NATURAL REGENERATION OF THE SPRUCE ON THE SELECTED WET SITES IN THE JIZERSKÉ MOUNTAINS*

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This study contains an evaluation of the spruce natural regeneration and comparison of its growth on the locality "Černá jezírka" with the results from the Jizera peat bog. The height increments throughout the last 5 years were measured, and stand characteristics such as a herbal vegetation, type of the growth substrate, upper tree layer, natural regeneration, nutrient state and underground water were described. The amount (24 500 pcs/ha) of the spruce natural regeneration correlate with the amount of mature or potentially fertile trees and the number of regeneration varied strongly (700–24 500 pcs/ha). The height increment of seedlings and very young trees depends on the surrounding vegetation, but this effect is diminished in the higher height classes. There was not a statistically significant difference in the increments from the Jizera peat bog (valley frost pool) and "Černá jezírka" peat bog (range).

Jizerské mountains; peat bogs; natural regeneration; mountain spruce forests; Norway spruce

INTRODUCTION

The Jizerské mountains are a part of the Krkonoše–Jeseníky Plutonian mountain system in the north of the Czech Republic. The precipitations are very high and range between 800 and 1705 mm so unique extensive peat ecosystems have been formed there, covering about 1500 ha of the Jizerské mountains upper plateau. It extends mainly in the altitude 800–1000 m, with the highest point at 1124 m a.s.l. Many of the peat bogs arise on the ridges with shallow depressions that are frequently in the main spring areas of the rivers (Jizera, Smědá, Kamenice, Černá and Lužická Nisa, Ploučnice (Jóža, Vonička, 2004; Vacek et al., 2003). In the peat-bogs there are rare species of boreo-montane and arctalpine character – e.g.: *Betula nana*, *Pinus mugo*, *Oxyccocus palustris*, *Andromeda polifolia*, *Empetrum nigrum*, *Trichophorum caespitosum*, *Scheuchzeria palustris*, *Carex pauciflora*, *Carex limosa*... (Mackovčin et al., 2002).

During the years after the 1980 the Jizerské mountains protected area was strongly influenced by air pollution, which led to the present physiological changes, and the bark beetle disaster, and to the 12 000 ha clear-cuts. Salvage fellings were at that time about 90% of the total felling, and this number decreased to 30–50% in 1995 (Vacek et al., 2003). Also forests surrounding peat bogs were strongly influenced. Naturally, the conditions on such stands are relatively harsh. Spruce on the site units 7–8 R has a relatively low height, grows often in the groups, and is negatively influenced by frost, wind and high underground water levels (Průša, 2001); so the wet sites are less stable and more susceptible to various types of damage.

The aim of this study is to determine the natural regeneration growth potential, and the characterization of its state, for the future development of spruce stands surrounding peat bogs. Although the main part of the adult trees declined during the immission calamity, there is a certain amount of natural regeneration, which can replace them, and thus provide a relatively unaltered condition for the peat bogs. The question is, if this amount and state of the regeneration is sufficient.

MATERIAL AND METHODS

Part of the plots was established by Tůma in 2003 (Tůma, 2004) in the Jizera valley – on the Polish border. Two transects have been established in the peat bog of Rybí loučky (stand A247), and three others in peat bog Jizera (A 244, D 246). In 2005, four other transects were established in the area of peat bog "Černá jezírka": "Tetřeví louka" (263 D) transects 1 + 2 (A, B), and "Malá Krásná louka" (262 D) transects 3 + 4 (A, B).

Stands characteristics: Bedrock is mainly formed by the biotic granite, porfyritic granodiorite, in some parts also by mica schists and orthogneiss (Jizera peat bog). The soils in the wet areas are mainly Gleysols and Organosols – usually poor in nutrients and relatively acid. The presumed mean year temperature is below +4 °C, the annual precipitation above 1450 mm and the growth period less than 100 days (avg. temperature/day ≥ 10 °C) (Balcar, 2001).

