

Litter-fall and humus accumulation in thinning experiment Kristianov in the Jizerske Hory Mts.

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ABSTRACT

Litter-fall and its accumulation and decomposition in the forest floor are essential parts of the nutrient cycle in Norway spruce [*Picea abies* (L.) Karst.] stands. The paper is focused on the results from the experiment Kristianov in the Jizerské hory Mts. established in 1986 in the 22-year-old Norway spruce thicket located in the Jizerske hory Mts. (NE part of Czechia). Investigation on the nutrient cycle with respect of thinning was initiated in 2001, when the experimental stands were 37-year-old. Research was focused on two main aspects: humus formation and litter-fall. The thinning regime based on the first very heavy thinning (reduction at the age of 22 years from initially 3 300 to 1100 trees per hectare by negative selection from below) resulted in a significantly lower amount of dry mass in humus horizons L and F under the thinned stand when compared to the control stand 17 years after thinning. Lower humus accumulation under the thinned stand was confirmed by a significantly lower amount of the annual litter-fall in the thinned stand compared to control in the period of 2003–2006, i.e. 17–20 years after thinning (39–42-year-old). These significant differences between variants were confirmed for N and P.

KEY WORDS

Picea abies, thinning, litter-fall, humus, nutrient cycle

INTRODUCTION

Thinning is one of the most important silvicultural measures with respect to quality, quantity and safety of future wood production. Continually, growth conditions of retained trees are changed after thinning. Higher values of sunlight, temperature and precipitation were found under thinned stands compared to untreated ones (Chroust 1977). It is supposed that this change can be important for the nutrient cycle. Litter-fall and its accumulation and decomposition in the forest floor is an essential part of the nutrient cycle in Norway spruce

[*Picea abies* (L.) Karst.] stands, especially those in the mountains, where soils are usually shallow and poor. Some results about litter-fall and humus accumulation under spruce stands were published (Šarman 1982a,b, Vesterdal et al. 1995, Castin-Buchet and Andre 1998, Jonard et al. 2008, Nilsen and Strand 2008), but primarily concerning older stands (50 years and older of age). Knowledge on young stands is not as extensive (Bille-Hansen and Hansen 2001, Podrazsky et al. 2006), and especially the effect of early thinning on litter-fall and humus accumulation has not been sufficiently described.

In the Czech Republic, complex research focused on the above aspects was initiated by the Forestry and Game Management Research Institute (Research Station at Opocno) in the 80–90ies of the last century. Therefore, relatively long-term results are now available from the stands of the main tree species. The present paper is focused on the results from thinning experiment Kristianov in the Jizerske hory Mts., where long-term effects of thinning on humus accumulation and litter-fall under young spruce stands were investigated.

MATERIAL AND METHODS

The experiment Kristianov was established in the 22-year-old Norway spruce thicket in the Jizerske hory Mts. (NE part of Czechia, coordinates in the World Geodetic System 1984: 50°49'01", 15°11'20") in 1986. The stand lies on the elevation of 860 m in the 7th zone of spruce with beech vegetation (*Fageto-Piceetum acidophilum* – *Calamagrostis villosa* according to Viewegh et al. 2003). Mean annual temperature is 5.7°C and the mean sum of precipitation is approximately 950 mm. The stand originated from artificial regeneration. The initial density was around 4500 trees per hectare. The

experimental series consists of three comparative plots with the dimension of which is 40 m × 25 m each. For this study two plots were used: plot 1 (control plot without thinning) and plot 3 (thinned plot). The thinning regime is based on the first very heavy thinning – reduction at the age of 22 years from initial 3300 to 1100 trees per hectare by negative selection from below (Fig. 1). From 1986 to 2005, the number of trees on the thinned plot decreased to 990 trees per hectare due to natural mortality. Second thinning was performed in 2005, when the age of the stand was 41 years and the number of trees was decreased to 760 trees per hectare. For litter-fall and humus layer development during the period of observation, important was the fact that the significantly lower basal area was found in the thinned treatment when compared to control.

Investigation on the nutrient cycle started in 2001, when experimental stands were 37 years old. Research was focused on two main aspects: humus formation and litter-fall. Humus formation was investigated on holorganic horizons samples (L, F and H) quantitatively in August 2001 (15 years after thinning) and quantitatively and qualitatively in May 2003 (17 years after thinning). A steel frame 25 cm × 25 cm was used for sampling on three replications on each plot. In order to determine the

