Litter-fall as a source of nutrients in mountain Norway spruce stands in connection with thinning

Lesní opad jako zdroj živin v horských porostech smrku ve vztahu k výchovným zásahům

Jiří Novák, Marian Slodičák

Abstract

The objectives of the study were to find out possible effect of thinning on quantity and quality of litter-fall as a source of nutrients in young Norway spruce stands in the mountains, where spruce monocultures are typical for productive forests. Research was done on two thinning experimental series Polom and Vrchmezí in the Orlické hory Mts. (Eastern Czechia). The thinning experiments are based on classical comparative method of different thinning regimes (Control - regime without thinning and Thinned - regime with very heavy first thinning from below). From the presented results in young mountain spruce stands, effect of silvicultural measures (thinning) on quantity and quality of litter-fall is apparent but not uniform. When Control plot was relatively undamaged and unthinned stand was closed (first half of observation period on experiment Polom), litter-fall (and consequently amount of falling nutrients) was higher on this Control plot compared with Thinned plot. Later, when Control plot was more damaged (mainly by snow), amount of litter-fall was higher on slightly damaged Thinned plot (both experiments).

Keywords: Norway spruce, litter-fall, nutrients, thinning, mountains

Abstrakt

Cílem prezentované práce bylo zjistit možný efekt výchovy na množství a kvalitu opadu jako zdroje živin v mladých smrkových porostech horských oblastí, kde jsou smrkové monokultury pro hospodářské lesy typické. Výzkum probíhal na dvou experimentálních sériích Polom a Vrchmezí v Orlických horách. Experimenty jsou založeny na klasickém porovnávání porostů s různými výchovnými režimy („Kontrolní" – bez zásahu a „Vychovávaný" – režim s velmi silnými prvními zásahy negativním výběrem v podúrovni). Z prezentovaných výsledků vyplývá zřejmý, avšak ne vždy jednotný efekt výchovy na kvantitu a kvalitu opadu. Pokud byl kontrolní porost relativně nepoškozený a zapojený (první polovina období sledování na experimentu Polom), bylo v něm zaznamenáno vyšší množství opadávané biomasy (a spolu s tím i živin) ve srovnání s vychovávaným porostem. Později, když byl kontrolní porost bez výchovy více poškozen (především sněhem), vykazoval vyšší množství opadu méně poškozený porost s výchovou (na obou experimentech).

Klíčová slova: smrk ztepilý, opad, živiny, výchova, hory

Introduction

Litter-fall is one of the important parts of nutrient cycling in the forest ecosystems. Even-aged Norway spruce (*Picea abies* (L.) Karst.) monocultures, as a main type of productive forest in the mountains, usually have not understorey and needle litter-fall is substantial for nutrient cycle. Litter-fall is, in fact, main source of nutrients in non-fertilized forests. What is the role of forest manager in this process? Is it possible, that active management can influence quantity and quality of

litter? Effect of thinning, as a main silviculture measure, on quantity and quality of litter-fall in Norway spruce stands was detected (Šarman 1982, Wilhelmi 1988, Vesterdal et al. 1995, Podrázský 1996, Castin-Buchet, Andre 1998, Slodičák et al. 2005, etc.). But a lot of published works are evaluated on the basis of relative short-term research. In the forest stand, amount of litter-fall varied during the years sometimes dramatically and therefore, long-term studies focused on this problem are demanded.

The objectives of the study were to find out possible effect of thinning on quantity and quality of litter-fall in young Norway spruce stands in the mountains, where spruce monocultures are typical for productive forests.

Material and methods

The data were collected on two thinning experimental series Polom and Vrchmezí in the Orlické hory Mts. (Eastern Bohemia). The first series Polom was founded in 1980 in 15 years old stand of Norway spruce originated from planting of 4 years old containerised plants in irregular spacing with density of 3,500 – 4,000 trees per hectare in 1965. The stand lies on 5% north-west slope on elevation of 800 m above sea level on cambic leptosol of 6th Beech with Spruce forest vegetation zone (*Piceeto-Fagetum acidophilum – Carex pilulifera*), acid category.

The second series Vrchmezí was founded in 1986 in 18 years old Norway spruce thicket originated from planting in irregular spacing with the density of 4,000 trees per hectare. The experimental series is located on 3% western slope, in elevation of 860 m above sea level on leptic-entic podzol of the 6th Beech with Spruce forest vegetation zone (*Piceeto-Fagetum acidophilum – Avenella flexuosa*), acid category.

The thinning experiments are based on classical comparative method, i.e. on comparing the stands with different thinning regimes (Control - regime without thinning and Thinned - regime with very heavy first thinning from below). Litter-fall research started during the observation of these experiments and the development of stand characteristics were published earlier (Novák, Slodičák 2002, Slodičák, Novák 2004).

The investigation started firstly on experiment Polom in 1990 when 16 collectors with area of 0.5 m^2 each were installed and on experiment Vrchmezí in 2000 when 6 collectors (with same area) were installed. Half of them (8 collectors on Polom and 3 collectors on Vrchmezí) were placed on unthinned control stand (Control) and the second half on comparative stand with thinning regime based on the first very heavy thinning from below with negative selection done in the period when the top height of the stand achieved 5 m (Thinned). Litter traps were placed on both plots in transects with regular spacing (4 m) in order to get representative situation of canopy on comparative plot including incidental irregularities. Collectors were emptied initially weekly (first two years on experiment Polom), later monthly (till 1996) and then to 2005 quarterly. All samples from particular collectors were dried first on open air and afterward in laboratory to constant weight at 70 °C and weighted. Nutrient content was assessed from composite samples from

each comparative plot (after mineralization by mineral acids). 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, and 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). Unless otherwise indicated, test levels of $p \leq 0.05$ were used throughout. Data sets (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.