"Černá jezírka": shallow part between the Střední Jizerský and the Vlašský ridges, area 66,35 ha, as a natural reservation protected since 1960. A systems of four peat bogs and peat meadows at an altitude 885–910 m, surrounded by wet spruce forests declined or strongly influenced by the immission situation in nineteen eighties. **Jizera peat bog**: An 11 km long stripe along the border of the Jizera river, area 189,11 ha, altitude 815–880 m, the main part is formed by complexes of dwarf pine stands,

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Table 1. Main site characteristics on the plots in the "Černá jezírka" locality

Plot	Orientation	Slope	Altitude (m a.s.l.)	Underground water level	Canopy (%)	Total mature trees amount (pc/ha)	Dead mature trees (pc/ha)
1A	300°	flat	910	–10 cm	40	1500	700
1B	300°	1°	910	–40 cm	0	700	700
2A	270°	flat	910	–10 cm	65	3300	2000
2B	270°	flat	910	–5 cm	25	2500	2000
3A	30°	flat	895	–50 cm	25	2500	2000
3B	30°	flat	895	–50 cm	40	3000	2200
4A	110°	1°	890	–5–10 cm	5	1600	1500
4B	110°	1°	890	–5 cm	40	2300	1500

peat meadows. It is also surrounded by strongly damaged spruce forests. A natural reserve protected since 1960. **"Rybí Loučky" peat bog**: A shallow cauldron in the Jizera river valley, area 37.9 ha, altitude 840–860 m, originally one of the oldest peat bogs in the Jizerské mountains. Also spruce forests partly declined due to the immission load. Protected as a natural reserve since 1965 (Jóža, Voničkа, 2004; Mackovčin et al., 2002). The transect conditions are summarized in Table 1.

The area of transects was 4 x 50 m (0.02 ha), evaluated as two replication of 4 x 25 m, respectively.

Measured characteristics were as follows: dendrometric parameters (height, diameter in 130 cm) of the upper layer (though mainly declined), height, last 5 increments and growth substrate for the natural regeneration. Herbal vegetation cover was evaluated during the mid-summer and herbal cover was estimated to 1% reliability.

For comparison of increments in the two localities (Jizera peat bog and "Černá jezírka") there were trees chosen at random, these were selected into 4 height groups of 30 individuals and 5 last increments were measured. Height classes were approximately 30 cm, 100 cm, 200 cm and 300 cm (± 15 cm) in each group. The reason for this extra selection was the strong difference in the height (and probably also age structure) and amount of natural regeneration in the two localities.

For the microsite conditions, there were few differentiated types: depending on the herbal layer (*Vaccinium*, *Graminaceae*, others) and depending on the dead wood type (nonwood site, mature trees foot (dead or alive), sites along the fallen logs or other dead wood sites (on the log, or deteriorated stumps).

Foliar samples were taken in the autumn of 2005 by standard methods (last year needles from the lateral, not shady shoots on the fourth whirl) as a bulk sample from 30 trees of natural regeneration per plot. Laboratory work was made by the accredited Laboratory Tomáš in the Opočno, VULHM VS. Sample mineralization was made by the H_2SO_4 and Se mixture (Zbíral, 1994).

The UNISTAT was used for statistical analysis, the analysis of variance, the Kruskall-Wallis and the Duncan tests were used. Influence of growth substrate and vegetation was evaluated in the height classes 0–20 cm, 20–70 cm, 70–150 cm and 150+ cm, due to the amount of regeneration in the partial height class and homogenous increment variance in the classes.

