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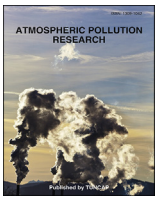

Original article

Effects of the urban environmental conditions on the physiology of lichen and moss

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ABSTRACT

The lichen *Evernia prunastri* (L.) Ach. and the moss *Ptilium crista-castrensis* (Hedw.) DeNot were exposed in three different urban sites along with the different pollution loads in order to evaluate the environmental quality. Physiological changes after the exposition were assessed by evaluating the content of photosynthetic pigments, chlorophyll fluorescence, membrane lipid peroxidation and integrity of cell membranes. The differences in response of fluorescence, chlorophylls contents and injuries of cell membranes were observed between the two species and between the sites. *E. prunastri* showed a great capacity to sustain the photosynthesis processes in the urban environment, while this capacity was very low in the transplanted moss *P. crista-castrensis*. The levels of malondialdehyde (MDA) indicated a significantly higher oxidative stress in the transplants at urban and residential sites. The integrity of cell membranes in moss samples was also more damaged than in lichen.

1. Introduction

The increased number in human population is leading to changes in the level of urbanization, which results in increasing levels of pollutants in the environment (Fenger, 1999; Duh et al., 2008). In such an environment, the main pollutants are nitrogen and sulphur oxides, heavy metals, mainly resulting from transport emissions and industrial activities. The increased concentrations of pollutants have a negative impact on health of living organisms including human (Brunekreef and Holgate, 2002; Gurjar et al., 2010). It is difficult to monitor the quality of the air due to the existence of different substances as well as temporal and spatial variation in their concentrations. In order to monitor atmospheric pollution, the biomonitoring methods based on using living organisms has attained an increasing attention in recent decades (Sujetoviene, 2015).

Cryptograms are directly dependent on the atmospheric deposition as the source of nutrients, and are sensitive to changes in their concentrations due to their physiology. Researchers have emphasized the significance of lichens and mosses as biomonitors of contaminants (Minger and Krahenbuhl, 1997; Conti and Cecchetti, 2001; Szczepaniak and Biziuk, 2003). It has been shown that mosses and lichens, in spite of all disadvantages, are good tools for the air pollution monitoring, however, the best results could be achieved if both of them are used together, because of the differences in their metal uptake and retention (Szczepaniak and Biziuk, 2003).

Biomonitors can serve as the means to get a spatial and temporal distribution of pollutants deposition. The comparative use of lichens and mosses in order to observe the source of pollution has been demonstrated by several authors. A larger part of studies has intended to compare the capacity to accumulate airborne heavy metals (Chiarenzelli et al., 2001; Bargagli et al., 2002; Szczepaniak and Biziuk, 2003; Culicov and Yurukova, 2006; Icel and Cobanoglu, 2009; Aprile et al., 2010; Spagnuolo et al., 2011; Balabanova et al., 2014; Gerdol et al., 2014; Kar et al., 2014) as well as organic compounds (Augusto et al., 2013; Bajpai et al., 2013b). Trace elements showed a higher accumulation in the moss than in the lichen (Coskun et al., 2009; State et al., 2012). In most cases, the moss was considered to be a better choice than the lichen for the biomonitoring of atmospheric deposition of metals, and it is argued that mosses may generally be more suited for this purpose as compared to lichens. The comparison with the measured and modelled N deposition data shows that lichens are particularly able to reflect the local N deposition (Boltersdorf et al., 2014). It was

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observed that the accumulation of gaseous pollutants is strongly influenced by biomonitor vitality and that lichen bags are a more reliable and effective tool for monitoring S, N and C atmospheric depositions in urban areas as compared to moss bags due to lichens resistance to dry and stressing conditions of an urban environment (Vingiani et al., 2004; Spagnuolo et al., 2011). Study on comparison of lichen abundance and data of N and trace metal accumulation in moss tissue showed that N concentration in moss tissues decreased along with increase in diversity of lichens (Gerdol et al., 2014).

The comparative studies on the physiological parameters of biomonitors are scarce. Severe ultrastructural injuries were observed in the moss *Hypnum cupressiforme* Hedw. and in the lichen *Pseudevernia furfuracea* (L.) Zopf after the exposure period in the urban area of Naples city (Spagnuolo et al., 2011). In this study the moss experienced irreversible ultrastructural changes, while the lichen, even, preserves its life and metabolism despite of the observed several stress marks. Thus, moss is expected to exhibit only passive mechanisms of element uptake, while lichen could also be involved in active mechanisms of accumulation. Data comparing the sample vitality under the different pollution loads in urban areas showed also considerable heavier damage in the moss *H. cupressiforme* than in the lichen *P. furfuracea* (Tretiach et al., 2007a).

The present study compares the ability of two biomonitors – lichens and mosses – to reflect deposition in an urban environment based on the changes in their physiological parameters. We monitored changes in air quality based on the changes in physiological parameters of bioindicators along the temporal and spatial scale. The aim of the study was to assess the effectiveness of lichens and mosses as biomonitors in order to reflect spatial and temporal trends in air pollution.

2. Methods

2.1. Sampling area and sampling sites

The study was performed in Kaunas city (54°53′50″N, 23°53′10′E), an urbanized area in central Lithuania at an altitude of 48 m above sea level (Fig. 1). The area is concentrated at the confluence of two rivers (Nemunas and Neris) and occupies about 157 km^2. The population is over 311,000. The climate is warm and humid continental with annual rainfall of 627 mm and predominant winds are SE. The mean annual temperature is 6.6 °C. The highest pollution level is characteristic of the city centre area, where the main sources of air pollution are mobile sources. The industrial activities are mainly located in the north-east part of the city.

Three sites were chosen for the lichen transplantation studies (Fig. 1):

Site 1: Suburban site (54°53′9″N, 23°50′49″E). The study site was a peripheral area located about 3 km east from the city centre. This study site is characterized as having a relatively high air quality with no factories and intensive motorways.
Site 2: Urban site (54°55′58″N, 23°58′14″E). This study site was located in the northeastern part of the city, about 7 km away from the city centre. This is an industrial area with intensive traffic (>25,000 vehicle per day).
Site 3: Residential site (54°55′58″N, 23°53′31″E). The study site was located in a densely populated area including public buildings and shops, where local transport is the main source of air pollution.

The sites were near the automatic monitoring stations where pollution (NO, NO_2 and SO_2) data were recorded for the whole exposure period. It was assumed that the there was no difference between conditions of the sites because the sampled sites and control sites belong to the same climatic region (control site – weather: 3 °C, wind SW at 5 m s^{-1}, 94% humidity; sampled sites – weather 3 °C, wind SW at 4 m s^{-1}, 93% humidity), the relief is similar with comparable altitude (altitude of the control site – 79 m, sample sites – 77 m). Air quality of the sampled sites was used for the comparison of the differences between these sites.

2.2. Sample collection and exposure

Samples of the moss *Ptilium crista-castrensis* L. and thallus of the lichen *Evernia prunastris* (L.) Ach. were collected in the district of Birštonas town forest (54°36′10″N 24°1′14.0″E) situated 30 km south of Kaunas, central Lithuania, far from large urban and industrial facilities. Birštonas is a resort town and a centre of the Nemunas Loops Regional Park. The surroundings of the town are considered to be unpolluted with high naturality and represent the initial (baseline) conditions of these species.

Fig. 1. Location of the study sites in Lithuania.

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