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Thinning experiment in the spruce and beech mixed stands on the locality naturally dominated by beech – growth, litter-fall and humus

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ABSTRACT: In 1997, long-term thinning experiment Všeteč in Southern Bohemia was established in the young 19-year-old mixed beech and spruce stand. Three variants (0.10 ha each) were investigated: 1 – control unthinned plot (only salvage cut was done), 2 – plot with positive selection from above and 3 – plot with negative selection from below. The aim of this paper is to evaluate the first results from the eleven-year investigation (at the age of 19–29 years) focused on the effect of thinning on growth, species composition, litter-fall and humus in young mixed stands in this experiment. Thinning (both variants) resulted in decreased salvage cut (dead, broken and uprooted trees). Continual diminishing of spruce portion (started quickly after dry season in 2003 on control unthinned plot) was slow or soft on both thinned plots. Annual litter-fall in experimental young spruce and beech mixed stands at the age of 27–29 years varied from 4.6 to 5.5 thousand kg/ha and dry biomass of humus horizons L, F and H represented altogether approximately 91 and 128 thousand kg/ha on plots 3 and 1, respectively (plot 2 was omitted from this part of investigation).

Keywords: thinning; spruce; beech; mixed stands; litter-fall; humus horizons

Conversion of pure Norway spruce monocultures to the stands with close-to-nature species composition and structure is topic theme of silvicultural practice and research in Central Europe. The main reason for conversion is spruce decline caused by various factors as wind, snow, drought and anthropic impact (acid depositions, management mistakes, etc.). Disturbed stands are very predisposed to subsequent damage by biotic harmful factors (insects and fungi). This problem is urgent especially at lower and middle altitudes naturally dominated by broadleaved. On the other hand, total elimination of Norway spruce might cause important production losses in these localities. However, little is known on the economics of mixed forests up to now (Knoke, Wurm 2006). Consequently Borken and Beese (2005) notified that conversion of lowland spruce monocultures into mixed (spruce/beech) or beech forests may negatively influence the carbon budged of forest soils in the long-term horizon. On the other hand, e.g. Kennel (1965) and Schütz et al. (2006) emphasized the positive effect of a spruce/beech mixture on stability and consequently sustainability of forest stand production.

One of the most important reasons for admixture of broadleaved into spruce monocultures is supposed ameliorative function of these tree species (e.g. Nihlgård 1971, 1972; Bücking 1987; Rothe 1997; Bauer et al. 1997; Rothe, Binkley 2001; Sariyildiz, Anderson 2005; Meier et al. 2005; Berger et al. 2006; Mund, Schulze 2006). Additionally, mixed stands (spruce with beech) may perform a superior growth to pure stands with either decreasing or increasing stand density (Pretzsch 2003).

However, most of the studies of forest mixtures were done in relatively old stands (e.g. Štefančík, Štefančík 2001); although some results (Schütz et al. 2006) show that the forest functions can be improved efficiently by using mixture regulation during the first development stage. Studies from the young stands (thickets, before age of 30 years) are not so wide (e.g. Bonnevie-Svendsen, Gjems 1957; Lebret et al. 2001; Štefančík 2006). Therefore management decisions in silviculture should be supported by more information from the young mixed stands. Such results are still insufficient in the Czech forestry and, therefore, experimental base for forest tending research (Novák, Slodičák 2003) – historically oriented on pure stands – is being extended to stands with typical mixtures. Thinning series Všeteč is one of this new experiments focused on structure, growth and development of spruce and beech mixed stands with different thinning regimes. The objectives of this study is to evaluate the effect of thinning of mixed beech-spruce stand on growth and species composition, especially on the proportion of beech and spruce in mixture, as well as on forest soil.