RESULTS AND DISCUSSION

Characteristics of the herbal cover were relatively similar, with different proportions of bilberry and grass

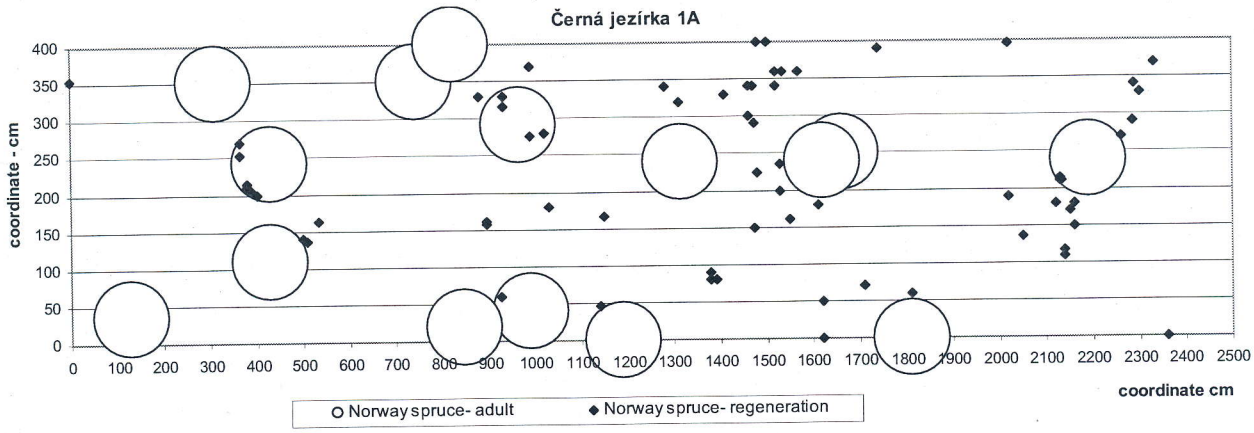

Fig. 1. Natural regeneration space distribution on the particular transects (4 x 25m)

Table 2. Some characteristics of the spruce natural regeneration amount depending on the floor cover

Plot	Spruce natural regeneration pcs/ha	Microstands for natural regeneration %				Herbal vegetation structure %			Mature parent trees*
		Vaccinium	Grass	Others	Dead wood	Vaccinium	Grass	Others	
1A	700	67.1	5.7	27.1	47.1	65	20	15	17
1B	9 700	66.0	0.0	34.0	49.5	60	30	10	17
2A	4 900	46.9	0.0	53.1	53.1	40	60	0	3
2B	6 300	44.4	0.0	55.6	46.0	30	55	5	3
3A	12 000	59.2	7.5	33.3	50.8	35	60	5	45
3B	24 500	54.7	8.6	36.7	16.7	65	25	10	45
4A	6 900	56.5	4.3	39.1	27.5	30	65	5	20
4B	8 100	75.3	8.6	16.0	56.8	20	70	10	20

* Mature, potentially or really fertile trees on the transect and in close neighbour (to 50 m)

cover and occasionally low proportion of some rare herb.

Transect 1A + B: *Vaccinium myrtillus* 65%, *Trientalis europea* +, *Calamagrostis villosa* 20%, *Eryophorum vaginatum* 5%, *Carex pauciflora* 3%, *Lycopodium annotinum* 7%, *Polytrichum commune*, *Sphagnum sp.* (100%).

Transect 2A + B: *Vaccinium myrtillus* 66%, *Vaccinium uva-ursii* 5%, *Trientalis europea* 2%, *Eryophorum vaginatum* 20%, *Molinia caerulea* 10%, *Lycopodium annotinum* 2%, *Polytrichum commune, Sphagnum sp.* 100%.

Transect 3A + B: *Vaccinium myrtillus* 35–65%, *Vaccinium uva-ursii* 1%, *Oxyccocus palustris* 0.5%, *Calluna vulgaris* 1%, *Molinia caerulea* 60%, *Deschampsia flexuosa* 0.5%, *Carex pauciflora* 1%, *Eryophorum vaginatum* 10%, *Lycopodium annotinum* 1%, *Polytrichum commune* 0.5%, *Sphagnum sp.* 90%.

