FORESTRY IDEAS, 2011, vol. 17, No 1 (41)

LONG-TERM EFFECT OF THINNING ON PRODUCTION AND FOREST-FLOOR CHARACTERISTICS IN SCOTS PINE STANDS IN THE POLABI LOWLAND (CZECH REPUBLIC)

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UDC 630.12

Received: 13 May 2010
Accepted: 12 July 2011

Abstract

We observed the long-term effect of management (two thinning regimes: 2a – by positive selection from above and 3b – by negative selection from below compared to 1c – unthinned control) on production characteristics and forest-floor status in the stands of Scots pine in Central Bohemia (Czech Republic). We found similar effect of treatment on production during the 45-year long period of investigation, i.e. lower periodic basal area increment of both thinned stands compared to control. About 6–9 thousand kg of dry-mass was stored per hectare in humus horizon L in the stands studied in 2008, with insignificant differences among the variants. In horizon F, we found about 14–18 thousand kg of dry-mass per hectare and differences among variants were again insignificant. Significantly higher amount of dry-mass was observed in horizon H in control unthinned plot compared to both variants with thinning (103, 45 and 60 thousand kg per ha in variants 1c, 2a and 3b, respectively). The results obtained indicate that studied thinning regimes resulted in significantly decreased amount of accumulated humus in forest-floor and consequently carbon and nitrogen under treated pine stands.

Key words: Scots pine, thinning, production, forest-floor.

Introduction

In the sustainable management of forests silvicultural measures should be directed not only at wood production, but also at sustainability of production capacity of site. In the Czech Republic, Scots pine (*Pinus sylvestris* L.) is the second most common species (about 17% in the tree species composition). Commercial forests with Scots pine stands are usually cultivated on the sandy sites in lowlands. In Central Bohemia, Scots pine stands are managed by clear-cutting system with relatively intensive soil preparation before planting (logging slash is removed completely and clear-cut area is ploughed after each rotation) and important part of forest ecosystem – humus horizons – are recreated in each rotation. Consequently, during the rotation period, foresters can influence development of stands by thinning. The aim of this study was to found possible long-term effect of thinning on production and forest floor in Scots pine stands in the Central Bohemia. Specifically, effect of thinning on stand basal area and amount of dry-mass, carbon and nitrogen in humus horizons under pine stands were investigated.

Material and Methods

Research was done on experimental series Kersko II established in 1962 in 34-year-old pine stands in site *Carpineto-Quercetum mesotrophicum* (according to Viewegh et al. 2003). Elevation of the stands is 205 m above sea level and the coordinates (in the World Geodetic System 1984) of the series are 50°08′40″ and 14°55′38″. Stands are located on arenic cambisol. According to data from the Czech Hydrometeorological Institute, during the period 1961–2000 mean annual precipitation was 501–550 mm and mean annual temperature was 8.6–9.0°C.

Intensive soil preparation by stump extraction and ploughing was done before planting. The experiment was established in 1962 at a stand age of 34 years. In the same year the first thinning was done. There were three treatments (each of an area 0.25 ha): a thinning treatments – positive selection from above (plot 2a), negative selection from below (3b) and unthinned control (plot 1c).

After the first thinning the stands were measured regularly at 5-year periods for diameter at breast height and height.

In autumn 2008 when the stands were 79-year-old, forest-floor humus horizons (L = fresh litter, F = fermented litter and H = humified litter) were investigated quantitatively and qualitatively on identical comparative plots. We used steel frames (25x25 cm) to define sampling area at six replications in each plot (1c, 2a, 3b). All samples were dried, first in open air, then in a laboratory oven at 80°C, and subsequently weighed (dry mass).

We measured the concentration of oxidizable carbon (C_{ox}) from composite samples (three per treatment) using the spectrophotometric determination of organic carbon in soil – oxidation by chromosulfuric mixture and determination colorimetrically (Walinga et al. 1992). Nitrogen content was assessed from composite samples (three per treatment) after mineralization by mineral acids and analysed using Kjeldahl procedure.

All statistical analyses were performed using multi-sample nonparametric tests (Kruskal-Wallis one-way ANOVA). Unless otherwise indicated, test levels of $p < 0.05$ were used throughout. For this analysis the Unistat (2000) statistical software package was used.