MATERIAL AND METHODS

Thinning experiment Všeteč was established in young 19-year-old stands with mixture of European beech (*Fagus sylvatica* L.) and Norway spruce (*Picea abies* [L.] Karst.) in the Southern Bohemia in 1997. The co-ordinates (in the WGS-84 system) of the series are 49°13'48''N latitude and 14°16'25''E longitude. The experiment lies on 7% western slope at an elevation of 440 m on Cambisol of 4th beech forest vegetation zone (acid category – *Fagetum acidophilum* – *Avenella flexuosa*). Mean annual temperature is 8°C and mean sum of precipitation represents ca 500 mm.

The thinning experiment consists of the variant stands (0.1 ha) with different thinning regimes: 1 – regime without thinning, 2 – regime with thinning from above and 3 – regime with thinning from below. Each comparative plot is divided into ten blocks by 100 m^2. For statistical evaluation of measured data, comparative plots were divided into 3 partial plots consisted of 3 blocks. The most extreme block was omitted from evaluation. Diameters of stems in breast height of all individuals and the height on representative sets of trees (n = 30) are measured annually. In 1999 (age of 21 years), density of the stand on comparative plot 2 was decreased by thinning with positive selection from above and on comparative plot 3 by thinning with negative selection from below. Tending of other interspersed species (larch, oak, aspen, rowan, and birch) is conformed to thinning regimes of main tree species (beech and spruce).

Table 1. Basic data of thinning experiment Všeteč in the spruce and beech mixed stands at the age of 19–29 years (1997–2007). Stars (for plots 2 and 3) indicate significantly different values compared to control plot (*P < 0.10, **P < 0.05)

Variant	Tree species	1997 (19 years)			1999 (21 years) before thinning			1999 thinning			1999 after thinning			SC 1997–2007 (19–29 years)		2007 (29 years)			I 1997–2007 (19–29 years)				I–SC 1997–2007	
		N	G (m^2)	d (cm)	N	G (m^2)	d (cm)	N	G (m^2)	d (cm)	N	G (m^2)	d (cm)	N	G (m^2)	N	G (m^2)	d (cm)	G (m^2)	(%)	d (cm)	(%)	G (m^2)	(%)
1	beech	2,756	9.0	6.2	2,756	10.1	6.6	–	–	–	2,756	10.1	6.6	256	0.2	2,500	15.0	8.1	6.2	69	1.9	31	6.0	67
	spruce	2,144	12.1	8.6	2,122	13.4	9.0	–	–	–	2,122	13.4	9.0	1,133	3.4	1,011	12.6	12.8	3.9	32	4.2	49	0.5	4
2	beech	2,400	4.6*	4.3	2,400	5.3*	4.6	233	1.4	6.0	2,167	3.9**	4.4	34	0.1	2,133	7.1**	5.9	4.0	87	1.6	37	3.9	85
	spruce	2,856	12.3	7.2	2,789	14.6	7.9	545	3.1	7.4	2,244	11.5	7.2	433	0.6	1,878**	19.7*	11.0	11.1	90	3.8	53	10.5	85
3	beech	2,689	7.8	5.7	2,678	8.8	6.0	1,200	1.6	4.3	1,478*	7.2	7.6	0	0.0	1,478*	12.4	9.8	6.2	79	4.1	72	6.2	79
	spruce	2,656	14.5	7.9	2,589	16.2	8.4	1,011	3.2	6.4	1,578	13.0	9.9	423	2.2	1,222	16.2	12.4	7.1	49	4.5	57	4.9	34

N – number of trees/ha, G – basal area/ha, d – diameter at breast height, SC – salvage cutting, I – increment including SC, I–SC – increment without salvage cutting, 1 – control plot without thinning, 2 – comparative plot with thinning from above, 3 – comparative plot with thinning from below

