INFLUENCE OF ALTERED PRECIPITATION REGIME ON MORPHOLOGY OF SAPLINGS OF SCOTS PINE AND SILVER BIRCH

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Abstract
Prolonged summer drought periods are forecasted for the Baltic Sea region during the 21st century, thus increasing the risk of drought stress of saplings used in forest regeneration. Nevertheless, the vitality of young stands might be increased by the selection of suitable planting material. The aim of this study was to estimate the effect of changes in distribution of summer precipitation on height increment, biomass distribution and root morphology of Scots pine and silver birch planting material commonly used in the forest regeneration in Latvia.
Containerized pine and bare rooted birch saplings, planted in three different soil types, were subjected to altered distribution of summer precipitation, provided by the use of automated shelter. Sheltered saplings were weekly irrigated with the sum of precipitation of a corresponding period, while afield planted saplings had an unchanged precipitation regime and served as control. Height increment was measured once per week and estimation of morphology of saplings was done after the end of every vegetation season.
Significant ($p<0.05$) differences in height increment, and shoot and root biomass were observed among the same planting material in different irrigation regimes and soil types. In the control plots of peat soil, pine had a significantly ($p<0.05$) larger height increment while birch-significantly ($p<0.05$) smaller compared to experiment. Forecasted longer drought periods might reduce the growth of Scots pine in fertile forest types but silver birch growth might be affected in fertile mineral soils in future.
Key words: water deficit, altered distribution of precipitation, biomass distribution.

Introduction

The shift of climatic zones northwards for 272-645 km (Ohlemüller *et al*., 2006) and transformation of forest ecosystems (Hickler *et al*., 2012) is forecasted for Europe as a result of global climate change in future. Till the end of the century, the north part of Europe and Baltic Sea region will experience an increased mean air temperature of 3.2 °C and more frequent periods (≥10 days) without precipitation; however, the amount of precipitation will remain the same as nowadays (Jansons, 2010; IPCC, 2014; Palmer, 1965).

An increase of mean air temperature in combination with longer meteorological drought periods intensifies evapotranspiration causing drought stress and hindering growth of saplings (Xu, Zhou, & Shimizu, 2010). During the vegetation period in the Baltic Sea region, insufficient soil moisture can be a limiting environmental factor for survival of saplings used in forest regeneration, particularly for the first year plantations (Dinger & Rose, 2009; Haase & Rose, 1993; Jansons *et al*., 2013; Matisons, Elferts, & Brūmelis, 2012; Possen *et al*., 2011; Rolando & Little, 2008; Thomas, 2009; Vegis, 1964).

Research on the effect of changes in distribution of summer precipitation on growth and vitality of Scots pine (*Pinus sylvestris* L.) and silver birch (*Betula pendula* Roth.) has not been done, although, both species have different levels of drought tolerance (Cregg & Zhang, 2001; Possen *et al*., 2011) and high economic importance in Latvia. Such experiments can provide us with a crucial information about the potential effect of future climatic changes. Therefore, the aim of this study was to assess the effect of changes in distribution of summer precipitation on height increment, biomass distribution, and root morphology of Scots pine and silver birch planting material commonly used in forest regeneration in Latvia.

Materials and Methods

The study was carried out during 2013 and 2014 in the central part of Latvia in Vecumnieki (24º29´44E, 56º37´51N). The location of the site corresponds to mean level of continentality of Latvia (Draveniece, 2007; Klavins & Rodinov, 2010). In both seasons, July was the warmest and driest month when the mean air temperature reached 17.9 and 19.4 °C; whilst monthly sums of precipitation were 32.2 and 21.3 mm in 2013 and 2014, respectively. In July 2014, 24 days without precipitation were observed, while only 17 precipitation-free days occurred in 2013. The longest continuous precipitation-free periods were 9 and 10 days in July 2013 and 2014, respectively (Figure 1).

