Beskydy, 2014, 7 (2): 107–114

ISSN: 1803-2451 (Print)
http://dx.doi.org/10.11118/beskyd201407020107

Assessment of the Norway spruce plantation growth on a mountain forest site disturbed by windrowing and ameliorated by green alder

F. Šach, V. Černohous

Forestry and Game Management Research Institute, public research institution, Strnady Research Station, 517 73 Opočno, Czech Republic, sach@vulhmop.cz; cernohous@vulhmop.cz

Abstract: Šach F., Černohous V. 2014: Assessment of the Norway spruce plantation growth on a mountain forest site disturbed by windrowing and ameliorated by green alder. *Beskydy*, 7 (2): 107–114

Mechanized windrowing in the top region of the Orlické hory Mts. has disturbed hundreds of hectares of immission clearcuts during eighties. The soil surface on the Velká Deštná Mountain was disturbed in 1987. One year later the Forest Research Station at Opočno established on this place the long-term research plot. Degree and extent of soil surface disturbance were recorded. Besides other experiments, the experimental Norway spruce plantation was established on three strips: control strip, strip treated by fertilizers or limestone (1991), and strip ameliorated by *Alnus viridis* plantation (1992). The effect of site degradation by mechanized windrowing has been indicated by young spruce growth for a long time period. The assessment of 17 years old spruce growth on the control strip shows significantly greater height increment on negligibly disturbed sites comparing to that on remarkably and very remarkably disturbed sites. Amelioration of spruce trees brings perspective outcomes on the strip biologically amended by *Alnus viridis*. High atmospheric depositions especially of nitrogen compounds, fungal disease by Ascocalyx abietina, climatic fluctuations, and high values of ground-level ozone have brought new problems into spruce plantation performance since 1999. Nevertheless, it has been more substantially reduced by green alder.

Key words: site preparation; mechanized windrowing; soil disturbance, biological amelioration; green alder; Norway spruce; plantation growth; Orlické hory Mts.

Introduction and problems outline

Mechanized windrowing in the top region of the Orlické hory Mts. has disturbed hundreds of hectares of immission clearcuts during eighties. The soil surface on the Velká Deštná Mountain was disturbed in 1987. One year later the Forest Research Station at Opočno established on this place the long-term research plot. Degree and extent of soil surface disturbance were charted and registered by Šach, Podrázský (1994). Removal of a great part of the forest floor and organomineral horizon A-horizon into windrows was notably serious. It was displaced as much as 200 cubic meters of topsoil from one hectare. Content and supply of organic matter in topsoil were also decreased. Besides other experiments, the Norway spruce plantation was established on three strips in 1991–1992: control strip, strip treated by fertilizers or limestone (1991), and strip ameliorated by green alder plantation (1992). As the review of works on green alder by Šach, Černohous (2009) documented, attention in Europe was paid to growth and functioning of green alder communities at timber line. The ameliorative and site-reclamation potential of green alder was pursued especially in Canada, USA and New Zealand. In national conditions, the green alder was used for afforestation and stabilization of extensive landslides in the Jeseníky Mts. (Czech Republic) and for

stabilization of pastures in the Slovenské rudohorie Mts. (Slovak Republic).

According to the Czech legislation, the green alder belongs to ameliorative and stabilization tree species. Green alder is recommended as a tree species ameliorating sites where the forest soil was degraded in consequence of lost topsoil, i.e. loss of LFH and A-horizons. Its ameliorative function like early successive pioneer tree species is attractive to use in the Czech Republic on sites prepared by bulldozer (e.g. Krušné hory Mts.) and likewise on sites intensively prepared by slashraker. The slashraker is able to remove forest topsoil (LFH, possibly also A-horizon) in various extension and intensity. It is possible to use green alder on immission clear-cuts, though not on sites with preserved profile of forest topsoil (Podrázský *et al.* 2005, Kuneš *et al.* 2011).

Therefore, the resulting aim of our paper is to assess the influence of biological amelioration by green alder on spruce plantation growing on a mountain site disturbed by slashraker windrowing.

Material and methods

Research object establishment

To address amelioration problems on sites with disturbed and displaced topsoil (Šach, Černohous 2000a), the experimental research areas were established in the summit part of the Orlické hory Mts. The study of mentioned unfavourable affects of mechanized windrowing was pursued in the region of the Mount Velká Deštná on the site with extreme immission-ecotope conditions. Some characteristics of the site and its degradation were brought in more detail by Šach, Podrázský (1992) and Šach (1994).

