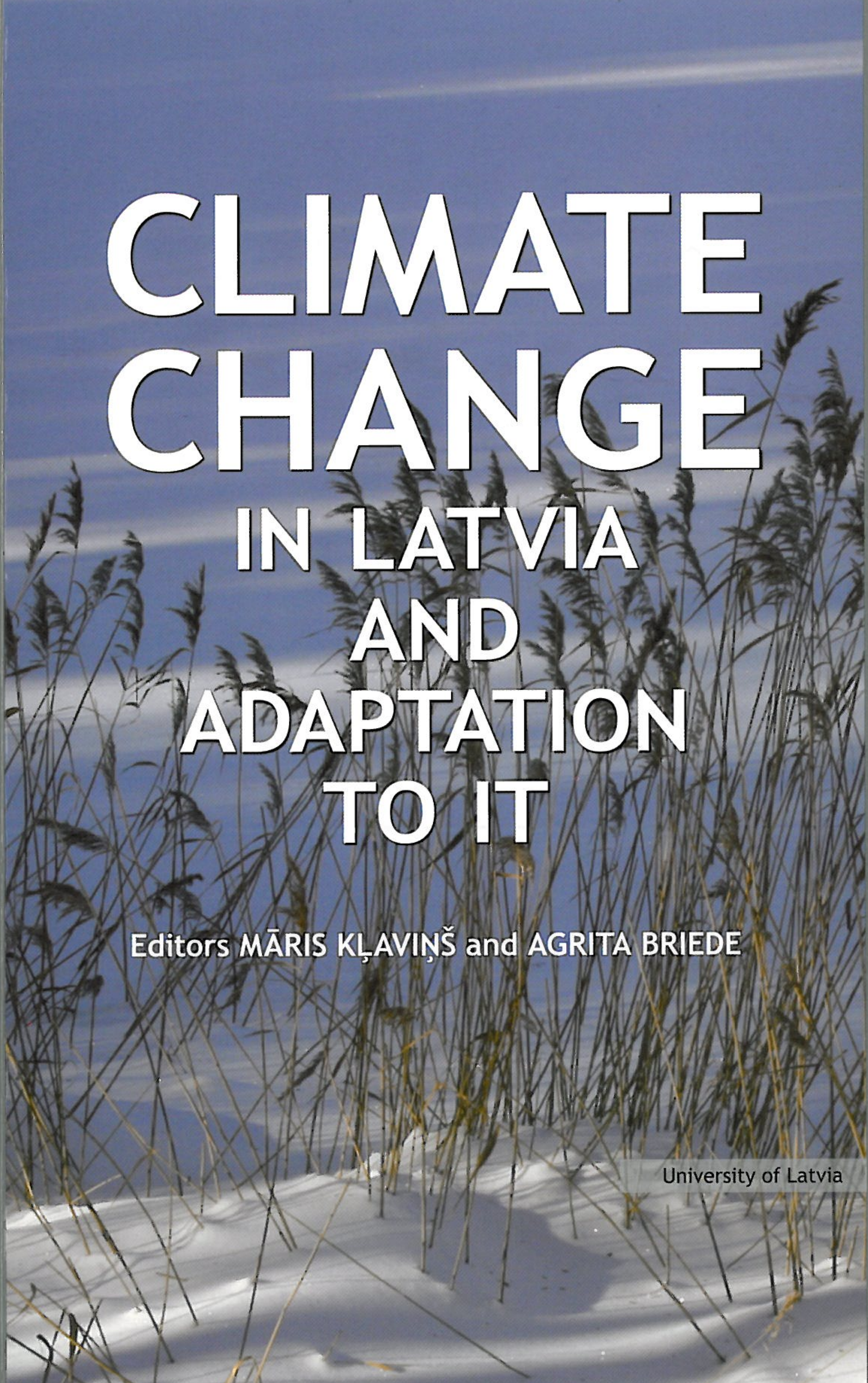

CLIMATE CHANGE IN LATVIA AND ADAPTATION TO IT

Editors MĀRIS KĻAVIŅŠ and AGRITA BRIEDE

University of Latvia

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Foreword

Climate change is happening! Of course discussion on its driving forces is continuing, but the fact itself is impossible to deny. Manifestations of climate change and climate variability might be very diverse and much should be done to identify their consequences and further to model possible changes in future. This book is an attempt to sum up research done in Latvia on climate change and climate variability character and impacts to give an contribution to understanding globally ongoing processes. However with studies of climate change and climate variability character and modelling of their character in future it is not enough. Impacts of climate change and climate variability are inevitable and the only way how to reduce adverse consequences is to adapt to climate diversity. In respect to some manifestations of climate change and climate variability adaptation need and approaches are relatively well known, as it is in case for adaptation to flood protection. For many other manifestations of climate change and climate variability adaptation solutions still have to be sought, but also dimension of ongoing climate change puts forward a need to revise existing concepts and approaches how to adapt to changes. Thus, for solving of possible and unavoidable problems a research is needed how to adapt to them. Another aim of this book is to look on ways how the adaptation to climate change and climate variability can be pursued.

Agrita Briede and Māris Kļaviņš

Tree Breeding as a Tool to Minimize Possible Adverse Effects of Climate Changes on Forest Trees

Āris Jansons
Latvian State Forest Research Institute "Silava",
Rigas str. 111, Salaspils, Latvia, LV-2169,
E-mail: aris.jansons@silava.lv

Abstract
Adaptation to changing climatic conditions is crucial to ensure survival and vitality of forest stands. Data about adaptive traits for the study were gathered in four open-pollinated progeny trials in the central part of Latvia at the age of 5 to 8 years. Significant differences between families were found in resistance against adverse effects, predicted to increase with climate change: needle cast damages and lammas growth. Provenance and family was a significant factor, determining tree growth and quality independently of geographic distance between them within Latvia. Tree breeding provides opportunity for significant improvement of adaptive traits without compromising other traits.