The study was an experiment aiming to assess the effect of precipitation regime on the growth of pine and birch saplings. Containerized Scots pine and bare rooted (PLUG+1) silver birch saplings, obtained from commercial nurseries, were planted in six blocks (10 m^2) filled with three different soils-fertile mineral soil from *Hylocomiosa*, peat soil from *Myrtillosa turf. mel.* and poor sandy soil from *Cladinoso-callunosa* stands. Three blocks were subjected to altered irrigation while other three received natural

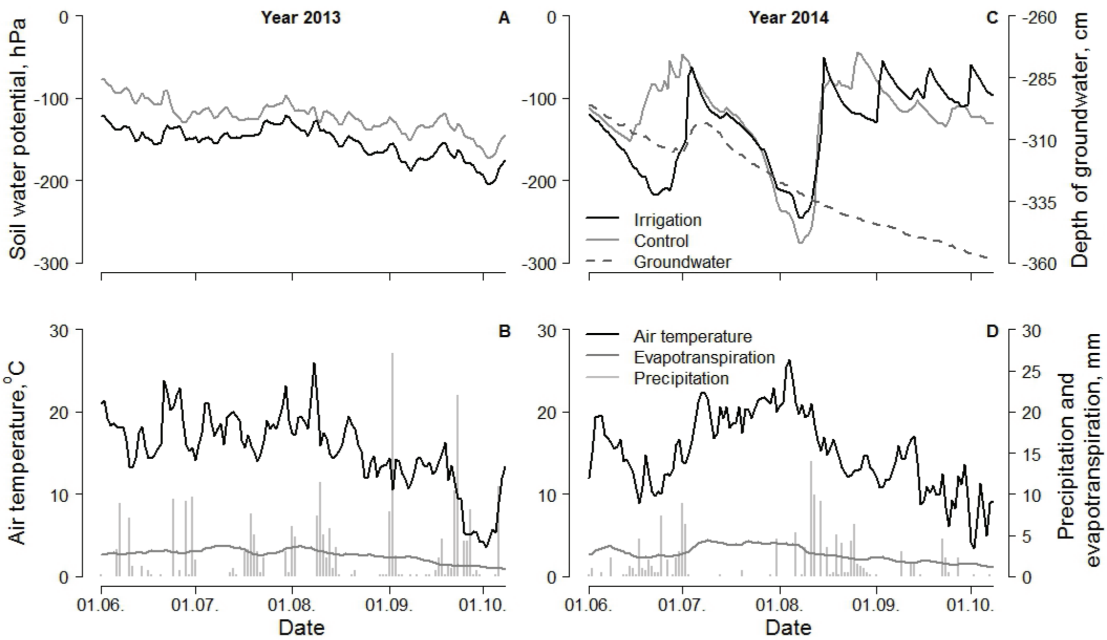

Figure 1. Daily average soil water potential in the depth of 0,5 m (A, C), depth of groundwater (C), daily average air temperature, evapotranspiration and daily sum of precipitation (B, D) in 2013 and 2014 (Krišāns *et al*., 2015).

precipitation as control, obtaining six combinations: fertile mineral soil with irrigation (FMW) and control (FMC); peat soil with irrigation (PEW) and control (PEC); and poor sandy soil with irrigation (PSW) and control (PSC). To prevent root competition and mechanical damage during excavation, each sapling was planted in geotextile bucket (volume = 10 l). Perimeter of each block was sealed with hydro isolation to avoid horizontal movement of soil water. Saplings were grown for one vegetation season.

The precipitation regime was altered by interception of natural precipitation and controlled irrigation. Automated polycarbonate shelter (81% transparency of visible light) controlled by rain sensor Rain-Click (Hunter Industries, Inc.) was used. The saplings were irrigated regularly - once per week in 2013 and once per 10 days in 2014. The amount of water supplied was the same as the natural precipitation in the respective period.

The height of saplings was measured after the plantation and before harvesting. In autumn, entire plants were harvested, roots were washed from soil. In the laboratory, above-ground and below-ground parts of saplings were separated, dried for 72 hours in 105 °C until constant mass and weighted with the precision of 0.01 g. Root morphometric parameters of Scots pine saplings grown in 2014 were measured with WinRHIZO (Regent Instruments Inc.). Meteorological parameters were monitored in the study site using Wireless Vantage Pro2 (Davis Instruments) weather station. Soil water potential at 0.5 m depth in each block was measured by T8 (UMS GmbH) tensiometers. Ground water level and temperature was recorded by Mini-Diver (Schlumberger Ltd.) sensor.

