GROWTH OF *FAGUS SYLVATICA* IN YOUNG MIXED STAND: CASE STUDY IN CENTRAL LATVIA

Liga Purina, **Andis Adamovics**, **Juris Katrevics**, **Zaiga Katrevica**, **Baiba Dzerina**
Latvian State Forest Research Institute 'Silava'
liga.purina@silava.lv

Abstract
Climatic changes are shifting the potential tree distribution limits of many tree species northwards. One of such species is *Fagus sylvatica*, currently represented in Latvia only by a few stands. In order to increase knowledge on its potential use in the forest management, the aim of our study was to characterize the growth of beech in a young stand in the central part of Latvia. The stand of beech and spruce, mixed in rows with an initial spacing of 2.5 x 2.5 m in *Oxalidosa* forest type was assessed. Survival of European beech in clearcut was similar to that observed for the native Norway spruce (73% and 79%, respectively), but both height and diameter were notably and significantly superior for wildlings at the mean age of 15 ± 2 years, reaching on average 7.4 ± 0.30 m and 8.9 ± 0.69 cm, respectively. Increasing ring width with increasing tree age for both tree species was observed until the last four years, when large and increasing superiority of beech over spruce, coinciding with reduction of ring width of spruce, was noted. It was most likely caused by intensified competition due to very wide crowns formed by young beech trees in the plantation with wide spacing: average crown radius reached 2.4 ± 0.16 m, for few trees exceeding even 4 m.
Key words: introduced tree species, mixed stand, adaptability, survival, European beech.

Introduction

Climate envelop models are used to predict changes of species distribution due to climatic changes. Generally, northward shift of the vegetation zones, therefore also the species distribution is expected in Europe (Walther *et al*., 2002; Kullman, 2008). However, the actual natural changes of the borders of tree species areals are much slower, since the spread is determined by the distance of seed dispersion, affected by numerous factors including forest fragmentation. To ensure that the expected improvement in forest productivity due to warmer climate (Lindner *et al*., 2010) is realized, the adjustments in forest management practice and introduction of potentially suitable tree species, in this way altering the predicted natural changes in forest composition (Hickler *et al*., 2012), are crucial (Petit *et al*., 2004). Increasing the number of tree species used in forestry also allows forest managers to diversify risks as well as find the most suitable alternative for any particular site, considering not only growth but also increasing probability of damages by abiotic factors (Seidl *et al*., 2014). It is predicted, that northeastern limit of European beech (*Fagus sylvatica* L.) might occur in the Baltic States by the end of the 21st century (Kramer *et al*., 2010), since the already occurring climatic changes in Latvia are reflected as an increase of temperature in the dormant period and spring (Lizuma *et al*., 2007), making the conditions more suitable for the requirements of this species (Bolte, 2007). However, it is not advisable to rely on the theoretical considerations, therefore ecological demands, i.e. climatic limitation of growth of this tree species should be comprehensively evaluated. Detailed information on climate-growth relationships can be obtained via dendrochronological analysis. This technique was applied for the assessment of relationships between tree ring width (TRW) and climatic variables for beech in Latvia. Chronologies of TRW, which covered the periods 1949 – 2012 were produced. Variation of TRW was affected by drought-related climatic variables, temperature in the previous July and August, as well as an effect of spring and autumn temperature was observed. It was found that during the recent decades July precipitation also has become significant (Jansons *et al*., 2015a). The latter might have a negative effect on beech growth since intensification of heat and drought events are expected (Avotniece *et al*., 2010).