In pursuance of the presented research, two variants were selected to investigate litter-fall and humus conditions: 1 (as unthinned) and 3 (as thinned by negative selection from below). In October 2003 (stand age of 25 years), forest-floor-humus horizons (L, F and H) were investigated quantitatively and qualitatively on identical comparative plots (1 and 3). In 2005, litter-fall collectors (five per variant) were installed in plots 1 and 3. The litter-fall samples were collected annually and annual litter-fall was calculated. All samples (humus horizons and litter-fall) were dried at 80°C, and weighed. Nutrient content was assessed from composite samples (after digestion by sulphuric acid and selenium). Total nitrogen (N) concentration was analyzed by Kjeldahl procedure and phosphorus (P) concentration was determined colorimetrically. An atomic absorption spectrophotometer was used to determine total potassium (K) concentration by flame emission, and calcium (Ca) and magnesium (Mg) by atomic absorption after addition of La. All statistical analyses were performed in statistical software package UNISTAT® (one-way ANOVA, Tukey and Dunnett tests). Unless otherwise indicated, test levels of $P < 0.05$ were used throughout.

RESULTS

Growth

Experiment Všeteč started in 1997 (age of 19 years). Initial number of trees (per hectare) varied from 2,756 on plot 1 to 2,400 on plot 2 for beech and from 2,856 on plot 2 to 2,144 on plot 1 for spruce (Table 1). Differences between variants were insignificant. The only exception was significantly (on the level of $P < 0.10$) lower value of basal area for beeches on plot 2 compared to control plot 1. In 1999 (age of 21 years), density of the stand on comparative plot 2 was decreased by thinning with positive selection from above:

- from 2,400 to 2,167 beeches (removed 10% *N* and 26% *G*),
- from 2,789 to 2,244 spruces (removed 20% *N* and 21% *G*).

In the same year, density of the stand on comparative plot 3 was decreased by thinning with negative selection from below:

- from 2,678 to 1,478 beeches (removed 45% *N* and 18% *G*),
- from 2,589 to 1,578 spruces (removed 39% *N* and 20% *G*).

Since the last revision at the age of 29 years (2007), the number of trees per hectare decreased:

- for beech
  - to 2,500 trees on control 1 (salvage cutting SC at the age of 19–29 years 256 individuals, i.e. about 9% of original status),
  - to 2,133 trees on plot 2 (SC at the age of 19 to 29 years 34 individuals. i.e. about 1% of original status),
  - to 1,478 trees on plot 3 (SC at the age of 19 to 29 years was not found),
- for spruce
  - to 1,011 trees on control 1 (SC an the age of 19–29 years 1,133 individuals, i.e. about 53% of original status),
  - to 1,878 trees on plot 2 (SC in the age of 19 to 29 years 433 individuals, i.e. about 15% of original status),
  - to 1,222 trees on plot 3 (SC in the age of 19 to 29 years 423 individuals, i.e. about 16% of original status).

On the observed experimental series Všeteč, the stand basal area *G*/ha before the first thinning (1999, age of 21 years) reached on control plot 1 values 23.5 m^2 (10.1 beech + 13.4 spruce) and on plot 3 – 25.0 m^2 (8.8 beech + 16.2 spruce). The lowest (significant for beech portion on the level $P < 0.10$) initial *G* was detected on plot 2 values 19.9 m^2 (5.3 beech + 14.6 spruce). The first experimental thinning decreased *G* on comparative plot 2 to 15.4 m^2 (3.9 beech + 11.5 spruce) and on comparative plot 3 to 20.2 m^2 (7.2 beech + 13.0 spruce).

After including *G* of all removed trees (i.e. including salvage cut), the basal area increment in the period of investigation (age of 19–29 years):

- was the highest on comparative plot 2 (15.1 m^2 – 4.0 beech and 11.1 spruce),
- then continued the increment on plot 3 (13.3 m^2 – 6.2 beech and 7.1 spruce),
- the lowest increment of *G* was formed on control plot 1 (10.1 m^2 – 6.2 beech and 3.9 spruce).