Presented study is oriented on results from litter-fall observation on experiment Polom in the 13-year period of 1992 – 2004 (age of 27 – 39 years) and on experiment Vrchmezí in the 4-year period of 2002 – 2005 (age of 33 – 36 years). Development of stands characteristics (N – number of trees, G – basal area) during the period of litter-fall study was partly different (fig. 1).

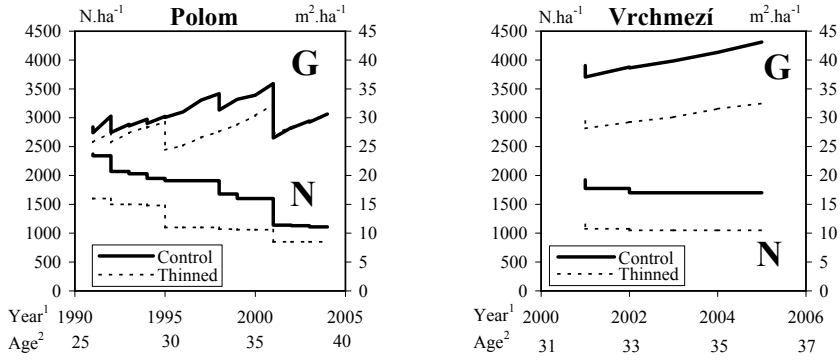

Fig. 1: Main stand characteristics (N – number of trees per hectare, G – basal area per hectare) on comparative plots (Control, Thinned) of experiments Polom (left) and Vrchmezí (right) in the period of litter-fall observation.
Hlavní porostní charakteristiky (N – počet stromů na hektar, G – výčetní kruhová základna na hektar) na srovnávacích plochách (Control – kontrolní bez zásahu, Thinned – s výchovnými zásahy) experimentů Polom (vlevo) a Vrchmezí (vpravo) v období sledování opadu ([1]Rok, [2]Věk).

In experiment Polom, the program on comparative plot with thinning started by opening the canopy with very heavy thinning. The number of trees decreased by negative selection from below from initial 2 950 to 1 630, i.e. by 45 %, which represented 39% of basal area. At the age of 27 years (when litter-fall observation started), thinned stand reached stocking 90% by basal area of Control plot (fig. 1). The treatment was repeated according the program at the age of 30 years (1995) again by negative selection from below removing of 26% N and 16% G, i.e. stocking of thinned stand decreased from 97% to 81%. Additionally, during the period of investigation (1992 – 2004), the experimental stands were three times damaged

by rime and snow (1992, 1998 and 2001, at the age of 27, 33 and 36 years respectively). At the end of observation (2004, age of 39 years), the stocking of thinned stand was 99% of Control.

In experiment Vrchmezí, comparative stand was thinned three times at the age of 15, 18 and 30 years (1984, 1987 and 1999), i.e. before start of litter-fall observation. At the age of 33 years (when litter-fall observation started on this experiment), thinned stand reached stocking 75% by basal area of control plot (fig. 1). During the period of investigation (2002 – 2005), the experimental stands were two times damaged by snow (2001 and 2002, at the age of 32 and 33 years). However, at the end of observation (2005, age of 36 years), the stocking of thinned stand was again 75% of Control.

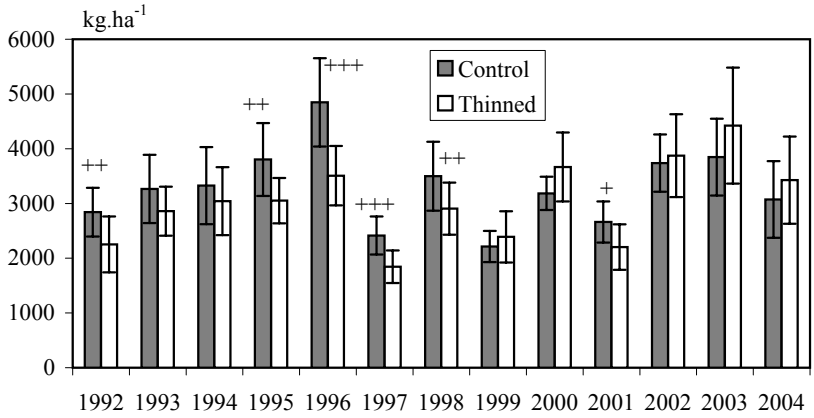

Fig. 2: Annual amount of litter-fall (kg.ha^{-1} with standard deviations) on comparative plots (Control, Thinned) of experiment Polom in the period 1992 – 2004 (age of 27 – 39 years). Significant differences: $p \leq 0.10$ (+), $p \leq 0.05$ (++), $p \leq 0.01$ (+++).
Roční množství opadu (kg.ha^{-1} se směrodatnými odchylkami) na srovnávacích plochách (Control – kontrolní bez zásahu, Thinned – s výchovnými zásahy) experimentu Polom v období 1992 – 2004 (věk 27 – 39 let). Průkazné rozdíly: $p \leq 0,10$ (+), $p \leq 0,05$ (++), $p \leq 0,01$ (+++).