Successful natural regeneration is the first indication of species to thrive in the particular conditions. Abundant regeneration has been found in canopy openings of the few existing beech stands in Latvia (Purina *et al*., 2013), limited mainly by light conditions (Jansons *et al*., 2016). Even so, the results proved very high shade tolerance of this tree species in comparison to other common trees species in Latvia (Jansons *et al*., 2016) as well as broadleaved tree species with northernmost point of distribution limit being in the territory of our country – European hornbeam (*Carpinus betulus* L.). Hornbeam understory distribution and abundance was significantly linked to light parameters, particularly – diffuse radiation (Purina *et al*., 2015). Growth of beech under shelterwood, as recommended for its regeneration (Ritter *et al*., 2005), mainly due to high spring frost risk (Aranda *et al*., 2002), was similar to that found for other shade-tolerant species – Norway spruce: the mean height in particular study plots was 62 and 64 cm, respectively (Jansons *et al*., 2016). However, the growth of young beech seedlings planted in clearcut (with higher temperature amplitude) has not been assessed previously in Latvia. Productivity of old beech trees, assessed in several permanent sample plots in the western part of Latvia, was high in comparison to native tree species (Dreimanis, 1995). However, only middle-aged and mature stands were assessed in this study, but not young stands. Due to already occurring changes in climatic conditions, meteorological factors (and periods) notably affecting increment of trees are changing (Jansons *et al*., 2015b), therefore gathering of information about early growth from currently mature trees (using sample tree cutting) is not advisable. In order to improve the knowledge on the potential of beech use in Latvia, the aim of our study was to characterize growth of this tree species in young stands in the central part of our country.

Materials and Methods

A planted stand of European beech (*Fagus sylvatica*) and Norway spruce (*Picea abies*) has been established in the entral part of Latvia on a flat terrain on fertile, well-drained clayey soil *Oxalidosa* forest type. Climate in the study area is mild, the mean annual temperature is ~ +6.1 °C, July is the warmest month, with mean temperature ~ +16 °C, and January is the coldest month, with mean temperature ~ -3.6 °C. The period when the mean daily temperature exceeds 5 °C is ~185 days. Annual precipitation sum is ~ 560. Most of the precipitation falls during summer.

Planting was carried out in spring of 2004 in clearcut using two-year old spruce plants and beech wildlings from natural regeneration under the canopy of beech stand in the western part of Latvia.

The ground was scarified in rows and single-row mixture of beech and spruce was used (one row of beech, adjacent – spruce etc.). Distance between rows varied from 2 to 3 meters (average 2.5 m) and distance between saplings in row was 2.5 meters.

The height and the diameter of breast height (DBH) of each tree on January 2016 were measured for altogether 116 beeches and 124 spruces. For beech the largest radius of crown (as defined by the longest branch) was measured. For spruce height increment of last three years was measured. Increment cores from several trees as close to ground as possible were taken with Pressler borer. In the laboratory, air-dried cores were fixed and gradually grinded (sandpaper roughness 100, 150, 250 and 400 grains per inch). Tree-ring width was measured using LINTAB 5 (RinnTECH) measurement system with the precision of 0.01 mm. There were no signs (like old stumps of young trees) that any pre-commercial thinning has been carried out before.

Significance of differences was calculated using ANOVA.

Results and Discussion

Density of trees was relative, similar to that expected at the particular height in young stands in Latvia for broadleaved trees: 580 ha^{-1} of beech and 620 ha^{-1} of spruce. The survival of beech was 73% and it was similar to that of Norway spruce (78%). A higher survival might be expected as a result of successful plantation; however, this level is also not uncommon in the plantation of native tree species, as reported, for example, for Silver birch in Finland, where survival was on average 82% after 6th growing season and 79% after 11th, and notable and significant effect of timely (and effective) weed control in the first years on this parameter was found (Hytönen & Jylhä, 2005). There was no information on the tending carried out in the studied area, therefore, the impact of it can't be analysed. Even a higher survival (94%) at the age of 8 years had been found in beech provenance trial in Croatia, noting general adaptedness and phenotypic stability of the material (most of the provenances) based on this information (Ivanković, Bogdan, & Božič, 2008).