Furthermore, on control plot, 3.6 m^2 of *G* (36% of increment in the period of 1997–2007 and 17% of original status in 1997) had to be removed during the period of investigation as salvage cut (dry trees), whereas salvage cut on plot thinned by program 2 reached only 0.7 m^2 (5% of increment in the period of 1997–2007 and 4% of original status in 1997) and on plot thinned by program 3 salvage cut reached 2.2 m^2 (i.e. 17% of increment in the period of 1997–2007 and 10% of original status in 1997). In 2007, at the end of observation period significant ($P < 0.10$) lower number of beeches (according to values directly after thinning in 1999) was found on plot 3 compared to control plot. On the other hand, we detected significantly ($P < 0.05$) higher number of spruces on plot 2, where no significant differences have been observed compared to control. Similarly, significantly higher ($P < 0.10$) basal area of spruce portion and lower ($P < 0.05$) basal area of beech portion were found on plot 2 in comparison with control plot. However, as mentioned above, basal area of beeches was significantly lower on plot 2 compared to control plot during the all period of investigation.

Species composition

Initial tree species ratio for number of trees (beech/spruce) varied from 1.3 on plot 1 to 0.9 on plot 2. The most balanced ratio for number of trees (*N*) was on plot 3 – 1.0 (Fig. 1). In 1999, the first experimental thinning changed this ratio on comparative plot 2 to 1.0 and on comparative plot 3 to significant ($P < 0.10$) lower value 0.9 compared to control plot (1.3). Therefore, thinning from above (plot 2) was characterized by increase of beech portion and decrease of spruce portion (i.e. species ratio after thinning was more balanced). On the other hand, by thinning from below (plot 3), beech portion on *N* was decreased and spruce portion was increased.

Salvage cut was relatively low until 2003 (age of 25 years). Later the tree species ratio was strongly influenced by salvage cutting, which was concentrated on dead trees – mainly spruce individuals on all plots. Since 2003, we found significantly ($P < 0.05$) lower ratio (beech/spruce) on thinned plots 2 and 3 compared to control. To the period of the last revision at the age of 29 years (2007), the main tree species ratio for number of trees (beech/spruce) achieved:

- 2.4 on control plot 1 (beech portion increased about 85%),
- 1.2 on plot 2 (beech portion increased about 33%),
- 1.3 on plot 3 (beech portion increased about 30%).

At the beginning of the experiment, initial ratio (beech/spruce) for basal area (*G*) varied from 0.4 to 0.6 on thinned plots 2 and 3, respectively. The most balanced ratio for basal area was on control plot 1– 0.8 (Fig. 1). The experimental thinning (1999, age of 21 years) changed this ratio on comparative plot 2 to 0.3 (significant lower value compared to control). Practically no change was detected on comparative plot 3. Therefore, thinning from above (plot 2) was characterized by slight increase of spruce portion and decrease of beech portion. On the other hand, basal area ratio on plot 3 after thinning from below was unchanged.

In the period of last revision in 2007 (age of 29 years), the ratio of main tree species for basal area achieved:

- 1.3 on control plot 1 (beech portion increased about 63%),
- 0.4 on plot 2 (ratio practically unchanged),
- 0.8 on plot 3 (beech portion increased about 33%).

Litter fall

The total weight of annual litter-fall (as mean annual values at the period of 2005–2007) in studied young spruce and beech mixed stands at the age of 27–29 years varied from 4.6 to 5.5 thousand kg/ha