Keywords: adaptation, lammas growth, needle cast, provenance regions

INTRODUCTION

Forest tree breeding has been carried out in Latvia since year 1957 (Gailis et al. 1973). Productive and qualitative stands have been selected and tallest trees without defects (so called plus-trees) within those stands chosen for grafting in seed orchards and establishment of provenance and progeny trials. Based on the results of these trials it became clear: even if the territory of Latvia is small and differences in climatic conditions not pronounced, these differences has affected and is affecting the growth traits of trees. For example Scots pine provenances from the eastern part of Germany demonstrates higher productivity than pines of local origin in trials located in a coastal western part of Latvia, differences levels out in trial in the central part of Latvia, but in eastern part of Latvia pines from Germany have notably lower productivity than local ones (Jansons, Baumanis 2005).

Climatic changes of similar or larger magnitude as presently observed in Latvia are predicted in the future (Bethers, Seņņikovs 2007; Jansons 2010) resulting, among others, in increased length of vegetation period and milder winters. Such conditions are predicted to have not only direct influence on tree phenology and possible damages by abiotic factors, but also indirect effects on forest stands, for example, by creating favourable conditions for spread and development of pathogenic fungi or insects.

Trees as organisms with long life span are capable to adapt and withstand influence of different stress factors. For example 80 year old Scots pine trees survives and recovers even from a complete defoliation in a few years (mits et al. 2008). However, at young age trees are sensitive to impact of various factors, including diseases (for example needle cast) and insect damages (for example pine weevil) that are capable to markedly influence survival and success of regeneration. Notable differences in resistance against those biotic factors among tree genotypes can be found and this trait has rather high heritability, as demonstrated for example, by Zas et al. (2005, 2008) in case of resistance of tree species of Pinacea against *Hylobius abietis* damages.

Most of the natural selection takes place early in the tree life span. Even in rather favourable conditions only 5-10% of all seeds, which sprouts, survive until the age of 4-5 years (Mangalis 2004). If the aim is to ensure adaptability and vitality of forest stands in future conditions, focus shall be on this phase of the tree life cycle.