For each sapling, absolute and relative height increment was calculated. To characterize biomass allocation, shoot/root ratio (SRR) was calculated. The differences of height increments, root morphometric parameters and biomasses among irrigation treatments and soil types were analysed by two-factor analysis of variance (ANOVA) using Tukey's HSD post-hoc test. The linear relationships between different sapling parameters were quantified by Pearson correlation analysis.

Results and Discussion

Changed distribution of summer precipitation did not affect the survival of pine and birch saplings during the study. Soil water deficit develops when the soil water potential drops below soil field capacity which for most of peat and mineral soils is between 100 and 330 hPa (Lambers, Chapin, & Pons, 2008; Parr & Bertrand, 1960; Ritchie, 1981). During the study, soil water potential did not fall below this level in any treatment combination. The dynamics of soil water potential differed between both studied periods (Figure 1). Compared to 2013, the soil water potential had a higher variation for both irrigation treatments in 2014, which can be explained by longer precipitation-free and inter-irrigation periods. Due to low daily precipitation and high air temperature, water from soil surface evaporates faster than during the irrigation

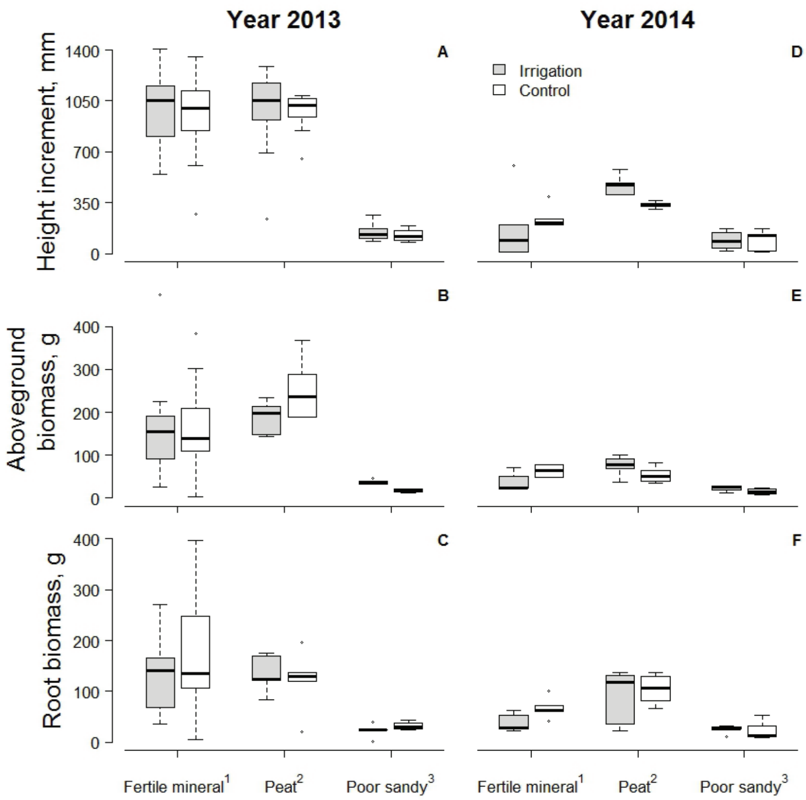

Figure 2. Height increment (A, D), above-ground (B, E) and below-ground biomass (C, F) of saplings of silver birch in all treatment combinations in 2013 and 2014 (1 – *Hylocomiosa*, 2 – *Myrtillosa turf. mel*., 3 – *Cladinoso-callunosa*).

when larger amount of water is supplied, providing deeper infiltration (Parr & Bertrand, 1960). This explains a lower soil water potential in the control in July 2014.