The experimental plots are situated at an altitude of 1060–1110 m above sea level and at time its establishment inside of A-zone of exposure to immission (forest lands with forest stands extremely loaded by immission, where injury of a mature spruce stand increases by one degree during five years). Aspect of the area is northwestern, windward to the main immission flux routing. Its slope inclination grows progressively from 7% to 19%. The forest site is represented by mountain ash-spruce stands with blueberry type in top sloping location (8Z2). It is situated on strongly distinct humus podzol, loamy-sand, very stony; underlying rock represents migmatized orthogneiss. Precipitations exceed 1200 mm per annum and mean annual air temperature is ca 4 °C.

Management activities

The previous 160-year-old spruce stand, severely damaged by air pollution, was harvested in 1986. The logging waste was windrowed by slashraker into the windrows in 1987. The slashraker displaced 199 $m^3.ha^{-1}$ surface soil into the windrowes. Disturbance of land surface (Šach, Podrázský 1992, Šach 1994) was as follows: windrowes (13%), soil surface undisturbed visually (28%), ground cover disturbed but kept on place (43%), ground cover (forest floor plus low vegetation) mixed with mineral soil, shallow rills (7%), ground cover removed, mineral soil exposed, deep rills (9%). Foresters established *Pinus mugo* operation plantation in 1988–1989.

Research programmes

The experiment has run on three downward sloping strips bounded by windrows (see illustrative scheme on the Fig. 1). Forest researchers established *Picea abies* and *Alnus viridis* experimental plantation in 1991–1992. The whole research area sized ca 1 ha was fenced in 1993.

Each of three mentioned strips represented the separate research programme. The programme I (on the strip I) included pursuance of an influence of different nutrition of spruce transplants in the forest nursery on the plant survival, growth and plant performance after outplanting. The programme I simultaneously performed a control programme for the programmes II and III. The programme II on the strip II served to verify available designs of spruce plantation fertilizing separately by urea, complex fertilizer cerrerit Z, bitter salt and liming into a planting hole with dolomitic limestone. The programme III on the strip III has tested the influence of an ameliorative tree species *Alnus viridis* (also named as *Alnus crispa* or *Alnus sinuata*) on survival, growth and performance of target tree species *Picea abies*. On the whole research area, influence of the previously mentioned four degree of land surface disturbance on survival, growth and performance of spruce plantation has been examined. Extent (percentage) of separate disturbance degree was derrived from number of spruce plants outplanted on single degree of disturbed area in relation to all spruce plants (spot method).

The programme on strip III consisted of three square subplots (400 m^2) that were arranged

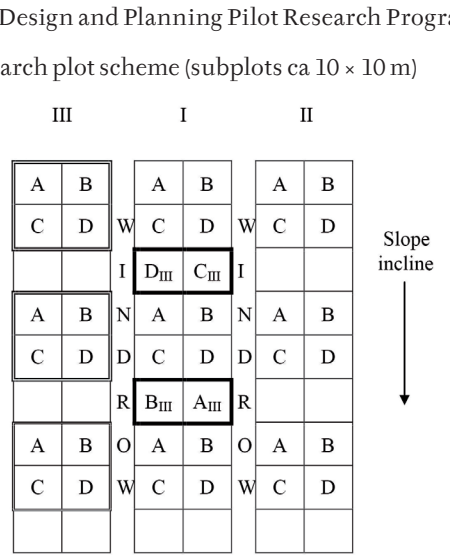

Fig. 1: Partial research plot scheme of the research object Velká Deštná Mountain in the Orlické hory Mts. Biological amelioration of Norway spruce by green alder on the strip III is bounded by double line. Compared partial spruce plots without amelioration by green alder are on the control strip I bounded by heavy line.

in down-hill direction and separated from each other by 20 m wide buffer belts. Each of the plots was 400 m^2 sized. Along contours the plots were separated by belts 20 m wide. 3500 spruce outplants and 3500 alder ones per ha were mixed in alternating downward tree lines. The control plot with the same spruce outplanting was located on the strip I but without alder tree line admixture. Five-year-old (3 + 2) bare-rooted transplants of autochthonous provenance were put in planting holes. Alders were containerized, one year old. The alder ameliorative effect was assessed using measure of spruce tree heights and height increments in time series 17 years long. Only in the first decade after outplanting, the spruce Basal stem diameter was measured. Math-statistical data processing was done with help of Excel, Statgraphics and Unistat software (parametric one-way analysis of variance, least significant difference).