Results

Total amount of dry biomass of litter-fall

Experiment Polom

Total weight of litter-fall varied from 1 800 to 4 800 kg.ha^{-1} (fig. 2) during the thirteen-year period of observation (age of the stand 27 – 39 years). At the beginning of observation on experiment Polom (in 1992), ca 2 800 kg of biomass per one hectare fell on plot Control (without thinning). Total amount of litter-fall increased in following years and in 1996 (age 31 years) the maximum (4 800 kg.ha^{-1}) was detected. In the next year, the amount of litter-fall on Control plot was noticeably decreasing. From 1998 to 2002, annual amount of litter-fall oscillated (in 1998,

2000, 2002 - increasing and in 1999, 2001 - decreasing) and the minimum (2 200 kg.ha^{-1}) was found in 1999. In 2003, second peak of biomass amount was detected (3 850 kg.ha^{-1}). In the last year of observation period, total amount of litter-fall decreased again on Control plot (3 070 kg.ha^{-1}).

On the Thinned plot (very heavy thinning from below), similar trend of litter-fall amount is apparent. However, from 1992 to 1998, annual amount of litter-fall on thinned plot was always lower than amount on control plot. These differences were statistically significant in 1992, 1995, 1996, 1997 and 1998. On the other hand, in 1999, 2000, 2002, 2003 and 2004 annual amount of litter-fall on Thinned plot was greater than on Control plot, but differences were found statistically insignificant. The only exception between last years is situation in 2001 which showed higher annual amount of litter-fall on control plot than on plot with thinning (significant difference on the level $p \leq 0.10$ only).

Totally, amount of litter-fall was during the period of observation (13-year period) about 8% higher on Control plot (42.7 thousand kg.ha^{-1}) compared with Thinned plot (39.4 thousand kg.ha^{-1}).

Experiment Vrchmezí

On the experiment Vrchmezí, total weight of litter-fall varied from 3 700 to 5 200 kg.ha^{-1} (fig. 3) during the four-year period of observation (age of the stand 33 – 36 years) on Control plot. The maximum was found in the first year of observation and in the following three years, similar amount of litter-fall was observed (from 3 700 to 3 800 kg.ha^{-1}).

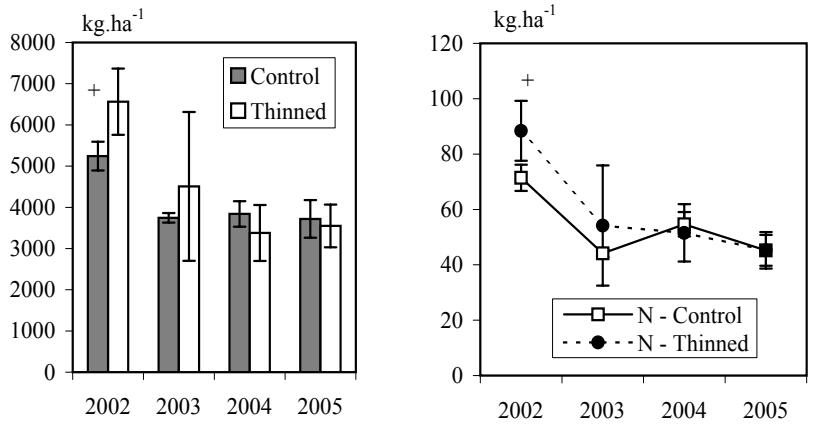

Fig. 3: Annual amount of litter-fall (left) and amount of Nitrogen (right) in litter-fall (kg.ha^{-1} with standard deviations) on comparative plots (Control, Thinned) of experiment Vrchmezí in the period 2002 – 2005 (age of 33 – 36 years). Significant differences: $p \leq 0.10$ (+).
Roční množství opadu (vlevo) a množství dusíku (vpravo) v opadu (kg.ha^{-1} se směrodatnými odchylkami) na srovnávacích plochách (Control – kontrolní bez zásahu, Thinned – s výchovnými zásahy) experimentu Vrchmezí v období 2002 – 2005 (věk 33 – 36 let). Průkazné rozdíly: p ≤ 0,10 (+).

On the Thinned plot (very heavy thinning from below), as well as on experiment Polom, similar tendency of litter-fall amount is apparent. However, at the beginning of observation (2002 - 2003), annual amount of litter-fall on thinned plot was always higher than amount on Control plot. On the other hand, last two years (2004 - 2005), falling biomass on Thinned plot was lower. Differences were statistically significant in 2002 only ($p \leq 0.10$).

Amount of litter-fall was during the period of observation (4-year period) about 9% higher on Thinned plot (18.0 thousands $kg.ha^{-1}$) compared with Control plot (16.5 thousands $kg.ha^{-1}$).