Growth rhythm of trees is under strong genetic control and is closely linked to the occurrence of frost damages, high frequency of ramicorns, lammas growth in situations where the genotype does not fit into the climatic conditions (Ekberg et al. 1984; Hannertz et al. 1999). Considering the fast rate of changes in climatic conditions, frequency of the above-mentioned damages can be predicted to increase in future, leading to deterioration of tree quality and lower survival of young stands at first years. Evidence of possible consequences can be found in the conditions, where re-colonization after the last glacial period happened most recently, like in the northern part of Scandinavian countries. In these areas local tree populations still has not completely adjusted their growth rhythm (Luomajoki 1993; Persson, Ståhl 1990) and flowering phenology (Luomajoki 1993) to the local conditions.

Aim of the study: assess the possibilities to improve adaptive traits of forest trees at the early stages of their growth. In order to reach the aim three different case studies are carried out, providing information about resistance against needle cast of Scots pine, lammas growth of Norway spruce and influence of seed transfer on growth of Silver birch.

MATERIALS AND METHODS

All research work is based on the analysis of differences among open-pollinated families (family – group of progenies of the same mother tree) in progeny trials.

Needle casts (*Lophodermium seditiosum* Minter, Staley & Millar) damages were assessed in two progeny trials of Scots pine plus trees originating from several locations (number of families in brackets): Misa (46), Smiltene (6), Baldone (4), Zvirgzde (2) and Kalsnava (2). For establishment of trial seed material was collected both directly from the original plus trees in the stands and from their clones in the seed orchard. Trials were planted in spring of year 2006 with one year old seedlings in clear cuts of old Scots pine stands a in dry sandy soil (*Mirtyllosa* forest type), located in the central part of Latvia in vicinity of Ogre (trial No 352) and Daugmale (No 441). Both trials are surrounded by Scots pine stands of different age and located no more than 20km apart. Distance between trees in a row 1.5m, between rows 2m. Families were distributed randomly in 4 replications (trial No 352) or 8 replications (trial No 441) using 28 (7×4) or 10 (5×2) tree block plots respectively.

Needle cast damages in trials were first detected in year 2008 and assessed in June of year 2009. Needles are infected by the disease in early autumn, but damages becomes visible (needle color turns brown) in the mid of next summer, therefore the assessment of the damage grade was done on shoots of the year 2008. Five grades were used for assessment, where grade 1 coincides with – 0% to 5% damaged needles, 2 – 6–35%, 3 – 36-65%, 4 – 66–95% and 5 – 96–100%. Trees from 4 replications, not shorter than 10 cm, were assessed in each trial. Tree height and height increment were also measured.

Lammas growth – the development of second height increment at the end of vegetation period – was assessed during 6th growing season in Norway spruce experiment No 74, located in the central part of Latvia close to Jelgava. Trial was planted in *Hilocomiosa* forest type and consists of 60 open pollinated families, randomly distributed in 4 replications, initial spacing 2×3 m. Lammas grows was registered on average on 20 trees per family, not shorter than 80 cm and without animal damages. Height and height increment were measured during the vegetation period with a frequency once per week on the average.

Effect of seed transfer on the tree growth was analyzed in silver birch progeny trial (experiment No 34), established in spring of year 1999 using one year old containerized seedlings. Seeds for the experiment have been collected in years 1995 and 1996. Superior stands have been selected based their growth characteristics from Sate forest register database and based on growth and quality in following inspection in the field. Superior trees and plus trees have been selected within these stands for seed collection. Altogether 25 provenances (geographic locations of seed collection), distributed across Latvia (covering all climatic variations from east to west and from south to north) were used in the trial, but the analysis covers only 21 provenance, represented by at least 8 families (26 families on the average). Families were distributed randomly in 4 replications using 32 (8×4) tree block plots. Trial has been established in a former arable land in the central part of Latvia in vicinity of Rembate, initial spacing 2×2 m (2500 trees ha^{-1}) and measured at the age of 8 years.