Results and discussion

Spruce plantation on the control plot without amelioration

The growth assessment of the spruce plantation on the **control plot without amelioration** in dependence on disturbance degree of topsoil implied that after seven years from outplanting a significant difference existed between mean height growth of spruce on the intact sites (0A) and sites very severely disturbed (IID) (Tab. 1). A more significant difference was recorded in 1999 for radial growth when mean spruce ground line diameter was significantly greater on sites less disturbed (0A, 0B and IC) than on sites very severely disturbed (IID).

Distinct differentiation of spruce height growth in dependence of disturbance degree (Fig. 2) happened already in the third year after outplanting (1995). On the graph, the equalization is further apparent of height increments among compared degrees of soil surface disturbance (1999). That time there was already a very strong epiphytotic blight of spruce by *Ascocalyx abietina*. The fungal disease afflicted shoots including terminal ones and it resulted in reduction of height increment. After the year 2000, the spruce height increment by degree of soil surface disturbance was again becoming more distinct. Concurrently with that, all spruce trees on the very severely disturbed soil surface (IID) died before the assessment in 2002. Nearly equalized and in time series practically minimal spruce height increments in 2004 on the less disturbed (0A, 0B and IC) sites were a consequence of low precipitation, high temperature fluctuation and extreme concentrations of ground-level ozone including its cumulative index AOT40 in 2003 (Šach, Černohous 2005a, b).

*Tab. 1: Performance of spruce plantation separately by degree of soil surface disturbance due to mechanized windrowing **without amelioration** (**control** to biological amelioration).*

Disturbance of soil surface			Plant height			Survival	Ground line diameter	
Degree	Desription	Percentage	1992	1999	2009	2009	1992	1999
			cm			%	mm	
intact by disturbance – **0A** – grass	Ground cover was not disturbed noticeably. (Deschampsia sod prevailed.)	40	38.7 a	107.0 a	346.4 a	21	9.0 a	26.3 a
negligible disturbance – **0B** – humus	Ground cover was disturbed but preserved. (Forest floor without litter and without weed prevailed.)	14	36.7 a	103.6 ab	237.2 b	26	8.4 a	26.4 a
severe disturbance – **IC**	Ground cover was mixed with mineral soil, shallow ruts below depth of 25 cm were formed.	20	39.1 a	90.9 ab	279.3 ab	26	9.3 a	25.4 a
very severe disturbance – **IID**	Ground cover was removed, mineral soil was exposed, deep ruts above depth of 25 cm were formed.	13	35.2 a	75.1 b	-	0	7.8 a	17.9 b
	windrows	13						

The same letters in columns denote non-significant differences between variants at $\alpha = 0.05$.

Spruce plantation on the plot with green alder amelioration

Favourable effect of green alder amelioration has already been reported in the mid-1990s (e.g. Jurásek 1996). The favourable trend in growth of spruce plantation ameliorated by green alder is validated in Tab. 2 and on Fig. 3.

Green alder alleviated the differences in height and radial growth of spruce among the compared disturbance regimes (Tab. 2.), whereas on the control plot without amelioration, these differences were clearly evident (Tab. 1). Biological amelioration favourably influenced especially the sites with a very severe topsoil disturbance. This can be clearly deduced from the comparison between the control and the ameliorated treatment (see Tab. 1 vs. Tab. 2).

