# Influence of lammas shoots on productivity of Norway spruce in Latvia

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**Abstract.** The Norway spruce is widely spread in Eastern Europe and it is managed mainly for the production of sawlogs, though its logging residues are now increasingly used for the production of wood chips for bioenergy. The growth of the Norway spruce is and will be affected by climatic changes; one of the possible effects might be an increase in the frequency of trees with lammas shoots. Therefore, the aim of this study was to assess the influence of lammas shoots on the length of height increment of young Norway spruce in Latvia. Tree height and height increment was repeatedly measured and the presence of lammas shoots, bud flushing grades and frost injuries were assessed in two young (8–13 years) open-pollinated progeny tests in the central part of Latvia (56°46′N, 24°48′E). The mean portion of trees with lammas shoots in one experiment was 6% at the end of 8$^{th}$ growing season. In another experiment, it was 8.7%, 26.9% and 8.1% at the end of 10$^{th}$, 11$^{th}$ and 13$^{th}$ growing seasons, respectively; 32.3% of trees had lammas shoots at least in one of three seasons. Faster growing and earlier flushing trees had a significantly higher frequency of lammas shoots. Lammas shoots increased the length of annual height increment by 10 to 14 cm, resulting in a 14–20% taller tree height at the age of 13 years. The reduction of height increment as a result of frost damages for very early flushing trees was less pronounced for trees with lammas shoots than without them.

**Key words:** height increment, tree height, open-pollinated family.

## INTRODUCTION

The Norway spruce is the most important commercial tree species in Northern European countries. It occupies 18 million ha of forest land, with a total growing stock of 2,700 million m$^3$ – which is a third of the wood resources in the region (Rytter et al., 2013). The Norway spruce is grown mainly for sawlog production; however, its sawdust and logging residues are increasingly used for bioenergy production. For example, the amount of wood chips produced from logging residues in Latvia's state forests has increased from 3 thousand m$^3$ in 2006 to 380 thousand m$^3$ in 2013 (Latvijas valsts meži, 2012). Harvest residues from the Norway spruce, consisting of branches and tops, are an important source of biomass energy in Finland and Sweden (Rytter et al., 2013). In Latvia, it was found that the biomass of dead and living branches forms 6.4% and 17.4% of the total above-ground biomass in 40-year old Norway spruce stand, respectively (Lībiete-Zālīte & Jansons, 2011).

Due to the economic importance of coniferous trees, a substantial amount of studies have been carried out to understand the possible effects of climatic changes on their vitality and growth (Gabrilavičius & Danusevičius, 2003; Bergh et al., 2005; Jansons et al., 2013a; Jansons et al., 2013b). Long term phenological observations in Latvia and other European countries have indicated a trend towards an earlier start of the spring (–0.54 days year$^{-1}$) and a longer (0.96 days year$^{-1}$) vegetation period (Stöckli & Vidale, 2004). This trend is predicted to continue in the future and, in combination with increasing temperatures, will lead to more frequent formation of lammas growth – additional height increment in the second half of the vegetation period. Formation of lammas shoots can lead to increased frequency of frost damages (Gabrilavičius & Danusevičius, 2003; Søgaard et al., 2011) and up to a 40% higher frequency of double leaders (Søgaard et al., 2011). In contrast, a significant correlation between the proportion of trees with lammas shoots and stem quality at provenance mean level was not found for young Norway spruce in Sweden (Danusevičius & Persson, 1998). It is suggested that the formation of lammas shoots could increase height increment of the trees (Rone, 1975), however, this effect has rarely been quantified. Therefore, the aim of our study was to assess the influence of lammas shoots on height increment of young Norway spruce in Latvia.