RESULTS

Needle cast damage grade varied notably and significantly between the trials, reaching 2.0 ± 0.05 in experiment No 352 and 3.5 ± 0.07 in experiment No 441. Family was a significant factor affecting grade of needle cast damages in both trials. Selection of 20% least affected families would result in a notable improvement: in this group average damage grade was 1.7 in the experiment No 352 and 3.1 in the experiment No 441. Least damaged families differed slightly among the experiments (family mean correlation $r = 0.40$, $p = 0.01$); however, none of the least damaged families in one experiment was among the most damaged in other.

Survival in Scots pine trial No 441 at the end of the first growing season in the field varied among families from 78% to 100%. At the age of 5 years survival ranged from 55% to 99% (average 83%) in the trial No 441 and from 72% to 100% (average 92%) in the trial No 352. Family mean correlation between the needle cast damage grade and survival at the beginning and end of the year was negative and significant in the trial No 441 ($r = -0.36, p = 0.01$), but week and insignificant in the trial No 352 ($r = -0.13$).

Tree height and height increment of the year 2009 differed significantly between sites and was 61.6 cm and 45.7 cm in the experiment No 352 and 36.8 cm and 22.3 cm in experiment No 441 respectively. Family was a significant factor affecting both tree height and length of annual increment. Family mean and rank correlation for tree height among experiments was significant in years 2008 and 2009 ($r = 0.38$ and $r = 0.40, p = 0.01$ respectively), but decreased in year 2010 ($r = 0.26, p = 0.05$).

Family mean correlation between the tree height at the beginning of year 2009 and the needle cast damage grade (Fig. 1) was weak and insignificant in the experiment No 352 ($r = -0.12$), but significant in the experiment No 441 ($r = -0.36$, $p = 0.01$). In trial No 441 in year 2008, when the disease was first detected there, correlation between the damage grade and height at the beginning of the year was also weak and insignificant ($r = -0.14$).

Family mean correlation between the needle cast damage grade and height increment of the same year was relative strong, but notably stronger and significant with the height increment of the following year in both experiments ($r = -0.53, p = 0.01$ on the average).

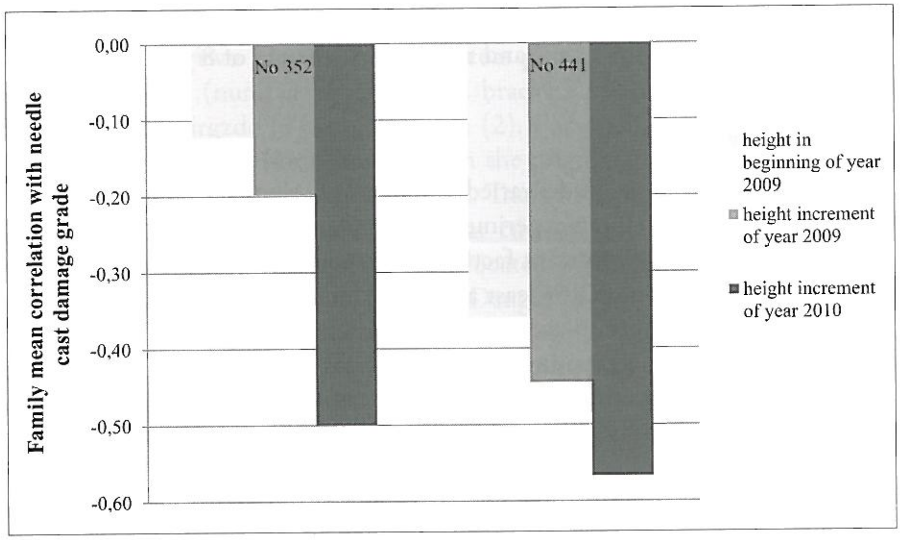

Figure 1 **Family mean correlation of needle cast damage grade and growth traits**

Lammas growth has been detected for 8% of trees on the average in the Norway spruce trial No 74. Proportion of trees with lammas growth in a family varied widely from 0 to 42%. The average proportion of trees with lammas growth reached 36% in the group of significantly (p = 0.05) most affected families (8% from the total number) These families were evenly distributed across the experiment; no trend of clustering could be detected.