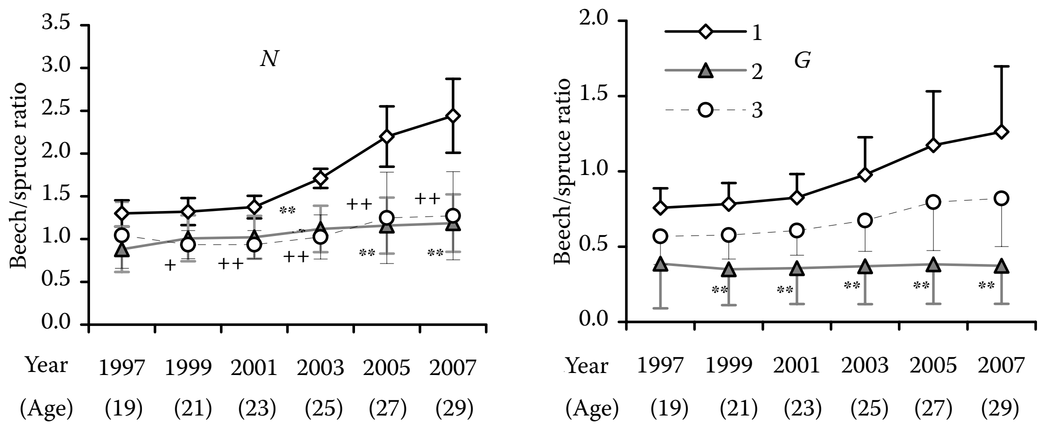

Fig. 1. Development of beech/spruce ratio (with standard deviation bars) for number of trees (*N* – left) and for basal area (*G* – right) on comparative plots (1 – control unthinned, 2 – thinning by positive selection from above, 3 – thinning by negative selection from below) of thinning experiment Všeteč in the spruce and beech mixed stands at the age of 19–29 years (1997–2007). Stars (for plot 2) and crosses (for plot 3) indicate significantly different values compared to control plot (* or + – $P < 0.10$, ** or ++ – $P < 0.05$)

Table 2. Total amount of dry mass and nutrients N, P, K, Ca and Mg (with standard deviation – S.D.) in humus horizons (L, F and H – sampled 2003 at the age of 25 years) and in annual litter-fall (sampled 2005–2007 at the age of 27–29 years) on comparative plots (1 – control unthinned and 3 – thinning by negative selection from below) of thinning experiment Všeteč in the spruce and beech mixed stands. Stars (for plot 3) indicate significantly different values compared to control plot (*$P < 0.10$, **$P < 0.05$)

	Index	Variant		Dry mass (1,000 kg/ha)	Nutrients N (kg/ha)	P	K	Ca	Mg
Humus horizons (2003)	L	1	mean	5.5	67.1	4.4	10.3	69.9	8.0
			S.D.	*1.66*	*21.66*	*1.31*	*3.01*	*27.91*	*2.11*
		3	mean	6.7	79.0	5.7	14.9	86.5	10.5
			S.D.	*1.94*	*29.72*	*1.94*	*5.33*	*40.46*	*3.62*
	F	1	mean	17.9	249.5	17.1	35.4	64.4	24.9
			S.D.	*3.51*	*74.19*	*5.13*	*5.95*	*12.81*	*6.11*
		3	mean	19.3	251.8	20.9	38.0	100.3**	28.9
			S.D.	*4.12*	*77.74*	*4.57*	*6.68*	*25.56*	*4.16*
	H	1	mean	104.6	760.7	75.1	264.3	18.7	137.8
			S.D.	*27.44*	*195.52*	*21.35*	*67.22*	*8.87*	*44.01*
		3	mean	65.0*	469.5**	42.8**	171.8	26.6	76.8
			S.D.	*20.68*	*98.27*	*9.58*	*84.54*	*12.58*	*46.10*
L+F+H		**1**	**Σ**	**128.0**	**1,077**	**97**	**310**	**153**	**171**
		3	**Σ**	**91.0**	**800**	**69**	**225**	**213**	**116**
Annual litter-fall*		1	mean	4.6	45.9	4.5	12.9	58.9	6.6
			S.D.	*0.68*	*6.80*	*0.66*	*1.91*	*8.72*	*0.97*
		3	mean	5.5	50.9	4.8	14.6	59.4	6.9
			S.D.	*0.91*	*8.45*	*0.80*	*2.42*	*9.85*	*1.14*

*Mean annual values (2005–2007)

on the variants 1 and 3, respectively (Table 2). Differences between variants were not significant. This amount of biomass represents about 45.9–50.9 kg of N, 4.5–4.8 kg of P, 12.9–14.6 kg of K, 58.9–59.4 kg of Ca and 6.6–6.9 kg of Mg annually per ha. We found higher amount of nutrients in all cases on thinned plot 3 probably due to higher amount of dry mass in annual litter-fall. But differences between variants were insignificant as well.

