

Spatial pattern of Norway spruce and silver fir natural regeneration in uneven-aged mixed forests of northeastern Bohemia

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ABSTRACT: Two permanent sample plots (both 0.25 ha) were established in a mixed forest in the Orlické hory Mts. Protected Landscape Area (northeastern Bohemia) to analyze the natural regeneration of Norway spruce (*Picea abies* [L.] Karst.) and silver fir (*Abies alba* Mill.). All the seedlings (height 0.1–0.5 m), saplings (height 0.5 m, $d_{1.3}$ 3 cm) and trees ($d_{1.3} > 3$ cm) were localized and measured. The analysis of the spatial pattern and statistical evaluation were carried out by means of Ripley's *K*-function. All the growth stages of the spruce and the fir showed an aggregated (clump) pattern, whereas the regeneration of fir was positively correlated with mature spruces and the regeneration of spruce was in a positive relation with mature firs. The results indicate that for germination and stable growth in the first stages of development, the fir can find more favourable conditions under the crowns of spruce trees and the spruce under mature firs.

Keywords: *Abies alba*; *Picea abies*; natural regeneration; spatial pattern; Protected Landscape Area

The forests of the Czech Republic consist first and foremost of even-aged coniferous stands established by artificial regeneration beginning primarily in the middle of the 19th century (NOŽIČKA 1957). A distinctive decline of the ecological stability of these problematic stands in the second half of the 20th century ended in an effort aimed at their closer-to-nature cultivation (KORPEL, SANIGA 1995). Problems of natural regeneration of these forests have attracted attention. Since natural regeneration in comparison with artificial regeneration brings along certain risks and difficulties, it is necessary to understand the process of natural regeneration as good as possible and to sum up this knowledge in practice (particularly with tending and regenerative interventions) (KORPEL, SANIGA 1995).

The continuing strong decline of the fir representation in the forests of Central Europe, having its beginning in the 19th century, is a complex problem (e.g. MÁLEK 1983; VRŠKA et al. 2000; JAWORSKI et al. 2002; ŠTEFANČÍK 2004, 2006; NAGEL et al. 2006). Its preservation in the stands is a priority requirement for the preservation of ecological stability and adequate roles of forest ecosystems. The representation of the silver fir as a species has been on a long-term decline, while the reasons are not fully known yet. Its natural regeneration, or its absence and slow growth, has been the greatest problem in the last decades, particularly in mountain areas (HLADÍK et al. 1993). The mountain forests of the Czech Republic are not an exception. The fir has gradually been replaced in the stands by the spruce or by the dynamically

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spreading European beech (MÍCHAL 1983; VRŠKA et al. 2000; JAWORSKI et al. 2002).

Pure fir-spruce forests have naturally been present in Central Europe only scarcely and temporarily, mainly at higher altitudes, where the ability of beech to compete is lower (HLADÍK et al. 1993). The current situation is above all a result of the clearing of broadleaved admixture (namely beech and sycamore maple) by the past management interventions, thus the fir lost its strong competitor, the beech (NOŽIČKA 1957). The relationships in the spruce and fir population dynamics in the forests and substitution of these species were also discussed by HEUZE et al. (2005a,b) or AMMER (1996). In this case, it was particularly the variation in the species composition and population dynamics in favour of the spruce in consequence of a greater pressure toward the fir by the browsing of the game.

The dynamics of natural and close-to-nature forests is derived from the gradual regeneration of species in smaller or larger gaps within the scope of the variation of developmental stages of these forests (MÍCHAL 1983; HLADÍK et al. 1993). The regeneration of the fir concentrates mainly in small gaps, particularly on their margins under the shade of the mature stand and its canopy. Larger gaps are occupied by other species – the spruce and particularly the beech, the fir is absent there (MÍCHAL 1983; HLADÍK et al. 1993; GRASSI et al. 2004; HUNZIKER, BRANG 2005). The formation and the initial growth of seedlings are fundamental for the regeneration and tending of ecologically stable fir stands. The dynamics of the spruce and fir regeneration individually is known quite well (KORPEL, VINŠ 1966). Mutual relationships (particularly the competitive ones) of both these species have not been fully clarified yet (MÍCHAL 1983). The relevant modern scientific results which describe these spatial relationships of the initial growth of the fir and spruce natural regeneration are only seldom available (GRASSI et al. 2004; PALUCH 2005a,b, 2006).

The conservation of the silver fir in the forests is important especially in the protected areas, thus the main objective of this study is to clarify the relationship of the regeneration of the spruce and the fir with their mature stand.