Also results of foreign researches proves positive effects of green alder on reproduction, growth, and timber production of forest stand of economic tree species on forest soils degraded by whole-area mechanized site preparation with linear windrows. Ballard,

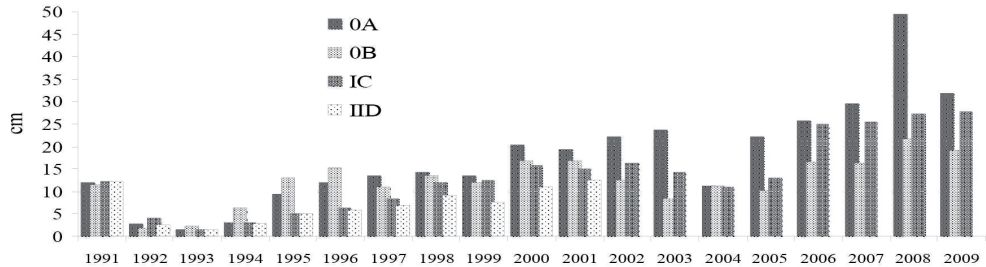

Fig. 2: Height increments of not amended spruce (control without alder) sorted by degree of soil surface disturbance – 0A – intact, 0B – negligible, IC – severe, IID – very severe.

Tab. 2: Performance of spruce plantation separately by degree of soil surface disturbance due to mechanized windrowing with amelioration by Alnus viridis.

Disturbance of soil surface			Plant height			Survival	Ground line diameter	
Degree	Desription	Percentage	1992	1999	2009	2009	1992	1999
			cm			%	mm	
intact by disturbance – **0A** – grass	Ground cover was not disturbed noticeably. (Deschampsia sod prevailed.)	44	42.6 a	126.4 a	340.2 a	26	10.0 a	29.5 a
negligible disturbance – **0B** – humus	Ground cover was disturbed but preserved. (Forest floor without litter and without weed prevailed.)	15	39.9 ab	100.6 b	345.6 a	23	9.8 ab	23.8 b
severe disturbance – **IC**	Ground cover was mixed with mineral soil, shallow ruts below depth of 25 cm were formed.	21	39.7 b	106.3 ab	329.3 a	15	9.0 b	24.3 ab
very severe disturbance – **IID**	Ground cover was removed, mineral soil was exposed, deep ruts above depth of 25 cm were formed.	7	37.6 b	106.8 ab	387.2 a	19	9.3 ab	25.2 ab
	windrows	13						

The same letters in columns denote non significant differences between variants at $\alpha = 0.05$.

Hawkes (1989) presented significantly greater height and height increment of eight-year-old plantation of *Picea glauca* among windrows on strips with green alder than on strips without green alder. Binkley *et al.* (1984) referred to young 23-year-old Douglas-fir stand. Its stocking and basal area were not significantly impacted by green alder advance growth, but mean breast height diameter, mean five-year basal-area increment and merchantable timber increment were greater by 13%, 33% and 40% respectively compared to Douglas-fir without green alder. Further information on soil conservative and ameliorative effects of green alder was analysed in the review by Šach, Černohous (2009).

Up to 1998, the positive effects of green alder were indicated by good health condition of spruce trees. The spruce showed efficient growth (without extreme high increments), hard-wearing and undistorted branching and richly green coloured needles.

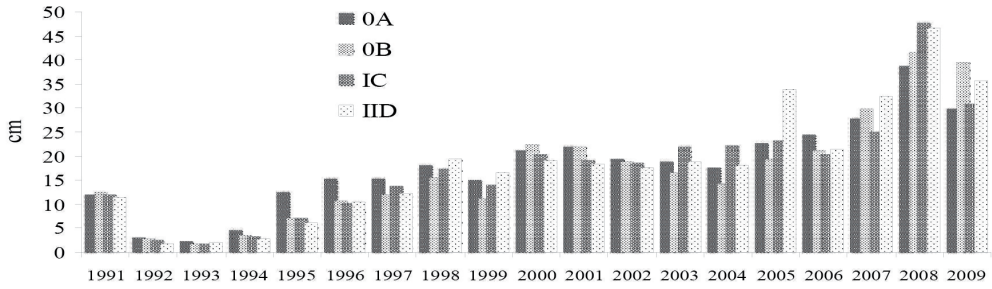

Fig. 3: Height increments of biologically amended spruce sorted by degree by degree of soil surface disturbance – 0A – intact, 0B – negligible, IC – severe, IID – very severe.