The average DBH of beech was 8.9 ± 0.68 cm and it significantly exceeded the average DBH of spruce (3.0 ± 0.41 cm) (Fig. 1). Also, the average height of

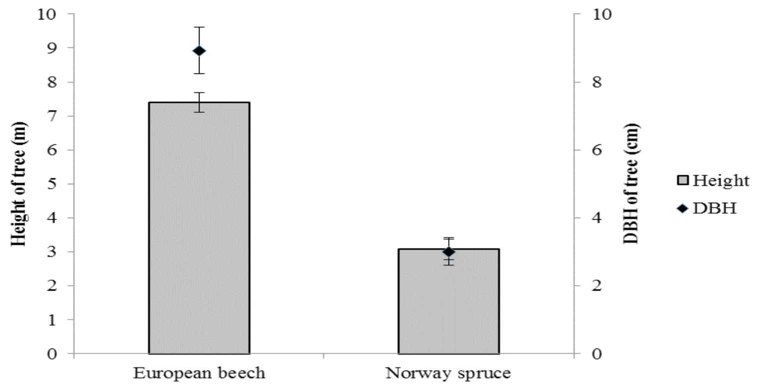

Figure 1. The average height and diameter of breast height (DBH) of European beech and Norway spruce (± confidence interval).

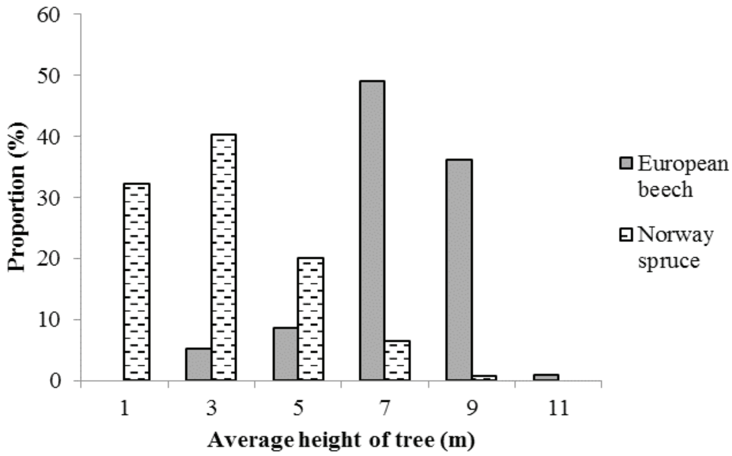

Figure 2. Tree distribution in the height groups.

beech was superior to the average height of spruce (7.4 ± 0.30 and 3.1 ± 0.30 m, respectively). Comparison of height curves of both tree species revealed that spruce with height under 7.5 m had greater DBH than beech. It was in accordance to the expected, since largest (dominant) spruces were compared to suppressed beeches. DBH of beech with height over 7.5 m become notably larger but there were no spruces so high to compare with.

The average values did not reflect the differences between species clearly enough, therefore trees were arranged into height groups (Fig. 2). At the moment in the area dominated beech; most of those had the height of 6.1 to 8 m (49%) and of 8.1 to 10 m (36%) and there was no beech with the height under 2 m. Meanwhile, the majority of spruce had the height of 2.1 to 4 m and of 0.1 to 2 m. Also there were no spruce trees higher than 10 m. Superiority of beech was even more pronounced in diameter the greatest proportion (28%) of beech had DBH from 10.1 to 12 cm while 66% of spruce had DBH less or equal 4 cm. The height of beech varied from 2.5 m to 10.5 m, DBH from 1.1 cm to 15.0 cm, for spruce the height of tree was from 0.5 m to 7.1 m and DBH was from 0.5 cm to 9.2 cm. In the analysis of natural regeneration in canopy opening in beech stand in Latvia Jansons *et al*. (2016) found a notably wider range of heights for beech than for spruce (from 7 to 254 cm *vs.* from 18 to 170 cm, respectively), even so the mean height of both tree species was similar (62 and 64 cm, respectively). Also, in our study the distribution was wider of beech, but presumably due to differences in spacing or competition, the interspecies differences were more pronounced for diameter of trees, than for height.

