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Regular research paper

Jiří MACH¹, Vojtěch LANTA², Marek BASTL¹

¹Department of Botany, Faculty of Science, University of South Bohemia, Branišovská 31, CZ-370 05 České Budějovice, Czech Republic, e-mail: jiri.mach@prf.jcu.cz (* corresponding author)

²University of Turku, Section of Ecology, 20014 Turku, Finland

THE EFFECT OF MINING AND VEGETATION SCARIFICATION ON THE SURVIVAL AND ESTABLISHMENT OF *PINUS ROTUNDATA* LINK. AND *P. SYLVESTRIS* L. IN CONTRASTING PEAT BOG HABITATS

ABSTRACT: The survival and establishment of tree seedlings represents a critical step in the process of forest stand regeneration. In this study, we evaluated the effect of peat mining and vegetation scarification (removal of understorey vegetation and peat moss layer up to depth of 15 cm) on seedling survival and establishment of two congeneric tree species, *P. rotundata* and *P. sylvestris*, under different moisture and light conditions. Two long-term experiments with planted and sown seedlings were conducted on three peat bogs in the Bohemian Forest and the Třeboň Basin (Czech Republic). Significant differences in seedling survival and establishment for both pine species were found. The positive effect of lower groundwater level and shading was the best predictor for survival and establishment of planted seedlings of both pine species in a mined peat bog, especially for *P. rotundata*. Nevertheless, low groundwater level and vegetation scarification had negative effect on *P. rotundata* seedling survival and establishment in pristine peat bogs. *P. rotundata* seems to be more adaptable to newly appearing conditions in both environments of abandoned mined peat bog and of vegetation scarification. Our results suggest that it is more reasonable to use seedlings of *P. rotundata* than seedlings of *P. sylvestris* to restore mined peat bogs.

KEY WORDS: mining, scarification, survival, *Pinus rotundata*, *Pinus sylvestris*, seedling, peat bog, groundwater, shading

1. INTRODUCTION

Central European peat bogs, dominated by Bog pine (*Pinus rotundata* Link.), represent one of the best preserved primary ecosystems which have continually persisted since the early Holocene (Svobodová *et al.* 2002). However, the current state of many localities has been strongly influenced by human activity (Gorham and Rochefort 2003, Vasander *et al.* 2003). Peat bogs were traditionally drained for peat mining and forestry. The consequences of drainage and peat mining are numerous and usually result in structural, functional and vegetation changes (Alan *et al.* 1991, Dierssen 1992). Hence, attempts to restore these ecologically and economically important landscapes are often unsuccessful by natural means, because of the extreme abiotic conditions left after peat mining. Disturbance by drainage and mining also enables the expansion of other competitive tree species, especially Scots pine (*Pinus sylvestris*), into the original habitats of *P. rotundata*. Schmid *et al.* (1995), and Begeot with Richard (1996) showed that *P. rotundata* can hardly compete with other tree species under changed environmental conditions. In addition, hybridiza-

tion between both pines (*P. rotundata* and *P. sylvestris*) may often occur (Staszkievicz and Tyszkiewicz 1972). This provides a threat in conservation of the gene pool of *P. rotundata* (Holubičková 1965), which may lead to overall degradation of areas having still natural character.

The development of pristine bog forests is characterized by the cyclic nature of tree regeneration (Hytteborn *et al.* 1991). Natural regeneration of the *P. rotundata* community is initiated by successful establishment of seedlings in naturally disintegrated forest, where suitable micro-disturbed habitats on denuded peat soil are created. Germination and survival of tree seedlings represent critical steps in this process. Although seeds may germinate, the seedling survival, growth and establishment may successfully start only under specific microclimatic and edaphic conditions, which provide adequate moisture, light and nutrients, without harmful pathogens and herbivores (Harper *et al.* 1965, Urbanska 1997). Consequently, the structure of the established communities in both mined and pristine peat bogs is probably determined by ecological characteristics of the tree species and microhabitat conditions (Lavoie *et al.* 2003). Nevertheless, except the only one study concerning the regeneration and growth of *P. rotundata* in southern Germany (Schmid *et al.* 1995), factors controlling the regeneration of *P. rotundata* stands are largely unknown.

