Dendrochronologia 40 (2016) 151–158

Contents lists available at ScienceDirect

Dendrochronologia

journal homepage: www.elsevier.com/locate/dendro

ORIGINAL ARTICLE

High-frequency variation of tree-ring width of some native and alien tree species in Latvia during the period 1965–2009

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ARTICLE INFO

Article history:
Received 7 March 2016
Received in revised form 17 October 2016
Accepted 19 October 2016
Available online 28 October 2016

Keywords:
Radial increment
Climate-growth sensitivity
Multi-species comparison
Introduced species

ABSTRACT

The plasticity of climate-growth relationships of trees is one of the main factors determining the climate-induced changes in forest productivity and composition. In this study, high-frequency variation of tree-ring width (TRW) of four native and three alien tree species and two hybrids of *Populus* L. growing in Latvia (hemiboreal zone) was compared using a principal component analysis based on TRW indices for the period 1965–2009. The effect of climatic factors was assessed using a bootstrapped correlation analysis. Influence of common climatic factors related to the length of the vegetation season, winter temperature, and water regime in summer was traced in the TRW of the studied species and hybrids. The combination and effect of the identified factors differed by species (and hybrids), to a certain extent explaining the diversity of TRW patterns. Nevertheless, some similarities among the species were also observed, suggesting the plasticity of growth response. Scots pine was generally sensitive to winter temperatures, but Norway spruce was mainly sensitive to summer water regime, while black alder was sensitive to winter temperatures and precipitation in spring. In contrast, silver birch showed the lowest sensitivity to the tested climatic factors (demonstrating sensitivity to winter precipitation in a few sites), suggesting tolerance to weather fluctuations. The TRW of the alien species was primarily sensitive to climatic factors related to water regime in the summer of the year preceding the formation of tree-ring, implying differences in mechanisms regulating wood increment. Nevertheless, temperature in the dormant period was significant for European larch in a few sites, suggesting sensitivity to cold damage. The variation of TRW of *Populus* hybrids diverged from others, as their growth was negatively correlated with the temperature in autumn, spring, and summer and positively correlated with water balance. Although the annual water balance in Latvia is positive, the effect of water deficit on tree growth was apparent.

1. Introduction

Considerable shifts in vegetation zones are predicted in response to climatic changes (Hickler et al., 2012) altering forest productivity (Lindner et al., 2010) and leading to economic consequences (Hanewinkel et al., 2012). Such changes already have been explicit in southern margins of the boreal zone, where thermophilic species have gained advantage over species favouring cooler climates, thus shifting stand composition (Goldblum and Rigg, 2005; Kullman, 2008). Hence, adjustments in forest management might be necessary to cope with the shifting conditions and to take advantage of them (Spittlehouse and Stewart, 2004; Kirilenko and Sedjo, 2007). Considering the predicted changes in vegetation zones in Eastern and Northern Europe (Reich and Oleksyn, 2008; Hickler et al., 2012), use of species or provenances suitable for a future climate (i.e., with high ecological plasticity or native to the regions with warmer climates) has been advised as one of the means for maintaining or even increasing forest productivity (Lindner, 2000; Bolte et al., 2009). Still, before applying any changes in policies, the advantages of novel and conventional species should be comprehensively evaluated. For this reason, information about tree growth patterns and sensitivity to climatic factors can be expedient.

Detailed information about tree growth and its reaction to climatic factors can be obtained through a retrospective analysis of increment, which is archived in the wood, e.g., in tree-ring width (TRW) (Speer, 2010). In this respect, trees that are growing near or even outside of their natural (climate-determined) distribution area are considered good indicators of environmental changes due to the expressed effect of limiting factors (Grace et al., 2002; Chmura, 2004; Kullman, 2008). Nevertheless, trees that are growing in the non-marginal parts of the distribution areas are also sensitive to climatic factors, but the influence is more complex

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http://dx.doi.org/10.1016/j.dendro.2016.10.003
1125-7865/© 2016 Published by Elsevier GmbH.

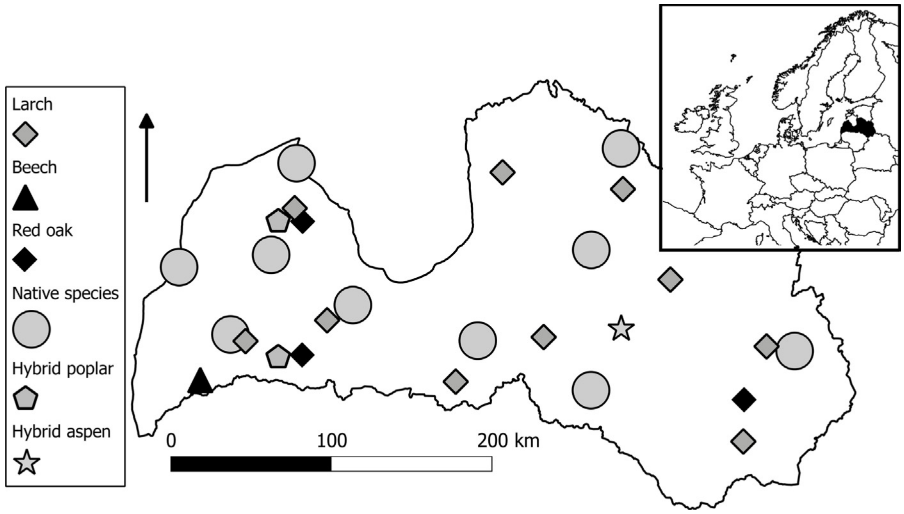

Fig. 1. The location of the studied stands of Scots pine, Norway spruce, silver birch, black alder, European larch, red oak, European beech, hybrid poplar, and hybrid aspen. The circles represent the locality of the sampled stands of native species (Scots pine, Norway spruce, silver birch, and black alder).