METHODS

Study area

The northern edge of the Orlické hory Mts., the area of research, has similar historical development like the majority of the other mountains in the Czech

Republic. In the Orlické hory Mts. the 16th century was the beginning of large-scale, selective cutting above all of firewood for the needs of nearby iron-mills, mines, and later on, glassworks. High-quality stems of hardwood species (beech, oak) were particularly selected. Vast mountain ridge areas were cleared to give way to animal husbandry and sheep and goat breeding. The aforementioned interventions led to the devastation of local mountain forests in the 18th century, to intensive understocking and modification of the forest composition in favour of coniferous species. These stands were often open, with discontinuous canopy and of a selection character. Until the end of the 19th century they were attacked by grazing livestock. For the reason of their bad condition and because of the lack of good-quality wood, they were replaced by artificially planted spruce stands before the end of the 19th century at the furthest. The use of non-autochthonous seed in the area of the Orlické hory Mts. led to a decrease in the vitality of local forests consequently (NOŽIČKA 1957).

The research was conducted in the northern part of the Orlické hory Mts. Protected Landscape Area (PLA; natural forest area 25, the urban area of Olešnice in the Orlické hory Mts. land register). The original spruce stand with the admixture of fir was damaged by incidental fellings at some places and progressive opening of the stand supported its natural regeneration since the 1920s. Fir regeneration occurred first, spruce with rowan came later. The harvesting of the last trees of the mature stand, and therefore the complete release of the growths, was done in 1960. Places locally damaged by harvesting were replenished by the planting of spruce. The current stand then originated through the combined regeneration with a long regeneration period (40–50 years), an important admixture of fir has been preserved until now. As a consequence of the introduced development, the mixed stand is markedly uneven-aged and structurally (in diameter and height) differentiated. A tending felling (reduction of the rowan representation) was carried out in 1970 and the spatial pattern in too dense groups was revised. Consequent interventions promoted the stability of the stand and the preservation of fir on the main level of the upper canopy (SOUČEK 2007). Following the air pollution load at the end of the 1970s, defoliation of fir and spruce occurred in the next 10–15 years (BALCAR et al. 1997). The air pollution load decreased to a bearable extent in the 1990s. Particularly the sanitation selection, intended to promote the quality specimens, has been applied since 1980. The area of research is strongly affected

by regular abiotic damage (snow and icing in particular), resulting in top and crown breakages. The research was also focused on the static stability of the stand. A great number of damaged spruce crowns have been recorded, and the fir appears to be a much more resistant species there (HOFMEISTER 2007). The current fir age ranges between 60 and 100 years, the spruce age between 45 and 70 years. No damage of seedlings and saplings caused by the game has been registered in the area of research.

The study area lies at the altitude between 780 and 800 m above sea level: forest site complex 6K (Acidic Spruce-Beech) with the *Fagetum abietino-picetosum* autochthonous forest community, target management set of stands 53, total precipitation in the vegetation period 620 mm, average temperature in the vegetation period 10.7°C, slope orientation of the plots is south-west, while the plots are situated on an easy slope (ca 10%). The prevailing soil type is Cambisol on mica schists (metamorphic rocks). Neither dead trees nor laying logs are present in the PSPs, all the stumps are older than 10 years, max. 20–25 cm in diameter and they are distributed more or less regularly on the plot. The vegetation cover of the soil does not create a continuous impenetrable cover disabling the growth of seedlings at any place of both PSPs, and litter can be found on the major part of the plot. From the aspect of the occurrence of stumps and herbaceous cover, both PSPs can be classified as homogeneous. Since the beginning of the 1970s the development of the structure of the fir-spruce stand has been monitored there, a prediction of the development of the local stands was presented by VACEK et al. (2007).

Data collection

Two permanent sample plots (PSP) were established in 2007 for the research on the stand and regeneration structure, both 50 × 50 m (0.25 ha) in size, representing the condition of local forests. For the data collection the FieldMap terrain system was applied, enabling to assign spatial coordinates to each of the trees. All the live tree species of the

height > 0.1 m were detected. The heights of the trees were measured with an optical hypsometer to the nearest 10 cm, the diameters of the trees with a band dendrometer to the nearest 1 mm, the widths of the crowns by their optical projection to the ground to the nearest 50 cm. The measured specimens were classified into three categories – seedlings (height 0.1–0.5 m), saplings (0.5 m, $d_{1.3}$ 3 cm) and trees (diameter $d_{1.3}$ > 3 cm). In total 1,403 seedlings, 202 saplings and 433 trees were measured.

The diameter of the mean stem, mean stand height, dominant stand height (characterized as an average height of the 100 highest trees per 1 ha for the individual species), stand density, volume and stand basal area (SBA) were calculated by regular dendrometric methods using the volume and mensurational tables. The crown projections were created by means of buffer zones from the values of the widths of the crowns.