## MATERIALS AND METHODS

The study was carried out in two Norway spruce experiments, planted on fertile abandoned agricultural land (corresponding to the *Oxalidosa* forest type), hereafter referred to in this text as 'A' and 'B', at ages of 8 and 13 years, respectively. Both experiments were located in the central part of Latvia (56°46′N, 24°48′E). According to the data from the nearest meteorological station (Skriveri) of the Latvian Environment, Geology and Meteorology Centre, long-term average annual temperature was +6.1 °C, and the sum of precipitation was on average 717 mm per year. Experiment B was located in three fields of close proximity, with slightly different soil and micro-relief conditions, hereafter referred to in this text as 'trials.' Tree height, length of the last season height increment and presence of lammas shoots were assessed at the end of the 8$^{th}$ growing season for 3,887 trees from 60 open-pollinated families in experiment A (October 2014), and at the end of the 10$^{th}$ (November 2011), 11$^{th}$ (October 2012), and 13$^{th}$ (November 2014), growing seasons for 3,412 trees from 112 open-pollinated families in experiment B. Bud flushing grade was assessed in experiment B trial 2 (1930 trees) at the beginning of 11$^{th}$ growing season (June 2012) using a four grade scale: grade 1 = very late flushing (length of current increment < 3 cm), grade 2 = late flushing (3–6 cm), grade 3 = early flushing (7–10 cm), grade 4 = very early flushing (> 10 cm). Also the presence (or absence) of spring frost damage on shoots was noted.

Data analysis was carried out using ANOVA, correlation and $\chi^2$ test and the mean values ± confidence intervals were calculated.

## RESULTS AND DISCUSSION

Mean height at the age of 8 years in experiment A was 117 ± 1.4 cm and height increment was 27 ± 0.6 cm. During the 8$^{th}$ growing season, lammas shoots formed for 6% of trees. Tree height at the age of 13 years in the each of the three trials of experiment

B was 394 ± 6.8 cm, 442 ± 5.8 cm, 439 ± 10.2 cm, and the mean height increment in the last 3 years in each of the trials was 64 ± 1.1 cm, 72 ± 0.9 cm, 80 ± 1.7 cm, respectively. Differences in height increment between the trials were statistically significant ($P < 0.001$); therefore, a separate analysis of lammas shoots (characterized as the presence of them in at least one of the three years of assessment) was carried out for each of them. The proportion of trees with lammas shoots in a particular year at the end of 10$^{th}$, 11$^{th}$ and 13$^{th}$ growing seasons in experiment B was 8.7%, 26.9% and 8.1%, respectively, and lammas shoots in at least one of the assessment years were found for 32.3% of trees.

The proportion of the Norway spruce trees with lammas shoots in this study was in a range of previously reported results from other countries. For example, in Sweden, in trials at the age of 5 years, 7% of spruces from Baltic State provenances had lammas shoots (Danusevičius & Persson, 1998); in Norway, in trials at the same age, 28% of spruces from Latvian provenances had lammas shoots (Søgaard et al., 2011).

In experiment A, the proportion of trees with lammas shoots was highest (reaching 20%) in classes of trees with the largest height and height increment, but was lowest (approximately 1%) in the classes of trees with slowest growth (Fig. 1); differences between the classes were statistically significant ($P < 0.001$).