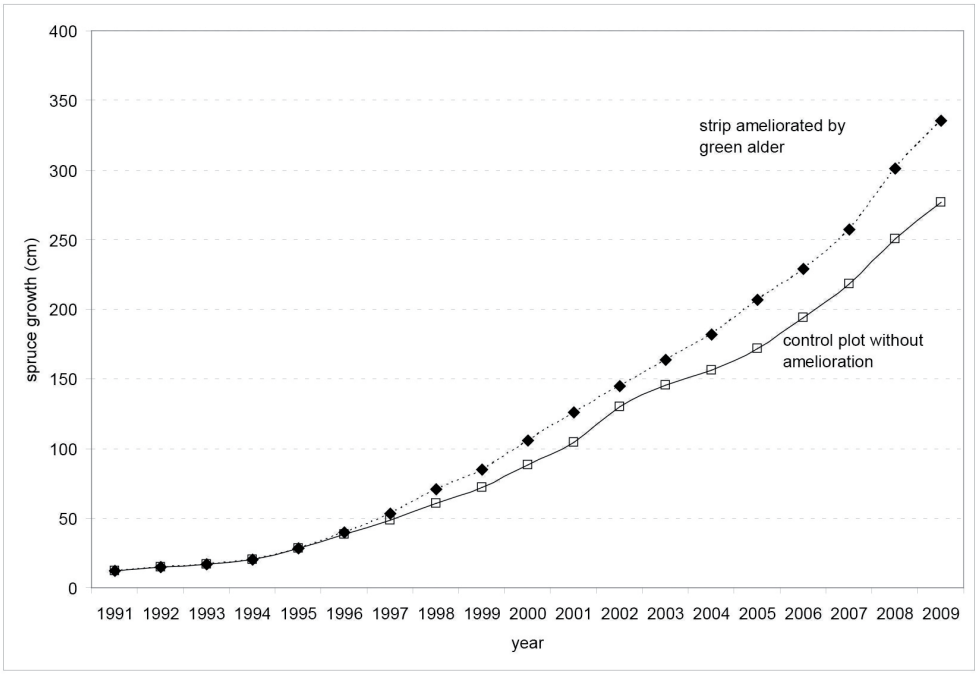

Fig. 4: Height growth of spruce trees ameliorated by green alder with comparing to control without amelioration on a mountain forest site disturbed by mechanised windrowing (height increment of 1991 arose in a forest nursery).

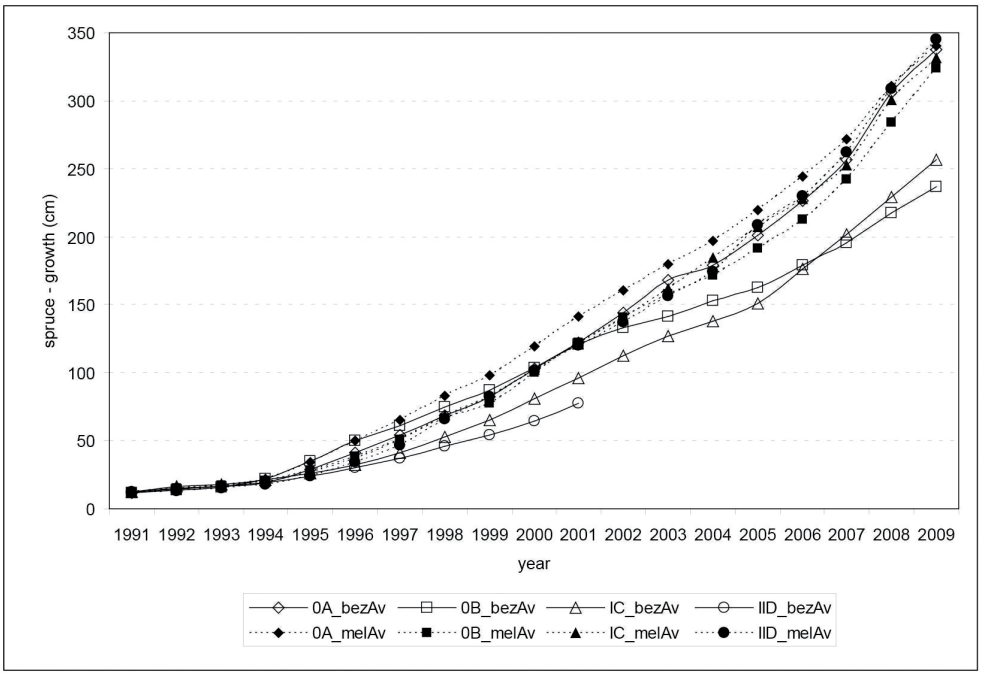

Fig. 5. Height growth of spruce plantations without (bezAv) and with green alder amelioration (melAv) by category of soil disturbance – 0A – intact, 0B – negligible, IC – severe, IID – very severe.