Statistical analysis

Univariate and bivariate Ripley's K analysis was applied to test the spatial independence of the individuals within the categories and between them. Ripley's K considers distances between all pairs of stems, thereby providing information at multiple scales (RIPLEY 1977; DIGGLE 1983). The distance matrix δ_{ij} between all pairs of the trees on the plot is tabulated and Ripley's K measures the degree to which the pattern deviates from randomness. $K(d)$ is calculated as

$$K(d) = A \sum_{i=1}^n \sum_{j=1}^n \frac{\delta_{ij}(d)}{n^2} \quad \text{for } i \neq j$$

where: area A – plot area with n trees,

δ_{ij} – distance between the tree i and the tree j .

The square root transformation $L(d)$ was used that linearizes $K(d)$, stabilizes its variance and has an expected value approximating zero (RIPLEY 1977, 1979). Ripley's $K(d)$ was computed using edge correction described by DIGGLE (1983). Monte Carlo methods simulate randomly generated plots of the same dimensions to compare the value of the func-

Table 1. Density of seedlings, saplings and trees in the PSPs (N/ha)

Sample plot	Seedlings		Saplings		Trees	
	spruce	fir	spruce	fir	spruce	fir
01	x^*	x^*	100*	4*	604	288
02	4,188	368	344	0*	384	456

*Insufficient number of individuals for statistical processing, x – undetected

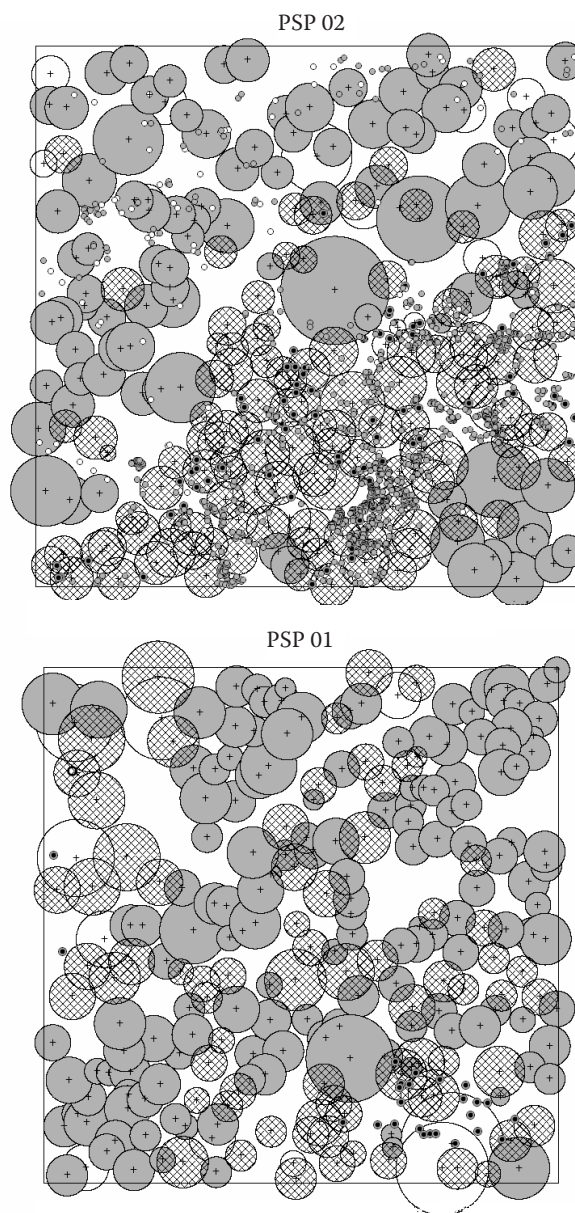
Table 2. Characteristics of the stand

Sample plot	Percentage in V			N (ha)	ρ	G (m ² /ha)	V (m ³ /ha)	h mean (m)	h_{100} (m)	$d_{1.3}$ mean (cm)
	spruce (%)	fir (%)	rowan and others (%)							
01	59.6	34.5	5.9	932	1.1	42.1	370.76	17.1	20.7	24.0
02	51.6	39.3	9.1	932	0.9	39.5	329.27	18.6	21.2	23.6

N – number of trees ($d_{1.3}$ above 3.0 cm), G – basal area, V – volume, $d_{1.3}$ – diameter at breast height, h – height, h_{100} – height of the 100 highest trees per ha, ρ – stand density

tion $K(t)$ with that expected from a randomly distributed group of points and to assess its significance ($P < 0.01$). The spatial pattern can then be described as clumped, random or regular (for univariate patterns) at any distance d if the calculated $K(t)$ function is greater than, equal to, or lower than the 99% confidence envelopes, respectively. In the case of complete spatial randomness, the expected value of the transformed function $L(d)$ is 0. For bivariate patterns the hypothesis of independent components was tested, the calculations are based on the same relations. The components of a bivariate pattern are independent (spatially uncorrelated) if they satisfy $L(d) = 0$, and they are positively/negatively correlated at a range d if $L(d)$ is positive/negative (HORÁK 2002; GRASSI et al. 2004; ŠMILAUER 2007). A distance of 25 m and an interval of 0.5 m were assumed as a maximal distance and a minimal interval of analysis, respectively. K -function is often applied to the testing of the spatial pattern of plant communities (e.g. see CHEN, BRADSHAW 1999; GRASSI et al. 2004; WOLF 2005; NAGEL et al. 2006; PALUCH 2006; KLIMAS et al. 2007).