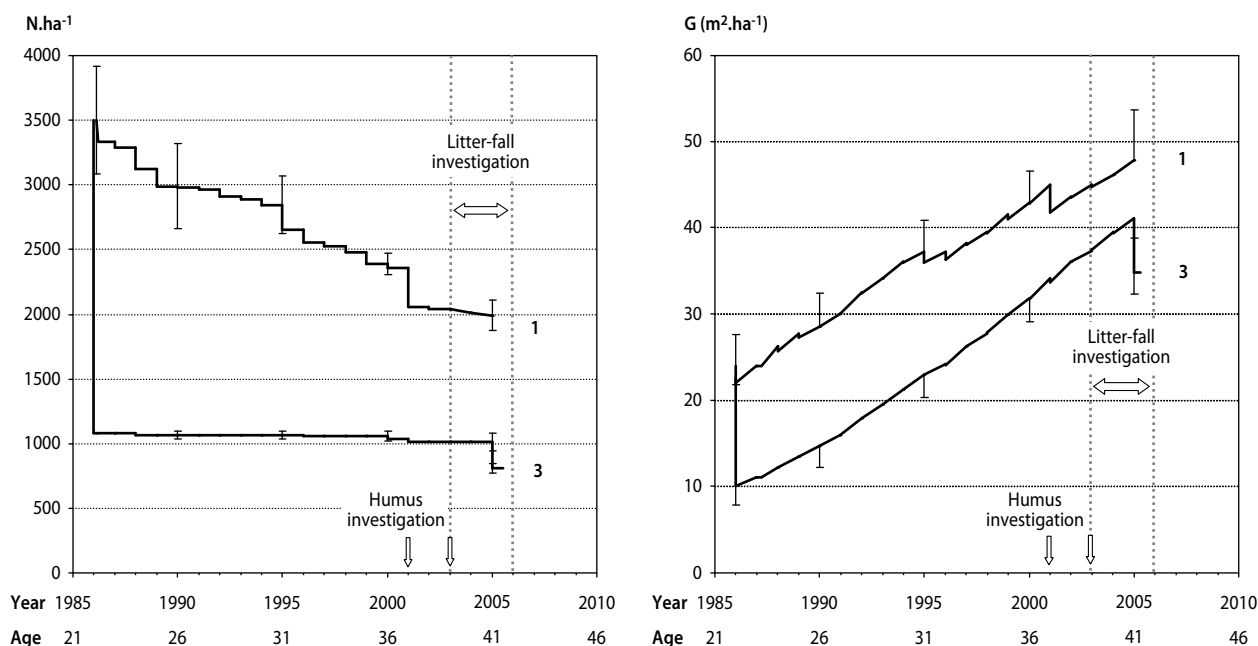


Fig. 1. Number of trees (N) and basal area (G) in thinning experiment Kristianov in 22–41-year-old stands (1 – control plot without thinning, 3 – thinned plot)

time needed for humus horizons formation, investigation of litter-fall was initiated. Litter-fall was measured by eight litter collectors, which were installed within the control plot (1) as well the plot with thinning regime (3) in 2003, i.e. 17 years after thinning. Litter-fall was collected once a year, and for this study data from September 2003 (age of 39 years) to October 2006 (age of 42 years) were assessed.

All samples (humus horizons and litter-fall) were dried first in open air and afterward in laboratory at 80°C and then weighted. Nutrient content was assessed after mineralization by mineral acids (for humus horizons for each sample and for litter-fall from composite samples from each year). Total nitrogen (N) concentration was analysed with the use of the Kjeldahl 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) was determined by atomic absorption after addition of La. The software UNISTAT 6.5 was used for statistical analyses. The data were tested with the parametric T-test and (only in the case of litter-fall) with the non-parametric Mann-Whitney test (Zar 2009).

RESULTS

Humus horizons

The results of the study showed that dry biomass accumulated in the horizon L (litter) on the control plot varied from 9.8 to 11.5 thousand kg per hectare and on the thinned plot it was from 7.1 to 8.5 thousand kg per hectare (Tab. 1). In the second horizon F (fermentation), there was found dry biomass from 54.8 to 56.6 thousand kg per hectare in the control stand and from 28.5 to 44.2 thousand kg of dry biomass per hectare in the thinned

stand. Most of dry biomass (about 178–199 thousand kg per hectare on the control stand and 207–223 thousand kg per hectare on the thinned plot) was accumulated in the horizon H (humus). Thus, under mountain Norway spruce monoculture (37 and 39 years of the age) 243–276 thousand kg of dry biomass were stored per hectare in the holorganic horizons (L + F + H).

In the horizon L, significant differences between variants were found only in 2003 (dry-mass stored under the thinned stand was about 38% lower compared to the control stand). On the other hand, differences concerning the horizon F were significant in both cases of sampling (under the thinned stand about 19 and 50% lower amount of dry-mass was observed when compared to control in 2001 and 2003, respectively). In the horizon H, no significant differences were found during the period of investigation.