(Wilson and Elling, 2004; Friedrichs et al., 2009). Hence, the analysis of increment and its relationships with climate might be used to assess the growth potential of different species (Stott and Loehle, 1998; Scheller and Mladenoff, 2005). The effect of climate and its changes on tree growth may vary regionally or even locally (Wilmking et al., 2004; Lindner et al., 2010); therefore, wide spatial extrapolation of such knowledge might be misleading, and local information is needed.

Latvia is located in the hemiboreal zone (Sjors, 1963), and more than half of its territory is covered by forests, which are often mixed. According to the data from the National Forest Inventory, at present, Scots pine (*Pinus sylvestris* L.), silver birch (*Betula pendula* Roth), Norway spruce (*Picea abies* H. Karst.), Eurasian aspen (*Populus tremula* L.), and black alder (*Alnus glutinosa* Gaertn.) are the most common and economically important tree species that occur in the mid-part of their distribution areas (EUFORGEN, 2009). Still, considerable changes in forest growth and species composition (i.e., expansion of the deciduous trees) is expected during the 21st century (Reich and Oleksyn, 2008; Hickler et al., 2012). Hence, the native deciduous and introduced southern species might already have some advantages over the native conifers.

Several introduction experiments have been established since the 19th century in Latvia (Laiviņš et al., 2009). European larch (*Larix decidua* Mill.) is the most commonly introduced tree species (ca. 1100 ha), which occurs north of its natural range (EUFORGEN, 2009). Red oak (*Quercus rubra* L.), which is native to central regions of North America, where the climatic conditions are comparable with Latvia (Sander, 1990), has been planted on ca. 50 ha, particularly since the 1960s. European beech (*Fagus sylvatica* L.) has been planted since the 1870s, and at present, occupies ca. 40 ha, particularly in the western part of Latvia, which, at present, comprises the north-easternmost beech stands in Europe (Bolte et al., 2007). The growth of these species has not been suppressed and successful self-regeneration has been observed (Laiviņš et al., 2009). Several plantations of hybrid aspen (*Populus tremuloides* Michx. × *P. tremula* L.) and hybrid poplar (*Populus balsamifera* L. × *P. laurifolia* Ledeb.) have remained as the long-term experiments since the 1960s (Mangalis, 2004).

The aim of the study was to assess the similarity of the high-frequency (i.e., annual) variation of TRW of the most common native and introduced tree species and hybrids, and to characterise their sensitivity to climatic factors during recent decades, when climate change has been accelerating. We hypothesised that species and hybrids express specific variation of TRW due to distinct ecological demands, and hence sensitivity to diverse climatic factors; yet, some common variation in TRW might be imposed by the changing climate.

2. Material and methods

2.1. Datasets

The studied datasets consisted of the time series of TRW (measured with the accuracy of 0.01 mm along two opposite radii) representing stem increment at 1.3 m height of the four most common native tree species (Scots pine, Norway spruce, silver birch, and black alder), three alien tree species (European beech, European larch, and red oak), and two hybrids of *Populus* L. (hybrid poplar and hybrid aspen). The native species were sampled in stands in 10 localities, and European larch was sampled in 11 stands that were regularly distributed across the country (Fig. 1). The number of the sampled stands of other alien species and hybrids was lower (Table 1), and they were distributed irregularly (Fig. 1). In each stand, 10 to 25 dominant trees were sampled. Stands of pine, spruce, birch, and larch were growing in dry mesotrophic sites on sandy or silty soils. Beech, red oak, and *Populus* hybrids were growing in dry fertile sites on silty soils, but alder was growing in periodically (in spring) waterlogged sites (particularly in depressions). The topography of all sites was flat. The elevation of the studied stands was low, ranging from 10 to 190 m a.s.l. The age of the studied trees, as determined from the collected wood samples, predominantly ranged from 70 to 110 years, except for beech and *Populus* hybrids, which were younger (45–70 years), and larch, which was older in a few stands (Table 1). The climate was temperate continental (Lindner et al., 2010); yet, the continentality increases in the eastern direction with the growing distance from the Baltic Sea. The mean annual temperature during the recent four decades was 6.7, 6.6, and 5.7 °C and the mean annual precipitation was 720, 640, and 610 mm in the western, central, and eastern part of Latvia, respectively. January and July were the coldest and the warmest months, respectively. The highest monthly precipitation occurred in summer months (Fig. 2). The vegetation period, when the mean diurnal temperature exceeds +5 °C, extended from mid-April to October; however, it was usually 10–15 days longer in the central part of Latvia. The climatic changes were mainly expressed as the increase of mean annual temperature (Lizuma et al., 2007),