Available online at www.sciencedirect.com
ScienceDirect
Environmental Pollution 156 (2008) 152–161
ENVIRONMENTAL POLLUTION
www.elsevier.com/locate/envpol

Phenogenetic response of silver birch populations and half-sib families to elevated ozone and ultraviolet-B radiation at juvenile age

Alfas Pliura [a,b,*], Asta Baliuckienė [a], Virgilijus Baliuckas [a,b]

[a] Lithuanian Forest Research Institute, Department of Tree Genetics and Breeding, Liepu 1, Girionys LT-53101, Kaunas District, Lithuania
[b] Lithuanian University of Agriculture, Studentų 13, LT-53361 Akademija, Kaunas District, Lithuania

Received 30 October 2006; received in revised form 5 December 2007; accepted 13 December 2007

Exposure to elevated UV-B and O_3 alters genetic variation of traits in progenies of silver birch populations.

Abstract

Phenogenetic response of silver birch populations and half-sib families to separate and combined elevated ozone (O_3) concentrations and ultraviolet-B (UV-B) radiation dozes was studied at juvenile age in the climatic chambers. Significant population and family effects were found for seedling height, lamina width, and leaf damage. The exposure to UV-B radiation decreased genetic variation at the stage of seed germination. Complex exposure to UV-B and O_3 caused an increase of genetic variation at the stage of intensive seedling growth: seedling height genetic variation in separate treatments increased from 23.7–38.6 to 33.7–65.7%, the increase for lamina width was from 10.2–13.9 to 13.6–31.8%. Different populations and families demonstrated differing response to elevated complex UV-B and O_3 exposure. Changes of genetic intra-population variation were population-specific. Such changes in genetic variation under the impact of stressors can alter adaptation, stability, and competitive ability of regenerating populations in a hardly predictive way.

Keywords: Genetic variation; *Betula pendula*; Populations; Half-sib families; Ozone; Ultraviolet-B radiation

1. Introduction

Constant reduction of stratospheric ozone layer and the increase of ultraviolet radiation intensity were observed in last two decades of 20th century (Krizek et al., 1998). Numerous studies have shown that impact of ultraviolet-B (UV-B) radiation on plant development can be miscellaneous. Exceeding ambient radiation intensity causes damage or negative impact on different plant cells, membrane and photosynthesis systems, phyto-hormones (Rozema et al., 1997; Jansen et al., 1998; Hollosy, 2002). Alteration and damage on molecular level necessarily alters the other processes: gene activity, metabolism, intensity of photosynthesis, and finally it changes plant development and heath status. Some genes being identified as regulated by UV-B radiation are involved in coding of protein responsible for biosynthesis of protective pigment, repair of DNA and activity of ferments – oxidation inhibitors (Brosché and Strid, 2003). According to Day et al. (1992), some life forms may be more tolerant to UV-B than others, because of differences in foliar epidermal screening capacity, and, in general, sensitivity might decrease as plant and foliage longevity increased in following order: herbaceous dicots > woody dicots > conifers. Diminished photosynthetic intensity caused by UV-B radiation is associated with decreased stomatal conductance and amount of photosynthetic pigments (Kull et al., 1996; Ambasht and Agrawal, 1997). Photosynthetic depression is often associated with alteration of leaf pigmentation, anatomy, and lamina thickness. UV-B radiation causes reduction of growth and biomass in many plant species (Ambasht and Agrawal, 1997, 1998; Correia et al., 1999; Mazza et al., 1999). Altitudinal clinality for UV-B radiation

* Corresponding author. Lithuanian Forest Research Institute, Department of Tree Genetics and Breeding, Liepu 1, Girionys LT-53101, Kaunas District, Lithuania. Tel.: +370 37 547289; fax: +370 37 547446.
E-mail address: genetsk@mi.lt (A. Pliura).

0269-7491/$ - see front matter
doi:10.1016/j.envpol.2007.12.023

sensitivity of ecotypes or population progeny is typical for majority of coniferous species in Canada – less sensitive populations originate from higher altitudes (L'Hirondelle and Binder, 2002). The investigation on impact of UV-B radiation on within population genetic variation in forest tree species has not been performed yet.

The other problem related to anthropogenic pollution is quite rapid increase of ground-level ozone concentration, caused by an increase of concentration of the main ozone predecessor – nitrogen dioxide in troposphere (Hough and Derwent, 1990). Ground-level ozone concentration in Lithuania increased by 1.5 times over the last 25 years (Girgzdiene and Girgzdys, 2001). The 1-h ozone concentration in forested areas now varies between 50 and 80 $\mu g/m^3$ and in 2005 the highest ozone concentration in Lithuania was 168.8 $\mu g/m^3$ (Girgzdiene, 2005). It was shown that seedlings and mature trees suffer from increased concentration of tropospheric ozone (McLaughlin, 1985; Shriner et al., 1990; Hanson et al., 1994). Being strong oxidant, ozone becomes detrimental and causes leaf damage, suppresses photosynthesis, and diminishes productivity. Increased ozone concentration decreased photosynthetic intensity and accelerated leaf senescence in broadleaved tree species (Kull et al., 1996). Positive compensative effect was revealed for silver birch (*Betula pendula* L.) in a series of studies where the growth rate and crown foliage increased in the following vegetative season after plants were exposed to ozone (Pääkkönen et al., 1993; Pääkkönen and Holopainen, 1995; Oksanen and Saleem, 1999; Oksanen and Rousi, 2001). Though compensative impact was detected only for some birch origins.