Nutrient content of litter-fall

During the period of observation, biomass from litter-fall contained different portion (in %) of nutrients in the individual years. From the observed nutrients on both experiments, Nitrogen has the highest portion in falling biomass (Polom - from 0.96 to 1.32%, Vrchmezí - from 1.18 to 1.53%). Phosphorus (Polom - from 0.07 to 0.20%, Vrchmezí – from 0.08 to 0.13%), Potassium (Polom - from 0.07 to 0.29%, Vrchmezí – from 0.09 to 0.22%) and Calcium (Polom - from 0.09 to 0.34%, Vrchmezí - from 0.06 to 0.22%) followed. The lowest percentage was found for Magnesium (both experiments - from 0.02 to 0.10%). Therefore, total amount of nutrients in biomass ($kg.ha^{-1}$) was under the influence of this oscillation in the individual years.

Experiment Polom

In accordance with lower amount of falling biomass on Thinned plot in the period 1992 – 1998, lower amount of observed nutrients was found (fig. 4 and 5). These differences were (similar results as amount of litter-fall) statistically significant and for N, P and K showed relatively stable trend. Partly different situation was observed for other nutrients (fig. 5). Differences between variants in amount of Ca in litter-fall have increasing tendency (mainly in the period of 1994 – 1996). On the other hand, amount of Mg was similar on both variants (without significant differences) in the period of 1992 – 1994.

In the following period (1999 – 2004), trends for amount of N, P and K were in accord with the results of litter-fall amount, i.e. without statistical significant differences between variants Control and Thinned. Only exception between last years is situation in 2001 which showed significantly higher annual amount of N, P and K on Control plot compared with Thinned plot. Contents of Ca and Mg in litter-fall were markedly influenced by aerial liming (dolomitic limestone), which was applied in 2000 and 2002 in the Orlické hory Mts. Besides the significantly higher values in 2001 on Control plot (similar results as amount of N, P and K), we found the same result in 2002 and 2004 for Ca, although amount of litter-fall was lower on Control plot in this period of observation. Effect of liming on amount of Mg (in dolomitic limestone as $HMgCO_3$) in litter-fall was more visible in 2002. But significant differences between variants (similarly as for Ca) were not found in following years.

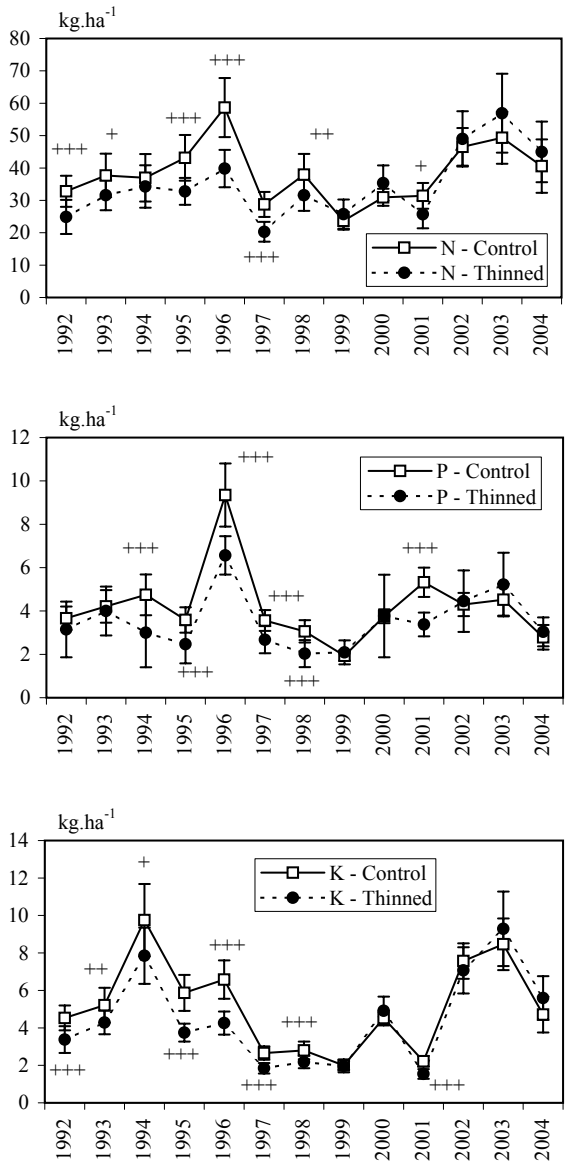

Fig. 4: Annual amount of Nitrogen (above), Phosphorus (middle) and Potassium (below) in litter-fall (kg.ha^{-1} with standard deviations) on comparative plots (Control, Thinned) of experiment Polom in the period 1992 – 2004 (age of 27 – 39 years). Significant differences: $p \leq 0.10$ (+), $p \leq 0.05$ (++), $p \leq 0.01$ (+++).
Množství dusíku (nahoře), fosforu (uprostřed) a draslíku (dole) v ročním opadu (kg.ha–1 se směrodatnými odchylkami) na srovnávacích plochách (Control – kontrolní bez zásahu, Thinned – s výchovnými zásahy) experimentu Polom v období 1992 – 2004 (věk 27 – 39 let). Průkazné rozdíly: p ≤ 0,10 (+), p ≤ 0,05 (++), p ≤ 0,01 (+++).