Organic layers were investigated qualitatively only in 2003 (see the chapter on methods). Altogether, the holorganic horizons (L + F + H) accumulated per hectare about 3648 and 3724 kg of N, 1305 and 827 kg of P, 564 and 613 kg of K, 147 and 93 kg of Ca and 151 and 100 kg of Mg under the control and thinned stands, respectively (Tab. 2). The differences between variants were not significant with the exception of amount of P. Significantly lower (about 36%) amount of P was found under the thinned stand when compared to not treated stand (control).

Tab. 2. Nutrient contents in humus horizons L + F + H ($\text{kg}\cdot\text{ha}^{-1}$) in 2003 (tree age – 39 years), significance of T-test * $p < 0.1$, ** $p < 0.05$

| | | N | P | K | Ca | Mg |
|---------|------|-------|--------|-------|------|-------|
| Control | Mean | 3648 | 1305** | 564 | 147 | 151 |
| | S.D. | 892.7 | 164.5 | 106.3 | 66.1 | 138.9 |
| Thinned | Mean | 3724 | 827** | 613 | 93 | 100 |
| | S.D. | 131.6 | 246.7 | 257.6 | 8.2 | 24.5 |

Tab. 1. Dry mass of humus horizons ($\text{thousand kg}\cdot\text{ha}^{-1}$), significance of T-test * $p < 0.1$, ** $p < 0.05$

| Year | Control | | | | | | Thinned | | | | | |
|------|---------|------|--------|------|-------|------|---------|------|--------|------|-------|------|
| | L | | F | | H | | L | | F | | H | |
| | Mean | S.D. | Mean | S.D. | Mean | S.D. | Mean | S.D. | Mean | S.D. | Mean | S.D. |
| 2001 | 9.8 | 4.2 | 54.8* | 6.3 | 178.0 | 40.0 | 8.5 | 2.3 | 44.2* | 0.5 | 223.3 | 34.6 |
| 2003 | 11.5* | 1.8 | 56.6** | 8.7 | 198.8 | 24.8 | 7.1* | 2.6 | 28.5** | 6.2 | 207.2 | 39.3 |

Litter-fall

The weight of litter-fall on the control plot was higher compared to the thinned plot in each year. During the three-year period (from September 2003 to October 2006), the total weight of litter-fall under Norway spruce stands was 13.6 thousand kg·ha⁻¹ (4.5 thousand kg per year) on the control plot and 9.7 thousand kg·ha⁻¹ (3.2 thousand kg per year) on the thinned plot (Fig. 2). Differences between variants were statistically significant at $p = 0.063$ by T-test and $p = 0.114$ by Mann-Whitney test.

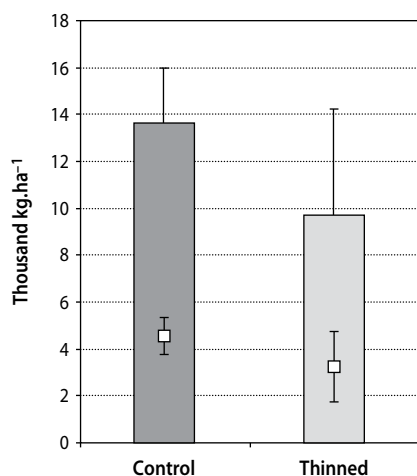


Fig. 2. Total weight of dry mass of litter-fall (period 2003–2006) and mean annual weight with 95% intervals of confidence

The mean annual amount of nutrients in litter-fall partly corresponds with the amount of dry-mass on both investigated variants. Annually, 56 and 38 kg of N, 2 and 1 kg of P, 4 and 3 kg of K, 28 and 21 kg of Ca and 2 and 2 kg of Mg were found per hectare on control and thinned variants, respectively (Tab. 3).

Tab. 3. Nutrient contents in litter-fall (kg·ha⁻¹), significance of T-test * $p < 0.1$ ** $p < 0.05$

| | | N | P | K | Ca | Mg |
|---------|------|------|-----|-----|-----|-----|
| Control | Mean | 56** | 2** | 4 | 28 | 2 |
| | S.D. | 6.5 | 0.2 | 0.4 | 3.2 | 0.3 |
| Thinned | Mean | 38** | 1** | 3 | 21 | 2 |
| | S.D. | 11.6 | 0.3 | 0.9 | 6.6 | 0.6 |

The amount of nutrients was significantly higher on the control plot only in the cases of N (about 46%)

and P (about 51%), whereas the annual amount of dry-mass was significantly higher on the control plot (about 41%) when compared to the thinned plot. Differences between amounts of other nutrients (K, Ca and Mg) were not significant.

DISCUSSION

The present results are based on several-year investigation of litter-fall and humus horizons. The observation started 15 years after first thinning with the aim to evaluate long-time effects of different stand density on humus formation. The observed experiment variants (control and thinned stands) significantly differed (by basal area) during the whole period of observation.

