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ARTICLE

Ozone biomonitoring at mountainous and lowland areas in Hungary

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ABSTRACT Our experiment started in June, 2007. For test-plant we applied the ozone bioindicator clover (*Trifolium repens* NC-S and NC-R) clones. For cultivation of plants and for assessing the injuries the protocol of the ICP Vegetation (International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and Crops) was used. The clover pots were located in three experimental sites. Gödöllő is in downs with moderate climate, Bugacpuszta is a lowland site with hot and dry climate while Mátraháza is a mountainous site. Besides injuries and total dry weight, the number of flowers and the leaf area index were also measured. Our results showed that the typical symptoms of ozone injury were appeared on sensitive clones on every site. The degree of injury increased gradually from June to September reaching the maximum in the middle of September. There were definite differences between the numbers of flowers: in Gödöllő and Bugac (where the ozone pollution was substantially lower) the plants developed much more flowers than in Mátraháza. Therefore the number of flowers could also be a useful indicator of tropospheric ozone in addition to the extent of ozone injuries.
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KEY WORDS

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Ozone and its precursors can easily float several hundred miles away from their sources. As farther away from the cities there are fewer chemical agents by which ozone can dissolve, and as ozone usually evolves from its precursors only while floating, the concentration of tropospheric ozone progressively increases as we move away from cities. Accordingly, tropospheric ozone risks cultivated as well as natural vegetations (Lorenzini and Saitanis 2003). Numerous examinations show that the concentration of ozone in the troposphere often exceeds the limit determined in the European Council's Directive, and that its amount grows by 5-20 percent every decade (Sandermann et al. 1998). Ozone affects plants in a short-time period and in a long time period manner as well. The short time effects are the visible symptoms (yellow or brownish spots on the leaf surface) and the reduction in photosynthetic activity. Long-term effects are the decrement of the plant's growth and yield, and the early senescence, which occur in case of frequent high ozone concentrations in the air for several months. There are more than twenty agricultural and horticultural species that show visible injuries as an impact of ozone pollution, which injuries even cheapen the commercial value of these crops. The estimated deficiency caused by ozone damage in Europe is approximately €6, 7 billion per year (Harmens et al. 2006), and the crop yield is predicted to be cut by 30% by 2010 relative to 1990 (Mills et al. 2003). There are also many potentially ozone-sensitive natural plant communities in Europe (Harmens et al. 2006). Consequently, economic and environmental considerations make it essential to establish phytotoxic values of ozone pollution. Examining the effects of ozone in the plant organism and identifying the endangered species are also of great importance.

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Materials and Methods

Experimental sites: Bugacpuszta (46°41'31"N, 19°36'06"E) represents one of the westernmost occurrence of the Eurasian

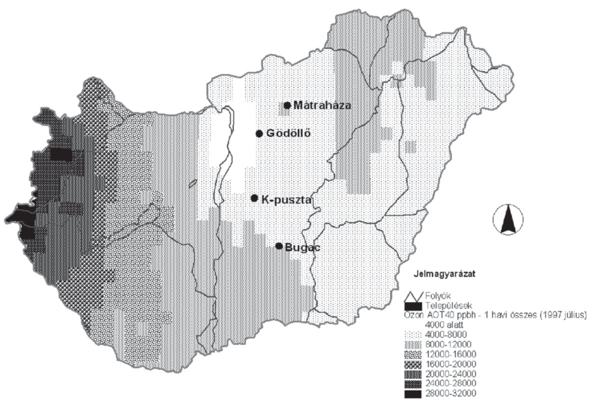

Figure 1. Modeled sum of AOT40 in Hungary for July, 1997, when global radiation was higher than 50 W/m2 (Mészáros and Lagzi 2007).

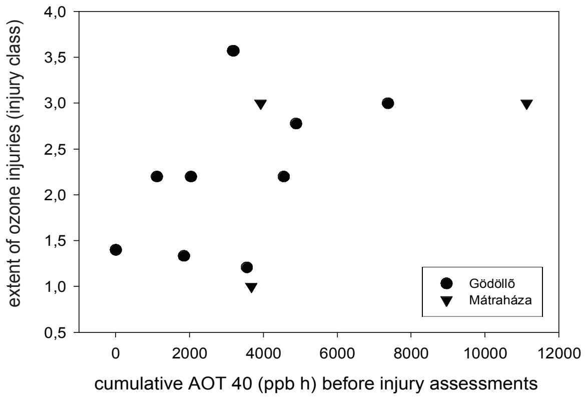

Figure 2.