Transect 4A + B: *Vaccinium myrtillus* 30%, *Vaccinium uva-ursii* 2%, *Oxyccocus palustris* 7%, *Molinia caerulea* 40%, *Deschampsia flexuosa* +, *Eryophorum vaginatum* 25%, *Lycopodium annotinum* 4%, *Polytrichum commune* 1%, *Sphagnum sp.* 95%.

Tree vegetation:

Picea abies 98%, other species just regeneration, *Pinus mugo* (planted): Transect 1A – 900 pcs/ha, 2A – 400 pc/ha, 2B – 700/ha; *Sorbus aucuparia*: Transect 1B – 300 pc/ha; *Betula pubescenc*: Transect 1A – 100 pc/ha, 1B – 500 pc/ha, 2A – 200 pc/ha, 2B – 100 pc/ha.

For the space distribution of natural regeneration there is a marked tendency to the cluster distribution. Fig. 1 shows the situation on a typical plot.

The amount of the spruce natural regeneration varies strongly on the different plots by 700 to 24 500 pieces per ha, and this trend is similar to those published by other authors (Kupferschmidt et al., 2006; Jonášová, Prach, 2004; Šerá et al., 2000). This variability is strongly influenced also by the seed source – the number of mature trees close to the particular plots (Table 2) especially time of their decline and possible seed store in the soil. According to Hladík et al. (1993), there should be 270–750 adult trees per ha and 320–3100 trees over the height 1.3 m in the close to nature mountain forest of an altitude 1100–1400 m a.s.l. in the stable last growth stage, which is in agreement with our results. The number of natural regeneration in the youngest age class depends on the last seed year – or upon the foliation of the upper tree layer, which changes light and temperature conditions (Collins et al., 1985). The structure of the evaluated stands (Figs 2 and 3) shows similar conditions on the plots: The state of the declined mature tree layer at the time of the heavy immission load in the nineteen eighties (Slodičák et al., 2005), the slow appearance of the regeneration in that time and the small amount of new seedlings due to only a few parent trees.

Microsite conditions further influence the height and increments of natural regeneration on the stand (Brang, 1998; Hanssen, 2002; Valkonen, Maguire, 2005; Kupferschmid et al., 2006). Importance of the dead wood microstands for the natural regeneration in natural spruce stands confirms e.g. (Hofgaard, 1993; Svoboda, 2005; Valkonen, Maguire, 2005). Thus there were differentiated a few types for the microsite conditions, depending upon the herbal layer and on the dead wood type (Table 3) in our case. The only statistically significant difference (95%) appears within the height class 20–70 cm for the wood and non-wood substrate type. As the most favorable microsite appears at the foot of mature trees, especially dead mature trees (a significant difference). The proportion of natural regeneration growing on the different types of wood substrate varies by 17–57% and is shown in Fig. 4. That corresponds with the Svoboda (2005) results, that in the mountain spruce forest the rate of spruce natural regeneration connected with dead wood varies between 22–72% of its total amount.

It seems that grass is not favorable herbal layer for the seedlings growth and proportion of the regeneration was much lower than proportion of this grass layer on the particular transects (Fig. 4). On the other hand, regeneration in the bilberry shrub on the floor area was slightly better, which corresponds with the results of Svoboda (2005), who described a relatively higher amount of natural regeneration in bilberry than in other types of the herbal layer – however in the "Černá jezírka", it could also be influenced by the fact that bilberry grows on a slightly uplift microsite. It is published by Průša (2001), on the sites 7 and 8 R natural regeneration is relatively rare, and it is better on the higher microsites (windbreaks, stumps, logs).

