LITTER-FALL AS A SOURCE OF NUTRIENTS IN SCOTS PINE STANDS WITH DIFFERENT THINNING REGIME

LESNÍ OPAD JAKO ZDROJ ŽIVIN V POROSTECH BOROVICE LESNÍ S RŮZNÝM REŽIMEM VÝCHOVY

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ABSTRACT

The presented paper analyses the effect of thinning on amount of nutrients returned by litter-fall in differently thinned 8 – 19 - year-old Scots pine (Pinus sylvestris L.) stands as the principal condition of their production. The results showed that during the 12-year period of observation (1993 – 2004), 44.2 thousand kg.ha^{-1} of dry litter-fall down on control variant, whereas periodic litter-fall on thinned variant represented 36.4 thousand kg.ha^{-1}. Therefore, during the period of observation, lower amount of nutrients (per 1 ha about 63 kg of N, 9 kg of P, 9 kg of K, 34 kg of Ca and 2 kg of Mg) was stored under thinned stand compared to unthinned control stand.

Keywords: Scots pine, litter-fall, nutrients, thinning

ABSTRAKT

V příspěvku je analyzován možný efekt výchovy na množství a kvalitu opadu jako principiálního zdroje živin v borových porostech ve věku 8 – 19 let. Bylo zjištěno, že v průběhu 12letého období sledování (1993 – 2004) představoval opad na kontrole 44,2 tisíce kg.ha^{-1}, zatímco na srovnávací ploše s výchovou to bylo pouze 36,4 tisíce kg.ha^{-1}. Během sledování se tudíž pod porosty s výchovou dostalo opadem v přepočtu na 1 ha o ca 63 kg N, 9 kg P, 9 kg K, 34 kg Ca a 2 kg Mg méně než pod porost kontrolní bez výchovy.

Klíčová slova: borovice lesní, opad, živiny, výchova

INTRODUCTION

As thinning reduces the number of trees participated in nutrient return by litter--fall, this problem can be very important on the naturally nutrient-poor sites in lowlands, where commercial forests with Scots pine stands are cultivated. Other ecological effects of thinning consist in increased penetration of precipitation under the canopy (decreased interception) and in increased temperature of forest soil. Both these effects contribute to quicker decomposition of litter and consequently to quicker nutrient return.

The presented paper analyses the effect of thinning on amount of nutrients returned by litter-fall in differently thinned young Scots pine (*Pinus sylvestris* L.) stands as the principal condition of their production.

MATERIAL AND METHOD

The thinning experiment in Scots pine Týniště was established in 6-year-old pine stand originated by planting in regular row spacing with ca 10,000 trees.ha^{-1} in 1991. The series is located in the eastern part of Bohemia on sandy nutrient-poor soils on the 1st Forest Vegetation Zone (*Pineto-Quercetum),* on altitude of 260 m above sea level. The mean temperature in the period of investigation (1992 – 2004) was 8.0 °C and annual sum of precipitation was in the same time 643 mm. Temperature during the vegetation period (IV – IX) reached 14.6 °C and sum of precipitation 395 mm.

The series is created by two comparative plots (1C – control without thinning, 2T – thinned) with dimension 0.09 ha. Each comparative plot consists of three partial plots with an area of 300 m^2.

Diameters of stems in breast height of all individuals are measured annually by millimeter caliper.

Development and growth of experimental stands has been investigated on the number of trees (N), basal area (G), diameter of mean basal area stem (d) and mean diameter of the dominant trees (d_{100}, i.e. 100 thickest trees per hectare).

Observation of quantity and quality of litter-fall started in 1993 when the stand was 8 years old. Litter-fall was collected by five collectors with an area of 0.5 m^2 placed randomly on each variant (altogether 10 collectors). Collectors were emptied initially weekly (first two years), later monthly (till 1996) and then to 2004 quarterly. All samples from particular collectors were dried first on open air and afterward in laboratory at 70 °C and weighted. Nutrient content was assessed from composite samples from each comparative plot (after mineralization by H_2SO_4 and H_2O_2). Total Nitrogen (N) concentration was analyzed by Kjehldahl procedure and Phosphorus (P) concentration was determined colorimetrically. An atomic absorption spectrophotometer was used to determine total Potassium (K) concentration by flame emission, Calcium (Ca) and Magnesium (Mg) by atomic absorption after addition of La.