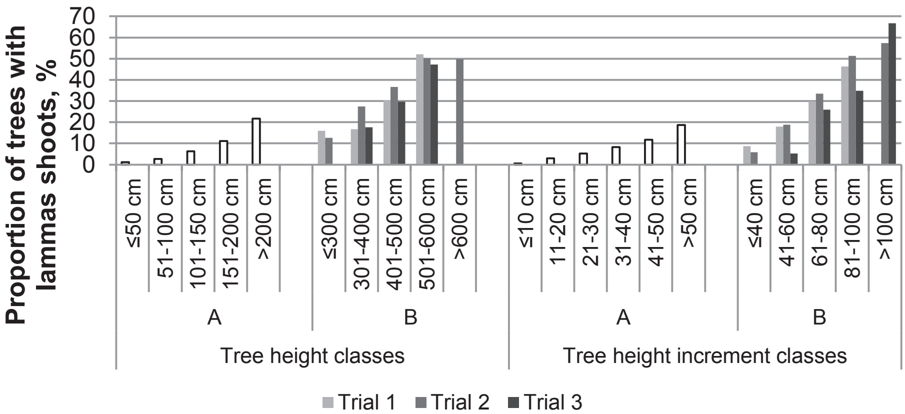


**Figure 1.** Proportion of trees with lammas shoots in experiment A (at the end of the 8$^{th}$ growing season) and B (at the end of at least one of the three assessment seasons) in different tree height and height increment classes.
In trial 1 (experiment B) trees of height increment 81–100 cm were clustered together with trees of height increment > 80 cm, and trees of height 501–600 cm were clustered together with trees of height > 500 cm.
In trial 3 (experiment B) trees of height increment 41–60 cm were clustered together with trees of height increment ≤ 60 cm, and trees of height 301–400 cm were clustered together with trees of height ≤ 400 cm.

Analyses of each of the trials in experiment B revealed a similar trend – faster growth was associated with higher frequency of lammas shoots: on average, 47–68% of the trees in the class with the largest height and mean height increment had lammas shoots, but lammas shoots were present in only 5–18% of the class with the smallest (the slowest growing) trees. The difference in the proportion of trees with lammas shoots between the classes was statistically significant ($P < 0.001$).

A significant association between tree height and frequency of presence of lammas shoots was also previously reported in Latvia in an analysis of more than 100 stands (Neimane et al., 2015, submitted) and tree breeding trials (Rone, 1975), as well as from analysis of provenance trials in other countries (Hoffmann, 1965). Significant positive correlation ($r \approx 0.3$; $P < 0.01$) was found at provenance mean level between tree height and proportion of trees with lammas shoots in analyses of a trial including 107 Swedish and 16 Eastern European spruce provenances at the age of 5 and 9 years (Danusevičius & Persson, 1998). In experiment A of this study, the proportion of trees with lammas shoots at family mean level had significant positive correlation with height increment ($r = 0.44$; $P < 0.001$) and weaker, non-significant correlation with tree height ($r = 0.22$; $P = 0.09$). Similarly, in experiment B, the proportion of trees with lammas shoots at family mean level had statistically significant ($P < 0.01$) correlation with tree height (when all trials were analysed together ($r = 0.49$) and separately ($r = 0.41...0.71$)) and height increment ($r = 0.51$ and $r = 0.48...0.70$, respectively).

In experiment A, the height increment of the 8$^{th}$ growing season for trees with lammas shoots (44 ± 2.4 cm) was notably (by 68%) and significantly ($P < 0.001$) larger than for trees without them (26 ± 1.7 cm) (Fig. 2). Similarly, in experiment B, spruces with lammas shoots had significantly ($P < 0.001$) larger mean height increment of the last three years than spruces without them: mean differences in these particular trials were from 10 to 14 cm.


**Figure 2.** Height increment of trees with and without lammas shoots (height increment of the 8$^{th}$ growing season in experiment A; mean height increment of the last 3 years in experiment B).

The cumulative influence of these seemingly small differences was notable (and significant – $P < 0.001$): at the end of the 13$^{th}$ growing season, the height of trees with lammas shoots was on average 450 ± 11.8 cm, while those without lammas shoots averaged at 374 ± 7.8 cm in trial 1; in trial 2 – 490 ± 8.1 cm and 416 ± 7.4 cm, respectively; in trial 3 – 481 ± 16.0 cm and 420 ± 12.2 cm, respectively (Fig. 3). Thus, trees with lammas shoots were 14–20% taller than trees without them. Also, in experiment A, trees with lammas shoots were 29% taller than trees without them (148 ± 5.8 cm vs. 115 ± 1.4 cm, $P < 0.001$).

The additional height increment due to lammas shoots might be dependent on the absolute length of the height increment. To evaluate whether this was the case, in each trial, trees with lammas shoots and trees without them were sorted according to height increments in descending order, and four groups (equal number of trees in each group) were formed. For example, in trial 2, the number of trees with lammas shoots in each group was 688/4 = 172, but without them was 1242/4 = 310. Height increment in each of the four groups was significantly ($P < 0.001$) higher for trees with lammas shoots than for trees without them in each of the trials.

