.85

N, number of trees; G, basal area; V_{7b}, volume of the timber to the top of 7 cm.
The values with the same letter are not significant on the level $\alpha = 0.05$.
Variant A → plot with 1,600 pcs ha^{-1} of spruce trees after the 1st intervention. Variant B → plot with 1,100 pcs ha^{-1} of spruce trees after the 1st intervention. Variant 0 → plot without intervention (control).

Table 6. An average annual diameter increment (i_d) with standard deviation of the target (crop) trees and trees from crown level of the stand (mm)

Plot/Variant	EP I /A	EP I /B	EP II /A	EP II /B	Control (0)
i_d (2007–2011)	11.23 ± 1.99^{a}	12.55 ± 3.04^{a}	11.40 ± 3.48^{a}	11.61 ± 2.71^{a}	11.91 ± 1.51^{a}
Crown level	9.38 ± 2.29^{a}	12.33 ± 2.89^{bc}	10.15 ± 3.33^{a}	11.33 ± 2.10^{ab}	10.46 ± 2.37^{ab}

The values with the same letter are not significant on the level α = 0.05.
Variant A → plot with 1,600 pcs ha^{-1} of spruce trees after the 1st intervention. Variant B → plot with 1,100 pcs ha^{-1} of spruce trees after the 1st intervention. Variant 0 → plot without intervention (control).



Variant A → plot with 1,600 pcs ha^{-1} of spruce trees after the 1st intervention. Variant B → plot with 1,100 pcs ha^{-1} of spruce trees after the 1st intervention.

Fig. 3. Thinning intensity according to the number of trees (N) and the basal area (G).

resulted in their diameter and height differentiation, as well as spatial arrangement of target (crop) trees – the bearers of the static stand stability. The static stand stability is the primary prerequisite for survival and fitness of trees growing under threat of abiotic injurious agents, especially snow.

Acknowledgement

This paper was supported by the project ITMS 26220220026 “Demonstration Object on the Transformation of Declining Spruce Forests into Ecologically More Stable Multifunctional Ecosystems“ supported by the ERDF-funded operational programme „Research and Development“.

References

Hančinský, L. 1972. *Lesné typy Slovenska* [Forest types in Slovakia]. Bratislava: Príroda. 307 p.

Hlásny, T., Kulla, L., Bucha, T., Konôpka, J. 2009. Súčasný stav a prognózy vývoja hynutia smrečín na Slovensku [Present situation and prognosis of spruce decline development in Slovakia]. *Les – Slov. Letokruhy*, 65/8 (3–4): 12 p.

Hlásny, T., Kulla, L., Barka, I., Turčáni, M., Sitková, Z., Koreň, M. 2010. The proposal of biotic hazard zones in selected spruce dominated regions in Slovakia. *J. Forest Sci.,* 56: 236–242.

Hlásny, T., Sitková, Z. (eds) 2010. *Spruce forests decline in the Beskids*. Zvolen: National Forest Centre. 182 p.

Hlásny, T., Holuša J., Štěpánek, P., Turčáni, M., Sitková, Z., Zajíčková, L. 2011. Expected impacts of climate change on forests: Czech Republic as a case study. *J. Forest Sci.*, 57: 422–431.

Chroust, L. 1997. *Ekologie výchovy lesních porostů: smrk obecný – borovice lesní – dub letní – porostní prostředí – růst stromů – produkce porostu* [Ecology of stand tending: Norway spruce – Scots

Európska únia
Európsky fond regionálneho rozvoja
Operačný program VÝSKUM a VÝVOJ

pine – pedunculate oak – stand environment – tree growth – stand yield]. Opočno: Výzkumný ústav lesního hospodářství a myslivosti, Výzkumná stanice Opočno. 277 p.

Košulič, M. 2010. Zahájení přestavby smrčin v mladém věku [Initiation of spruce conversion in young age]. *Lesn. Práce*, 89: 236–237.

Kulla, L., Sitková, Z. (eds) 2010. *Hynutie a rekonštrukcie smrečín na Slovensku* [Dying and reconstruction of spruce stands in Slovakia]. Recenzovaný zborník odborných prác vydaný na DVD. Zvolen: NLC – LVÚ. 242 p. + 16 príloh.