All statistical analyses were performed in statistical software package UNISTAT® (version 5.1). Test levels of $p \leq 0.05$ were used throughout. Data sets (N, G, d, amount of dry biomass, nutrient contents) were analyzed using one-way ANOVA. Where the main effects were significant or interactions were detected, multisample comparisons were undertaken using a Tukey test. Data set characterising dominant trees (d_{100}) was tested using by multisample nonparametric test (Kruskal-Wallis one-way ANOVA – methods: t-distribution, comparisons against a control group - Dunnett, Dunn).

Results

Growth

Experimental thinning started 1 year after the establishment of the experiment, in 1992, when the stand reached the age of 7 years. The first thinning was done by the combined selection, i.e. ca 25% of trees was removed schematically cutting down each fourth row and next ca 25% was removed by negative selection from below. From initial 10,344 we removed 4 600 individuals, which represented 47% of trees and 31% of basal area (tab. 1). The second thinning was done nine years later in

Tab. 1: Basic data of the experiment Tyniste with thinning of Scots pine stands (1C – control variant, 2T – thinned variant).
Základní údaje o experimentu Týniště s výchovou borových porostů (1C – kontrolní varianta, 2T – varianta s výchovnými zásahy).

Index			1991 Age of 6 years	SC	1992 Age of 7 years Before T	T	T%	After T	SC	2001 Age of 16 years Before T	T SC	T%	After T	SC	2004 19 years Before T	I 6 - 19 years	I minus SC
1C	N ha^{-1}	Mean	9 756	466	9 290	◊	◊	9 290	2 434	6856	534	8	6322	822	5500	◊	◊
		S.D.	776		831			831		527	212		509		581		
2T		Mean	10 344	456	9 889	4600	47	5289	533	4756	767	16	3989	200	3789	◊	◊
		S.D.	641		627	587		330		368	122		369		379		
1C	G m^2.ha^{-1}	Mean	3.8	0.1	6.4	◊	◊	6.4	1.3	30.7	0.7	2	30.0	1.4	32.7	32.4	29.6
		S.D.	0.4		0.6			0.6		2.2	0.4		2.3		2.6		
2T		Mean	3.8	0.1	6.3	2.0	31	4.4	0.5	28.0	4.7	17	23.4	0.3	27.3	31.1	30.2
		S.D.	0.4		0.6	0.4		0.3		1.3	1.0		1.1		1.4		
1C	d cm	Mean	2.2	1.6	3.0	◊	◊	3.0	◊	7.6	4.0	◊	7.8	◊	8.7	◊	◊
		S.D.	0.1		0.1			0.1		0.4	0.9		0.4		0.5		
2T		Mean	2.2	1.4	2.9	2.3	◊	3.3	◊	8.7	8.8	◊	8.7	◊	9.6	◊	◊
		S.D.	0.1		0.1	0.2		0.1		0.4	0.8		0.4		0.5		
1C	d_{100} cm	Mean	4.4	◊	5.5	◊	◊	◊	◊	14.3	◊	◊	◊	◊	15.8	◊	◊
		S.D.	0.3		0.2					0.9					1.0		
2T		Mean	4.0	◊	5.2	◊	◊	◊	◊	14.4	◊	◊	◊	◊	16.1	◊	◊
		S.D.	0.1		0.1					0.7					0.9		

Notes: N – Number of trees per hectare (*počet stromů na 1 ha*), G – Basal area (*výčetní základna*), d – Diameter of mean stem (*výčetní tloušťka středního kmene*), d_{100} – Mean diameter of 100 thickest trees per hectare (*střední tloušťka 100 nejsilnějších stromů na 1 ha*), S.D. – Standard deviation (*směrodatná odchylka*), T – Thinning (výchovný zásah), SC – Salvage cutting *(nahodilá těžba), I* – Increment (*přírůst*),
Mean – *průměr*, Age – *věk*, Before T – *před zásahem*, After T – *po zásahu*

2001, when the experimental stand reached the age of 16 years. By this treatment we decreased the density from 4 756 to 3 989 trees removing 16% of individuals and 17% of basal area positive selection from above.