Both species had significantly ($p<0.05$) larger annual height increments and biomasses in fertile mineral and peat soils compared with poor sandy soil for both studied periods (Figure 2 and Figure 3). Maximum height increment for birch reached 1400 and 605 mm in 2013 and 2014, respectively; whilst maximum height increment of pine was 280 and 330 mm, respectively. Differences in height increments between moisture regimes were not significant ($p<0.05$) for both species in 2013. However, in 2014, significantly ($p<0.05$) larger height increments and above-ground biomasses for birch were observed in FMC compared with FMW. Surprisingly, the opposite was observed for birch in peat soil, where height increment and above-ground biomass were significantly ($p<0.05$) larger in the irrigated treatment (Figure 2). Pine saplings planted in peat had significantly ($p<0.05$) larger height increment and root biomasses in control than in irrigation, although above-ground biomasses were significantly ($p<0.05$) larger in irrigation. In fertile mineral soil, both biomasses of pine from control were significantly ($p<0.05$) larger compared with irrigation; however, height increment did not differ significantly ($p<0.05$). The only differences of morphometric parameters between irrigation regimes of pine saplings in 2013 were for root biomass in poor sandy soil (Figure 3).

In the control plots, Scots pine saplings had larger relative height increments compared with irrigated ones in all soil types. In fertile mineral soil, the difference was significant ($p<0.05$), reaching 151% and 130.1% in control and irrigation, respectively. In poor sandy soil, initially significantly ($p<0.05$) smaller control saplings had larger relative height increment compared with the irrigation treatment (108.7% and 98.6%, respectively) (Figure 3 and Figure 4). In peat soil, pine saplings of the control plots had a larger relative height increment (146.6%) compared to irrigation (128.2%); however, differences were not significant ($p<0.05$). Birch saplings had significantly ($p<0.05$) smaller relative height increments compared to pine. Additionally, the only significant ($p<0.05$) difference was observed between PEC (49.1%) and PEW (66.4%); however, in other soil types, the control saplings had a larger relative height increment.

It has been shown that moderate water deficit may stimulate the formation of root biomass, increasing fine root surface area and depth, reaching water

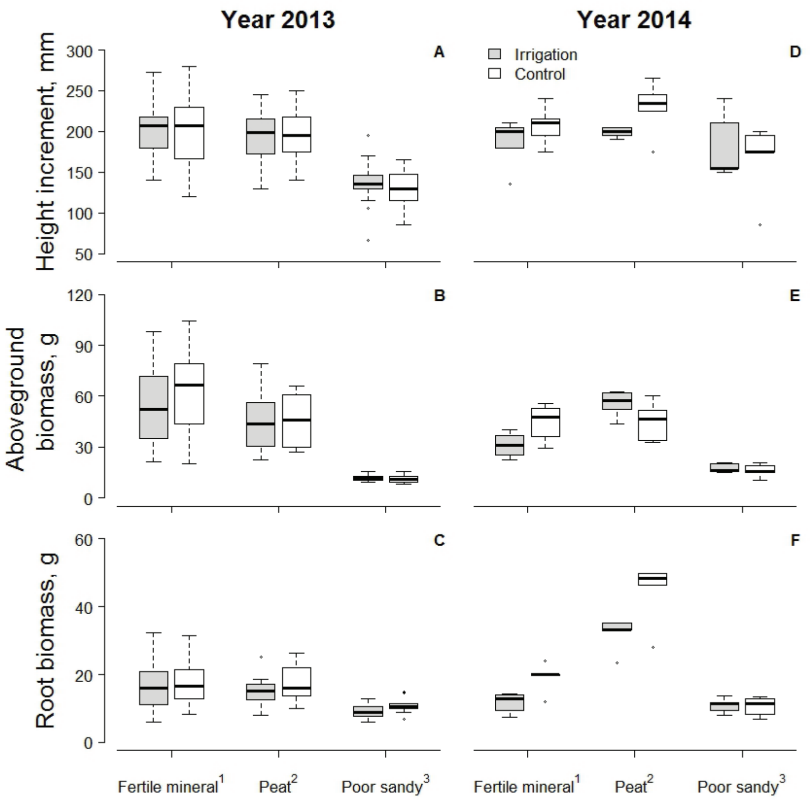

Figure 3. Height increment (A, D), above-ground (B, E) and below-ground biomass (C, F) of Scots pine saplings in all treatment combinations in 2013 and 2014 (1 – *Hylocomiosa*, 2 – *Myrtillosa turf. mel.*, 3 – *Cladinoso-callunosa*).