Kuneš, I., Koňasová, T., Balcar, V., Baláš, M., Zahradník, D., Kacálek, D., Vítámvás, J., Jakl, M., Jaklová-Dytrtová, J. 2011. Growth response of Alnus viridis to application of crushed limestone and amphibolite and forestry potential of the species in harsh acidic mountain sites. *J. Forest Sci.,* 57: 200–209.

Magnuski, K., Jaszczak, R., Malys, L. 2001. Struktura cech biometrycznych jodly pospolitej (Abies alba Mill.) pochodzacej z podsadzenia w przebudowywanym drzewostanie swierkowym (Picea abies (L.) Karst.) o ropznym stopniu przerzedzenia [Structure of biometric traits in common fir (Abies alba Mill.) derived from underplanting in a reconstructed spruce (Picea abies (L.) Karst.) stand with varying canopy opening]. *Sylwan*, 145: 5–13.

Mauer, O., Palátová, E. 2010. Decline of Norway spruce in the Krkonoše Mts. *J. Forest Sci.,* 56: 361–372.

Mráček, Z., Pařez, J. 1986. *Pěstování smrku* [Silviculture of spruce]. Praha: SZN. 203 p.

Novák, J., Slodičák, M., Dušek, D. 2011. Aboveground biomass of substitute tree species stand with respect to thinning – European larch (Larix decidua Mill.). *J. Forest Sci.,* 57: 8–15.

Pecháček, J., Vavříček, D., Samec, P. 2011. Soil environment and nutrient status of Norway spruce (Picea abies [L.] Karst.) underplantings in conditions of the 8th FAZ in the Hrubý Jeseník Mts. *J. Forest Sci*., 57: 141–152.

Remeš, J., Ulbrichová, I., Podrázský, V. 2004. Využití podsadeb a meliorace půdy při umělé obnově [Underplanting and soil amelioration in artificial regeneration]. *Lesn. Práce*, 83: 352–356.

Rizman, I. 2007. Poznatková báza o zastúpení drevín v lesných typoch Slovenska, základný predpoklad pre tvorbu modelov TUOL [Knowledge basis of tree species composition of forest types in Slovakia, the fundamental assumption for designing Sustainable management models]. In Rizman, I. (zost.). *Lesnícka typológia a zisťovanie stavu lesa vo väzbe na trvalo udržateľné obhospodarovanie lesov. Zborník prezentácií a príspevkov zo seminára konaného 3. 12. 2007 vo Zvolene.* Zvolen: Národné lesnícke centrum. 1 electronic optical disk (CD-ROM).

Skrzyszewski, J., Skrzyszewska, K. 2004. Species conversion of spruce stands in the Wisla Forest District. *Dendrobiology,* 51, Suppl.: 95–99.

Slodičák, M. 1987. Výchova mladých smrkových porostů ohrožených sněhem a její vliv na růst a statickou stabilitu stromů různých stromových tříd [Tending of young spruce stands jeopardized by snow breaks and the influence of tending measures on the growth and static stability of trees belonging to various tree classes]. *Lesnictví,* 33: 1091–1106.

Slodičák, M., Novák, J. 2001. Zásady výchovy smrkových porostů v podmínkách antropogenně změněného ekotopu [Thinning principles for Norway spruce stands in conditions changed by anthropogenic influences]. In Slodičák, M. and Novák, J. (eds). *Současné otázky pěstování horských lesů: Actual problems of silviculture in mountain forests. Sborník z III. česko-slovenského vědeckého sympozia pedagogickovědeckých a vědeckovýzkumných pracovišť oboru Pěstování lesa. Opočno 13. 9.–14. 9. 2001*. Opočno: Výzkumný ústav lesního hospodářství a myslivosti, Výzkumná stanice Opočno, p. 351–370.

Slodičák, M., Novák, J. 2007. *Růst, struktura a statická stabilita smrkových porostů s různým režimem výchovy* [Growth, structure and static stability of spruce stands under different tending regimes]. Folia Forestalia Bohemica, 3. Kostelec nad Černými lesy: Lesnická práce. 144 p.