At the beginning of investigation at the stand age of 6 years (1991), the basal area of both comparative stands was the same (3.8 $m^2.ha^{-1}$) as well as the diameter of mean basal area stem (2.2 cm). Some difference in favour of control stand (4 mm) was found in mean diameter of dominant trees (d_{100}), probably as a consequence of a 6% higher initial density of the stand 2T.

After the first experimental thinning at the age of 7 years (1992), number of trees on thinned plot 2T decreased to 57% and the basal area to 68% compared to control plot (1C). The diameter of mean stem increased as a result of shift after removing of smaller trees from 2.9 cm before treatment to 3.3 cm after treatment an become 3 mm higher than on control (3 cm).

In the next 9-year period, the number of trees decreased due to salvage cut on control by 26% from 9 290 to 6 856 individuals per hectare while on thinned plot 2 the salvage cut represented only 10% (decrease from 5 283 to 4 756 individuals per hectare). In this period, we found dramatic increase of basal area on both plots, from 6.4 $m^2.ha^{-1}$ to 30.7 $m^2.ha^{-1}$ (480%) on control plot 1 and from 4.4 $m^2.ha^{-1}$ to 28 $m^2.ha^{-1}$ (640%) on thinned plot 2. Similar effect we found in mean diameter which increased from 3.0 cm to 7.6 cm (by 4.6 cm) on control and from 3.3 cm to 8.7 cm (by 5.4 cm) on thinned plot 2. Slight effect of thinning was recognised even on dominant trees where initially significantly thinner trees on plot 2 become thicker (insignificantly).

The basal area of plot 2T reached 91% of control (1C) before the second thinning at the age of 16 years (2001). This treatment by positive selection from above again decreased the basal area to 78% of control. Next two years, basal area of control increased from 30.0 $m^2.ha^{-1}$ to 32.7 $m^2.ha^{-1}$ (by 2.7 $m^2.ha^{-1}$) while on thinned plot 2T from 23.4 $m^2.ha^{-1}$ to 27.3 $m^2.ha^{-1}$ (by 3.9 $m^2.ha^{-1}$). The mean diameter increased on plots 1C and 2T to 8.7 cm and 9.6 cm and slightly deepened the difference between the mean diameters of dominant trees in favour of thinned plot 2T.

Thought relatively better growth parameters of thinned stand 2T, periodic increment I 6 – 19 years (including salvage cut) was higher on unthinned control stand 1C (by 1.3 $m^2.ha^{-1}$).

Nutrient return

The total weight of litter-fall in studied young pine stands at the age of 8 – 19 years varied from 1 300 to 5 400 $kg.ha^{-1}$ (tab. 2). One year after the first thinning, the annual amount of litter-fall was practically the same (1 271 $kg.ha^{-1}$ on control 1C and 1 295 $kg.ha^{-1}$ on thinned variant 2T). The next several years the differences continually increased to statistically significant level at the age of 11 years (1996), i.e. four years after thinning, we measured on control 1C ca 4 500 $kg.ha^{-1}$ while in thinned stand 2T only ca 3 022 $kg.ha^{-1}$ of litter-fall. Then, during the next five years, the difference between the annual amounts of litter-fall decreased and before

Tab. 2: Annual amount of litter-fall (dry biomass in $kg.ha^{-1}$) on control unthinned stand (1C) and on thinned stand (2T) of Scots pine thinning experiment Týniště at the age of 8 – 19 years (1993 – 2004).
Roční množství opadu (sušina v $kg.ha^{-1}$) v kontrolním (1C) a vychovávaném (2T) porostu experimentu Týniště s výchovou borovice lesní ve věku 8 - 19 let (1993 – 2004).