Results

Growth

During the 44-year investigation (1962–2007), the basal area of the control 1c and treated plots 2a and 3b exhibited different trends (Fig. 1). Experimental series started at the age of 34 years having initial basal area 38.7, 37.8 and 35.9 $m^2.ha^{-1}$ on the plots 1c, 2a and 3b, respectively (differences were insignificant). After the third experimen-

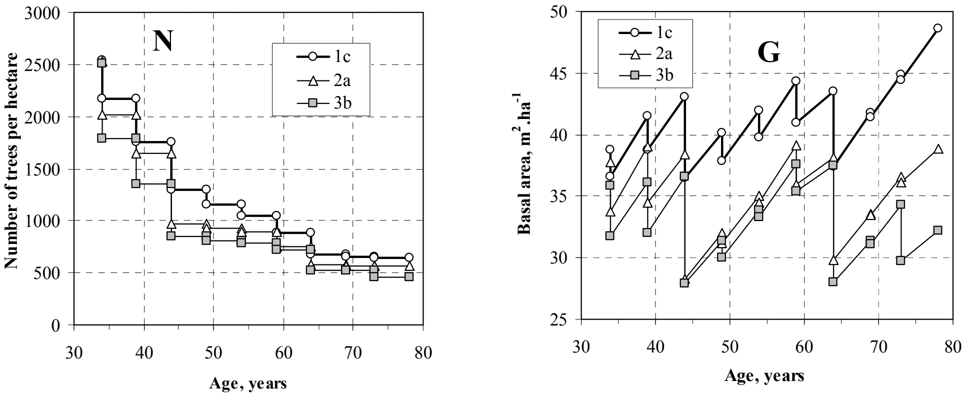

Fig. 1. Number of trees (N) and mean basal area (G) development in the pine thinning experimental series Kersko II in the Central Bohemia.
Legend: plot 1c – control treatment; plot 2a – positive selection from above; plot 3b – negative selection from below.

tal treatment (1972), the basal area of the control and thinned plots differed significantly. The basal area was 36.5, 28.3 and 27.9 m^2.ha^{-1}, respectively, for control 1c and thinned plots 2a and 3b. These differences continued to the end of observation period. At the age of 78 years, the control stand 1c had reached 48.7 m^2.ha^{-1}, whilst the basal area of the thinned stands was 38.9 and 32.3 m^2.ha^{-1} on plots 2a and 3b, respectively.

Status of humus layers

In 2008 (age of 79 years), 6–9 thousand kg.ha^{-1} of dry-mass was stored per hectare in humus horizon L (Tab. 1). This horizon consisted of about 2.1–4.0 thousand kg of mosses, 1.3–1.6 thousand kg of dry bark and twigs, 1.2–2.3 thousand kg of cones and 1.2–1.5 thousand kg of needles per hectare. Differences were significant only for moss amount and for total dry mass between 1c and 2a in the frame of horizon L.

In the F horizon we found 13.9–17.6 t.ha^{-1} dry mass with insignificant differences between the treatments. The greatest amount of dry mass was found in the H horizon: 102.9, 45.4 and 60.1 t.ha^{-1} on plots 1c, 2a and 3b, respectively. Comparison of the control 1c to the both thinned treatment 2a and 3b showed significantly greater dry mass (about 126% more compared to plot 2a and about 71% more compared to plot 3b) under unthinned stand.

Altogether, horizons L+F+H contained 123.0 (1c), 69.7 (2a) and 86.7 (3b) t.ha^{-1} of dry mass. Differences between treatments were also significant. We found greater amount of dry mass under unthinned control stands (about 76% more compared to plot 2a and about 42% more compared to plot 3b), largely due to contributions of the H horizon.

Consequently, the significantly lower amount of dry mass in the H horizon resulted in lesser amount of accumulated oxidizable carbon (C_{ox}) under treated pine stands 2a and 3b (Fig. 2). While on control plot we found about 10.9 t.ha^{-1}

Table 1. Amount of dry mass in humus horizons in the pine thinning experimental series Kersko II in the Central Bohemia at the age of 79 years.

Horizon	Treatment						Significance p*		
	1c	S.E.	2a	S.E.	3b	S.E.	1c/2a	1c/3b	2a/3b
L (moss)	2.1	(0.42)	3.7	(0.30)	4.0	(0.48)	0.04	0.01	n.s.
L (bark + wood)	1.3	(0.28)	1.6	(0.20)	1.4	(0.45)	n.s.	n.s.	n.s.
L (cones)	1.2	(0.42)	1.3	(0.40)	2.3	(0.93)	n.s.	n.s.	n.s.
L (needles)	1.5	(0.38)	1.2	(0.13)	1.3	(0.18)	n.s.	n.s.	n.s.
L (total)	6.1	(0.36)	7.8	(0.43)	9.0	(1.3)	0.07	n.s.	n.s.
F	13.9	(2.00)	16.5	(0.46)	17.6	(1.01)	n.s.	n.s.	n.s.
H	102.9	(9.59)	45.4	(2.33)	60.1	(6.36)	0.0002	0.002	n.s.
L + F + H	123.0	(9.09)	69.7	(2.12)	86.7	(7.72)	0.0004	0.008	n.s.