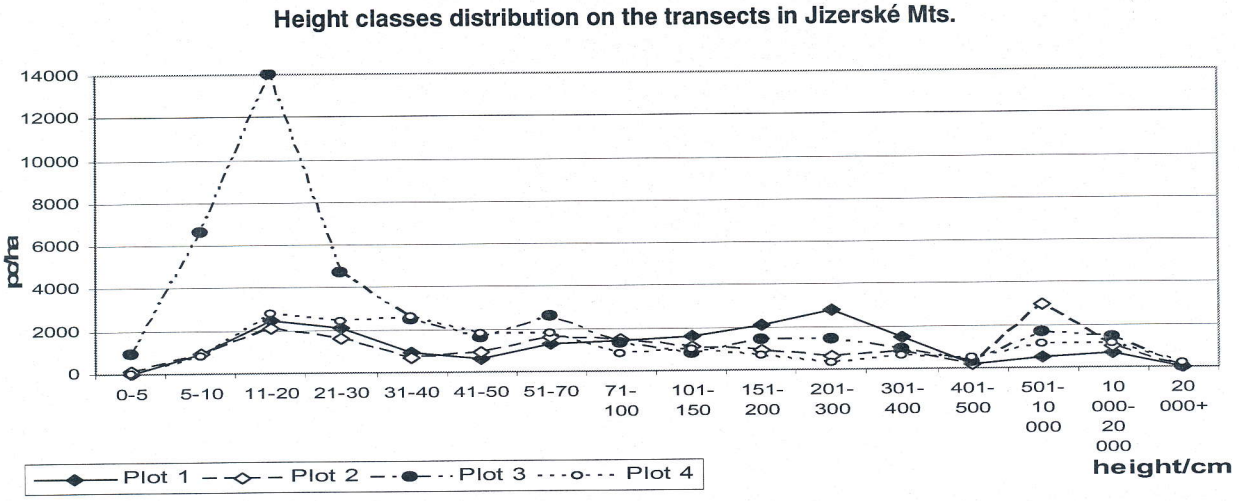

Fig. 2. The distribution of the trees in relevant height classes (including natural regeneration) on particular plots in the "Černá jezírka" area

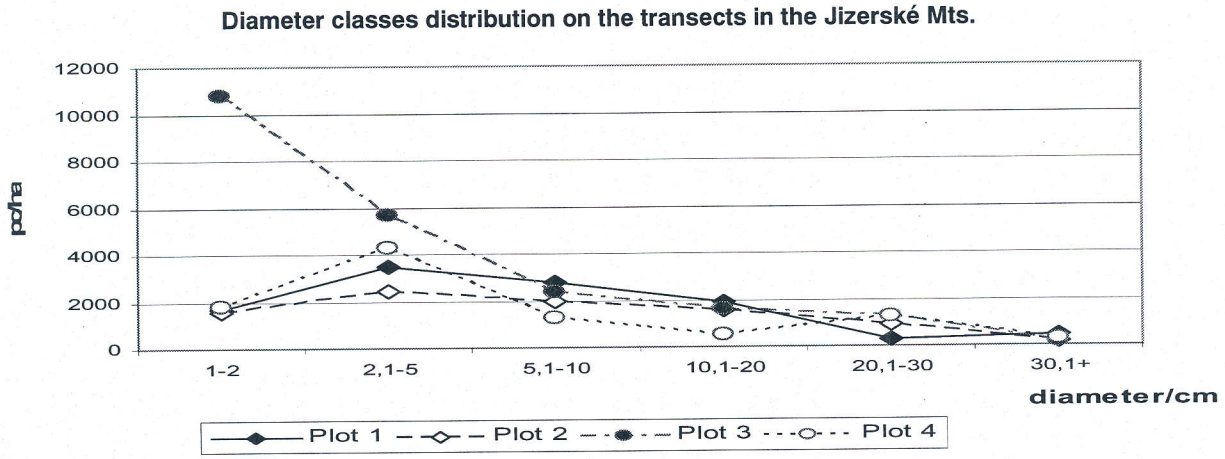

Fig. 3. The distribution of the trees in relevant diameter classes (including natural regeneration) on particular plots in the "Černá jezírka" area