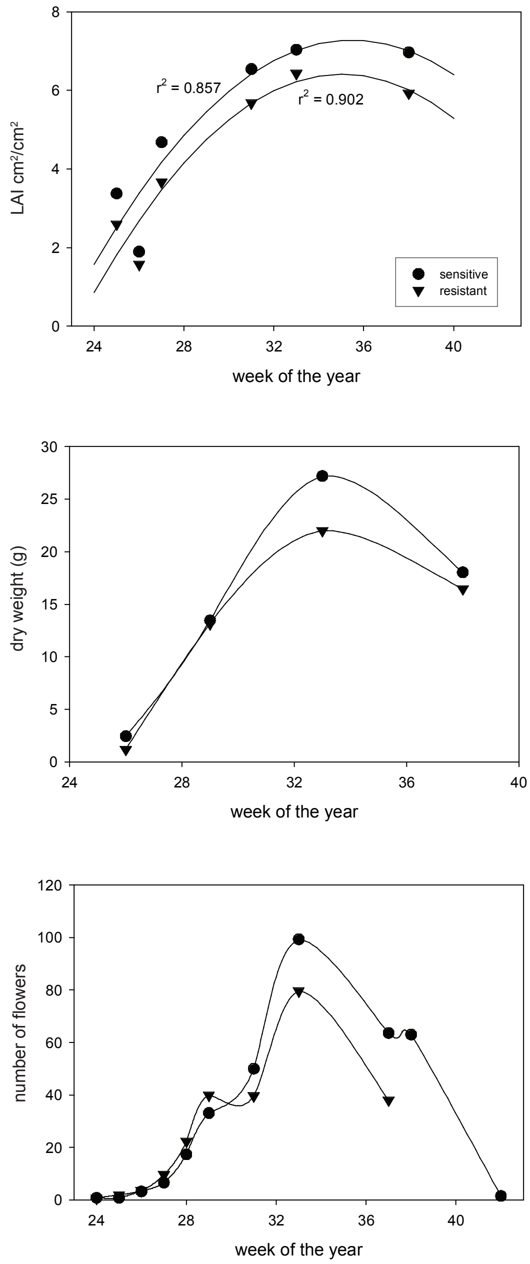

Figure 3. LAI, dry weight and number of flowers of sensitive and resistant clones in Gödöllő.

steppe zone. This is a part of the Kiskunság National Park and has been under extensive management (grazing) for the last 20 years. The climate is temperate continental, the mean annual temperature and sum of precipitation are 10,4°C and 562 mm, respectively. The site's altitude is 117 m above sea level. In the region of Bugacpuszta, the soil is a chernozem type sandy soil. The vegetation is semi-arid sandy grassland; main species are *Festuca pseudovina, Carex stenophylla*, and *Salvia pratensis*.

Gödöllő is situated on the slopes of the Gödöllő Hills (47°36' N, 19°21' E) at an altitude of 249 m above sea level. The distance of this site from the capital city is 40 kilometers, so it is might be affected by the pollutants of the town. The climate is temperate continental, with a mean annual temperature between 9 and 10°C. Yearly average precipitation is about 560 mm. The characteristic natural vegetation of the territory is Aceri campestri-Quercetum roboris, developed on a generally calcareous and sandy alluvial soil with about patches of clay. The experimental site is in the Szent István University's botanical garden. It is inside a smaller town with urban traffic. The total area of the garden is about 6 hectares. The garden includes 2 hectares of natural forest of cool, continental forest vegetation of hornbeam mixed maple woodland. Mátraháza (Nyírjes) (47°52'N 19°57'E) is in the Mátra mountain at an altitude of 702 m above sea level. There are also temperate continental climate, mean annual temperature is between 9,5 and 10 °C. Yearly average precipitation is between 550 and 600 mm. The experimental site is situated in a forestal environment with planted pine-forest. The dominating tree species are beech and spruce, but in the closest surroundings there are considerable stocks of larch.

The three experimental sites and K-puszta are marked on the modeled ozone map of Hungary (Fig. 1). Ground level ozone is measured at the meteorological station of K-puszta. We used the data from K-puszta for estimating the ozone values of Gödöllő. As the modelled AOT 40 values refer only to one month, it has to be emphasized that the results for Gödöllő are only rough estimates.

Plants studied were the *Trifolium repens* L. cv. Regal NC-S and NC-R clones. The experimental plants were grown in pots.

Planting and transplanting of white clover clones and also injury assessments was performed according to the Protocol of the ICP-Vegetation (Hayes et al. 2006). Besides assessment of ozone injuries measuring of total dry weight, leaf area index and number of flowers were also performed.