Nevertheless, fungal disease by *Ascocalyx abietina* appeared also on the strip III ameliorated by green alder. In case of the ameliorated spruces, however, the fungal disease showed minor intensity and extension than in case of the spruce on reference plots of the control strip I. Also the recovery of shoots and needle foliage during growth season proceeded visually better than on the control strip I (Šach *et al.* 2000b). Consistently with our knowledge, also the foreign authors assessed influence of green alder on health status of outplanted economic tree species positively (see the review by Šach, Černohous 2009).

Summary and conclusions

In 1992, Norway spruce was planted on a site disturbed by mechanized windrowing using a slashraker within the Velká Deštná Mountain research area. Spruce trees were planted on partial control plots without amelioration located on the control strip II and on plots with concurrently established green alder treatment on the strip III referred to as biological amelioration. Both tree species were mixed in alternating lines. Trend of increment of Norway spruce linearly mixed with green alder has indicated long-run and sustainable effect of biological amelioration (Tab. 2 and Fig. 4).

As for the control plot without amelioration, spruce height growth seemed to be dependent indirectly on degree of topsoil disturbance. Significant differences particularly occurred on sites with slightly disturbed soil surface (degree 0A, 0B) and on sites with severe and very severe soil surface disturbance (degree IC, IID). Up to 1998, differences in height increment of spruce among particular degrees of soil surface disturbance increased (Fig. 2). On plot with green alder amelioration, the differences in height increment of spruce among various degrees of topsoil disturbance had been continuously alleviated (Fig. 3). This indicated a progress in recovering of soil production capability attributable to biological amelioration of the formerly windrowed sites using the mechanized slashraking.

After the outbreak of fungal (*Ascocalyx abietina)* disease accompanied by high air pollution deposition of nitrogen compounds, high concentration and accumulation of ground-level ozone and climatic fluctuations spruce trees were affected. The important changes such as growth trends and survival of spruce plants occurred. Topsoil disturbance degree after mechanized windrowing along with the above mentioned harmful impacts were more substantially mitigated by soil-improving green alder shrubs (Fig. 5). As for plots without amelioration, the only spruce treatment from intact site 0A (solid line) showed growth similar to spruce treatments ameliorated with green alder (dotted lines). Non-ameliorated spruces with disturbance degrees 0B and IC (solid lines) were by 1m lower at the end of investigation in 2009. On sites with disturbance degree IID, all the spruce trees without amelioration became extinct.

Results from the research area Velká Deštná in the Orlické hory Mts. are also of a big practical importance on the other sites that experienced linear windrowing of slash by bulldozers in the Krušné hory Mts. Therein the Mendel's University in Brno has been performing investigation for a long time. On the basis of our results and suggestions, Vavříček *et al.* (2009) established further experimental investigation focusing on green alder in areas, where settled windrows were not spread out representing ca 60% of area where spreading out of windrows had been in progress up to the year of 2007 (Šach 2007).

Acknowledgement:

The investigation was financed from institutional subsidy provided to long-term conceptual development of research organization by MZe ČR – Decision no. RO0114 (reference number 8653/2014-MZE-17011).

References

Ballard, T. M., Hawkes, B. C. 1989: *Effects of burning and mechanical site preparation on growth and nutrition of planted white spruce.* Information Report BC-X-309. Victoria, B. C., Forestry Canada, Pacific and Yukon Region, Pacific Forestry Centre, 19 pp.

Binkley, D., Lousier, J. D., Cromack, K. 1984: Ecosystem effects of Sitka alder in a Douglas-fir plantation. *Forest Science*, 30: 26–35.

Jurásek, A. 1996: *Pěstování lesa v ekotopech narušených antropogenní činností* [Silviculture in ecotopes disturbed by human activities]. Výroční zpráva o průběhu řešení výzkumného záměru. Opočno, VÚLHM – Výzkumná stanice, 106 pp.