Humus horizons

In horizon L (Litter), amount of dry biomass varied from 5.5 to 6.7 thousand kg/ha (Table 2). Second horizon F (Fermentation) accumulated from 17.9 to 19.3 thousand kg/ha of dry biomass. The highest value was found in horizon H (humus) – from 65.0 to 104.6 thousand kg/ha. Altogether, horizons L, F and H accumulated approximately 91.0 and 128.0 thousand kg/ha of dry biomass on plots 3 and 1, respectively. On thinned plot 3, dry biomass content was higher (but without significant differences) in layers L and F. On the other hand we observed significantly higher value of dry biomass in horizon H on control plot 1 compared to plot 3.

Total nutrients values, which were determined in horizons L, F, H, corresponded generally with the results from dry mass investigation, i.e. higher amount of dry mass means higher amount of nutrients and *vice versa*, lower amount of dry mass means lower amount of nutrients (Table 2). These results were significant for nitrogen and phosphorus content in horizon H. On the other hand, in horizon F we found significantly higher amount of calcium on thinned plot 3 compared to control 1. Amount of Ca was also higher (but insignificant) on plot 3 in horizon H, although amount of dry mass was higher on control plot 1.

Altogether, horizons L, F and H accumulated per ha approximately 128 and 91 thousand kg of dry biomass on plots 1 and 3, respectively. It means that thinned variant 3 reached about 71% of values detected on control plot 1. This ratio was almost confirmed for total nutrient amount (nitrogen – 74% of control, phosphorus – 71%, potassium – 73% and magnesium – 68%). The only exception was total amount of calcium, which represented on variant 3 about 134% compared to control 1. Generally in all horizons (L+F+H), 800–1,100 kg of N, 70–100 kg of P, 230–300 kg of K, 150–210 kg of Ca and 120–170 kg of Mg was accumulated under investigated stands.

DISCUSSION AND CONCLUSION

Presented results are based on eleven-year investigation (three years before and eight years after the first thinning) and therefore, conclusions are concentrated on main indications from the thinning series. The most pronounced effect of thinning consisted in decreased amount of basal area, which had to be removed as salvage cut (dead trees). Similar investigation of the thinning effect on development of species composition, but in older stands, is described in studies of Štefančík (1990) and Klíma (1994). However, the grade and form of mixture was actively influenced only in the young stands (Krissl, Müller 1988; Schütz et al. 2006). In this context, results published by Pretzsch (2005) are interesting. From the analyses of long term experiments in Germany, it was concluded that whereas spruce reacts most positively on thinning under poor site conditions and with increment reduction on favourable sites, beech behaves oppositely.

From our study it was concluded that eight years after thinning beech portion increased on all three plots, but the most (and significantly higher) increase of beech portion was found on control unthinned plot 1 compared to both thinned plots 2 and 3. This result is in accordance with some Slovakian long-term studies (Štefančík, Štefančík 2003; Štefančík 2006) which were done in mixed spruce-fir-beech stands. In our experiment, rapid start of mortality of spruce have been found since 2003. Vegetation period was very hot and dry in this year generally in the Czech Republic (Pavlík et al. 2003) and also directly in part of Southern Bohemia (Fiala 2006), where our experiment is placed.