Both pine species *P. rotundata* and *P. sylvestris* occur in pristine as well as disturbed (*i.e.*, drained and/or mined) peat bogs. *P. rotundata* is an endemic species of Central Europe growing mainly in waterlogged habitats from lowlands to submontane regions. As a typical peat bog plant, it is adapted to severe environmental conditions (*i.e.*, high ground water Table, anaerobic conditions, low pH, insufficient amount of nutrients, high concentrations of Fe, Mg, Al) (Schmid *et al.* 1995, Freléhoux *et al.* 2003). *P. sylvestris* is the most widely distributed member of the family Pinaceae in the world (Boratynski 1991). Its geographical range coincides with the distribution of peatlands in the northern temperate and boreal regions. Forests dominated by *P. sylvestris* typically occur

on different types of well-drained mineral soils, representing a broad range of variation in pH, water, nutrient availability and vegetation cover (*e.g.*, Persson 1980, Ohlsson 1995, Oleskog and Sahlen 2000). *P. sylvestris* has also been widely used for afforestation of mined peat bog (Brooks and Stoneman 1997).

The objective of this study was to assess (i) the effect of peat mining and different moisture and light conditions on the survival and establishment of planted seedlings of *P. rotundata* and *P. sylvestris* in mined and pristine peat bog, and (ii) the effect of vegetation scarification and different moisture and light conditions on the initial survival and establishment of *P. rotundata* and *P. sylvestris* based on the sowing experiment in pristine peat bogs.

2. STUDY SITES

The study was conducted at two peat bogs in the Bohemian Forest (called "Nová Hůrka" and "Soumarský Most" and located in Šumava National Park) and one peat bog in the Třeboň Basin (called "Červené Blato" Nature Reserve), where peat bogs are most abundant in the Czech Republic. The distance between the furthest sites was approximately 120 km, and the altitude above sea level ranged from 470 to 875 m (Table 1). The predominant climatic, hydrological and hydrochemical conditions characterize these sites as typical continental raised bogs (*sensu* Neuhäusl 1972). Annual variations in temperature and precipitation during the course of the study are shown in Figure 1. Table 1 gives the geographical location of the closest climatological stations used.

The natural vegetation composition was quite similar among the sites. A typical Central European *Pino rotundatae-Sphagnetum* community Kästner *et* Flössner 1933, *corr.* Neuhäusl 1969 is dominated by *Sphagnum magellanicum* Brid., *S. falax* Klinggr., *Dicranum polysetum* Sw., *Hylocomium splendens* Hedw. and *Polytrichum strictum* Brid. in the ground cover and herbs such as *Eriophorum vaginatum* L. together with ericaceous dwarf shrubs (*e.g.*, *Vaccinium*, *Oxycoccus* and *Andromeda*) in the field layer. Dense and multilayered populations of *P. rotundata*

Table 1. Geographical location of the three peat bog sites and the closest climatological stations.

	Local name	Coordinates	Altitude (m above sea level)
Peatland site			
1	Červené Blato	48°51'N, 14°48'E	470
2	Soumarský Most	48°54'N, 13°50'E	740
3	Nová Hůrka	49°09'N, 13°19'E	875
Climatological station			
1	Byňov	48°49'N, 14°47'E	475
2	Lenora	48°55'N, 13°48'E	786
3	Hojsova Stráž	49°11'N, 13°13'E	890