Tolerance to ozone can be attributed to the ability of leaves to limit gas exchange ratios (*avoidance* strategy, see Kolb et al., 1997), as well as to their capacity to activate detoxifying systems (*repair* strategy). Skärby and Pleijel (1996) have shown that broadleaved tree species are more sensitive to ozone than coniferous. Broadleaved forest tree species can be put in decreasing order by sensitivity to ozone: *Prunus serotina*, *Salix viminalis*, *B. pendula*, *Prunus avium*, *Fraxinus excelsior*, *Alnus viridis*, *Fagus sylvatica* and *Acer pseudoplatanus* (VanderHeyden et al., 2001). Birch species and their hybrids differ in sensitivity to ozone as well (Oksanen and Rousi, 2001). It was found in *Populus tremuloides* (Berrang et al., 1986; Keller, 1988) and *B. pendula* (Pääkkönen et al., 1993, 1996, 1997; Oksanen and Saleem, 1999; Oksanen and Rousi, 2001) that clones differ in tolerance or sensitivity to ozone, which means the existence of genetic variation in sensitivity to ozone. Medium strong and statistically significant correlations between Scots pine female trees and their half-sib progeny were obtained for resistance to ozone and sulphur dioxide, indicating that tree resistance to pollution is inheritable (Oleksyn, 1991). Family heritability estimates for foliar injury by ozone was medium to strong in the experiment with open-pollinated families of black cherry (Lee et al., 2002). The same study experimentally proved that there is fairy good progeny-parent relationship in ozone sensitivity. Lee et al. (2002) suggested that the existence of heritable variation in ozone sensitivity in wild populations enables the use of bioindicators in forest health monitoring.

Inter-specific hybridisation improved not only seedling growth and adaptation at juvenile age, but also tolerance to ozone stress (Oksanen and Rousi, 2001). It was argued, that inter-specific competition, species composition and the dynamics in the development of forest ecosystems may be affected by air pollutants due to change in carbon allocation (Matyssek et al., 1998).

Ground-level ozone formation intensity is much dependent on UV radiation, thus understanding of complex UV-B and ozone impact to vegetation becomes relevant. External stressors can diminish plant tolerance to other negative factors if internal reserves of organism are consumed to cope with an impact of the first stressor (Pianka, 1978; Duchovskis et al., 2002). In case if plant adaptive mechanisms to various stressors are similar, plants already adapted to some stressor appear to be less sensitive to another one (Cox and Hutchinson, 1980; Larcher, 1995). Such phenomenon is called compensative pre-adaptation.

In case of existence differences among populations, families, and individual genotypes in their sensitivity to various types of detrimental factors, the less resistant genotypes may not survive due to direct effects of separate or interacting components of pollution or consequences of global climate change. Such selection process would cause a decrease of genetic diversity, the core component of biodiversity, and alteration in genotypic structure of populations. Changes of genetic diversity would influence sustainability, survival, and possibilities for evolution of populations and species. Alteration or degradation of gene pool possibly has already taken place in course of severe decline of spruce, elm, ash, and oak species during the last decade in Lithuania and Central-Eastern Europe. Research on genetic variation in forest tree species in relation to adaptation to changing environment or pollution were initiated in many countries (e.g. Oleksyn, 1987, 1991; Jonsson and Eriksson, 1989; Smintina, 1993; Ramanauskas et al., 1993; Giertych, 1995; Kleinschmit et al., 1996; Menzel, 1997; Pliura and Eriksson, 2002; Abraitienė et al., 2002; Baliuckas, 2002; Baliuckas and Pliura, 2003). However, very limited studies have been performed on changes of among- and within-population genetic variation of adaptive traits and on population-specific and family-specific reactions to elevated ground-level ozone and UV radiation. Such studies are needed to better understand possible consequences of elevated exposure to these stressors on structure, competitive ability, and physiological and genetic adaptation of populations.

The objective of this study was to estimate phenogenetic response of silver birch populations and half-sib families to short-term exposure to elevated separate and combined ozone and ultraviolet-B radiation, to estimate G $\times$ E interaction and the change of genetic variation in different treatments and populations at juvenile age.

2. Materials and methods

Two distant Polish populations were selected for the study to represent populations from contrasting adaptive environments: Chelm (C) population