Similar results, but from older stands in Germany were published by Nikolova et al. (2009). They found that despite similar mean annual soil temperature, drought conditions of 2003 reduced total soil respiration in both tree species (spruce and beech), although total soil respiration was reduced more strongly underneath spruce than beech. Additionally, although water deficits persisted during 2003 underneath spruce and beech, periods of exhausted plant-available soil water (0–40 cm soil depth) were longer in spruce (75 vs. 45 days in beech). Higher probability of drought stress underneath spruce than beech was also concluded by Borken and Beese (2005). Another study from the mixture stand (Jost et al. 2004) showed that higher interception of spruce stand results in lower soil water recharge when compared to beech. Water deficiency as a main reason of continual decreasing of spruce portion in the mixture (with pine, larch and broadleaved) was also detected on site *Fageto-Quercetum mesotrophicum* in uplands (Jelínek, Kantor 2001).

Spruce has higher predisposition for drought stress especially in the mixture with beech. Vertical stratification of beech and spruce fine root systems was found in the mixed stand due to a shift in beech fine roots from upper to lower soil layers (Bolte, Villanueva 2006). On the other hand, spruces had the shallower fine root systems in mixed stand (with beech) compared to pure spruce stand (Schmid 2002; Schmid, Kazda 2002). Rötzer et al. (2009) found significant changes of above and belowground biomass of spruce and beech when temperature and radiation were increased additionally to decreased precipitation. The reduction in biomass increments of spruce was lower above than below ground, but, in contrast, the results for beech were the opposite (the belowground increments were reduced more).

We found that the total weight of annual litter-fall in experimental young spruce and beech mixed stands at the age of 27–29 years varied from 4.6 to 5.5 thousand kg/ha. Although, litter-fall may vary considerably from year to year, results from relatively long-term studies showed, that annual amount of litter-fall in young monocultures of these both species (spruce and beech) are comparable – approximately 3–5 thousands kg/ha/y (Novák, Slodičák 2004, 2006, 2008; Malek 2006).

The results of our investigation showed that first and second horizons L and F (litter + fermentation) accumulated per ha 23–26 thousand kg/ha of dry biomass. These values are comparable with the results from the 33-year-old spruce monoculture in the mountains condition – L+F 25–26 thousand kg/ha (Podrázský et al. 2006). On the other hand, under 50-year-old spruce stand in lower site at elevation 400 m half values (13–15 thousand kg/ha) were determined (Šarman 1982a). In the 85-year-old beech monoculture, even lower (8–9 thousand kg/ha) amount of dry biomass in horizon L+F was found (Šarman 1985). However, sampling in this study was done in July and annual litter-fall was partly not included. Another study (Podrázský, Viewegh 2005) presented amount of dry biomass in horizons L+F under beech thicket on values ca 14–18 thousand kg/ha. These horizons accumulated ca 22 thousand kg/ha under older beech stands within the same study.

Our results from nutrient content analysis showed considerable variability in the relatively homogeneous site conditions. Therefore, simple comparison with another studies are not so correct. However, this study showed better humus conditions (especially for nutrient content) under observed mixed spruce beech stands compared with the results from pure spruce monocultures (Novák, Slodičák 2004; Podrázský, Remeš 2005; Podrázský et al. 2006). It corresponds with the study, which was done in broadleaved and coniferous stands (Prescott et al. 2000; Albers et al. 2004; Borken, Beese 2005; Pernar et al. 2008). These results generally indicate that litter decay is faster in broadleaved or mixedwood forests. But this effect is not simply due to differences in leaf litter quality or to mixing of litters. On the other hand, Šarman (1982b) found in the mountain conditions (elevation 870–900 m) better physical and chemical characteristics of humus horizons under broadleaved mixed stand (ash + maple) compared with spruce monoculture, but with beech monoculture as well.