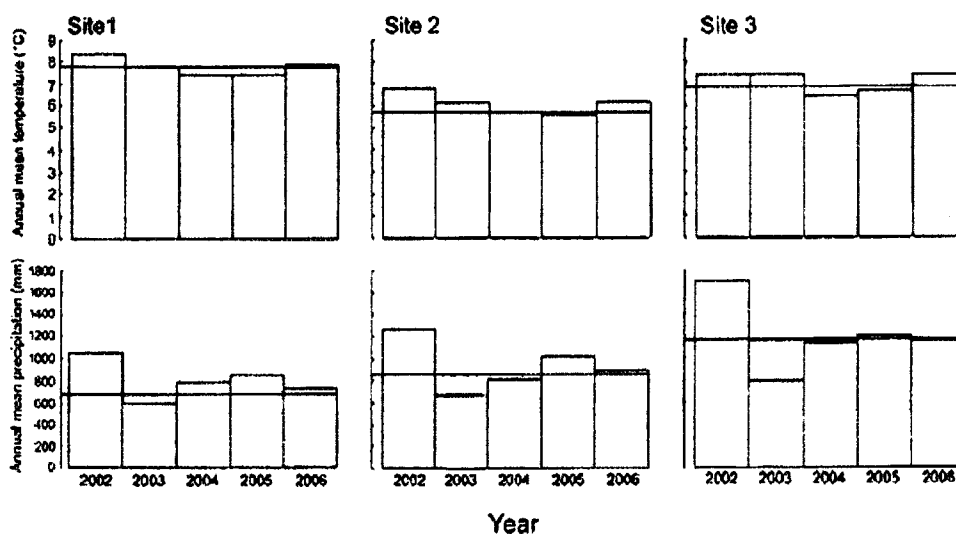


Fig. 1. Annual mean temperature and precipitation recorded from climatological stations closest to the study sites (cf. Table 1). The lines indicate mean values for the 15-year monitoring period 1990–2005.

with singlelayered populations of *P. sylvestris*, together with their hybrids (*P. × digenea* Beck.), and *Picea abies* L., form the tree layer. The bedrock consists mainly of acid, nutrient poor granite and clay (bog "Nová Hůrka"), which are potentially covered by alluvial deposits (bogs "Červené Blato" and "Soumarský Most").

All the study peat bogs had been mined for the peat in the past. The "Soumarský Most" peat bog was disturbed several times during the last 200 years. From 1958 to 1998, the peat bog was intensively mined for horticultural peat using the milling method,

which requires an effective drainage system, and then, the surface vegetation was removed and put aside. The mining of the moss and peat layers followed, altering the relief and hydrological properties of the site. The bog is now flat, with maximum depth of the residual peat approximately 1 m and initial successional stages in depressions and along ditches. There are still fragments of pristine *P. rotundata* forest adjacent to the mined part in some places. In 2005, the main drainage channels were blocked and water now accumulates successfully. The "Nová Hůrka" peat bog was locally block-

cut mined from the 18th century up to the 1980s. The "Červené Blato" peat bog was also locally disturbed by extensive block-cut mining from the 18th century up to World War I. Nowadays, the bogs continually regenerated in natural way due to revegetation by flora similar to those occurring in pristine peat bogs.

3. MATERIAL AND METHODS

3.1. Planting experiment – disturbance by mining

The effects of peat mining and moisture and light conditions on the survival of planted seedlings of *P. rotundata* and *P. sylvestris* in mined and pristine peat bog were studied in the "Soumarský Most" peat bog in eight sample plots. Four sample plots were established in an abandoned mined

part and four in a pristine *P. rotundata* forest. The sample plots (3 × 4 m) differed in water regime and exposure to light (Fig. 2). Seedlings (12 per species; i.e. 96 in total) were planted randomly at each sample plot in October 2002.

For the experiment we used seedlings of both species originated from seeds collected in three natural peat bog populations (described in Table 1) in February 2000. Seeds were stored in a deep freeze (−20°C) before their sowing. After seed recruitment seedlings were grown for five months (March–August) at pots in moist and unfertilized peat in a greenhouse (temperature 20 ± 3°C, relative humidity 70%). Seedlings were placed outdoor to acclimatize for two months before planting in the field.

We checked the germination capacity of seeds before their use in the experiment. According to the standard germination tests

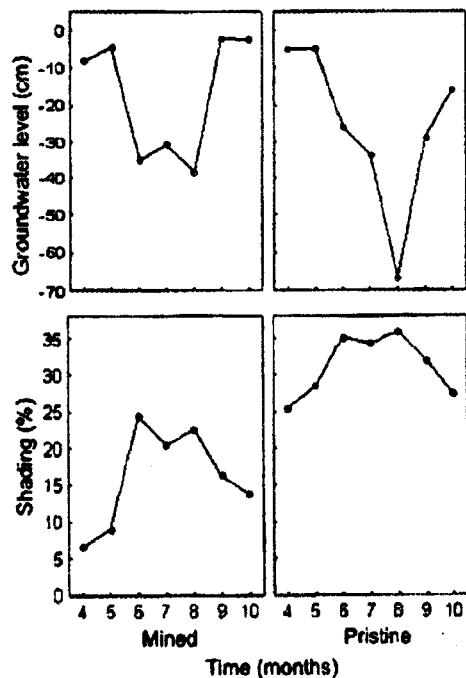


Fig. 2. Seasonal mean values of groundwater level and shading in mined and pristine sample plots in the "Soumarský Most" peat bog in 2003. Similar trends were detected for other years.