At individual tree level lammas growth was not related to the tree height at the beginning of vegetation period or length of height increment. The same was true for the proportion of trees with lammas growth at the family mean level. There was also no correlation between the length of used vegetation period (active growth period till the bud-set) and proportion of trees with lammas growth.

Results suggest, that the relationship between lammas growth and other growth traits is relatively weak and it is possible to select families with low proportion or no trees with lammas growth, without compromising on the total length of height increment or pattern or its formation (Fig. 2).

Height of Silver birch in trial in a former agricultural land at the age of 8 year reached 5.9 m on the average, ranging from 4.9 m to 6.3 m for particular provenances. Variation among families was notably larger – from average height 3.7 m to as much as 7.8 m.

Provenance (and families) was found to be a significant factor (p = 0.05), determining not only the tree height, but also such quality traits as diameter of thickest branch up to two meters height and branch angle.

When plotting the geographical distance between provenances versus the height difference among them (Fig. 3) no trend have been detected (R^2 = 0.00).

The finding was true both when using all measurement data or selection of 10 highest trees per replication and family thus excluding trees, that are suppressed due to competition.

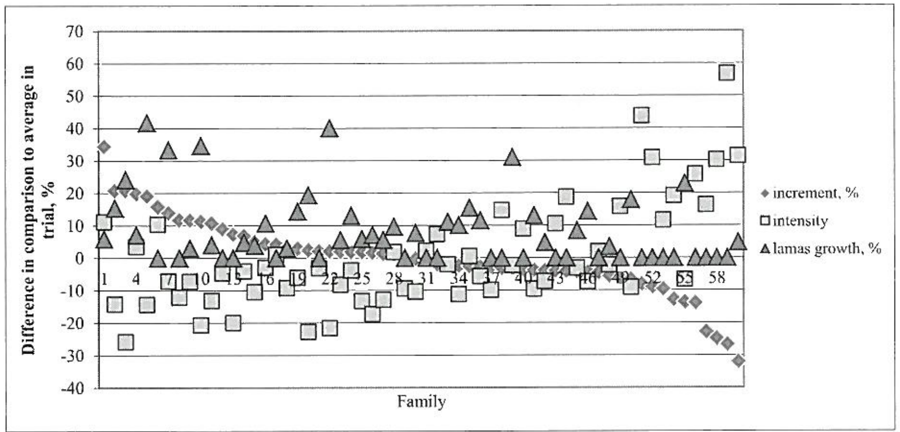

Figure 2 **Characteristics of Norway spruce families: proportion of trees with lammas growth, length of height increment in relation to the total height, proportion of increment formed in a week with highest growth intensity**

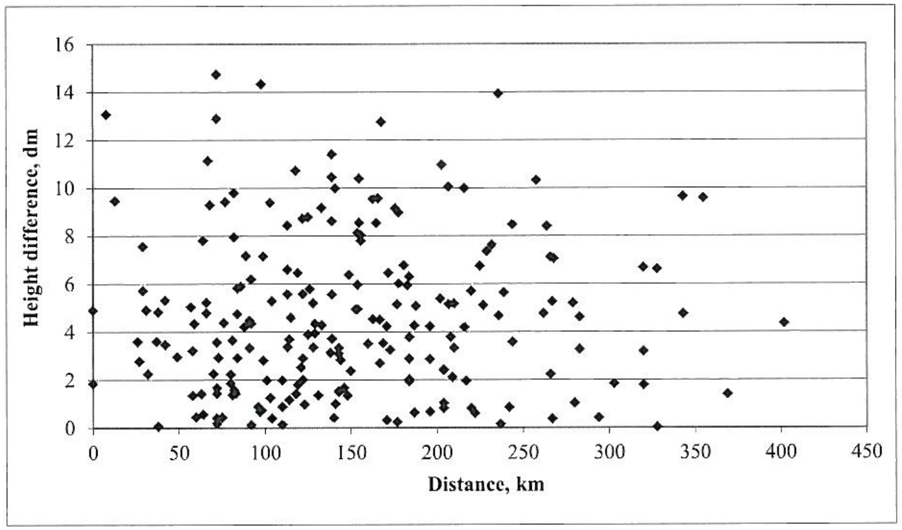

Figure 3 **Differences in mean height of Silver birch provenances in plantation in Rembate depending on the geographic distance between them**