Annual increment depends both on growth intensity (mm day^{-1}) as well as on the length of the growing period. Notable differences between spruce and beech in the timing of height growth had been observed in Slovakia: height increment of beech trees started earlier than that of spruce, but lasted a shorter time (~45 days vs. ~70 days, respectively); however, the total length of the annual shoot of both species was similar (Konôpka, 2014). In contrast, high importance of determination of the total length of height increment (and therefore growth superiority over other tree species) due to a very long growth period had been found for hybrid aspen (*Populus tremuloides* × *P. tremula*) in Latvia (Jansons *et al*., 2014). Radial and height growth of different tree species often is affected by contrasting meteorological factors, as demonstrated in numerous dendrochronological analyses (Senhofa *et al*., 2016; Matisons *et al*., 2015; Jansons *et al*., 2013a; Jansons *et al*., 2013b). Therefore, the increment might be larger for one species at a particular year and for another – in the next year and it is important to evaluate the total increment over longer time. Overall, a faster growth in young stands, especially after the initial years of establishment, had been found for Norway spruce than for beech, even so beech might outcompete other shade-tolerant species in the situation with limited light availability (Galbraith-Kent & Handel, 2008; Wagner *et al*., 2010). In older stands the productivity of beech might be similar or higher than that of spruce trees in appropriate soil conditions, as found also in the sample plots in beech stands in western Latvia at the age of 115 years, where the height of dominant trees was 34.8 m, basal area 50.5 m^2 and yield 818 m^3 (Dreimanis, 2006).

Since our study site was a mixed stand with not a very high density, it is important to notice the results of meta-analysis of data from beech-spruce mixed stands in Europe: in these stands maximum productivity is reached in lower density than in pure beech or spruce stands (Pretzsch, 2003). Growth of beech can be promoted by admixture of spruce, particularly on fertile sites (Pretzsch *et al*., 2010), but overyielding of mixed stands occurs less frequently on rich sites

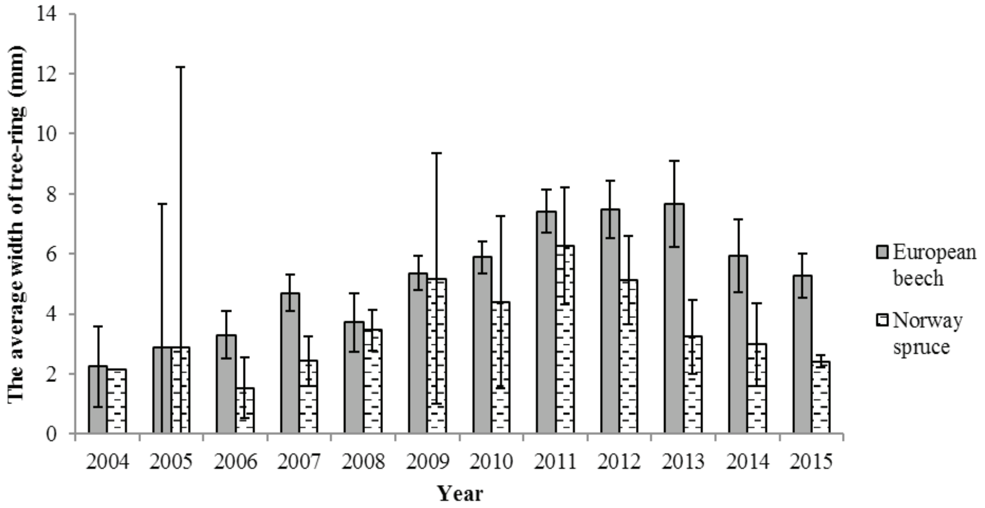

Figure 3. The average width of annual tree ring (± confidence interval) for European beech and Norway spruce.

than on poor and appears to be based on an admixture effect, with spruce reducing the severe intra-specific competition common in pure beech stands (mostly naturally regenerated with high density, that is not the case in our study site).

Differences in growth might be part of the explanation of observed height and diameter superiority of beech in our site. Another potential source is unknown differences in initial tree parameters. Based on analysis of increment cores, the age of beech wildlings varied from 12 to 19 years (on average 15 ± 1.9 years), while the age of planted spruce was 12 years. It means that beech wildings could be higher and with a larger root system at the start that could have caused greater increment in the first years (even so the growth could have been affected by re-planting stress, possible root damages). Nevertheless, due to large initial spacing, the effect of size differences on spruce due to competition most likely was negligible during the first 3-6 years, but might have affected it during later years. It was in line with findings of radial increment analysis (Fig. 3), demonstrating large and increasing superiority of beech over spruce during the last four years (coinciding with the reduction of ring width of spruce) and some growth reduction also of beech during the last two years, most likely due to further intensified competition, since the overall trend of increasing radial increment with increasing age of plantation can be observed and was disrupted. The ring width of the largest cored beech trees also was marginally reduced during the last two years. The width of tree ring for spruce was more varying. The maximal tree ring width for beech was 7.7 ± 1.2 mm, for spruce – 6.3 ± 1.9 mm.