The distribution of all the mature trees together (integration of spruce, fir, rowan and other broadleaves into the “all trees” category) as well as the spatial pattern of the trees of the main species separately were evaluated by the univariate method, but the broadleaves were omitted here for their poor representation. The regeneration was analyzed separately according to the species. Using the bivariate method, we analyzed the influence on the regeneration of the spruce trees and fir trees together, as well as the influence on these two species individually according to each of the species. The mentioned light-demanding broadleaves were again excluded from the analysis. In all the cases we took the regeneration separately according to the species. With the integration of all the main mature trees into one group, we can deduce whether the natural regeneration is generally in a (positive/negative) relation with the spatial pattern of the tree stems. Thus it is possible to determine whether the regeneration occurs in the approximation of the tree crowns (dense patches) or in the gaps. With the differentiation according to species



grey projections – spruce, lattice projections – fir, white projections – rowan and others, grey circles – spruce seedlings, black-and-grey circles – spruce saplings, white circles – fir seedlings

Fig. 1. Tree maps and distribution of regeneration in PSP 01 (below) and PSP 02 (above), PSP 01 is presented particularly for the documentation of the variant form of the mixture of fir and spruce in the same stand

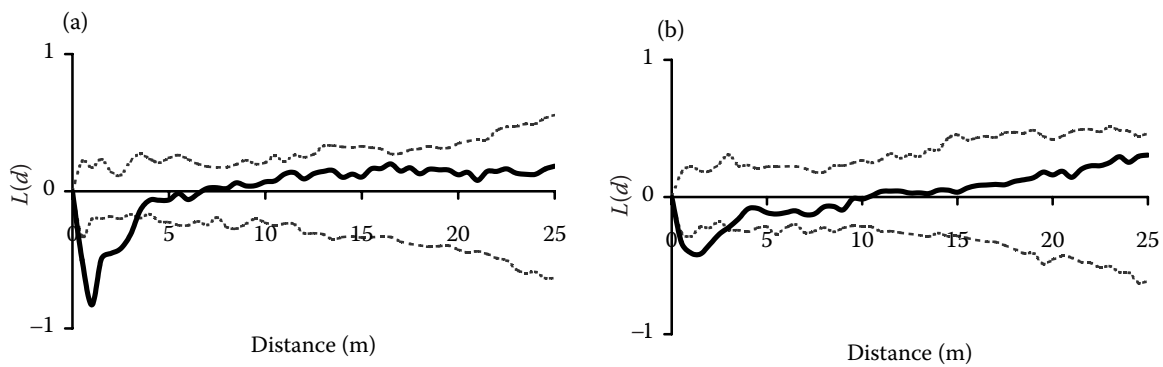


Fig. 2. Univariate $L(d)$ function (solid line) for all trees in PSP 01 (a), PSP 02 (b) and the Monte Carlo envelope (99% confidence level, thin dashed lines)

we can trace the relationship of the distribution of the regeneration with the particular species. In PSP 01, regarding the insufficient number of seedlings and saplings for a predicative statistical processing, at least the trees category was later evaluated to enable the comparison with PSP 02 (Table 1).

RESULTS

The calculated dendrometric data are shown in Table 2. PSP 01 presents higher stand density, volume and SBA. However, the height characteristics of the

stand are lower than those of PSP 02. The stand is in the stage of a prospective large-diameter stand, the natural regeneration is either in the initial or slightly advanced stage. PSP 02 contains solely fir seedlings of a height below 0.5 m.

Fig. 1 illustrates an overview of the pattern of the tree crowns and the distribution of the spruce and fir natural regeneration. PSP 01 is presented here to primarily document a variant form of the mixture of fir and spruce in the same stand, which is likely the cause of a small number of spruce saplings represented here in comparison with PSP 02.