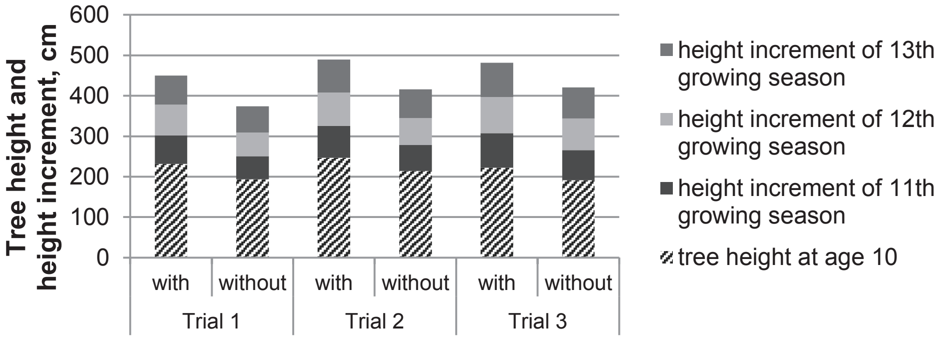


**Figure 3.** Height and height increment of trees with and without lammas shoots in trials 1–3 of experiment B ('with' – trees with lammas shoots; 'without' – trees without lammas shoots).

The frequency of lammas shoots was linked not only to tree height increment, but also to their bud flushing phenology: earlier flushing trees had a higher frequency of lammas shoots. For example, in trial 2, for trees with flushing grade 4 (very early), 56% of trees had lammas shoots, but in grade 1 (very late), only 22%. Within every flushing grade, the mean height increment was significantly ($P < 0.001$) higher for spruces with lammas shoots than without them (Fig. 4).

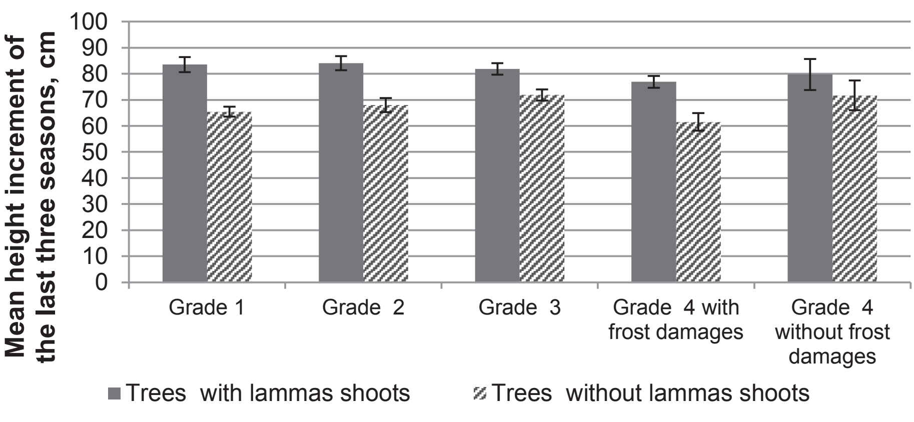


**Figure 4.** Height increment of the last three seasons for trees with and without lammas shoots in different bud flushing grades in trial 2 of experiment B.

This contrasts the observations by Danusevičius & Persson (1998), who found a higher proportion of trees with lammas shoots for provenances with later flushing. Frost damages were not observed for very late and late flushing trees (grades 1 and 2), but were observed for 2% of early flushing and 87% of very early flushing trees (grades 3 and 4). The reduction of height increment as a result of frost damages for very early flushing trees was less pronounced for trees with lammas shoots than for those without them (Fig. 4).

## CONCLUSIONS

Results indicate that lammas shoots are linked to an increase in height increment and can reduce the impact of frost damages on the length of height increment. Increased frequency of the formation of lammas shoots due to climatic changes would raise the height increment of the Norway spruce.

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