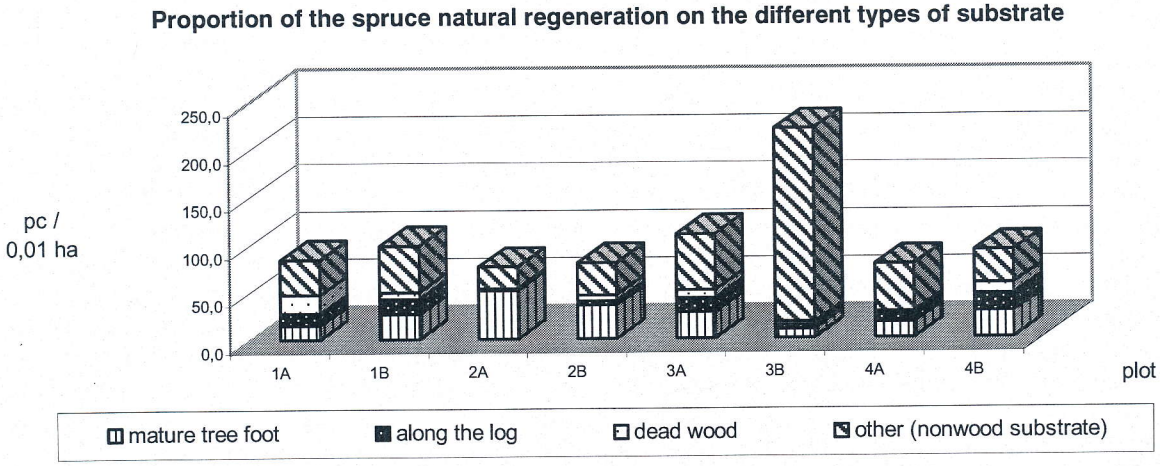

Fig. 4. The natural regeneration number and proportion found on particular plots on the different types of substrate

Table 3. The results of Duncan test for the natural regeneration on the different transects

Group	Transects	Locality	Average	95% confidence interval	
Natural regeneration characteristics (height)					
Group 1	2A, 3B, 4B, 2A, 1A, 3A	"Černá jezírka"	13.57	11.31	15.83
Group 2	4A, 1B	"Černá jezírka"	35.98	31.58	40.37
Group 3	7A, 5A, 5B	Jizera + Rybí loučky	52.97	49.72	56.22
Group 4	8B, 9B	Jizera peat bog	64.56	60.70	68.42
Group 5	9B, 6A, 7B	Jizera + Rybí loučky	69.89	65.96	73.81
Group 6	8A, 9A, 6B	Jizera + Rybí loučky	104.19	98.67	109.71

Table 4. The nutrient state of natural regeneration as the results of foliar samples analysis

Transect	N %	P %	K %	Ca %	Mg %	S %
"Černá jezírka"	1.140 (0.037)	0.080 (0.00)	0.585 (0.052)	0.252 (0.042)	0.076 (0.004)	0.125 (0.016)
Jizera	1.040 (0.069)	0.085 (0.005)	0.510 (0.038)	0.350 (0.022)	0.103 (0.009)	0.157 (0.020)
Limit**	1.20	0.10	0.35	0.15	0.06	0.12–0.16

* Number in brackets is standard deviation, ** limit of deficience – standards of ICP Forest (B o h á č o v á et al., 2003)

As for the substrate and herbal vegetation influence on the increment, no significant statistical differences were observed in the height classes 0–20 cm and over 70 cm.

On the other hand, the types of herbal vegetation surrounding young trees influenced increments by 20 to 70 cm height (although not significantly). The highest increment average during the last 5 years (in the height class 20–70 cm) have been in the thin bilberry cover (4.4 cm), the second was other herbal vegetation (3.9 cm) and in the last group were dense bilberry or grass cover (3.4 cm). In the substrate, there were three significantly different groups: The highest average increments were in the microsite along the fallen log (4 cm), the second on the microsite with the dead wood (means logs or stumps in the different stage of decomposition – 3.4 cm) and the last group with lower increments formed the sites with other, nonwood substrate and mature tree foot (2.9 cm).