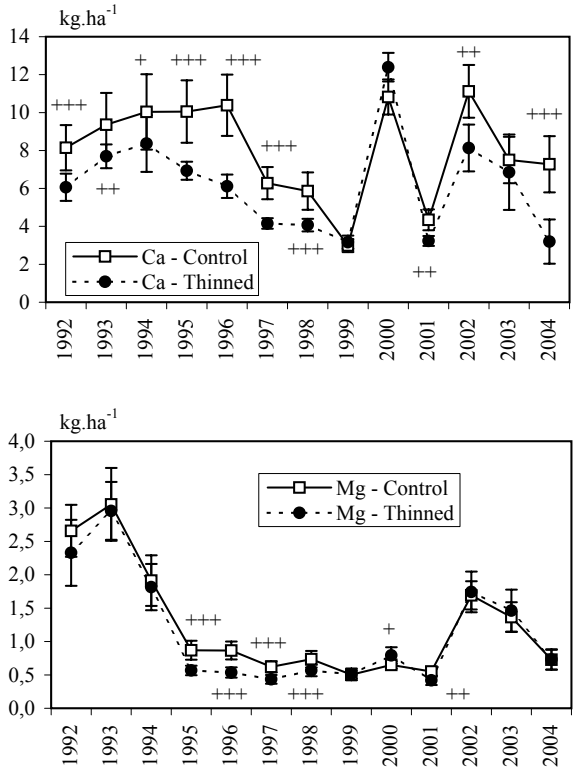

Fig. 5: Annual amount of Calcium (above) and Magnesium (below) in litter-fall (kg.ha^{-1} with standard deviations) on comparative plots (Control, Thinned) of experiment Polom in the period 1992 – 2004 (age of 27 – 39 years). Significant differences: $p \leq 0.10$ (+), $p \leq 0.05$ (++), $p \leq 0.01$ (+++).
Množství vápníku (nahoře) a hořčíku (dole) v ročním opadu (kg.ha^{-1} se směrodatnými odchylkami) na srovnávacích plochách (Control – kontrolní bez zásahu, Thinned – s výchovnými zásahy) experimentu Polom v období 1992 – 2004 (věk 27 – 39 let). Průkazné rozdíly: $p \leq 0,10$ (+), $p \leq 0,05$ (++), $p \leq 0,01$ (+++).

Totally, amount of nutrients was during the period of observation (13-year period) higher on Control plot compared with Thinned plot on experiment Polom:

- about 9% of N (Control - 498 kg.ha^{-1}, Thinned - 453 kg.ha^{-1}),
- about 16% of P (Control - 55 kg.ha^{-1}, Thinned - 46 kg.ha^{-1})
- about 13% of K (Control - 67 kg.ha^{-1}, Thinned - 58 kg.ha^{-1})
- about 13% of Ca (Control - 104 kg.ha^{-1}, Thinned - 80 kg.ha^{-1}),
- about 6% of Mg (Control - 16 kg.ha^{-1}, Thinned - 15 kg.ha^{-1}).

Experiment Vrchmezí

Generally, amount of nutrients in litter-fall showed the same trend as development of amount of falling biomass on this experiment (fig. 3 and 6). During the period of observation (2002 – 2005), amount of nutrients generally decreased and diffe-

rences between variants coming down as well. In accordance with the results from experiment Polom in this period (since 2002), amount of nutrients was higher on Thinned plot compared with Control plot. However, differences between variants were significant in the first year (2002) only. Contents of Ca and Mg in litter-fall were probably influenced by aerial liming in 2002 in the Eagle Mts. In contrast to results from the experiment Polom, on experiment Vrchmezí we found significant differences of amount of Mg (fig. 6). But effect of amount of litter-fall on total amount of Mg was probably higher compared with the experiment Polom.

