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Impact of browsing damages on growth and quality of silver birch plantations in Latvia

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Abstract. Silver birch is widely used both in forest regeneration and afforestation of abandoned agricultural lands, since it has high productivity and phenotypic plasticity and is relatively seldom damaged by biotic or abiotic factors. In Baltic States significant browsing damage of this tree species had not been noted in contrast to other countries with notably higher ungulate population densities. Therefore the aim of our study was to evaluate the impact of browsing damages on tree and stand parameters as a basis for further recommendations for stand protection. Data for the analysis were collected in central Latvia (56°22´N, 23°7´E) in a large plantation with areas of different browsing intensity. At the age of 16 years, tree height and diameter was measured and traits characterising damages were assessed. Browsing had caused a significant decrease in survival: from 87% survival in areas with light browsing to 56% survival in areas with heavy browsing. Browsing had caused a reduction of tree growth: mean tree height in areas with slight browsing was 13 ± 0.4 m, but only 2 ± 0.3 m (i.e. reaching height of red deer and moose) in areas with heavy browsing. Heavy browsing had created irreversible loss of productivity: even if browsing would not continue, it would take double as much time for the birches in these areas to reach target diameter for cutting (27 cm) than in slightly browsed areas. Frequency of spike knots and crooked stems was statistically significantly higher for trees with browsing damage.

Key words: browsing, ungulates, spike knots, stem straightness, rotation period, *Betula pendula*.

INTRODUCTION

Wood from plantations is an important source of renewable material and energy and, therefore, can contribute to carbon sequestration both in forest products and in soil (Bardulis et al., 2016) and to the accomplishment of the emission reduction targets of the European Union. Silver birch (*Betula pendula*) is one of the tree species that can be used for the establishment of such plantations. This tree species currently dominates in afforestation (in total, including both planting and natural regeneration) of abandoned agricultural lands in the Baltic States (Liepins et al., 2008; Lazdins et al., 2010). In the context of climatic changes meteorological factors determining growth (radial or height increment) of trees have been tested for various species in Latvia (Jansons et al., 2013a; 2013b; 2015a; 2015b; Šēnhofa et al., 2016) but not for Silver birch. However, its high phenotypic plasticity is known from various trials (Silfver et al., 2009) and, therefore, use of Silver birch is recommended to minimize potential climate-related risks. Even so climate change might not be so beneficial in terms of (predicted) increase of productivity for this tree species in comparison to coniferous trees (Briceño-Elizondo et al., 2006; Jansons, 2012). Productivity of Silver birch, as for other tree species, is at least partly genetically determined (Jansons, 2005; Jansons et al., 2006); it can be significantly boosted by use of improved (bred) plant material: for example, stem volume of seed orchard progenies exceeded that of stand progenies by 26–29% in Finland (Hagqvist & Hahl, 1998). Financial efficiency of birch breeding is high and might exceed that of other broadleaved tree species; however, the efficiency is heavily dependent on the level of deployment of improved plant material in the annual area of regeneration or afforestation (Gailis & Jansons, 2010; Jansons et al., 2011). The choice of regeneration method depends on cost and expected benefits (on growth and quality), as well as risks, including browsing (Lazdina et al. 2013). For example, in Finland browsing by roe deer (*Capreolus capreolus*) or moose (*Alces alces*), as well as (locally) white-tailed deer (*Odocoileus virginianus*) and reindeer (*Rangifer tarandus*), is a common reason for the failure of birch regeneration and, therefore, a dramatic reduction of planting (both in forest and abandoned agricultural lands) of this tree species (Van Hees et al., 1996; Helle, 2001; Viherä-Aarnio & Heikkilä, 2006). Browsing damages not only reduces survival of trees but also stem quality, leading to crookedness and, due to infection by fungi, also wood discoloration and decay (Heikkilä et al., 1993; Arhipova et al., 2015). Generally, browsing damages have not been a significant problem in birch stands in the Baltic States and therefore have not been analysed before; however, the density of ungulate populations is increasing rapidly (similar to other European countries) and this trend is expected to continue. Therefore the aim of our study was to evaluate the impact of browsing damages on tree and stand parameters as a basis for further recommendations for stand protection.