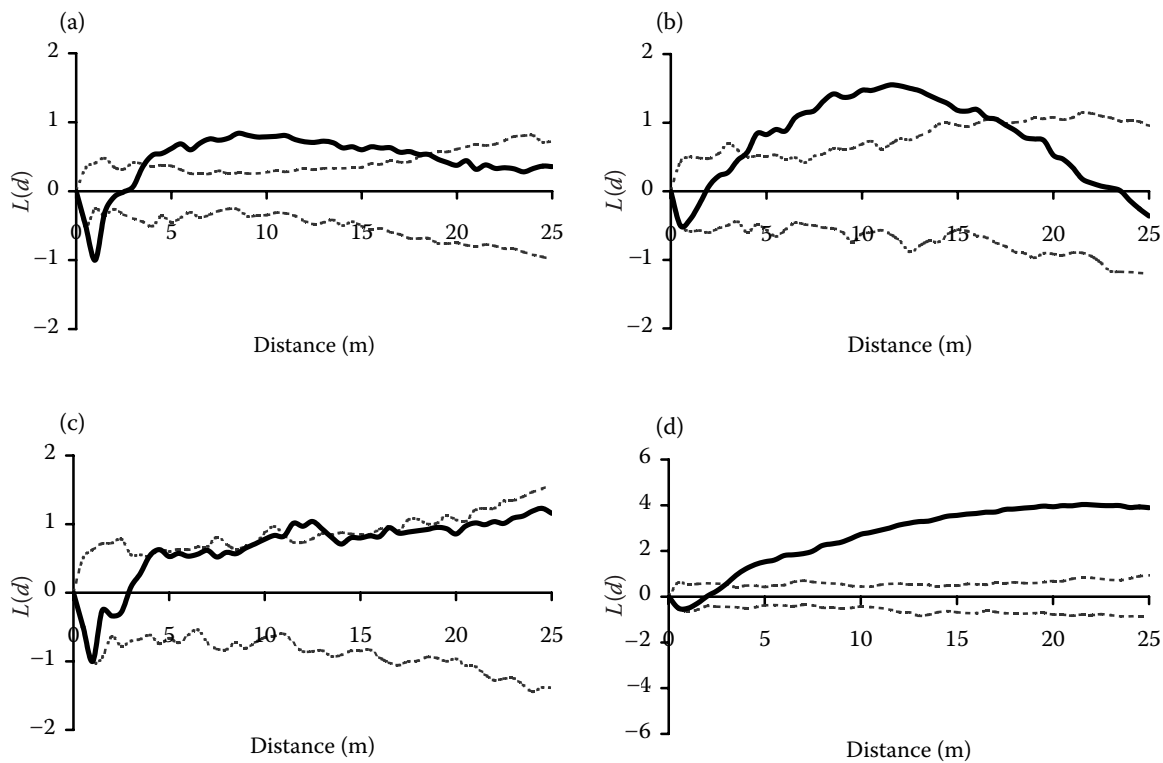


Fig. 3. Univariate $L(d)$ function (solid line) for spruce trees in PSP 01 (a), spruce trees in PSP 02 (b), fir trees in PSP 01 (c), fir trees in PSP 02 (d) and the Monte Carlo envelope (99% confidence level, thin dashed lines)

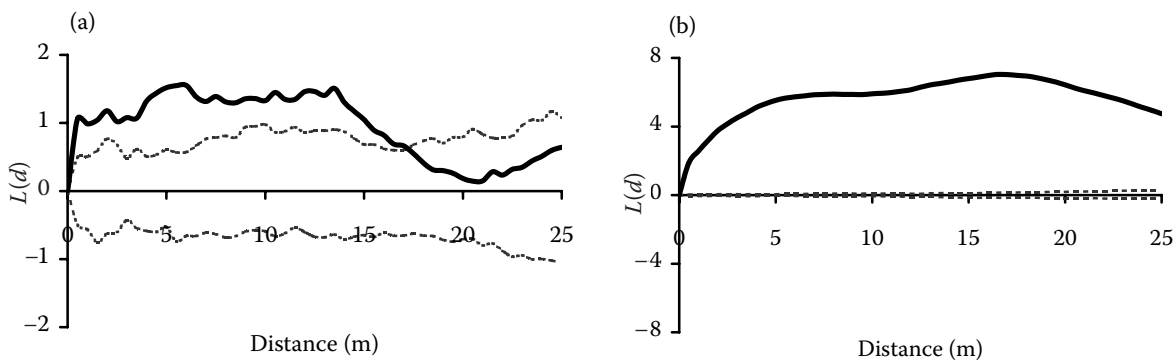


Fig. 4. Univariate $L(d)$ function (solid line) for fir seedlings (a) and spruce seedling (b) in PSP 02 and the Monte Carlo envelope (99% confidence level, thin dashed lines)

At the assessment of the distribution of all the trees disregarding the species, both plots have coincidental arrangement. At the distance of 0–2.5 m the trees repulse each other significantly ($P < 0.01$), i.e. they tend to have a significantly regular distribution (Fig. 2).