in deeper soil layers (Grossnickle & Blake, 1987; Lambers, Chapin, & Pons, 2008); whilst formation of an above-ground biomass could be ceased. Such phenomena have been observed for Norway spruce saplings in a similar experiment (Krišāns *et al*., 2015); however, pine and birch saplings did not have such a tendency in this study (Figure 2 and Figure 3). Moreover, saplings with larger height increments had larger root biomass indicating better growth in both treatments (Figure 2 and Figure 3).

The SRR can be used to characterize distribution of above-ground (water transpiring) and root (water absorptive) biomasses (Pallardy, 2008), hence drought adaptive strategies (Bernier, Lamhamedi, & Simpson, 1995). In our study, mean SRR values for pine saplings were 2.7 and 2.73 in 2013 and 2014, respectively, whilst for birch only 2.06 and 1.31, respectively. These results correspond with differences in biomasses and height increments between the study years (Figure 3). Lower values of SRR means a potentially higher drought tolerance (Maass *et al*., 1989; Bernier, Lamhamedi, & Simpson, 1995), as water absorptive surface is larger than transpiring. The SRR values compared with the height increment and the initial height of sapling before planting describes the potential susceptibility of the planting material to drought. Significant ($p<0.05$) Pearson correlation between SRR and height increment was observed only for pines in both treatments ($R^2 = 0.38$; $p<0.001$ and $R^2 = 0.12$; $p<0.05$ in control and irrigation, respectively) in 2013 (Figure 5). Hence larger and faster growing saplings might be affected by drought more severely, particularly, in the first vegetation season after planting. Relation between SRR and the height of pine sapling before planting ($R^2 = 0.38$; $p<0.001$ in both control and irrigated plots) was similar. Hence the initial height of containerized Scots pine saplings apparently is not related with susceptibility to water deficit during the first season after planting.

Significant ($p<0.05$) differences in morphology of Scots pine roots were observed (Figure 6) between both treatments. In both peat and fertile mineral soils, saplings from the control treatments had significantly ($p<0.05$) larger roots compared to irrigation treatment. Only the root volume and projected area of roots did not differ significantly ($p<0.05$) between the treatments in fertile mineral soil. Yet, on mineral soils, root parameters between treatments were similar ($p>0.05$). Mean values of root morphological parameters from PSC were larger than PSW, although the initial height of pine saplings before planting was significantly ($p<0.05$) larger in PSW, suggesting faster