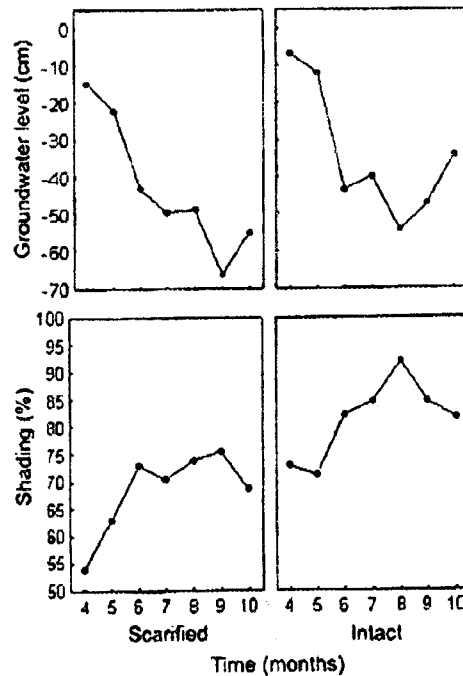


Fig. 3. Seasonal mean values of groundwater level and shading in scarified (removal of understorey vegetation and peat moss layer up to depth of 15 cm) and intact sample plots. The example describes the "Nová Hůrka" peat bog in 2004. Similar trends were detected for other localities and years.

(see ISTA 1985 for details) we estimated mean seed viability (± 1 SEM; 21-day-test). The test showed that germination capacity for both species ($70.7 \pm 9.9\%$ and $74.3 \pm 4.2\%$ for *P. rotundata* and *P. sylvestris*, respectively) was high and similar.

3.2. Sowing experiment – vegetation scarification

During this experiment, we attempted to determine if vegetation scarification together with microhabitat conditions (moisture and light) affect the survival of sown *P. rotundata* and *P. sylvestris*. Sowing experiment was carried out in the "Červené Blato", "Soumarský Most" and "Nová Hůrka" peat bogs since 2004 to 2005. At each peat bog 12 sample plots (1×1 m) of natural fluctuation of groundwater level and exposure to light (Fig. 3) were established. Six plots were scarified, when understorey vegetation and peat moss layer was removed up the depth of 15 cm, and six plots were not scarified and left intact. For the experiment we used the same seeds collected in three populations as has been already described in planting experiment. 50 seeds per each population and species (10800 in total) were sown directly in the three microsities (20×20 cm), which were fully randomized in each sample plot. To monitor tree regeneration due to naturally fallen seeds we also established three reference microsities (20×20 cm) in each sample plot.

3.3. Measurements

We measured three different plant traits describing seedling survival in seasons 2003–2005 and April 2006 (planting experiment) and for 2005 and April 2006 (sowing experiment). At first, we counted the number of surviving planted or emerged seedlings during both experiments (here called "survival"). Further "establishment" in both experiments was estimated from survival analysis as percentage of survival in relation to planted or emerged seedlings. And finally, we estimated "seedling emergence" as percentage proportion of appearing seedlings at the soil surface only in sowing experiment. This was done at the start of the experiment.

To describe external environmental conditions (moisture and light), we measured groundwater level and light exposure. Groundwater level was measured using perforated PVC pipes inserted permanently in the peat at each sample plot. Light exposure (*i.e.*, irradiance) was expressed as the percentage of shading and was measured twice in the same time either at the tip of the terminal shoot of each seedling (used in planting experiment) or at 10 cm above the peat surface in each microsite (the case of sowing experiment) and in open space (reference point) using a QRT1 Quantitherm light meter thermometer (Hansatech Instruments Ltd., Norfolk, UK). The entire groundwater level and shading data sets were then averaged to calculate the long-term mean and simplify the data for statistical analyses. Environmental data were recorded monthly (April–October) during both experiments.