*n.s. = not significant ($p > 0.05$), S.E. – Standard error.
Legend: L = litter, F = fermentation, H = humus (means with standard errors) for control treatment (plot 1c) and thinned treatments (plot 2a – positive selection from above, plot 3b – negative selection from below).

of C_{ox} in the H horizon, only 5.9 and 4.2 $t.ha^{-1}$ of C_{ox} were stored in this horizon on the treated plots 2a and 3b, respectively.

The total amount of C_{ox} in the H horizon was by 84 and 159% higher on the control 1c compared to the thinned treatment 2a and 3b.

The amount of nitrogen in the H horizon displayed similar trends as carbon, i.e. larger quantity of nitrogen was stored under control plot. The differences between treatments of about 94 and 106% (control 1c 1334 and thinned 2a and 3b 687 and 649 $kg.ha^{-1}$ of N) were significant ($p = 0.0001$).

Discussion

In our experiment we found negative effect of thinning on the basal area of pine stands in the 35-year period of observation. This observation is partly supported by published results (Pirogowicz 1983, Huss 1983) showing that intensive thinning in 50-year-old and older pine stands did not result in higher diameter increment. An important factor in evaluating humus layer formation is the significantly different basal area of comparative plots (control and thinned) during the more than 30 years (age of 44–70 years).

No effect of thinning on dry-mass content in the L (with the only exception of moss content) and F horizon was found. Altogether, the combined L+F horizons contained 20–27 t.ha^{-1} of dry mass. These data correspond with the value of 32.5 t.ha^{-1} published by Komlenović (1997) or 25 t.ha^{-1} reported by Podrázský (1995), although the pine stands investigated in these studies were only 30 years old.

Our study found an effect of thinning on the amount of dry mass in the H horizon. Opening the canopy (and consequently a decrease in basal area) resulted in reduction of dry mass in the H horizon at the end of the observation period. This partly corresponds with Sariyildiz (2008), who reported significant effects of tree canopy on litter decomposition rates in pine stands. His study showed that the tree canopy can significantly alter litter decomposition rates of Scots pine.

The L+F+H horizons together contained 123 t.ha^{-1} of dry mass on the control plot. This amount is higher as compared to the published values of 60 t.ha^{-1} in a 33-year-old stand (Podrázský 1995) and 46 t and 71 t.ha^{-1} in 49- and 63-year-old stands, respectively (Muys 1995). For all horizons (L+F+H) the differences between the observed treatments were significant and consequently, the investigated thinning regime resulted in loss of dry mass (by 42–76%) in humus horizons by the end of the observation period.

Clearly, the most significant differences between treatments were in the H horizon. In this layer we found about 11 t.ha^{-1} of C_{ox} on unthinned control treatment. Different amounts of carbon have been reported for other Scots pine stands: 500–2,500 kg.ha^{-1} (Kurbanov et al. 2007) and 20–38 t.ha^{-1} (Heinsdorf 1997), but these results represent all horizons (forest floor). However, comparison is rather complicated because different methods of carbon analysis (C_{ox} or C_{tot}) were used.

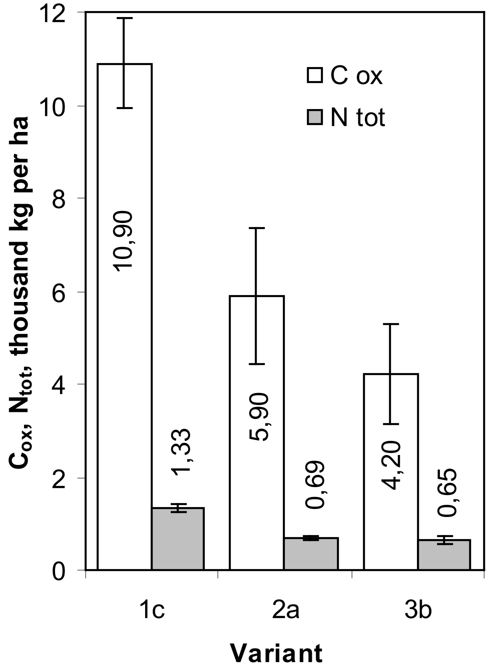

Fig. 2. Mean amount of oxidizable carbon C_{ox} and total nitrogen $N_{tot.}$ in the pine thinning experimental series Kersko II in the Central Bohemia at the age of 79 years.
Error bars denote standard errors in horizon H for control treatment (plot 1c) and thinned treatments (plot 2a – positive selection from above, plot 3b – negative selection from below).