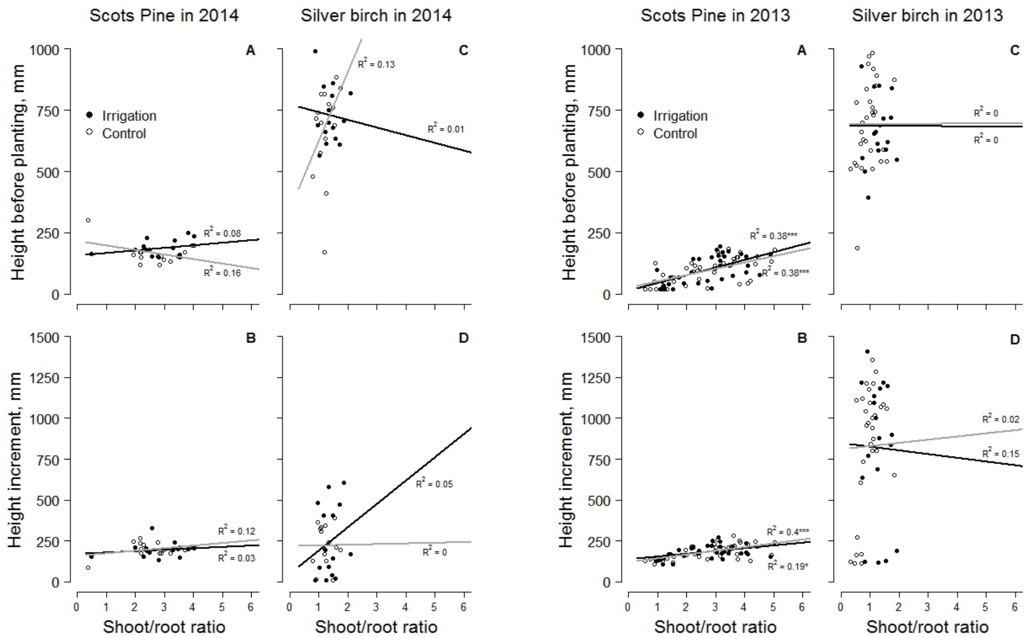

Figure 5. Relation between shoot-root ratio of saplings (Scots pine - A, B; silver birch - C, D) and the height of saplings before planting and height increment in all treatment combinations in 2013 and 2014. Significance of correlation coefficients – p – value <0.05 (*), <0.01 (**), <0.001 (***)).

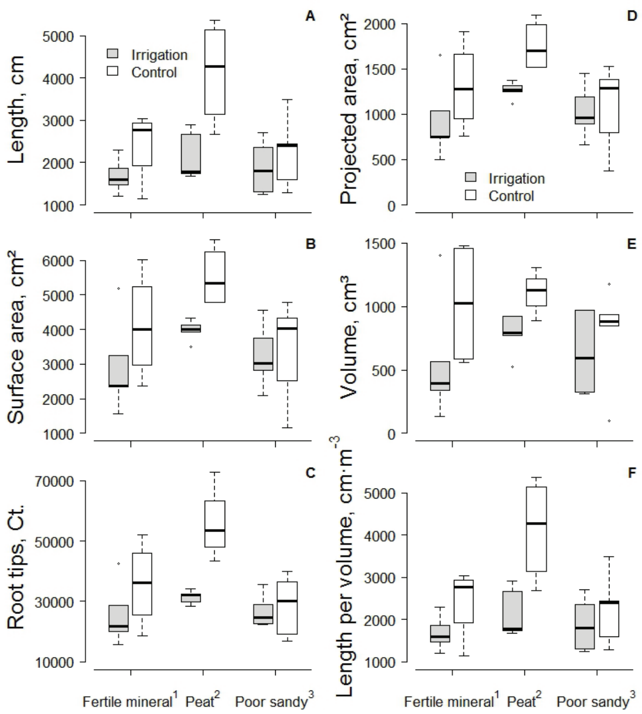

Figure 6. Total length (A), surface area (B) count of tips (C), projected area (D), volume (E) and length per volume of roots (F) of pine saplings in all treatment combinations in 2014 (1 – *Hylocomiosa*, 2 – *Myrtillosa turf. mel*., 3 – *Cladinoso-callunosa*).

growth of Scots pine saplings under more frequent precipitation regime. Significantly ($p<0.05$) larger total lengths and numbers of root tips in peat soil can be explained by a higher soil porosity and higher field capacity facilitating root distribution.

The results of this study showed a significant ($p<0.05$) negative effect of altered distribution of summer precipitation on growth of containerized Scots pine saplings. Significantly ($p<0.05$) larger relative height increments of pine saplings in control plots indicate disturbed growth under extended precipitation-free periods. Although containerized saplings from commercial nurseries have noticeable reserves of nutrients, soil fertility had a significant effect on growth as shown by differences in increment among different soils. Also, soil fertility had mediating effect on susceptibility to precipitation regime, as the differences (absolute and relative) between the irrigation treatments were greater in fertile soils.

Conclusions

1. Altered distribution of summer precipitation that corresponds to RCP8.5 global climate change scenario did not affect the survival of saplings of Scots pine and silver birch. Although the altered precipitation regime decreased height increment of containerized Scots pine saplings, the opposite was observed for silver birch, particularly on peat soil, suggesting positive effect of less frequent but stronger precipitation.
2. Containerized Scots pine saplings develop significantly ($p<0.05$) larger total root biomass in a peat compared to mineral soils under natural precipitation regime; however, surface area and total root volume did not differ significantly ($p<0.05$) between soil types.

Acknowledgement

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