The tendency of height increment of spruce in the last three years was similar to the tendency of

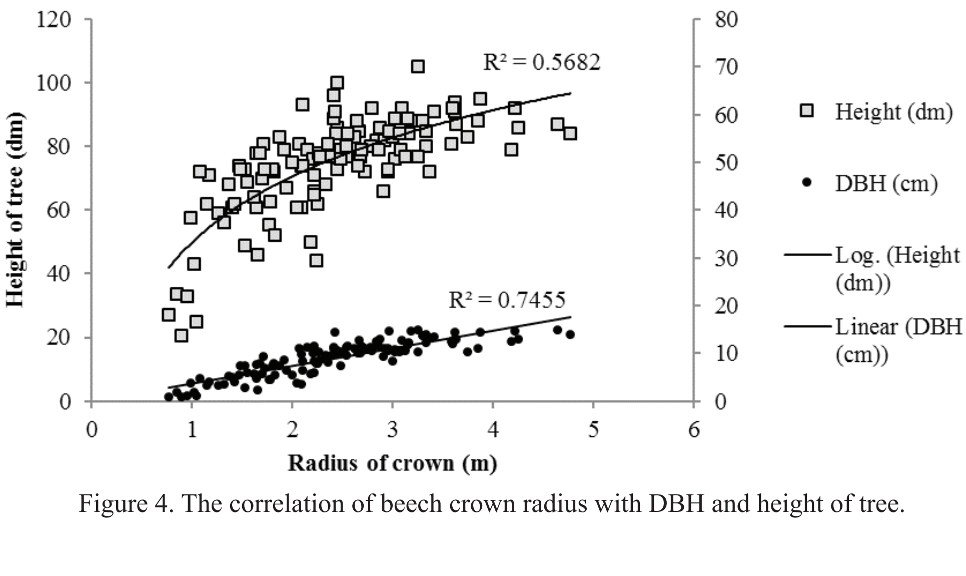

Figure 4. The correlation of beech crown radius with DBH and height of tree.

radial increment – it was slightly, but not significantly decreasing. Presumably, the relatively smaller spruce trees invested most resources into the height increment (retaining it on average 38 ± 2.7 cm – not large for spruce at that age comparing to those which have been measured in tree breeding trials) to catch up with beech and get better light conditions. On average, beech were higher and less affected by competition in the dense stand.

Very intense competition in the stand was demonstrated also by the largest crown radius of beech, reaching on average 2.4 ± 0.16 m, i.e. the distance between the trees in row and between rows. In fact, the number of trees value of this parameter even exceeded 4 m (Fig. 4). The growth of beech trees was notably affected by the length of branches - used as an indicator of crown size, i.e. the total production of organic matter. This parameter had a strong and significant correlation with both the height of the tree and DBH ($r = 0.71$ and $r = 0.87$, respectively).

Our results are in line with findings of other studies, suggesting that both species might co-occur, at least in fertile sites (Madsen & Larsen, 1997; Bolte *et al*., 2007). However, with low initial density beech occupies the area more efficiently, relating long branches and using all the light resources available. The tree species in natural stands adapt in such a way and persist in understorey with limited light for a long period, until a disturbance creates canopy opening and releases its growth (Wagner *et al*., 2010).

Conclusions

1. Survival of European beech in clearcut in mixed stand with Norway spruce was similar to that observed for the native tree species. At the age of 15 ± 2 years the average height of beech trees was 7.4 ± 0.30 m, the average DBH was 8.9 ± 0.69 cm.
2. European beech wildings exceeded the height and diameter of Norway spruce saplings 12 years after planting significantly and notably: by 140% and 196%, respectively.
3. The mean annual radial increment of European beech almost three times exceeded the increment of Norway spruce in the same conditions (0.74 and 0.25 cm per year, respectively).

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