Variant[1]	Age[2]	8		9		10		11		12		13	
	Year[3]	1993		1994		1995		1996		1997		1998	
1C	Mean[6]	1272	a	2058	a	2542	a	4500	a	4387	a	3897	a
Control[4]	S. D.[7]	134.4		594.9		789.0		252.3		429.5		715.2	
2 T	Mean	1295	a	1562	a	1685	a	3022	b	3778	a	3224	a
Thinned[5]	S. D.	118.5		341.8		335.6		232.7		854.8		852.0	

Variant	Age	14		15		16		17		18		19		8 - 19	
	Year	1999		2000		2001		2002		2003		2004		1993 - 2004	
1C	Mean	4405	a	3705	a	2972	a	5398	a	5020	a	4033	a	44 187	a
Control	S. D.	556.6		373.9		280.2		466.4		1096.3		618.1		3983.7	
2 T	Mean	3949	a	3268	a	2940	a	4526	b	3887	a	3293	a	36 429	b
Thinned	S. D.	678.4		543.9		990.7		638.5		1085.9		555.1		6197.3	

Different letters within a single column indicate differences based at $p \leq 0.05$, S.D. – Standard deviation
[1] Varianta, [2] Věk, [3] Rok, [4] Kontrolní bez zásahu, [5] Vychovávaný, [6] Průměr, [7] Směrodatná odchylka
Rozdílná písmena v jednotlivých sloupcích označují signifikantní rozdíly na hladině $p \leq 0,05$.

Tab. 3: Amount of nutrients returned in litter-fall on control unthinned stand (1C) and on thinned stand (2T) of Scots pine thinning experiment Týniště at the age of 8 – 19 years (1993 – 2004).
Množství živin navrácených ve formě opadu v kontrolním (1C) a vychovávaném (2T) porostu experimentu Týniště s výchovou borovice lesní ve věku 8 - 19 let (1993 – 2004).

Variant[1]		Nutrients[2] (kg.ha^{-1})									
		N		P		K		Ca		Mg	
1C – Control[3]	Mean[6]	339.9	a	37.5	a	51.6	a	166.6	a	17.4	a
	S. D.[7]	31.3		2.9		4.8		14.4		1.6	
2T – Thinned[4]	Mean	276.6	b	28.8	b	42.5	b	133.1	b	14.5	b
	S. D.	48.1		4.9		6.7		21.9		2.3	
Differences (Control minus Thinned)[5]	(kg.ha^{-1})	63.3		8.7		9.1		33.5		2.9	
	%	19		23		18		20		17	

Different letters within a single column indicate differences based at $p \leq 0.05$, S. D. – Standard deviation
[1] Varianta, [2] Živiny, [3] Kontrolní bez zásahu, [4] Vychovávaný, [5] Rozdíl (Kontrolní mínus vychovávaný), [6] Průměr, [7] Směrodatná odchylka
Rozdílná písmena v jednotlivých sloupcích označují signifikantní rozdíly na hladině $p \leq 0,05$.

the second thinning at the age of 16 years (2001), it was nearly the same on both comparative plots (2 972 kg.ha^{-1}on control 1C and 2 940 kg.ha^{-1} on thinned plot 2T). After the second thinning the annual amount of litter-fall differentiated again in favour of unthinned control.

Generally, during the 12-year period of observation, 44.2 thousand kg.ha^{-1} of dry biomass fall down on control variant, whereas periodic litter-fall on thinned variant represented 36.4 thousand kg.ha^{-1}. Therefore, we found that thinning on above mentioned schedule resulted in 7 758 kg.ha^{-1} lower amount of litter-fall biomass in 12-year period. This amount of biomass represents ca 63 kg of N (19%), 9 kg of P (23%), 9 kg of K (18%), 34 kg of Ca (20%) and 2 kg of Mg (17%) per 1 hectare (tab. 3).

Discussion and conclusions

Positive effect of thinning on stand environment as increased soil moisture and soil temperature with consequent better condition for litter decomposition has already been confirmed in Norway spruce (Novák, Slodičák 2004, Slodičák et al. 2005) stands as well as in Scots pine stands (Pausas 1997, Slodičák, Novák 1999).

Low ability of Scots pine, occupying mostly poor sites, to react on thinning by revitalization of increment is known from literature (e.g. Chroust 1973, 1977). One of the reasons of this phenomenon is probably the fact that growth of Scots pine on poor sites depends on nutrient return by litter-fall (Binkley 1986, Pedersen, Bille-Hansen 1999, Blanco et al. 2006). The study in young Scots pine stand in Eastern Bohemia confirmed a weak growth reaction of pines to thinning even in very young age of 7 years.