In both PSPs the spruce trees show significantly ($P < 0.01$) aggregated distribution at the distance of 4–16.5 m (Figs. 3a,b). In PSP 02 the fir trees show a significantly ($P < 0.01$) strong aggregated pattern from 3 to 25 m (maximum is at 21.5 m) (Fig. 3d). In PSP 01, there is an evident tendency toward the

formation of clumps once again, not as strong as in PSP 02, though significantly ($P < 0.01$) only between 11.5 and 13 m (Fig. 3c).

Seedlings in PSP 02 have a strongly aggregated pattern: fir seedlings significantly ($P < 0.01$) at the distance of 0–17 m (maximum at 6 m) (Fig. 4a), while spruce seedlings have a very strongly aggregated pattern in the whole d profile – significantly ($P < 0.01$), maximum at 16.5 m (Fig. 4b). The spruce saplings present similar results like the spruce seedlings (maximum at 17.5 m).

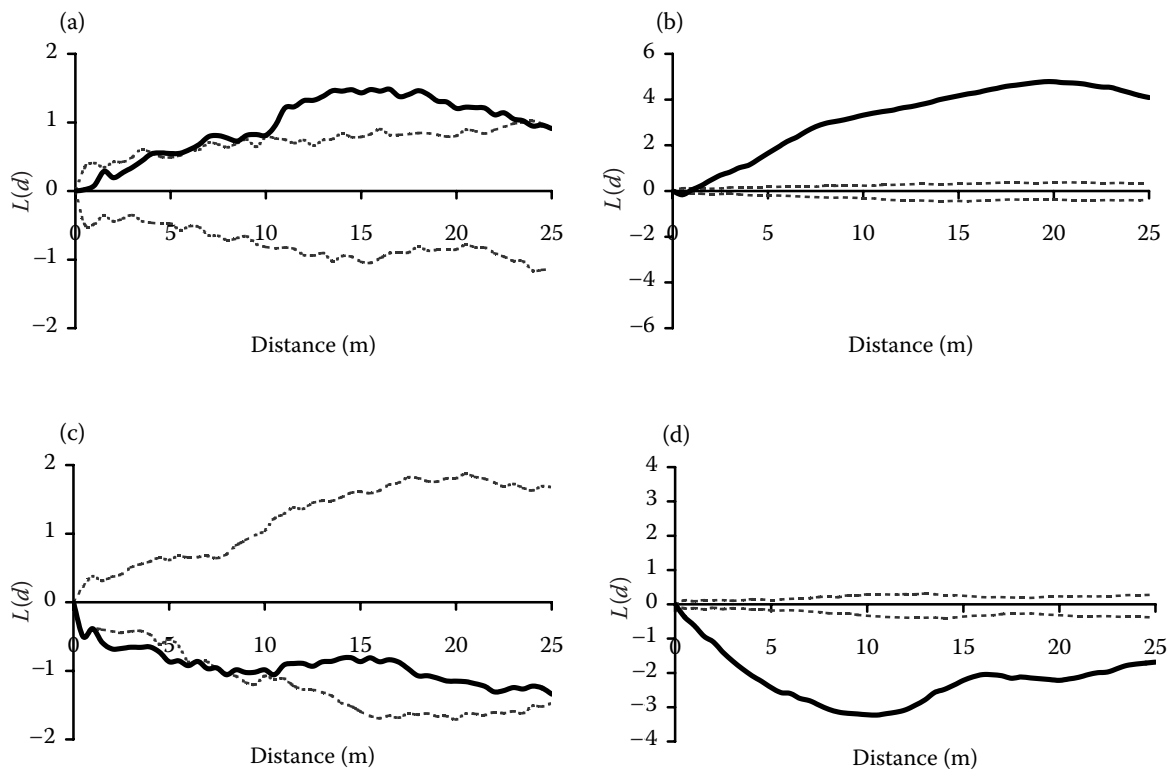


Fig. 5. Bivariate $L(d)$ function (solid line) for spruce trees to fir seedlings (a), fir trees to spruce seedlings (b), fir trees to fir seedlings (c) and spruce trees to spruce seedlings (d) in PSP 02 and the Monte Carlo envelope (99% confidence level, thin dashed lines)

The relationship of the spruce and fir trees in PSP 02, disregarding the species, with the separate spatial distribution of young firs and spruces is neutral, with the tendency to form a random pattern.

However, the results of the distribution of the trees according to species were highly significant. The fir seedlings are in a negative relation with the mature firs – significantly ($P < 0.01$) at the distance between 1.5 and 7 m (Fig. 5c), while they are reversely positively associated with the spruce mature trees – significantly ($P < 0.01$) at the distance of 4.5–23.5 (maximum at 16.5 m) (Fig. 5a). The distribution of the spruce seedlings has quite a contrary tendency, it is positively associated with the fir mature trees – significantly ($P < 0.01$) at the distance of 1.5–25 m (maximum at 19.5 m) (Fig. 5b) and with the spruce trees it is in a negative relation – significantly ($P < 0.01$) at the distance of 0–25 m (maximum at 10.5 m) (Fig. 5d). The spruce saplings have similar progression as the spruce seedlings once again. They are positively associated with the fir trees – significantly ($P < 0.01$) at the distance of 1–25 m (maximum at 22 m), with the mature spruce trees then negatively – significantly ($P < 0.01$) at the distance of 1–22.5 m (maximum at 12 m). However, the spruce seedlings and saplings show a negative relation with the mature firs at the shortest distances up to 0.5 m, but the values are not significant (see Fig. 5b). The spruce saplings show similar results in all the relationships like the spruce seedlings, therefore they are not presented in the figures.