The comparison of the annual increments between comparable height groups on the two localities shows no statistically significant differences, although one of the localities – "Černá jezírka" is on the ridge and other in the valley frost hole (Jizera), and there are differences in the height class distribution (Table 3) within the two localities.

Health and nutrition state:

The results of the bulk foliar samples analysis shows a relatively equal nutrient state on the all plots, with a slight difference of foliar nitrogen on the localities "Černá jezírka" and Jizera and also significantly higher immission load shown by foliar sulphur in the Jizera peat bog. Typically poor and acid stands, such as peat bogs, concern low amount of nitrogen and phosphorus, which are below the limit of sufficient amount (B o h á č o v á et al., 2003). According to P a s u t h o v á and L o m s k ý (1998) results, since 1994 the nutrient state of spruce deteriorated in nitrogen, phosphorus and potassium content was recorded.

The health state was relatively good in spring 2005, the colour of needles was green and discoloration was not found, although the defoliation of mature trees was visible. In the autumn in the same year the health state had visibly deteriorated– the discoloration of the older needles on the natural regeneration appeared on approximately 20%, and for the mature trees – yellowing, and average defoliation was over 50% on the "Černá jezírka" plots.

CONCLUSION

The amount of the spruce natural regeneration was highest on the plots with the highest amount of mature trees or potentially fertile trees and at the same time on the plots with a deeper level of soil watertable (maybe more favourable towards the surviving during the time of a high immission load).

The increment of seedlings and very young trees depends on the growth substrate and surrounding vegetation, but this effect is diminished in height classes higher than 70 cm.

There is natural regeneration in the considerably higher classes on the Jizera locality, probably due to a quicker decline in the more harsh conditions of a cold valley, in the comparison of Jizera peat bog and "Černá jezírka" peat bog. There were no statistically significant differences in increments on the both localities.

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Přirozená obnova smrku na vybraných podmáčených lokalitách v Jizerských horách.

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Přestože na některých rašeliništích Jizerských hor došlo vlivem silné imisní zátěže v průběhu osmdesátých let k silnému poškození a ztrátě vegetačního krytu, byly porosty ponechány přirozenému vývoji a nebyl narušen povrch půdy ani přirozená obnova, která se nacházela pod krytem porostu. Cílem příspěvku bylo mapování současného stavu této smrkové obnovy na vybraných transektech v oblasti Černých jezírek (hřebenová poloha) a v mrazové kotlině rašeliniště Jizery. Další popis lokalit je uveden v tab. 1.

Podrobněji sledováno bylo množství a rozmístění a přírůsty přirozené obnovy smrku na vybraných transektech. Dále bylinná vegetace, která mohla přímo ovlivňovat růst semenáčků, mrtvé dřevo, na kterém semenáčky rostly, a hladina podzemní vody (měřením ve vykopané sondě). Srovnání přírůstů přirozené obnovy (5 let) v obou lokalitách bylo provedeno na skupinách 30 jedinců s přibližně stejnou výškou, přičemž výškové třídy byly přibližně 30 cm, 100 cm, 200 cm a 300 cm (± 15 cm). Na podzim 2005 byly odebrány listové vzorky pro hodnocení stavu výživy přirozené obnovy, standardní metodou (Zbíral, 1994), a laboratorně zpracovány v akreditované laboratoři Tomáš, a.s., se sídlem ve Výzkumné stanici VÚLHM, Opočno.

Bylinná vegetace je blíže charakterizována v anglickém textu, stromová vegetace má následující charakter: *Picea abies* 98 %, ostatní druhy jen ve formě zmlazení, nikoli dospělí jedinci: *Pinus mugo* (pravděpodobně výsadba): transekt 1A – 900 ks/ha, 2A – 400 ks/ha, 2B – 700 ks/ha; *Sorbus aucuparia*: transekt 1B – 300 ks/ha; *Betula pubescenc*: transekt 1A – 100 ks/ha, 1B – 500 ks/ha, 2A – 200 ks/ha, 2B – 100 ks/ha.