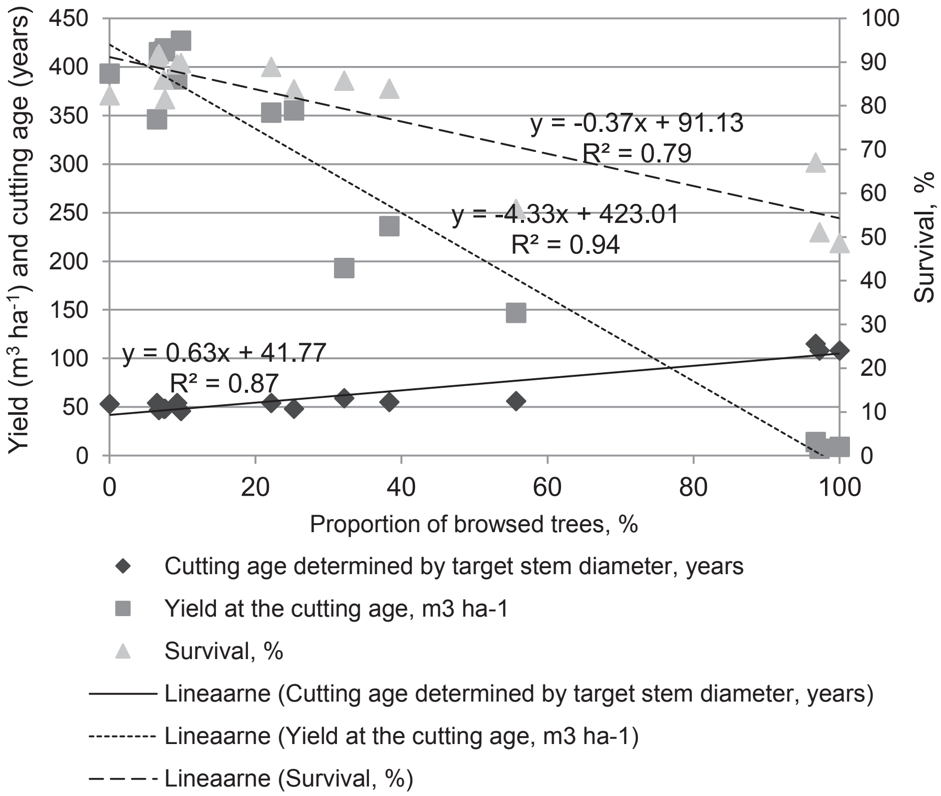
MATERIALS AND METHODS

Study site was located in large birch plantation (total area > 20 ha) in central part of Latvia (56°22´N, 23°7´E). One-year old containerized birch seedlings, grown in the same nursery from the same seed lot were planted in autumn of 1999 in former agricultural land (flat relief, no changes of soil type within the area) in prepared soil (ploughing) with spacing 2 x 2 m (density 2,500 trees ha^{-1}). Based on visual assessment the site was divided into 3 parts: limited browsing (< 10% of trees with browsing damage), medium browsing (10–90%) and heavy browsing (> 90% of trees browsed). Browsing of each tree was classified as ‘yes’ or ‘no’. Presence of browsing for the tree was noted, if tree top and/or more than 1/3 of side branches and/or bark more than 2/3 of stem circumference were damaged and it was not possible to attribute the particular damage to any other cause then browsing by cervids (*Cervidae*). Accumulated damage was assessed. Plots with an area of 0.1 ha, separated by a distance from 50 to 460 m, were established in each of the parts of the area in randomly selected location, the number of plots being proportional to the size of area in each browsing level: 11 in light (limited) browsing, 6 in moderate and 3 in heavy. In plots for each tree at the age of 16 years the presence of browsing damages, spike knots (separately for stem section below or above 2 m height) and multiple stems or tops (below or above 2 m height) were assessed. Stem straightness was evaluated in 5 grade scale, where 1 – straight, 2 –slightly bent, 3 – at least one bend – deviation from supposed vertical line along the stem edge exceeding 5 cm, 4 – two bends, 5 – more than two bends. Tree height and diameter at breast height measured. Further development of plots (stands) was estimated using growth models based on National forest inventory data (Donis, 2014; Zeps et al., 2016a) and assuming cutting by target diameter (≥ 27 cm).