Štefančík, I., Kamenský, M. 2009. Výskum prirodzenej obnovy a výchovy v odumierajúcich smrečinách v oblasti Kysúc [Research on natural regeneration and tending in dying spruce forests of the Kysuce region]. In Štefančík, I., Kamenský, M. (eds). *Pestovanie lesa ako nástroj cieľavedomého využívania potenciálu lesov. Zborník recenzovaných príspevkov z medzinárodnej vedeckej konferencie konanej dňa 8. a 9. septembra 2009 vo Zvolene*. Zvolen: Národné lesnícke centrum – Lesnícky výskumný ústav, p. 158–171.

Štefančík, I., Kamenský, M. 2011. Vychovávame smrekové porasty dostatočne intenzívne? [Do we tend our spruce stands with sufficient intensity?]. *Les – Slov. Letokruhy,* 67 (10): 2–15.

Štefančík, L. 1974. *Prebierky bukových žrďovín* [Thinning in beech pole stands]. Lesnícke štúdie, č.18/74. Bratislava: Príroda. 141 p.

Vacek, S., Lepš, J. 1987. Changes in the horizontal structure in a spruce forest over a 9-year period of pollutant exposure in the Krkonoše Mountains, Czechoslovakia. *Forest Ecol. Mgmt*, 22: 291–295.

Vacek, S., Lepš, J. 1991. Použití Leslieho matic pro predikci vývoje smrkových porostů pod vlivem imisí [The use of Leslie´s matrices for the prediction of development of spruce stands exposed to air pollution stress]. *Lesnictví,* 37: 133–150.

Vacek, S., Bastl, M., Lepš, J. 1999. Vegetation changes in forests of the Krkonoše Mts over a period of air pollution stress (1980 – 1995). *Pl. Ecol.*, 143: 1–11.

Vacek, S., Matějka, K., Simon, J., Malík, V., Schwarz, O., Podrázský, V., Minx, T., Tesař, V., Anděl, P., Jankovský, L., Mikeska, M. 2007. *Zdravotní stav a dynamika lesních ekosystémů Krkonoš pod stresem vyvolaným znečištěním ovzduší* [Health status and dynamics of forest ecosystems under air pollution stress in the Giant Mts]. Folia Forestalia Bohemica, 4. Kostelec nad Černými lesy: Lesnická práce. 216 p.

Vacek, S., Matějka, K. 2010. Health status of forest stands on permanent research plots in the Krkonoše Mts. *J. Forest Sci.,* 56: 555–569.

Rastové odozvy smrekovej žŕdkoviny na rozdielny zásah v oblasti hromadného odumierania nepôvodných smrekových porastov

Súhrn

Príspevok sa zaoberá zhodnotením rastovej reakcie 26-ročnej smrekovej žŕdkoviny nachádzajúcej sa v oblasti hromadného odumierania smrekových porastov v závislosti od rozdielnej sily vykonaného zásahu. Zásah sa vykonal vo veku porastu 22 rokov tak, aby sa znížila jeho hustota na 1 600 ks ha^{-1}, resp. 1 100 ks ha^{-1}. Analyzovali a porovnali sa charakteristiky kvantitatívnej produkcie (počet stromov, kruhová základňa, objem hrubiny, hrúbkový prírastok) podľa uvedených variantov vykonaných zásahov. Osobitná pozornosť sa venovala vyhodnoteniu cieľových stromov (400 ks na 1 ha). Výsledky po štyroch rokoch po vykonanom zásahu rozdielnej sily ukázali zmeny v hrúbkovej i výškovej štruktúre sledovaných plôch. Zmeny v kvantitatívnych parametroch, resp. hodnotách štíhlostného kvocientu sa vzhľadom na krátky čas prejavili zatiaľ v menšom rozsahu. Silnejší zásah sa priaznivejšie prejavil na hrúbkovom prírastku cieľových stromov v porovnaní so slabším zásahom. Vykonaným zásahom sa dosiahla určitá hrúbková a výšková diferenciácia porastu a tiež priestorové rozmiestnenie cieľových stromov, ktoré tvoria základ statickej stability porastu, ktorá je najdôležitejšou zložkou jeho existencie v daných podmienkach ohrozenia abiotickými škodlivými činiteľmi, najmä snehom. Výsledky potvrdili opodstatnenosť silných zásahov v smrečinách v mladších rastových fázach aj v oblastiach ich hromadného odumierania.

Received December 8, 2011
Accepted March 15, 2012