Differences among families from 3 geographic regions in Latvia – west, south, and north – defined according to borders of former seed transfer regions, were statistically significant (Table 1).

Table 1 **Values of growth and quality traits of birches from different seed transfer (provenance) regions**

Trait	Provenance region				
	West	North	South	West	East
Height, dm	57.7	58.1	61.6	57.7	59.2
Branch diameter, mm	10.8	10.5	10.9	10.8	10.6
Branch angle, °	47.2	46.7	47.0	47.2	47.0

The same holds true for differences among current seed transfer regions (west and east).

DISCUSSION

Resistance of forest trees against pathogenic fungi and insects involves a genetic component. For example, Persson (2009) reported notable and significant variation among families of Scots pine in the resistance to pine blister rust (*Cronartium flaccidutn* Alb. and Schw. & *Peridermium pini* (Pers.) Lev.), ranging from 0% infected trees up to 100%. Notable differences among families in the level of damages by white pine weevil (*Pissodes strobe* Peck) were found in the trials of white pine and jack pine (Verrez et al. 2010). Similarly to the results of our study, significant differences of resistance to needle cast among Scots pine families have been reported by other authors as a result of mainly short-term nursery studies (Baumanis 1993; Martinsson 1979; Ostry, Nicholls 1989; Squillace et al. 1975; Stephan, Scholz 1981; Vuorinen 2008). Needle cast infection affects the most photosynthetically active, one year old needles of the tree. Negative effect of the infection on growth (annual increment, total height or diameter of young trees) has been found in our study and reported also previously (Baumanis 1975; Martinsson 1979; Ostry, Nicholls 1989; Squillace et al. 1975).

Our study provides previously un-reported evidence of cumulative effect of the disease on a tree growth. Damage grade was very weakly dependent on the initial tree height, but the height increment of respective and especially next year was notably affected. Partly this might be due to limited possibilities of photosynthesis of damaged tree and therefore growth and storage of nutrients, partly because of repeated infection of the same trees and families. For the young trees with limited nutrient reserves and needle mass, repeated needle infection and damages might lead also to the decrease of survival, as it was found in this and previous studies (Jansons et al. 2008).

More precipitation at the end of summer and warm winters favour spread of needle cast (Ostry, Nicholls 1989; Stenström, Arvidsson 2001). Those are exactly the conditions forecasted according to climate change scenarios

(Bethers, Seņņikovs 2007; Jansons 2010). Further studies on the climate – disease interactions to improve the predictions of possible threats for adaptation are essential and are carried out in the Scandinavian countries with fungi species with similar climatic requirements as needle cast (Bernhold et al. 2008; Hansson, Ottosson-Löfvenius 2008; Müller 2007; Vuorinen 2008).

Resistance to pathogenic fungi and insects tend to have relative high heritability (Persson 2009; Verrez et al. 2010) that in combination with large variation provides excellent opportunities for selection of these traits. Besides, efficient selection can be carried out already at nursery stage. Possible success of tree breeding in improvement of resistance against needle cast can be limited by high genetic diversity of *Lophodermium* species and effective gene migration (Müller, Hantula 2008) that might lead to changes of most affected pine genotypes. It can also be limited by genotype-environment interaction. However, as demonstrated in our study, closely located, similar trials can have notably different needle cast damage levels, but selection of the least affected families in one site would lead to decrease of damages also if used in other site.

Breeding of resistance against needle cast would require long time before first material becomes available. Meanwhile, improvement can be done, collecting seeds for reforestation of affected sites from resistant clones in seed orchards or populations (Jansons et al. 2008).