Kuneš, I., Koňasová, T., Balcar, V., Baláš, M., Zahradník, D., Kacálek, D., Vítámvás, J., Jakl, M., Dytrtová, J. 2011: Growth response of *Alnus viridis* to application of crushed lime-

stone and amphibolite and forestry potential of the species on harsh acidic mountain sites. *Journal of Forest Science*, 57: 200–209.

Podrázský, V.V., Ulbrichová, I., Kuneš, I., Folk, J. 2005: Green alder effects on the forest soils in higher elevations. *Journal of Forest Science*, 51 (Special Issue): 38–42.

Šach, F., Podrázský, V. 1992: Ovlivňování úrodnosti lesních půd mechanizovaným úklidem klestu a vápněním v extrémních imisně ekologických poměrech [Influencing of forest soil fertility by mechanized slash removal and liming in extreme immissions-ecotope conditions]. In: *Les – drevo – ekológia*. Sekcia č. 3. Zvolen, Technická univerzita, 178–185.

Šach, F. 1994: Dopady mechanizovaného shrnování klestu na produktivnost stanoviště v hřebenové partii Orlických hor [Impacts of mechanized slash-raking into windrows on site productivity in a top region of the Orlické hory Mts.]. In: *Práce VÚLHM*, 79: 125–139.

Šach, F., Černohous, V. 2000a: Redukce úrodnosti půdy a růstu smrkových kultur v důsledku mechanizovaného shrnování klestu [Reduction of soil fertility and young spruce stand growth due to mechanized windrowing]. In: Slodičák M. (ed.): *Lesnické hospodaření v imisní oblasti Orlických hor*, Opočno, VÚLHM - Výzkumná stanice, 65–72. ISBN 80-902615-9-0.

Šach, F., Černohous, V., Podrázský, V. 2000b: Druhová diverzita a zdravotní stav restaurovaných smrkových kultur [Tree species diversity and health stage of restored spruce plantation]. In: Slodičák, M. (ed.), *Lesnické hospodaření v imisní oblasti Orlických hor*. Opočno, VÚLHM - Výzkumná stanice, 81–86. – ISBN 80-902615-9-0.

Šach, F., Černohous, V. 2005a: Declining experimental Norway spruce plantation in air pollution region of the Orlicke hory Mts., Czech Republic. In: Hůnová, I. *et al.* (eds.): Acid Rain 2005. *7th International Conference on Acid Deposition*. Conference abstracts. Prague, June 12–17, 2005. Praha, Český hydrometeorologický ústav, 315–315. – ISBN 80-86690-25-3.

Šach, F., Černohous, V. 2005b: Přízemní ozón a jeho možný vliv na chřadnutí experimentální smrkové kultury v imisní oblasti Orlických hor, Česká republika [Ground-level ozone and its potential influence on declining experimental Norway spruce plantation in immission region of the Orlicke hory Mts., Czech Republic]. In: Saniga M., Jaloviar P. (eds.): *Súčasné otázky pestovania lesa*. Zvolen, Technická univerzita: 101–106. – ISBN 80-228-1489-X.

Šach, F. 2007: Oponentský posudek [*Peer review* (In Czech)] podle smlouvy č. 1/2003 pro projekt GS LČR Revitalizace půdního prostředí valů v 7. LVS Krušných hor s návrhem dalších opatření pro obnovu lesa [*Project of GS LČR: Soil environment revitalization of windrows in the 7th forest vegetation zone of the Krušné hory Mts supplemented with proposal of further treatments for forest renewal*] – dílčího realizačního výstupu č. 4/2007. Teplice, PŘ Lesy ČR, 6 pp.

Šach, F., Černohous, V. 2009: Protierozní a meliorační účinky olše zelené [Soil conservative and ameliorative effects of Alnus viridis]. *Zprávy lesnického výzkumu-Reports of Forestry Research*, 54 (4): 267–274.

Vavříček, D. *et al.* 2009: Revitalizace půdního prostředí valů v 7. LVS Krušných hor s návrhem dalších opatření pro obnovu lesa [*Project of GS LČR: Soil environment revitalization of windrows in the 7th forest vegetation zone of the Krušné hory Mts supplemented with proposal of further treatments for forest renewal* (In Czech)] – dílčího realizačního výstupu č. 2/2009 (Parciální realizační výstup Grantové služby LČR –1005/3GT/413). Teplice, KŘ Lesy ČR, 110 pp.