Regarding the low numbers of seedlings and saplings in PSP 01, these categories cannot be statistically evaluated. Nevertheless, for example the pattern of spruce saplings shows a similar arrangement like in PSP 02 (see Fig. 1).

DISCUSSION

Regarding the predominant evaluation of the unestablished regeneration (seedlings up to 0.5 m), from the listed results we can particularly deduce relationships of this regeneration with the mature trees from the aspect of successful germination and survival in the initial years of the growth.

Our results show that both the mature trees and the regeneration have the clump distribution. The existence of the fir and spruce regeneration in clumps was supported by a number of authors (e.g. GRASSI et al. 2004; PALUCH 2005b, 2006). This fact is probably given in spruce trees by the past tending interventions in the area of research (SOUČEK 2007).

PSP 01 shows a low number of seedlings and saplings whereas the rates of SBA, stand density and volume are higher than those of PSP 02. Even though the differences in these variables are not great, it seems that they are not favourable yet for the occurrence and steady growth of the natural regeneration in PSP 01 (of the spruce particularly). The spatial pattern of mature trees is also slightly different, the fir does not form there as big clumps as in PSP 02 (see Fig. 1).

Although the existence of fir and spruce regeneration in the gaps was mentioned by many authors (e.g. MÍČHAL 1983; GRASSI et al. 2004; HUNZIKER, BRANG 2005), no greater distribution of spruce or fir regeneration has been observed in nor around the gaps, as shown by our results. In reference to all the trees irrespective of the species we cannot say with certainty whether the regeneration takes place rather at the trees or in the gaps.

The tendency of the fir to regenerate and survive under strong shadowy conditions is well known (KORPEL, VINŠ 1966; MÍČHAL 1983; PALUCH 2005a). The fir natural regeneration very often takes place under a closed stand, where the fir (as far as mature firs are present in the neighbourhood) regenerates naturally as the first species and creates so called sapling bank there (KADLUS 1969; GRASSI et al. 2004; SZYMURA 2005). For the other species, especially for spruce, there are still unsatisfactory growth conditions, defined by the low light intensity (STANCIOIU, O'HARA 2005). At least a slight shade is ideal for the fir whereas the spruce has an advantage on a site exposed to light since the fir tends to slightly slower its growth in direct sunlight (STANCIOIU, O'HARA 2005). Our results correspond with these facts, the fir regeneration takes place under the dense mature spruces, not in the gaps.

PALUCH (2005a,b, 2006) stated that the fir regeneration in the Carpathian Mountains depended rather than on the light conditions on the easy-to-change edaphic factors, such as humus forms or acidity in the upper soil horizons, while these features are retroactively derived from the structure of the mature stand. Poor acidic sites, with raw acidic forms of humus layers, suit the fir regeneration well, especially in mountain areas, very often being situated directly on a mineral soil (MÁLEK 1971, 1983; MÍČHAL 1983). Thus on humus forms, in standard circumstances formed under the spruce stands (e.g. PODRÁZSKÝ 1997). These sites are known for the lower effects of pathogenic fungi, causing the damping off and root rot of fir seedlings (SENN, SUTER 2003; JANKOVSKÝ 2005). These facts correspond to our results again. We found the fir regeneration spa-

tially under the mature spruces where these acidic sites are situated.

Just in the area of the current PSPs KADLUS (1969) researched the dynamics of spruce, fir and beech regeneration. He indicated in particular the influence of the closure of mature stand (the canopy class) on the distribution of natural regeneration. Consequent natural regeneration of these species is postulated with the treatment of the stand by tending interventions to benefit the clump structure of the mature stand. The natural regeneration of the same species under mature trees is expected. As our research shows, it does not always have to be like that. The results point to the relationships between spruce and fir from the aspect of the survival and establishment of natural regeneration. In the history various causes of the mutual replacement of species in the same stand were reported (MÍČHAL 1983; HLADÍK et al. 1993; VRŠKA et al. 2000). In the spruce-fir relationship, we cannot ascribe these variations to a different age of survival since both species naturally live on average for the same time (300–400 years) (MÍČHAL 1983; HLADÍK et al. 1993). Research in the past already showed an interesting phenomenon when the fir regenerated better under the spruces and on the contrary, the spruce regenerated better under the fir crowns (MAYER 1960 and GÜRTH 1988 according to DOBROWOLSKA 1998). The results of our research correspond with this proposition. Young fir (seedlings) centralize chiefly under the spruce crowns, the spruces (seedlings and also the saplings) under the fir crowns (Fig. 5). It is known that the fir regenerates well under the crowns of birch and pine (DOBROWOLSKA 1998) or larch (ROBAKOWSKI et al. 2004), thus under the light-demanding species, particularly in comparison with the poor regeneration under firs or spruces (AMMER 1996). However, the respective light-demanding species in the area of research do not usually take up a large part of the species composition.