Possible negative effects of lammas growth are related to changes in frost hardiness – poorly developed hardiness in the bud formed on lammas shoot or earlier flush of this bud next spring notably increases the risk of autumn or spring frost damages respectively. Such damages may result in growth reduction and/or severe reduction of the tree quality (forking and spike knots).

Growth rhythm and development of forest hardiness are genetically determined as a response to changes in meteorological conditions and differ between provenances and families (Danusevicius 1999).

Climatic conditions became milder in last decades and that has changed the early spring phenology phases of forest trees (Kalvāne et al. 2009) and increased the length of vegetation period. The trend is predicted to continue in future (Jansons 2010). This will lead to increased time between the end of shoot elongation (bud set) and actual winter that might in turn potentially increase the incidences of lammas shoot formation.

Our study found significant differences among families in proportion of trees with lamnas growth. It is in line with studies concerning 2 and 3-year-old *Pinus radiata* seedlings, that also reported significant differences among families in number of summer flushes (lammas growth) (Codesido, Fernández-Lopez 2009). Results suggested that notable improvement (significant reduction of proportion of trees with lammas growth) can be reached in Norway spruce plantations, if only a small number of most affected families are pre-selected and excluded from further testing and eventual selection to serve as parent-trees in seed orchards. This selection would not necessarily cause changes in the shoot elongation pattern or compromise total length of height increment (height growth).

Further studies needed to address the issue of genotype-environment interaction of this trait and correlation between different ages of trees. This information would serve as a basis for increase in the accuracy of predictions of possible gains from the tree breeding in avoidance of trees with lammas growth.

Significant differences in growth and quality traits between clones, families and provenances have been reported for Silver birch (Koski 1991; Raulo, Koski 1977; Viherä-Aarnio, Velling 2001) that is in accordance with the findings of our study. Growth traits (especially height) and some of quality traits (branch diameter, branch angle) have high heritability (Stener, Hedenberg 2003) that ensures the potential of notable improvement in tree breeding process. Differences between progenies of trees from a single stand often exceed the differences from progenies from different stands (at provenance level) (Raulo, Koski 1977).

Silver birch has high plasticity and seed transfer of up to two degrees northwards can ensure even better yield than use of seeds of local origin (Viherä-Aarnio, Velling 2008). Based on results from 10 test sites across southern Sweden Stener and Jansson (2005) concluded, that all the studied territory can be regarded as a single breeding (seed transfer) zone and selections made are valid for use in all this territory. That is in line with our findings, that differences between provenances are not related to the distance among them, but rather can be attributed to the characteristics of particular provenances (and families). Slightly lower height of provenances from more maritime climate in the western part of country was detected and in the trial in the eastern provenance region with more continental climate. That is in line with findings in Scots pine trials in Latvia. Results of studies of this species do not suggest the reverse trend – provenances from more continental part of the country planted in western regions does not demonstrate inferior growth or quality. Climate is predicted to become milder and warmer in future. This prediction in combination with the above-described trends and phenotypic plasticity of silver birch suggests increasing importance of selection of particular, well tested genotypes rather than reliance on any seed source of particular region for collection of seeds in order to ensure high productivity of future birch stands.

CONCLUSIONS

1. Needle cast has a significant negative influence on survival and cumulative negative influence on the height growth of young Scots pines (family mean correlation between needle cast damage grade and height increment of current year $r = -0.30$, increment of next year $r = -0.53$). Significant differences exist between families in needle cast damage grade.

2. Average proportion of trees with lammas growth reaches 8% in young Norway spruce plantation. Significant differences exist between families and most affected of them have on average 36% of trees with lammas growth.
3. Provenances and families were found to be a significant factor, determining tree height, branch diameter and angle in a young silver birch plantation. The distance between them does not explains the differences in the tree height.
4. Tree breeding provides opportunity for significant improvement of productivity as well as traits important for adaptation at current and predicted future climatic conditions.

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