Linear regression was used to calculate the trends in the data (plot or individual tree level) and ANOVA was used to test significance of differences between categories (i.e. height of browsed and not-browsed trees), χ^2 – between proportions. Analysis was carried out in SPSS.

RESULTS AND DISCUSSION

Browsing damages had a statistically significant (*P* < 0.05) negative influence on survival of trees: in plots with light browsing (total number of measured trees n = 1,273) survival was 87%, indicating good planting and tending quality, but in plots with heavy browsing (n = 221) survival was on average only 56% (Fig. 1).



Plot mean values used in regression

Figure 1. Yield, cutting age (determined by target stem diameter) and survival (at age of 16 years) in plots with different proportion of browsed trees.

Even such a low survival rate would be sufficient for the establishment of a productive stand, since it corresponds to 1,400 trees ha^{-1} i.e. similar to the initial density recommended for birch plantations in Finland (Hynynen et al., 2010) and it has been found that density not exceeding 1,000 trees ha^{-1} is optimal to maximize diameter growth of dominant trees in birch plantations (Niemistö, 1995). However, in our trial heavy browsing had not only reduced the survival of trees, but also dramatically and significantly ($P < 0.05$) impacted on their height and diameter (Fig. 2). In plots with light browsing the mean height was 13 ± 0.4 m (here and further in text ±95% confidence interval), and mean diameter was 10 ± 0.4 cm, but in plots with heavy browsing the respective figures were only 2 ± 0.3 m and 2 ± 0.3 cm. Also, analysis of variance of data on a tree basis revealed that height and diameter for birches without browsing damage were significantly ($P < 0.05$) higher than for birches with damage: 12 ± 0.1 m and 10 ± 0.2 cm *vs.* 5 ± 0.2 m and 5 ± 0.2 cm. This was in accordance with earlier finding demonstrating that birch is capable to survive even in sites with very high browsing pressure (Heikkilä et al., 1993). Birch has high capacity to recover after damages of foliage alone, as found by studies on insect herbivory (Silfver et al., 2009). However, ungulates (especially moose) have much more pronounced impact on tree growth, since, while reaching for leaves and young twigs, they often break larger branches or even the stem of relative large saplings (Löyttyniemi & Lääperi, 1988). Speed et al. (2013) found that browsing of approximately half of shoots of 1 m high saplings prohibited their height growth. Noticeably in our study, the mean height of birches in the most heavily browsed plots was 2 ± 0.3 m – the reaching height of large ungulates (moose or red dear) during feeding, confirming, that further height growth of these trees was deterred. In these plots 17.6% of trees were lower than 1 m (and height was between 1 m and 1.5 m for of 35.6% of trees), while in the rest of the plantation – only 0.4% of the trees were lower than 1 m.