In our study non-uniform effect of thinning (by negative selection from below – plot 3) on observed humus characteristics was found. Significant differences between variants were observed only: (*i*) in horizon H for total amount of dry mass and total amount of N and P – significant higher values on control plot 1, (*ii*) in horizon F for total amount of Ca – significant higher values on thinned plot 3. Our conclusion partly corresponds with the results from the 50-year-old spruce (Šarman 1982a) and 74-year-old beech (Šarman 1985) monocultures. In these studies, control plots and plots with negative selection from below showed similar results. On the other hand, the best physical and chemical characteristics of humus and upper soil horizons were found under the stands thinned by positive selection from above (in both studies). Consequently, plot 2 with positive selection from above will be included in the litter-fall and humus forms investigation in our experiment.

We found higher content of Ca in holorganic horizons (L+F+H) under stand thinned by negative selection from below, although amount of dry mass and amount of other nutrients were lower on thinned plot. Significantly lower portion (by *N* and *G*) of beech (characterized by faster decomposition – see above) and higher portion of spruce is possible reason of this result.

From the results of eleven-year investigation of thinning experiment Všeteč in mixed beech and spruce stands, it can be concluded:

– The most pronounced effect of thinning consisted in decreased amount of basal area, which had to be removed as salvage cut (dead trees). On control plot, 3.6 m^2 of G (36% of periodic increment and 17% of original status) had to be removed during the period of investigation (age of 19–29 years) as salvage cut, whereas salvage cut on plot thinned by positive selection from above reached only 0.7 m^2 (5% of periodic increment and 4% of original status) and on plot thinned by negative selection from below salvage cut reached 2.2 m^2 (i.e. 17% of periodic increment and 10% of original status).
– Continual decrease of spruce portion (started quickly after dry season in 2003 on control unthinned plot) was slow or soft on both thinned plots.
– Annual litter-fall in experimental young spruce and beech mixed stands at the age of 27 to 29 years varied from 4.6 to 5.5 thousand kg/ha. This amount is comparable with values from young monocultures of these both species (spruce and beech).
– Altogether, horizons L, F and H accumulated per ha approximately 128 and 91 thousand kg of dry biomass on plots 1 and 3, respectively. Generally in all horizons (L+F+H), 800–1,100 kg of N, 70–100 kg of P, 230–300 kg of K, 150–210 kg of Ca and 120–170 kg of Mg was accumulated under investigated stands. These values showed better humus conditions (especially for nutrient content) under observed mixed spruce beech stands compared with the published results from pure spruce monocultures.

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Experiment s výchovou smíšených porostů smrku a buku na stanovišti s přirozenou dominancí buku – růst, opad a humus

ABSTRAKT: Experiment Všeteč s výchovou smíšených porostů buku a smrku byl založen v jižních Čechách v roce 1997 v mladém 19letém porostu ve třech variantách (každá o velikosti 0,10 ha): 1 – kontrolní plocha bez výchovy (pouze nahodilá těžba), 2 – plocha s pozitivním výběrem v úrovni a plocha 3 – plocha s negativním výběrem v podúrovni. Cílem práce bylo vyhodnotit první výsledky z 11letého sledování experimentu (věk porostů 19–29 let), zaměřené na vliv výchovy na růst, dřevinnou skladbu, opad a humus mladých smíšených porostů. Výchovné zásahy (obě varianty) vedly ke snížení objemu nahodilé těžby, tj. podílu suchých, zlomených a vyvrácených jedinců. Kontinuální snižování podílu smrku ve směsi (stupňující se rychle po suchém období v roce 2003 na kontrolní ploše bez výchovy) bylo na plochách s výchovou pomalejší nebo mírnější. Roční opad sledovaných smíšených porostů ve věku 27–29 let kolísal v rozmezí 4,6 až 5,5 t/ha a sušina humusových horizontů L, F a H reprezentovala dohromady na plochách 3 a 1 (plocha 2 nebyla v této části výzkumu sledována) 91 a 128 t/ha.

Klíčová slova: výchova; smrk; buk; směsi; opad; humusové horizonty

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