Although having the full foliage, the firs with their needles absorb minimally the same amount of light as spruces (MÍČHAL 1983), the spruce finds a better environment for its growth here. The concentration of the spruce regeneration under the crowns of mature firs can be explained by greater fir damage (defoliation) by air pollutants in the 1980s (ca 20 years ago) (BALCAR et al. 1997). The spruce regeneration found better light conditions under these damaged fir crowns than under the mature spruces. According to many historical records the spruce is able to grow very well even in direct sunlight where it has a better photosynthetic effectivity than the fir (GRASSI, BAGNARESI 2001 according to STANCIOIU,

O'HARA 2005). In the long run, the spruce finds here the best conditions for its growth (spruce saplings) solely under the canopy of firs, not in the gaps. The present harsh mountain abiotic conditions are the most probable cause of this fact. The spruce regeneration finds shelter under the mature firs, not in the gaps, which are exposed to frost and wind. The fact that the spruce regeneration is in a negative relation with the fir trees at a distance smaller than 0.5 m corresponds to the fact that the spruce is unable to survive at extremely shadowed places. Thus it does not grow near the stems of the fir where only the least amount of light infiltrates the understory.

Compared to the spruce, a dense canopy suits the fir also well for the origin and preservation of dense fir regeneration (e.g. KADLUS 1969; GRASSI et al. 2004; HUNZIKER, BRANG 2005). Logically due to the above-mentioned facts, the fir seedlings would also find ideal conditions under old firs which let through a certain amount of diffused light. Contrary to these expectations they centralize only under the crowns of mature spruces. We can formulate a hypothesis that the spruce in this case regenerates under mature firs because it temporarily finds enough light and shelter there, and on the contrary, the fir in the first stages of growth is depending rather on the soil and humus conditions under the mature spruces than on light conditions.

Nevertheless, in the long run stable height growth in the climatically adverse mountain areas fir requires a certain minimal intensity of light (KORPEL, VINŠ 1966). The question is whether the fir will be able to grow henceforth under the closed spruce crowns or whether its development will stagnate.

CONCLUSIONS

The more will we know about relationships between the population dynamics of the spruce and the fir, the greater will be the chance to preserve the fir representation in local forests. The natural regeneration is present there, spatially the fir regeneration is in particular correlated with the mature spruce trees, the spruce regeneration then conversely with the mature firs. With the future development of the forest regeneration, this fir natural regeneration could enact with importance. The lead of the fir in regeneration is crucial for its preservation in successive stands and also for the preservation of the genetic resources of this species in the Orlické hory Mts. The structured natural regeneration is very important for the stability of the future mountain forests.

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Prostorová struktura přirozeného zmlazení jedle a smrku ve smíšených nestejnověkých lesích severovýchodních Čech

ABSTRAKT: Ve smíšeném lese v Chráněné krajinné oblasti Orlické hory (severovýchodní Čechy) byly založeny dvě trvalé výzkumné plochy (obě o velikosti 0,25 ha) pro analýzu přirozené obnovy smrku ztepilého (*Picea abies* [L.] Karst.) a jedle bělokoré (*Abies alba* Mill.). Byly lokalizovány a změřeny všechny semenáčky (výška 0,1–0,5 m), stromky (výška 0,5 m, $d_{1,3}$ 3 cm) a stromy ($d_{1,3} > 3$ cm). Analýza prostorové struktury a statistické vyhodnocení bylo provedeno pomocí Ripleyho *K*-funkce. Všechny vývojové (růstové) fáze smrku i jedle vykazovaly agregované (shlukovité) uspořádání, přičemž zmlazení jedle bylo pozitivně korelováno s mateřským porostem smrku, smrkové zmlazení bylo v pozitivním vztahu k dospělým jedlím. Na základě výsledků lze usuzovat, že jedle zde má příhodnější podmínky pro klíčení a stabilní růst v prvních fázích vývoje pod korunami smrků a naopak smrk pod mateřským porostem jedle.

Klíčová slova: *Abies alba*; *Picea abies*; přirozená obnova; prostorová struktura; chráněná krajinná oblast

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