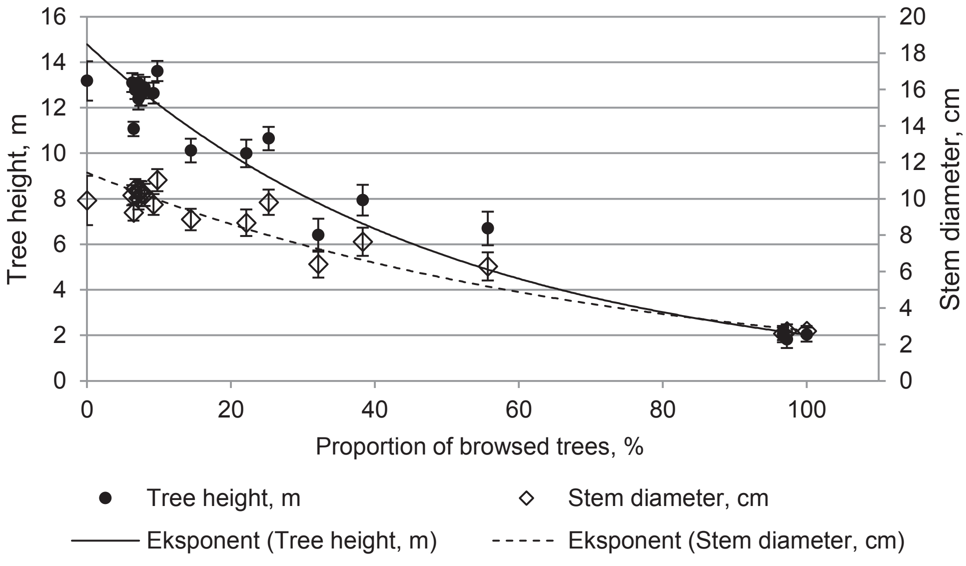


Figure 2. Tree height and stem diameter in plots with different proportion of browsed trees (± 95% confidence interval of respective trait).

Long-term consequences of the browsing on the development of plantation was predicted using growth models with the assumption that browsing will not be continued and that trees will grow normally (according to soil conditions). Modelling revealed, that with this assumption and current parameters, more than 100 years will be required (110 ± 10.3) for the trees in the heavy browsed plots to reach the mean target diameter for cutting (27 cm). In the light browsed plots, applying the same thinning criteria – the time was less than half that (50 ± 3.2 years) (Fig. 1). It indicated that maintenance of the most heavily browsed birches was not a sensible decision. Similar long-term negative effect of browsing on survival and increment of trees, increasing the cutting age of the stands, had been found for Sitka spruce (Scott et al., 2009).

Browsing damage affected not only growth of the trees, but also stem quality and therefore the potential assortment structure. A statistically significantly ($R^2 = 0.92$, $P < 0.05$) higher proportion of trees with spike knots below 2 m height (mostly indicating notable damage at least once before the tree exceeded this height) had been found in heavily browsed plots (Fig. 3). Similar conclusion on negative effect of browsing on quality of trees can be drawn from the positive and statistically significant link between browsing damages and stem straightness ($R^2 = 0.80$, $p < 0.05$). In contrast, no relationship between the proportion of trees with browsing damage and the proportion of trees with stem defects higher than 2 m (multiple leaders or spike knot above 2 m) were detected ($R^2 = 0.003$, $P > 0.05$), indicating, that browsing was most likely the cause of these defects in the lower (most valuable) part of the stem.