Typ a shlukovité uspořádání přirozeného zmlazení je zachyceno na příkladu typického transektu v oblasti Černých jezírek (obr. 1).

Množství přirozeného zmlazení smrku na jednotlivých sledovaných plochách kolísá mezi 700 a 24 500 ks/ha. Rozdíly jsou ovlivněny rozdílem ve stavu mateřského porostu (na některých plochách silně poškozený), přítomností plodných stromů a také mikrostanovištními podmínkami pro jednotlivé jedince přirozeného zmlazení (tab. 2 a 3).

Výšková a tloušťková struktura zmlazení je zachycena na obr. 2 a 3, které ukazují podobný stav na všech sledovaných plochách: odumírání mateřského porostu následkem imisní zátěže v 80.–90. letech, pomalé odrůstání přirozené obnovy z tohoto období a následně relativně nízký počet zmlazení z pozdější doby. Množství přirozeného zmlazení

smrku kladně korelovalo s přítomností dospělých a relativně nepoškozených jedinců smrku na ploše nebo v jejím blízkém okolí a s hlubší hladinou spodní vody (nad 50 cm).

Podíl zmlazení rostoucího na mrtvém dřevě se pohyboval mezi 17 a 57 % (obr. 3). To odpovídá výsledkům dalších autorů (Svoboda, 2005), týkajícím se horských smrkových lesů. Podle výsledků získaných při hodnocení vlivu bylinné vegetace není pro zmlazení příliš vhodný travní porost – podíl semenáčků v tomto typu vegetace byl podstatně nižší, než činí plošný podíl této vegetace na jednotlivých transektech (obr. 4). Na druhou stranu přirozené zmlazení v borůvčí bylo vyšší a zdá se, že borůvčí, pokud není příliš mohutné a husté, je pro přirozenou obnovu smrku relativně dobrým vegetačním pokryvem, což odpovídá výsledkům dalších autorů (Svoboda, 2005; Šerá et al., 2000; Průša, 2001). Jako velmi výhodné mikrostanoviště z hlediska růstu se ukázal kořenový náběh mateřských stromů, zvláště souší (statisticky významný rozdíl).

Přírůst u semenáčků a zmlazení do cca 40 cm závisel výrazněji na okolní bylinné vegetaci a případně substrátu (mrtvé dřevo), ale v pozdějším věku a vyšších výškových třídách tento efekt mizel.

Stav výživy (tab. 4) byl na většině sledovaných transektů velmi podobný, rozdíl mezi lokalitami se projevil pouze mírně u obsahu dusíku v asimilačních orgánech (nižší na lokalitě Jizera přibližně o 7 %). Významně se na obou lokalitách lišil obsah síry, který na lokalitě „Černá jezírka" nepřekračoval normální obsah (0,12 %) a na lokalitě Jizera indikoval o něco vyšší imisní zátěž. Podle výsledků Pasuthové a Lomského (1998) je možné usoudit, že stav výživy smrku se v Jizerských horách od roku 1994 zhoršil pro dusík, fosfor a draslík.

Zdravotní stav byl sledován jen orientačně na základě defoliace a žloutnutí. V jarním období byl relativně dobrý, na podzim byl průměrný podíl žloutnoucích jedinců okolo 20 %. Stav dospělých porostů je podstatně horší, na lokalitě Jizera jsou přímo na transektech jen odumřelí jedinci, na Černých jezírkách mají průměrnou defoliaci okolo 50 %.

Při srovnání dvou lokalit – rašeliniště Jizera a rašeliniště „Černá jezírka" – nebyly zjištěny statisticky významné rozdíly v přírůstech odpovídajících výškových skupin zmlazení, přestože zastoupení těchto výškových skupin je na obou lokalitách rozdílné (tab. 3), pravděpodobně vlivem dřívějšího silnějšího poškození dospělých porostů imisemi v mrazové kotlině Jizery.

Jizerské hory; rašeliniště; přirozená obnova; horské smrčiny; *Picea abies*

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