From the study it can be concluded that, during the 12-year period of observation, at the age of 8 – 19 years, two treatments (low thinning removing 31% G at the age of 7 years and high thinning removing 17% G at the age of 16 years) resulted in 7 758 kg.ha^{-1} lower amount of litter-fall biomass. This amount of biomass represents ca 63 kg of N (19%), 9 kg of P (23%), 9 kg of K (18%), 34 kg of Ca (20%) and 2 kg of Mg (17%) per 1 hectare.

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Souhrn

Porosty borovice lesní jsou v ČR často kultivovány na přirozeně chudých stanovištích nižších poloh. V příspěvku je analyzován možný efekt výchovy na množství a kvalitu opadu jako principiálního zdroje živin v mladých borových porostech rostoucích v těchto podmínkách. Výzkum probíhal na experimentu Týniště, který byl založen v roce 1991 v tehdy 6letém porostu borovice lesní vzniklém řadovou výsadbou o původní hustotě ca 10 000 ks.ha^{-1}. Série je lokalizována ve východních Čechách na chudých půdách SLT 1M v nadmořské výšce 260 m. V období sledování (1992 až 2004) zde byla zjištěna průměrná roční teplota 8,0 °C (14,6 °C za vegetační období IV – IX) a roční úhrn srážek 643 mm (395 mm za vegetační období IV – IX).

Experiment je složen ze dvou srovnávacích variant (1C – kontrolní bez zásahu, 2T – se zásahy, tab. 1). Každá varianta je dělena na 3 dílčí plochy o velikosti 300 m^2. Růst a vývoj porostů je hodnocen pomocí počtu stromů (N), výčetní základny (G), tloušťky středního kmene (d) a tloušťky dominantních stromů (d_{100} - 100 nejsilnějších jedinců na 1 ha).

Sledování kvantity a kvality opadu bylo zahájeno v roce 1993 v tehdy 8letém porostu pomocí opadoměrů o velikosti 0,5 m^2 rozmístěných rovnoměrně na obou variantách (po 5 ks). Vzorky byly odebírány týdně (první dva roky), později měsíčně (do roku 1996) a do roku 2004 čtvrtletně. Ve vzorcích byl laboratorně stanoven podíl sušiny a hlavních živin (N, P, K, Ca, Mg).

Roční množství opadu kolísalo ve sledovaném borovém porostu ve věku 8 až 19 let v rozmezí 1 300 až 5 400 $kg.ha^{-1}$ (tab. 2). Rok po prvním zásahu bylo zjištěno téměř shodné množství opadu na obou variantách pokusu (1 271 $kg.ha^{-1}$ na kontrole 1C a 1 295 $kg.ha^{-1}$ v porostu se zásahy 2T). V dalších letech se rozdíl v množství opadávané biomasy zvětšoval až k statisticky signifikantním hodnotám ve věku 11 let (1996), tj. čtyři roky po zásahu, kdy bylo zaznamenáno množství opadu na kontrolní variantě 1C ca 4 500 $kg.ha^{-1}$, zatímco na variantě 2T se zásahy pouze ca 3 022 $kg.ha^{-1}$. Později, během následujících 5 let se rozdíly mezi variantami opět snižovaly a před druhým zásahem ve věku 16 let (2001) bylo zjištěno téměř shodné množství ročně opadávané biomasy na obou variantách (2 972 $kg.ha^{-1}$ na kontrole 1C a 2 940 $kg.ha^{-1}$ na variantě 2T se zásahy). Po druhém zásahu se rozdíly v ročním množství opadávané biomasy opět zvýšily ve prospěch porostu bez zásahu (varianta 1C).

Během 12 let sledování opadlo na kontrolní variantě 1C celkem 44,2 $t.ha^{-1}$ sušiny, zatímco na variantě 2T se zásahy bylo zjištěno signifikantně nižší množství opadu (36,4 $t.ha^{-1}$). Výchovné zásahy v mladém borovém porostu tak vedly v období 8 až 19 let věku ke snížení množství opadávané sušiny o 7 758 kg na jeden hektar. Toto množství reprezentuje ca 63 kg dusíku (19 %), 9 kg fosforu (23 %), 9 kg draslíku (18 %), 34 kg vápníku (20 %) a 2 kg hořčíku (17 %) na jeden hektar (tab. 3).

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