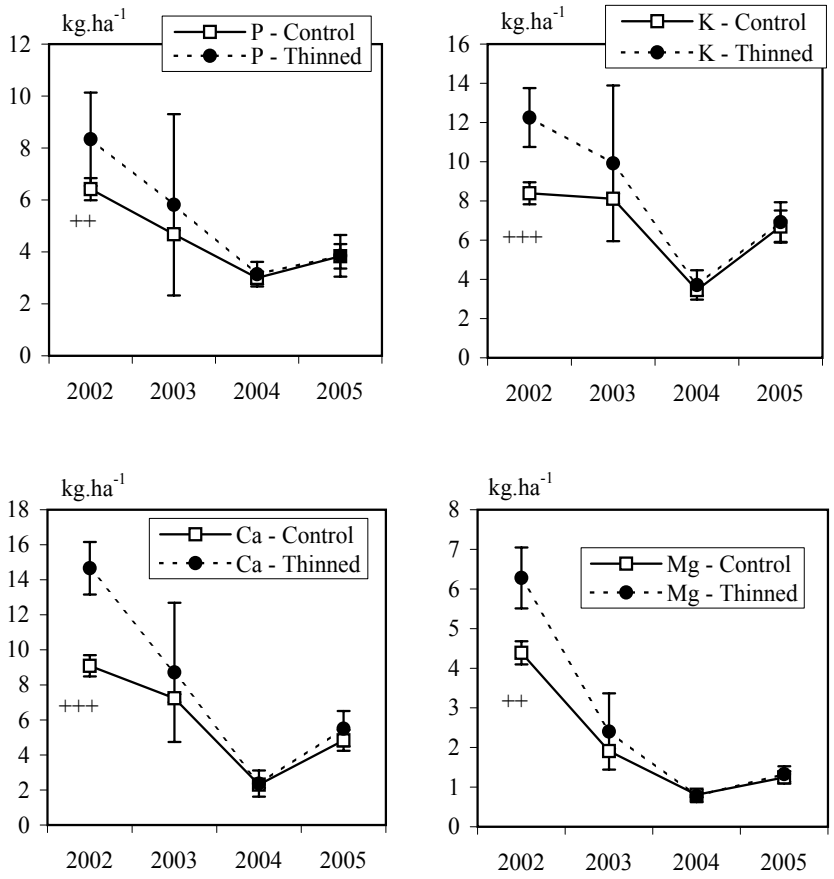

Fig. 6: Annual amount of Phosphorus (left above), Potassium (right above), Calcium (left below) and Magnesium (right below) in litter-fall (kg.ha^{-1} with standard deviations) on comparative plots (Control, Thinned) of experiment Vrchmezí in the period 2002 – 2005 (age of 33 – 36 years). Significant differences: $p \leq 0.10$ (+), $p \leq 0.05$ (++), $p \leq 0.01$ (+++).

Množství fosforu (vlevo nahoře), draslíku (vpravo nahoře), vápníku (vlevo dole) a hořčíku (vpravo dole) v ročním opadu (kg.ha–1 se směrodatnými odchylkami) na srovnávacích plochách (Control – kontrolní bez zásahu, Thinned – s výchovnými zásahy) experimentu Vrchmezí v období 2002 – 2005 (věk 33 – 36 let). Průkazné rozdíly: $p \leq 0.10$ (+), $p \leq 0.05$ (++), $p \leq 0.01$ (+++).

Totally, amount of nutrients was during the period of observation (4-year period) lower on Control plot compared with Thinned plot on experiment Vrchmezí:

- about 10% of N (Control - 215 kg.ha^{-1}, Thinned - 239 kg.ha^{-1}),
- about 14% of P (Control - 18 kg.ha^{-1}, Thinned - 21 kg.ha^{-1}),
- about 18% of K (Control - 27 kg.ha^{-1}, Thinned - 33 kg.ha^{-1}),
- about 26% of Ca (Control - 23 kg.ha^{-1}, Thinned - 31 kg.ha^{-1}),
- about 27% of Mg (Control - 8 kg.ha^{-1}, Thinned - 11 kg.ha^{-1}).

Discussion

The objectives of the study were to find out possible effect of thinning on quantity and quality of litter-fall in young Norway spruce stands in the mountains, where spruce monocultures are typical for productive forests. From the presented results in young mountain spruce stands, effect of silvicultural measures (thinning) on quantity and quality of litter-fall is apparent. Except of thinning, salvage cutting influenced amount of litter-fall (mainly in 2001) on both experiments. This damage (primarily by wet snow) was always higher on Control plots.

It is beyond doubt that annual amount of litter-fall is influenced by other factors and these factors can affect diversely on stands with different thinning regime. This is supported by previous study from the experiment Polom (Novák, Slodičák 2004), which concluded that the total annual weight of litter-fall was influenced by climatic factors (precipitation and temperature), by growth processes (basal area increment) and by health condition (defoliation). Correlation between amount of litter and increment of basal area in 21 years old Norway spruce stand detected also Holstener-Jørgensen et al. (1979). On the other hand, litter-fall in some European coniferous forests as dependent on climate was published by Berg, Meentemeyer (2001).

In observed experiments Polom and Vrchmezí, we found that annual amount of litter-fall has relatively wide variability. Therefore, long-term research is essential for litter-fall investigation. Maximum amount of litter-fall was detected at the age of 31 years (1996) on experiment Polom and at the age of 33 years (2002) on experiment Vrchmezí. These peaks are conducted in accordance with the end of culmination of green needle biomass growth. The period between the ages of 20 – 25 years is indicated by Chroust (1993) as maximum of growth of green needle biomass in young spruce stands.

In our study, annual amount of litter-fall on Control plots varied from 1 800 to 4 800 kg.ha^{-1} on experiment Polom and from 3 700 to 5 200 kg.ha^{-1} on experiment Vrchmezí. It corresponds with the results Bill-Hansen, Hansen (2001), who found that in forty years old Norway spruce stands the foliar litter-fall varied between the years from 1 100 to 5 700 kg.ha^{-1}. On the other hand, in similar spruce monocultures (age of 39 years) higher maximum values of litter-fall amount (up to 8 700 kg.ha^{-1}) was detected (Slodičák et al. 2005). But these results were observed on the high productivity sites on former agricultural land.

Annual return of N by litter-fall represented per one hectare 20.3 – 58.7 kg of N on experiment Polom and 44.1 - 88.4 kg of on experiment Vrchmezí. It partly cor-

responds with the data published by Klimo, Kulhavý (1994) – 43 kg $N.ha^{-1}.y^{-1}$ and Gundersen, Rasmussen (1995) - 37 kg $N.ha^{-1}.y^{-1}$. Higher maximum values on our experiments are probably influenced by very high Nitrogen deposition in the Eagle Mts., which was observed in last decade (Hruška et al. 2000).