3.4. Data analysis

Survival and establishment of planted seedlings of *P. rotundata* and *P. sylvestris* in sample plots of mined and pristine part of peat bog and survival and establishment of emerged seedlings in scarified and intact sample plots in pristine peat bogs was evaluated with using survival analysis method (Kaplan-Meier). This method compares the cumulative probability of survival at any specific time according to formula:

$$S = \prod_t \left[\frac{n-j}{n-j+1} \right]^{\delta(j)} \quad (1)$$

where S is seedling survival, \prod denotes the geometric sum across all cases (records) less than or equal to t (time after planting or emergence), n is the total number of records, $\delta(j)$ is a constant that is either 1 if the j^{th} record is dead, and 0 if it is still alive. Statistic of *Chi-square* test is then computed based on the sums for each group (in our case pine species in sample plot). If the whole model of survival analysis was significant at the 0.05 significance level, post hoc comparisons between the species with using the nonparametric Gehan's generalized Wilcoxon tests were calculated (Z statistic).

The effects of groundwater level and shading on the survival of both pine species were tested together using partial logistic regressions models:

$$S = \frac{e^{a+(b_1X)+(b_2Y)}}{1 + e^{a+(b_1X)-(b_2Y)}} \quad (2)$$

where S is seedling survival, e is the base of the natural logarithm, a is the intercept, and b_1 and b_2 are regression coefficients (slopes) for groundwater level (X) and shading (Y). Data were analyzed using STATISTICA 7.1 (StatSoft 2001).

4. RESULTS

4.1. Planting experiment – disturbance by mining

The differences in the survival and establishment between tree species in mined and pristine part of the peat bog were significant (Chi-square = 86.65, $P < 0.001$; Fig. 4). There was a higher survival of planted seedlings of *P. rotundata* in the mined part having higher establishment (78.6%) there compared to *P. sylvestris* (45.0%). A significant difference between the species was found ($Z = 5.76$, $P < 0.001$). However, the results were opposite in the pristine part, where the survival of *P. sylvestris* was higher having higher establishment (95.0%) than that of *P. rotundata* (64.3%). The difference between the species was also significant ($Z = -5.92$, $P < 0.001$).

Long-term means (\pm SD) for groundwater level and shading were 25 ± 17.9 cm

and $24.6 \pm 25.7\%$, respectively, in the sample plots of mined part of the peat bog and 49.2 ± 38.7 cm and $34.9 \pm 10.9\%$, respectively, in the sample plots of pristine part. A significant positive relationship was found between low groundwater level, shading and survival of both pine species in mined part of the peat bog (Table 2). A negative effect of low groundwater level and positive effect of shading on the survival of both pine species was revealed in the pristine part of the peat bog (Table 2). The survival of *P. rotundata* was more positively affected by low groundwater level in the mined part and negatively in the pristine part than was found for *P. sylvestris*. Increased shading positively affected survival of both pine species, but the effect was more pronounced for *P. sylvestris* in both mined and pristine parts of the peat bog.

4.2. Sowing experiment – vegetation scarification

Seedling emergence was low for both pine species, though slightly higher for *P. sylvestris* (2.4%) than *P. rotundata* (1.9%) in the scarified sample plots and similar in the intact sample plots – for *P. sylvestris* (2.8%) and for *P. rotundata* (2.9%). Natural tree regeneration was negligible.

The differences in the survival and establishment between tree species in scarified and intact sample plots of the pristine peat bogs were significant (Chi-square = 39.66, $P < 0.001$; Fig. 5) and separated the scarified sample plots as being better for the survival of sown *P. rotundata* seedlings, however

Table 2. Results of the logistic regressions explaining the effect of groundwater level and shading in the mined and pristine part of the "Soumarský Most" peat bog on the survival of planted *P. rotundata* and *P. sylvestris* seedlings during the experiment. Regression coefficients a (intercept), b (slope) and probability levels (P) are presented.