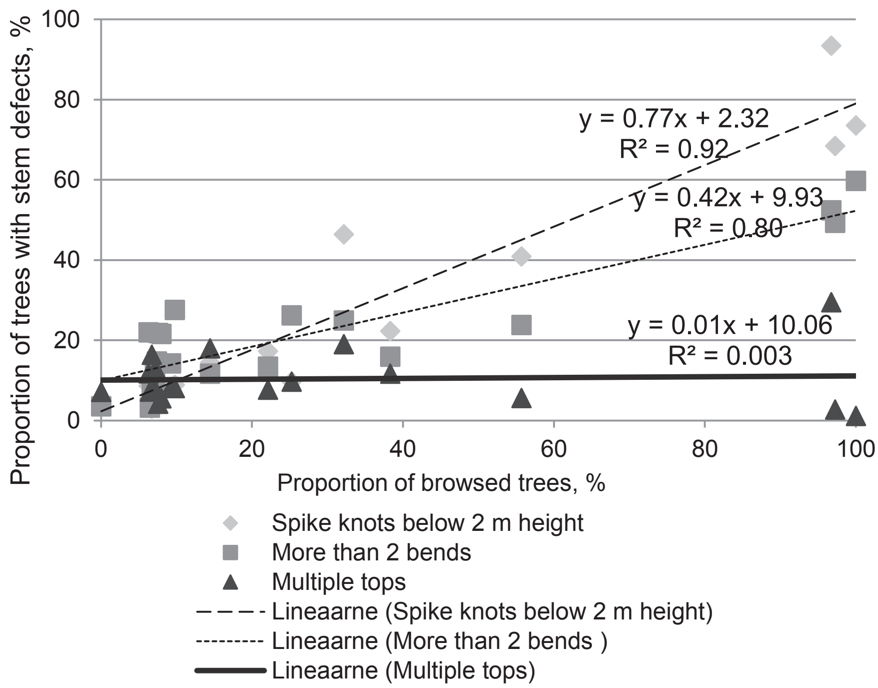


Figure 3. Proportion of trees with stem defects (spike knots, multiple tops, heavy crookedness) in plots with different proportion of browsed trees.

Analysis of data on a tree basis revealed a similar trend: trees with browsing damages had spike knots in up to 2 m height in 50% of cases, trees without browsing damages – in 10% (difference significant, $P < 0.05$). This result also indirectly indicated that trees with currently visible damages had been browsed several times (all types of recent damages correlated positively with the extent of previous damages). Similar conclusions – both on repeated damages of the same trees and negative effect of browsing damage on stem quality were reached in a comprehensive evaluation of Scots pine in Sweden (Bergqvist et al., 2001).

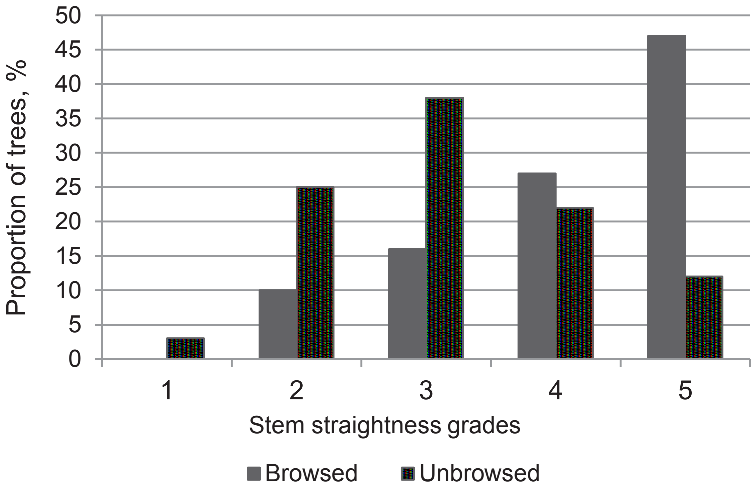


Figure 4. Distribution of browed and unbrowsed trees in different stem straightness grades.

Browsing had a negative effect on stem straightness: the proportion of trees with very crooked stems (grade 5) reached 47% for birches with browsing damage and 12% for birches without them (difference statistically significant, $P < 0.05$) (Fig. 4). Stem breakage (during browsing by moose) had been linked to crookedness in analysis of silver birch in Finland (Heikkilä et al., 1993). Stem quality reduction due to browsing damages (all aspects together) had lead to a 10–28% decrease of timber value for Sitka spruce in Scotland (Scott et al., 2009). Browsing causes not only easily observable stem defects, but also discoloration and decay of wood, further reducing its value, and, in contrast to similar damages caused by insects – also contributing to reduction of tree growth (Heikkilä et al., 1993; Zeps et al., 2016b).

The Results clearly demonstrated the significant negative influence of browsing damage on tree quality both at stand and indivudual tree level.

CONCLUSIONS

Heavy browsing damage of birch had caused statistically significant decrease of survival and growth of trees up to a point where the predicted rotation age was more than double that of the slightly browsed areas and maintenance of the plantation was no longer financially viable. Browsing had a notable and significant negative effect on the occurrence of spike knots below two metres in height and on the stem straightness of affected birches.

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