The H horizon contained about 1,330 kg.ha^{-1} of nitrogen on unthinned control. Comparable amounts (900–1,700 kg.ha^{-1}) were found in another study (Heinsdorf 1997) but that was for the complete forest floor. Differences between treatments for nitrogen were not as pronounced as they were for carbon content. However, the amount of nitrogen under thinned stands was lower and the difference was significant.

Conclusions

During the 46-year long period of investigation the basal area of control plot and treated plot exhibited similar trends. After the third experimental treatment (1972) the basal area of the control 1c and thinned plots 2a and 3b significantly differed.

• In terms of humus layers investigation it was basically important that more than 30 years led to significantly lower basal area on thinned variants compared to control.

• At the age of 79 years, horizon L contains about 6–9 thousand kg of dry-mass under pine stands.

• In horizon F, we found from 13.9 to 17.6 thousand kg of dry-mass per hectare.

• The highest amount of dry-mass was found in horizon H – from 45 to 103 thousands kg per hectare. Differences between variants were significant only for horizon H and consequently for the complete forest floor (L + F + H).

• Studied thinning regimes (positive selection from above and negative selection from below) resulted in decreased amount of accumulated humus and consequently carbon and nitrogen stock in H horizon under treated pine stands.

Acknowledgements

This study was supported by the post-doctoral project 526/08/P587 of the Czech Science Foundation (Grant Agency of the Czech Republic) and by the long-term project of the Czech Ministry of Agriculture MZE-0002070203.

References

Heinsdorf M. 1997. Boden- und ernährungskundliche Untersuchungen in Kiefern- und Kiefern-Buchen-Mischbeständen auf verschiedenen Standorten Brandenburgs. Beiträge für Forstwirtschaft und Landschaftsökologie 31: 119–124.

Huss J. 1983. Durchforstungen in Kiefernjungbeständen. In: Huss J. et al. (eds.) Kiefernwirtschaft. Forstwissenschaftliches Centralblatt 102: 1–17.

Komlenović N. 1997. Utjecaj kultura četinjača na tvorbu i kemijska svojstva organskog i humusnoakumulativnog horizonta lesiviranog tla. [The impact of conifer cultures on the formation and chemical properties of organic and humus accumulative horizon of luvisol]. Rad Šumar Institut Jastrebarsko 32: 37–44. (in Croatian).

Kurbanov E., Vorobyov O., Gubayev A., Moshkina L., Lezhnin S. 2007. Carbon sequestration after pine afforestation on marginal lands in the Povolgie region of Russia: A case study of the potential for a Joint Implementation activity. Scandinavian Journal of Forest Research 22 (6): 488–499.

Muys B. 1995. The influence of tree species on humus quality and nutrient availability on a regional scale (Flanders, Belgium). In: Nilsson L.O., Hüttl R.F., Johansson U.T. (eds.) Nutrirent uptake and cycling in forest ecosystems. Kluwer Academic Publishers: 649–660.

Pirogowicz T. 1983. Wpływ trzebiezy na produkcyjnosc i strukture drzewostanow sosnowych na przykładzie stałych powierzchni doswiadczałnych połozonych w Nadłesnictwach Ruciane, Krutyn i Ryjewo. [Influence of thinnings at productivity and structure of pine stands on the example of permanent experimental plots in the

Ruciane, Krutyn and Ryjewo Forest District]. Prace Instytutu Badawczego Łesnictwa 621: 3–38. (in Polish).

Podrázský V. 1995. Effect of Thinning on the Organic Matter Accumulation and Quality in the Submountain Spruce and Lowland Pine Forest. In: Matějka K. (ed.) Investigation of the Forest Ecosystems and of Forest Damage. Proceedings of the workshop held in Opočno on April 25–27, 1995. Praha: 164–170.

Sariyildiz T. 2008. Effects of tree canopy on litter decomposition rates of *Abies nordmanniana*, *Picea orientalis* and *Pinus sylvestris*. Scandinavian Journal of Forest Research 23: 330–338.

Unistat 2000. Unistat 5.0. Statistical Package for Windows. User's Guide. Unistat House, London. 801 p.

Viewegh J., Kusbach A., Mikeska M. 2003. Czech forest ecosystem classification. Journal of Forest Science 49: 85–93.

Walinga M., Kithome M., Novozámský I., Houba V.G.J., Van der Lee J.J. 1992. Spectrophotometric determination of organic carbon in soil. Communications in Soil Science and Plant Analysis 23 (15 & 16): 1935–1944.