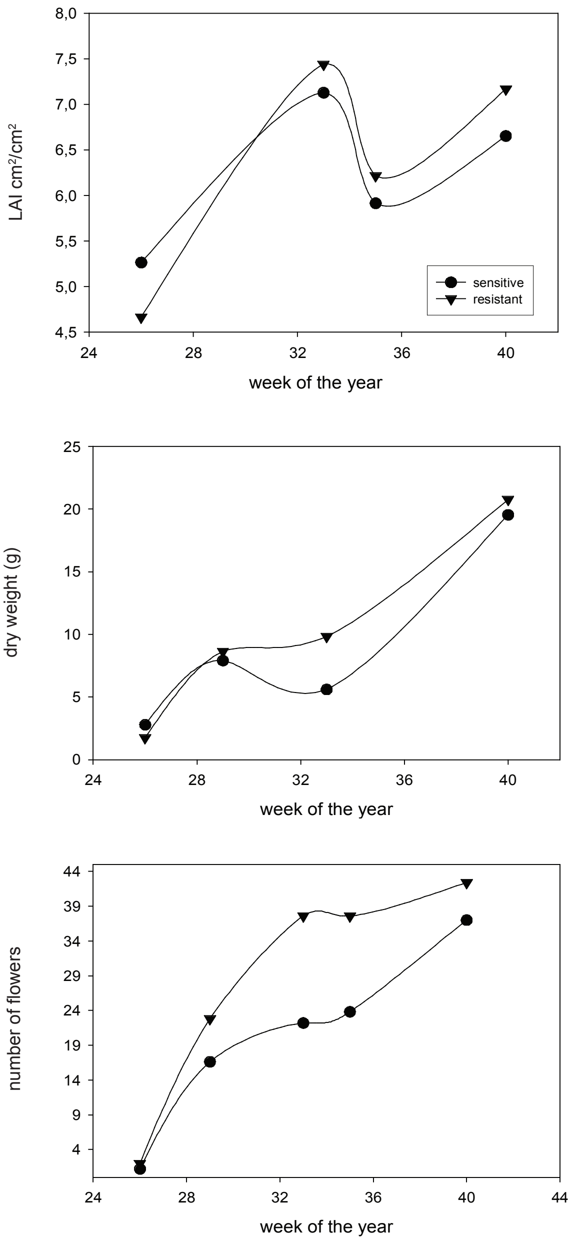

Figure 4. LAI, dry weight and number of flowers of sensitive and resistant clones in Mátraháza.

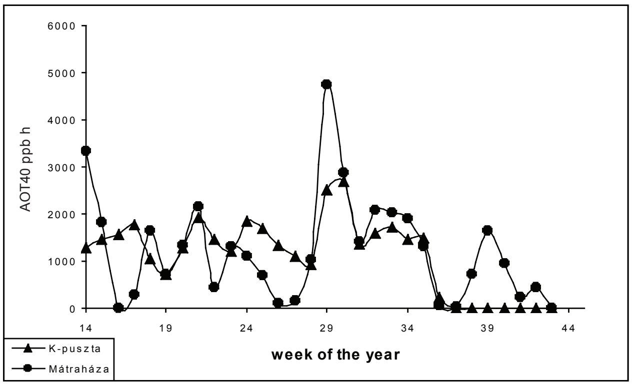

Figure 5. Sum of weekly AOT 40 values of two experimental sites: Gödöllő (K-puszta) and Mátraháza in the vegetation period of 2000.

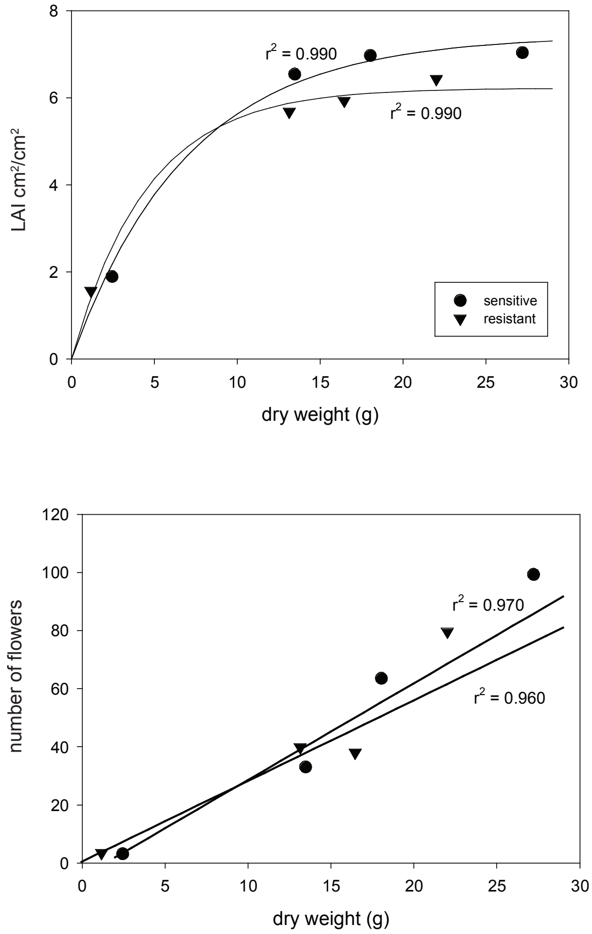

Figure 6. Relationship between dry weight and LAI; and dry weight and number of flowers at Gödöllő site.