Species	Factor	Mined			Pristine		
		a	b	P	a	b	P
<i>P. rotundata</i>	groundwater level	-0.097	0.119	<0.001	-15.606	-0.748	<0.001
	shading		0.019		1.858		
<i>P. sylvestris</i>	groundwater level	-1.009	0.069	<0.001	-18.083	-0.716	0.002
	shading		0.021		1.907		

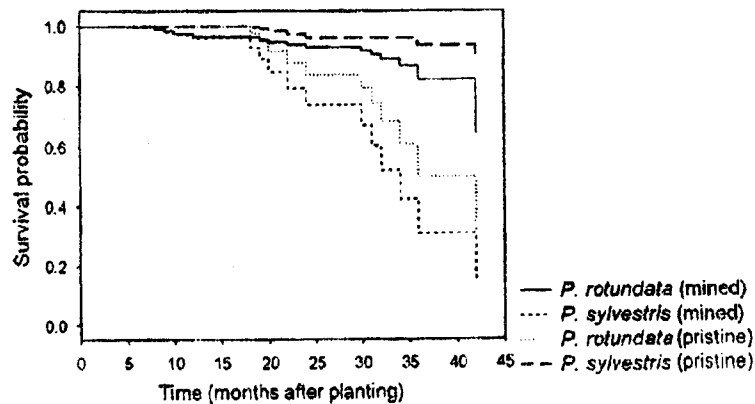


Fig. 4. Survival of *P. rotundata* and *P. sylvestris* planted seedlings in mined and pristine part of the "Soumarský Most" peat bog during the course of the study.

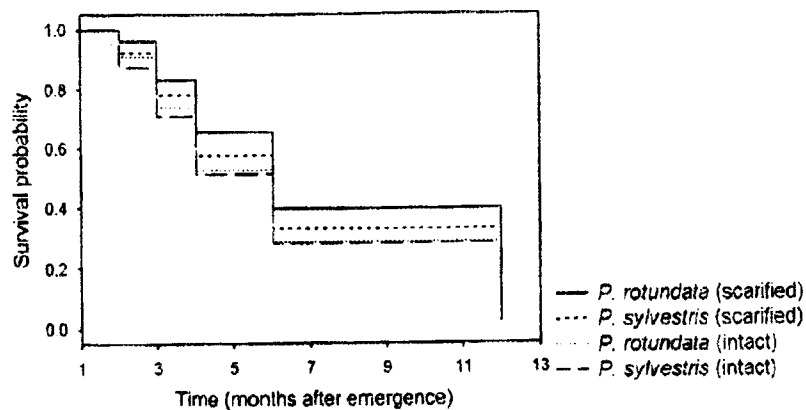


Fig. 5. Survival of *P. rotundata* and *P. sylvestris* sown seedlings in scarified (removal of understorey vegetation and peat moss layer up to depth of 15 cm) and intact sample plots within pristine peat bogs during the course of the study.

having a lower establishment (5.8%) compared to *P. sylvestris* (13.9%). A significant difference between the species was found ($Z = 2.89$, $P = 0.004$). The differences in the survival and establishment between the species were not significant ($Z = 1.32$, $P = 0.170$) in the intact sample plots. However, there was a higher survival of sown *P. rotundata* seedlings in the intact sample plots having higher establishment (15.4%) there compared to *P. sylvestris* (8.0%).

There was not so large difference in mean values (\pm SD) of groundwater level and

shading between scarified and intact sample plots. The values were 46.8 ± 25.3 cm and 62.3 ± 9.7 in the scarified and 44.7 ± 23.1 cm and 80.4 ± 6.8 in the intact sample plots. Survival of *P. rotundata* in the scarified sample plots and survival of *P. sylvestris* in the intact sample plots were significantly negatively affected by low groundwater level and positively by shading (Table 3). Survival of *P. rotundata* in the intact sample plots was significantly positively affected by low groundwater level and negatively by shading (Table 3).

Table 3. Results of the logistic regressions explaining the effect of groundwater level and shading in scarified (removal of understorey vegetation and peat moss layer up to depth of 15 cm) and intact sample plots in pristine peat bogs on the survival of sown *P. rotundata* and *P. sylvestris* seedlings during the experiment. Regression coefficients *a* (intercept), *b* (slope) and probability levels (*P*) are presented.