In the period 2000 – 2002, the total amount of Ca in litter-fall markedly varied and increased from 3 to 12 $kg.ha^{-1}$ (300%) during one year, while total amount of litter-fall increased 40% only. Ca content was partly influenced by aerial liming (dolomitic limestone), which was applied in 2000 and 2002 in the Eagle Mts. However, possible influence of liming on total amount of Mg in litter-fall (in dolomitic limestone as MgO) was found in 2002 only. This continually low content of Mg in litter-fall may signalise its gradual exhaustion from the cycle of nutrients in investigated forest ecosystem.

Conclusion

- On experiment Polom, total weight of litter-fall varied from 1 800 to 4 800 $kg.ha^{-1}$ during the thirteen-year period of observation (age of the stand 27 – 39 years). Amount of litter-fall was higher on Control plot compared with Thinned plot in the first half of observation period. On the other hand, the second half of observation period was characterized by higher amount of litter-fall on Thinned plot. In total, amount of litter-fall was during the period of observation (13-year period) about 8% higher on Control plot (42.7 thousand $kg.ha^{-1}$) compared with Thinned plot (39.4 thousand $kg.ha^{-1}$).
- Consequently, amount of nutrients was during the period of observation (13-year period) higher on Control plot compared with Thinned plot on experiment Polom: 9% of N (Control - 498 $kg.ha^{-1}$, Thinned - 453 $kg.ha^{-1}$), 16% of P (Control - 55 $kg.ha^{-1}$, Thinned - 46 $kg.ha^{-1}$), 13% of K (Control - 67 $kg.ha^{-1}$, Thinned - 58 $kg.ha^{-1}$), 13% of Ca (Control - 104 $kg.ha^{-1}$, Thinned - 80 $kg.ha^{-1}$), 6% of Mg (Control - 16 $kg.ha^{-1}$, Thinned - 15 $kg.ha^{-1}$).
- On the experiment Vrchmezí, total weight of litter-fall varied from 3 700 to 6 500 $kg.ha^{-1}$ during the four-year period of observation (age of the stand 33 – 36 years). In accordance with the results from the second half of observation period on experiment Polom, amount of litter-fall was during the all period of observation (4-year period) about 9% higher on Thinned plot (18.0 thousands $kg.ha^{-1}$) compared with Control plot (16.5 thousands $kg.ha^{-1}$).
- Consequently, amount of nutrients was during the period of observation (4-year period) lower on Control plot compared with Thinned plot on experiment Vrchmezí: 10% of N (Control - 215 $kg.ha^{-1}$, Thinned 239 $kg.ha^{-1}$), 14% of P (Control - 18 $kg.ha^{-1}$, Thinned 21 $kg.ha^{-1}$), 18% of K (Control - 27 $kg.ha^{-1}$, Thinned 33 $kg.ha^{-1}$), 26% of Ca (Control - 23 $kg.ha^{-1}$, Thinned 31 $kg.ha^{-1}$), 27% of Mg (Control - 8 $kg.ha^{-1}$, Thinned 11 $kg.ha^{-1}$).

From the presented results in young mountain spruce stands, effect of silvicultural measures (thinning) on quantity and quality of litter-fall is apparent but not uniform. When Control plot was relatively undamaged and unthinned stand was clo-

sed (first half of observation period on experiment Polom), litter-fall was higher on this Control plot compared with Thinned plot. Later, when Control plot was more damaged (mainly by snow), amount of litter-fall was higher on slightly damaged Thinned plot (both experiments). It was mentioned, that the results from long--term observation are the bases for litter-fall analyses in forest stands. Presented work is one contribution to mosaic of this problem.

References

Berg, B., Meentemeyer, V.: Litter-fall in some European coniferous forests as dependent on climate: a synthesis. Can. J. For. Res. 31, 2001, pp. 292 – 301.

Bille-Hansen, J., Hansen, K.: Relation between defoliation and litterfall in some Danish *Picea abies* and *Fagus sylvatica* stands. Scand. J. For. Res. 16, 2001, pp. 127 – 137.

Castin-Buchet, V., Andre, P.: The influence of intensive thinning on earthworm populations in the litters of Norway spruce and Douglas fir. Pedobiologia, 42, 1998, pp. 63 – 70.

Gundersen, P., Rasmussen, L.: Nitrogen mobility in a nitrogen limited forest at Klosterhede, Denmark, examined by NH_4NO_3 addition. Forest Ecology and Management, 77, 1995, pp. 75 – 88.

Hruška, J., Fottová, D., Šach, F., Černohous, V.: Změny chemismu půd a povrchových vod v důsledku dlouhodobé acidifikace Orlických hor. In: Lesnické hospodaření v imisní oblasti Orlických hor. Sborník referátů z celostátního semináře. Opočno, 31. 8. - 1. 9. 2000. Ed. M. Slodičák. Opočno, VÚLHM - Výzkumná stanice 2000, pp. 13 - 24.

Holstener-Jørgensen, H., Veracion, V. P., Yao, C. E.: Litter-fall studies in an irrigation trial in Norway spruce. Forstl. Forsøgsv. Danm. 36, 1979, pp. 414 – 432.

Chroust, L.: Biomass of needles in spruce (*Picea abies*) and net photosynthesis rates. Lesnictví – Forestry, 39, 1993, pp. 265 – 272.

Klimo, E., Kulhavý, J.: Nitrogen cycling in Norway spruce stands after clear cutting. Lesnictví – Forestry, 40, 1994, pp. 307 – 312.