Results and Discussion

Sensitive plants showed visible ozone symptoms on all the three experimental sites. However, the extent of symptoms was not proportional to the ozone pollution (AOT 40 values, Accumulated exposure Over a Threshold of 40 ppb). Figure 2 represents the observed ozone injuries plotted against total amounts of AOT 40 between the time of harvests and injury assessments. It can be seen that the average ozone injuries do not show close connection with the ozone levels, as more extended visible injuries may happen at lower levels of AOT 40 and vice versa. Consequently, the role of ozone injuries

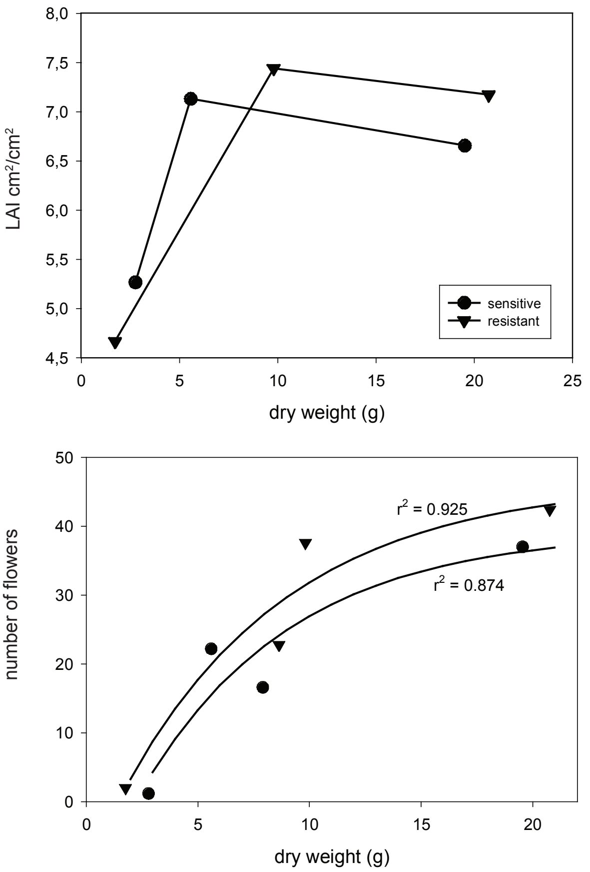

Figure 7. Relationship between dry weight and LAI; and dry weight and number of flowers at Mátraháza site.

is only to indicate the phytotoxic levels of ozone at least if fewer data are available.

This is also supported by the fact that despite the similar classes of ozone injuries on the sensitive clones, other examined parameters differed on Gödöllő and Mátraháza (Fig 3 and 4). While LAI, dry weight and the number of flowers of sensitive plants were higher than those of resistant plants in Gödöllő, all the three parameters of sensitive clones were lower in Mátraháza. The difference may be due to different extent of ozone pollution on the two sites. The 28 day AOT40 values are not higher at Mátraháza than at Gödöllő every time, however on the chart of sum of the AOT 40 values per week (Fig. 5) it can be seen that the maximum values are more outstanding at Mátraháza. It can be concluded that there are more high-level ozone episodes in Mátraháza than in Gödöllő. The longer period of phytotoxic levels of ozone in Mátraháza is also apparent from this figure.

The first response of sensitive plants to ozone pollution may be the strengthened growth and productivity. Thus the plant can avoid the harmful effect of the stressor. However, if the pollution exceeds a certain extent, the highly stressed sensitive plants can not sustain even their normal metabolic processes.

Quantity of dry weight on the less polluted Gödöllő site can be explained by the changes in number of flowers, as the two parameters reveal linear relationship (Fig. 6). However, these parameters exhibit saturating curve on Mátraháza (Fig. 7). Thus, the stressor possibly causes inhibition in generative processes first before affecting vegetative growth.

Our results show that the number of flowers could also be a useful indicator of ozone pollution as it showed the most significant differences among the parameters examined.

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