Species	Factor	Scarified			Intact		
		<i>a</i>	<i>b</i>	<i>P</i>	<i>a</i>	<i>b</i>	<i>P</i>
<i>P. rotundata</i>	groundwater level	-3.075	-0.027	<0.001	0.719	0.012	0.009
	shading		0.054			-0.023	
<i>P. sylvestris</i>	groundwater level	-2.724	-0.009	0.056	-4.273	-0.011	<0.001
	shading		0.034			0.049	

5. DISCUSSION

Seedling survival is a crucial characteristic in determining tree establishment in pristine peat bogs (Gunnarsson and Rydin 1998). Our results showed that there was a difference in the survival and establishment of both studied pine species *P. rotundata* and *P. sylvestris*. Seedling survival was also influenced by habitats, where pines were planted or sown. We found that survival of both pine species depended on external factors such as groundwater level and shading. Nevertheless, we are aware that seedling survival and establishment might be affected by other factors, which confound the effect of environmental conditions. These effects are predation (Peterson *et al.* 1990, Nystrand and Granstrom 2000), allelopathic inhibition by peat bog plants (Hytönen 1992) and the influence of mycorrhizal fungi (Thormann *et al.* 1999). However, there are two main environmental factors: groundwater level and light exposure in sense of shading (see also Sliva *et al.* 1997) playing major role in peat bogs. Our results for the survival and establishment of planted and sown seedlings corresponded with earlier findings obtained from experiments conducted with coniferous trees in the survival-limiting conditions of the boreal zone (Ohlson and Zackrisson 1992, Hörnberg *et al.* 1997, Jonsson 1999). In the field we observed that the survival and establishment of seedlings of both pine species could be affected by age of seedlings. Survival and establishment were lower for young seedlings recruited from seeds than was observed for older planted seed-

lings. Thus, seedling plantations can eliminate the negative effects of stressful environmental conditions. Similarly, Donovan and Ehleringer (1991) showed that juveniles are more sensitive to moisture and light conditions, because their metabolic activity and stress resistance mechanism are not still fully developed.

5.1. Planting experiment

Mined peat bogs are hostile environments, where microhabitat conditions characterized by moisture and light extremes, are both important limiting factors affecting the development of trees. In contrast, pristine peat bogs have more stabilized moisture and light conditions because the peat profile is more homogenous and stabilized by natural vegetation relationships. Thus, tree survival is expected to be much more related to moisture and light in mined peat bogs. Our results surprisingly showed that survival and establishment of the native peat bog species *P. rotundata* was highest in the mined part, while survival and establishment of *P. sylvestris* was highest in the pristine part of the "Soumarský Most" peat bog.

Many studies have emphasized the negative effect of a low groundwater level on the regeneration of native peat bog species in mined peat bogs (Laine *et al.* 1995, Sliva *et al.* 1997, Lavoie *et al.* 2003), especially in relation to summer drought and substrate stabilization by initial vegetation. In the mined part of the "Soumarský Most" peat bog the groundwater level was higher than in the pristine part because of overflooding

of central part of peat bog. That was the reason why the effect of low groundwater level on the survival of the planted seedlings of both pine species was positive, especially for *P. rotundata*. It was found that survival of *P. rotundata* could be seriously affected by waterlogging, anaerobic conditions in the microhabitat (Gunnarsson and Rydin 1998, Sarkkola *et al.* 2004) and frost hardening during the winters (Price 1997, Groeneveld and Rochefort 2002). Such studies (Laine *et al.* 1995, Sliva *et al.* 1997, Lavoie *et al.* 2003) considered this effect to be a significant environmental factor influencing the development of natural peat bog vegetation in undisturbed conditions. This was also evident during the course of our experiment when the survival of both pine species, and especially for *P. rotundata*, was negatively affected by low groundwater level in the pristine part of the peat bog.

There were also differences in the survival of *P. rotundata* and *P. sylvestris* seedlings related to different light conditions. Survival was positively affected by shading from the surrounding vegetation in both mined and pristine parts of the peat bog, especially for *P. sylvestris*. In addition, the comparison of mined and pristine part of the peat bog indicated that shading could be better predictor for survival of both pine species in the pristine part than groundwater level (Table 2). This corresponds with Lanta and Hazuková (2005) study demonstrating higher leaves biomass of birch seedlings (*Betula pubescens*) under shaded treatment. Nevertheless, Pukkala *et al.* (1993) showed a positive relationship between seedling survival and growth and high irradiance in pristine boreal forests. In our study, shading probably reduced evapotranspiration in pristine part of the peat bog where groundwater level was lower than in mined part. Such environmental conditions were more favourable for survival and establishment of *P. sylvestris* in pristine part of the peat bog. On the other hand, in spite of the groundwater level was higher in mined part of the peat bog, there can be a potential risk of drying up of the substrate and water deficiency during summer drought if there is no vegetation cover. It seems that such conditions are favourable for survival and establishment of *P. rotundata*.