Novák, J., Slodičák, M.: Dlouhodobý efekt silných podúrovňových zásahů ve smrkových porostech v Orlických horách. In: Současné trendy v pěstování lesů. Výroční mezinárodní seminář pracovišť zabývajících se pěstováním lesů v České a Slovenské republice. Kostelec nad Černými lesy, 16. a 17. 9. 2002. Ed. J. Karas a V. Podrázský. Praha, Česká zemědělská univerzita 2002, pp. 149 – 157.

Novák, J., Slodičák, M.: Structure and accumulation of litterfall under Norway spruce stands in connection with thinnings. Journal of Forest Science, 50, 2004, pp. 101 – 108.

Podrázský, V.: Silvicultural effects on soil organic matter: preliminary results. Lesnictvi – Forestry, 42, 1996, pp. 237 – 241.

Slodičák, M., Novák, J.: Norway spruce thinning experiment Polom (Eastern Bohemia) after 22 years of observation. Journal of Forest Science, 50, 2004, pp. 1 – 10.

Slodičák, M., Novák, J., Skovsgaard, J. P.: Wood production, litter-fall and humus

accumulation in a Czech thinning experiment in Norway spruce (*Picea abies* (L.) Karst.). Forest Ecology and Management, 209, 2005, pp. 157 – 166.

Šarman, J.: The influence of thinning on the surface humus in spruce stand. Lesnictví – Forestry, 28, 1982, pp. 31 – 42.

Vesterdal, L., Dalsgaard, M., Felby, C., Raulund-Rasmussen, K., Jorgensen, B. B.: Effects of thinning and soil properties on accumulation of carbon, nitrogen and phosphorus in the forest floor of Norway spruce stands. Forest Ecology and Management, 77, 1995, pp. 1 – 10.

Wilhelmi, V.: Düngung und Durchforstung als kombinierte Waldsanierungsmaßnahme. Allgemeine Forstzeitschrift, 159, 1988, pp. 844 – 846.

Souhrn

Cílem prezentované práce bylo zjistit možný efekt výchovy na množství a kvalitu opadu v mladých smrkových porostech horských oblastí, kde jsou smrkové monokultury pro hospodářské lesy typické. Výzkum probíhal na dvou experimentálních sériích Polom a Vrchmezí v Orlických horách (obr. 1). Experimenty jsou založeny na klasickém porovnávání porostů s různými výchovnými režimy („Kontrolní" – bez zásahu a „Vychovávaný" – režim s velmi silnými prvními zásahy negativním výběrem v podúrovni).

Na experimentu Polom kolísalo množství opadávané nekromasy v rozmezí 1 800 až 4 800 kg.ha^{-1} během 13leté periody sledování (věk 27 – 39 let, obr. 2). Množství opadu bylo vyšší na kontrolní variantě v první polovině sledovaného období. Druhá polovina sledovaného období byla naopak charakterizována vyšším množstvím opadu na variantě s výchovou. Celkově bylo množství opadu za 13 let sledování o ca 8 % vyšší na kontrolní ploše (42,7 t.ha^{-1}) ve srovnání s vychovávanou variantou (39,4 t.ha^{-1}).

V souvislosti s tím bylo zjištěno během 13 let sledování vyšší množství živin v opadu na kontrolní variantě ve srovnání s vychovávanou variantou experimentu Polom: ca o 9 % N, 16 % P, 13 % K, 13 % Ca a 6 % Mg (obr. 4 a 5).

Na experimentu Vrchmezí kolísalo množství opadávané nekromasy v rozmezí 3 700 až 6 500 kg.ha^{-1} během 4leté periody sledování (věk 33 – 36 let, obr. 3). Podobně jako u výsledků z druhé poloviny sledovaného období na experimentu Polom, také zde bylo zjištěno vyšší množství opadávané biomasy na variantě s výchovou. Ve srovnání s kontrolní variantou (16,5 t.ha^{-1}) byl za 4 roky sledování zjištěn vyšší opad biomasy ve vychovávaném porostu o ca 9 % (18,0 t.ha^{-1}).

Na kontrolní variantě experimentu Vrchmezí bylo za 4 roky sledování také zjištěno vyšší množství živin v opadu: ca o 10 % N, 14 % P, 18 % K, 26 % Ca, 27 % Mg (obr. 3 a 6).

Z prezentovaných výsledků vyplývá zřejmý, avšak ne vždy jednotný efekt výchovy na kvantitu a kvalitu opadu. Pokud byl kontrolní porost relativně nepoškozený a zapojený (první polovina období sledování na experimentu Polom), bylo v něm zaznamenáno vyšší množství opadávané nekromasy (a spolu s tím i živin) ve srovnání s vychovávaným porostem. Později, když byl kontrolní porost bez vý-

chovy více poškozen (především sněhem), vykazoval vyšší množství opadu méně poškozený porost s výchovou (v obou experimentech).

Acknowledgments

This study was supported by the long-term Research Intention of the Czech Ministry of Agriculture (MZE-0002070201).

Address of authors:

Ing. Jiří Novák, Ph.D.
Doc. RNDr. Marian Slodičák, CSc.
FGMRI, Research Station at Opočno
CZ - 517 73 Opočno
novak@vulhmop.cz, slodicak@vulhmop.cz