The results obtained showed that dry biomass accumulated in the horizon L (litter) under the 37 and 39-year-old Norway spruce stand, ranged from 7.0–8.5 (thinned plot) to 10.0–11.5 (control plot) thousand kg per hectare. These results correspond with the results from spruce stands 30-year-old (8–9 thousand kg·ha⁻¹, Podrazsky 1996), 40-year-old (9–11 thousand kg·ha⁻¹) (Novak and Slodicak 2004) and 50-year-old (7–9 thousand kg·ha⁻¹) (Šarman 1982b). In thinning experiment Kristianov carried out in this study, the amount of dry-mass in the horizon L represents (if the mean litter-fall was 4.5 and 3.2 thousand kg per hectare on control and thinned plots, resp.) biomass of 2–3 years litter-fall on both investigated variants.

The results of this study showed that the first and second horizons L and F (litter+fermentation) accumulated 65–68 (on the control plot) and 36–53 thousand kg·ha⁻¹ of dry biomass. This amount is relatively high when compared to the results published by Šarman (1982b), i.e. 13–15 thousand kg·ha⁻¹ under the 50-year-old spruce stand. However, this older stand was located lower – at elevation 400 m, where conditions for litter decomposition are better. The results obtained from mountain spruce stands indicate higher values – 25–26 thousand kg·ha⁻¹ under 33-year-old stand (Podrazsky et al. 2006) and data – 46–49 thousand kg·ha⁻¹ under 36-year-old stand (Novak and Slodicak 2004).

In thinning experiment Kristianov, the amount of dry-mass in horizons L + F represent approximately (recalculated by the mean litter-fall) biomass of

14 (control) and 16 (thinned) years litter-fall in 2001 (i.e. 15 years after thinning) and of 16 (control) and 11 (thinned) years litter-fall in 2003 (i.e. 17 years after thinning). This simple comparison shows that upper horizons L+F were created during the period after thinning and it is clear, that thinning negatively affected the amount of litter-fall and its deposition under the observed spruce stands. This result is supported by significant differences of dry-mass amounts in both L (in 2003) and F (in 2001 and 2003) horizons between the variants of experiment. On the basis of presented analysis it can be concluded, that the horizon H consists of biomass from litter-fall before thinning and a part of this horizon probably did exist also in the frame of the last rotation.

The results of nutrient analyses of the humus horizons (L + F + H) showed significant differences in the case of P (lower amount under the thinned stand). This corresponds with the results of Prescott et al. (1993) indicating that P released from litter immediately.

The total weight of annual litter-fall in experimental young Norway spruce stands of 39–42 years of age varied from 3.2 to 4.5 thousand $\text{kg}\cdot\text{ha}^{-1}$. These results correspond with the results from 30–40 years old spruce stands published by Bille-Hansen and Hansen (2001) whose results were from 1.1 to 5.7 thousand $\text{kg}\cdot\text{ha}^{-1}$ or Novak and Slodicak (2004) – from 1.8 to 4.8 thousand $\text{kg}\cdot\text{ha}^{-1}$.

Wilhelmi (1988) and Novak with Slodicak (2004) reported that the amount of litter-fall in approximately 40-year-old spruce stands was influenced by thinning. The effect of thinning, i.e. a lower amount of litter-fall in thinned stands when compared to untreated control, was also observed in thinning experiment Kristianov conducted in this study. The mean annual amount of nutrients in litter-fall corresponds with the amount of dry-mass on both investigated variants, but differences were significant only for N and P. This can be caused by experimental methodology used for quantitative analysis (composite sample from collectors on a given variant).

The results obtained in this study showed that annual return of N through litter-fall per hectare amounted to 56 and 38 kg of N on the control and thinned plot, respectively. This corresponds with the results from spruce stands published by Klimo and Kulhavy (1994) – 43 $\text{kg}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$, Gundersen and Rasmussen

(1995) – 37 $\text{kg}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$ or Novak and Slodicak (2004) – 20–60 $\text{kg}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$.

CONCLUSION

In the mountain spruce stand, the thinning regime based on the first very heavy thinning (reduction at the age of 22 years from initial 3 300 to 1 100 trees per hectare by negative selection from bellow) resulted in:

- the significantly lower amount of dry mass in the horizons L (about 38%) and F (about 50%) under the thinned stand compared to the control stand in the year 2003 (stand age: 39 years), i.e. 17 years after thinning;
- the significantly lower amount of P (about 37%) in the horizons L + F + H under the thinned stand compared to control in 2003;
- the significantly lower amount of the annual litter-fall (about 29%) in the thinned stand compared to control in the period of 2003–2006 (stand age: 39–42 years), i.e. 17–20 years after thinning. These significant differences between variants were confirmed for N and P.

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