5.2. Sowing experiment – vegetation scarification

The effect of removal of understorey vegetation and peat moss layer up to depth of 15 cm can positively influence survival of *P. rotundata*. These results confirmed those of many earlier studies which have emphasized the positive effect of vegetation scarification on forest structure, regeneration and species composition, especially due to reduced above-ground interference after understorey vegetation removal (Hörnberg *et al.* 1998, Engelmark and Hyteborn 1999). Similarly with our findings, Hautala *et al.* (2001) also showed the indirect positive effect of understorey vegetation removal. They found that the release of earlier unavailable resources, such as light and nutrients had great importance for the success of the natural regeneration of pines in peat bogs.

However, our results showed that emergence and establishment of *P. rotundata* was surprisingly lower in scarified sample plots than in intact sample plots. On the base of our observations, the long-term mean of groundwater level and shading was relatively low in the scarified sample plots than in intact plots. It suggests that *P. rotundata* survival benefits more from higher groundwater Table and shading. Gunnarsson and Rydin (1998) showed that scarification of an intact mire surface providing appearance of bare peat led to intensive desiccation on hummocks and waterlogging in hollows. These effects of scarification are thus proposed as one of the most likely mortality factors. That is why favourable conditions could be characterized as a transition between the two moisture extremes, which is very important for the survival of *P. rotundata* seedlings in scarified sample plots. Nevertheless, increased shading by the surrounding vegetation in the scarified sample plots have so called "nurse" positive effect in protecting seedlings against summer drought (Groeneveld and Rochefort 2002). On the other hand, frost heaving (which causes high winter mortality of seedlings, see Price 1997) probably resulted in lower establishment of *P. rotundata* seedlings in the scarified sample plots. This was confirmed by our observations of high frost disturbance (cracking) of peat surface there.

Seedling emergence, survival and establishment on pristine peat bogs has been intensively studied in the past, especially in relation to different moss species composition (Ohlson and Zackrisson 1992, Hörnberg et al. 1997, Hanssen 2002), and mostly was found negative competitive effects of mosses. Our results supported this hypothesis because survival of both pine species was significantly lower in intact sample plots, although emergence and establishment were both higher. Higher emergence and establishment was probably a consequence of the presence of a dense canopy of *Sphagnum* carpets, which codominated the sample plots. *Sphagnum* species are considered to be the best for seedling emergence (Ohlson and Zackrisson 1992, Hörnberg et al. 1997, Ohlson et al. 2001), especially because it provides favourable moisture conditions. *Sphagnum* usually prefers waterlogged or shaded habitats but it is possible to grow in fast and to reach higher competitive potential (Rocheft 2000) here. Since *Sphagnum* tends rapidly to overgrow tree seedlings, it is sometimes considered as to be not favourable for seedling establishment (Hanssen 2002). Similar effect could influence our experiment and explained the positive relationship between *P. rotundata* survival and low groundwater level and the negative relationship between shading and survival. On the other hand, survival of *P. sylvestris* in the intact sample plots was negatively related to low groundwater level and positively related to shading. Consequently, it is likely that *P. sylvestris* had better survival and growth in moist and shaded microhabitats, which enables seedlings to keep assimilating needles above the permanently growing moss surface (Ohlson et al. 2001).

6. CONCLUSIONS

There is a species-specific response in seedling survival and establishment to groundwater level and shading for *P. rotundata* and *P. sylvestris* planted seedlings in mined and pristine part of the peat bog as well as for sown seedlings in the conditions of vegetation scarification and intact mire surface. On the base of our results we propose that in case of restoration activities (mined

peat bogs) and management approaches (pristine peat bogs), it would be important to consider survival and establishment of both pine species, which are intimately related to abiotic factors. This needs especially to focus on moisture (i.e., low groundwater level and flooding) and light conditions (i.e., facilitation effect of shading by surrounding vegetation).

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