Clover as a bioindicator for phytotoxic ozone

Gunilla Pihl Karlsson

Abstract

Environmental objectives and critical levels concerning ozone exposure has been adopted both on national and international levels. The UNECE (United Nations Economic Commission for Europe) has developed critical levels with regard to the effects of ozone on vegetation. These critical levels are used to design effect-based control strategies to reduce emissions of ozone precursors under the UNECE Convention on Long-Range Transboundary Air Pollution (CLRTAP). At present, critical levels are based on an ozone exposure index known as AOT40 (Accumulated exposure Over a Threshold), which refers to the accumulated exposure during daylight hours in excess of 40 ppb. The AOT-concept is based on the ozone concentration in the air surrounding the plants. The short-term critical level has the purpose to ensure protection of plants to acute ozone injury. Results presented in this thesis clearly indicated that the current short-term critical levels do not accurately explain the ozone effects in terms of observed visible injury on the leaves. Today new ozone exposure indices are being developed that focus on the amount of ozone that is taken up by plants, rather than simply the concentration in the ambient air. One objective of this thesis was to parameterise and use a simple stomatal conductance model driven by solar radiation, air temperature, air water vapour pressure deficit (VPD) and ozone exposure. Using this model an uptake-based ozone exposure index, CUO (Cumulated Uptake of Ozone), was defined. A comparison between a concentration-based ozone exposure index (AOT) and an ozone uptake-based exposure index (CUO) was made. The uptake-based exposure index was considerably better correlated with observed visible injury, compared to the concentration-based and currently used exposure index AOT. Furthermore, a new short-term critical level for ozone was suggested based on experiments performed in Austria, Belgium ans Sweden with subterranean clover (*Trifolium subterraneum*). The suggested, new short-term critical level was 75 μmol m^{-2} on a total leaf area basis, using the ozone exposure index CUO^{10} (with a cut-off of 10 nmol m^{-2} s^{-1}) during an exposure period of eight days. This ozone exposure index is suggested to prevent plants against visible injury on more than 10% of the leaves.

Another objective of this thesis was to analyse the different factors influencing ozone sensitivity. Subterranean clover was the most ozone sensitive species and red clover (*Trifolium pratense*) was the least ozone sensitive among red clover, white clover (*Trifolium repens*) and subterranean clover. Moderately old subterranean clover leaves were more sensitive to ozone injury compared to young expanding leaves and compared to non-senescent leaves on the oldest leaf age classes. This thesis showed that the stomatal conductance for red clover was lower than for subterranean clover and that red clover and white clover had thicker leaves than subterranean clover. Furthermore, old leaves had lower stomatal conductance and thicker leaves than younger leaves. The stomatal conductance and the leaf thickness were likely to explain a substantial part of the difference in ozone sensitivity between the three clover species and between different leaf age classes for subterranean clover. One major factor for the ozone sensitivity found in this thesis was the stomatal conductance and the parameters that influenced the stomatal conductance: VPD, solar radiation, temperature and ozone dose. Also the species, cultivar, leaf age and leaf thickness had important impacts of ozone sensitivity in different clover species.

The last objective of this thesis was to evaluate the use of clover as a suitable system for bioindication of ozone levels harmful to the vegetation. This thesis concluded that clover can be used as a bioindicator for phytotoxic ozone in many different sites and surroundings. The clover species that performed best was subterranean clover. It was very sensitive to ozone, it was easy to grow and it had the most important property for a bioindicator, it showed characteristic responses for ozone. The symptoms of ozone injury on clover were numerous small discoloured spots, partly necrotic in character on the leaves, both on the abaxial and adaxial side of the leaves.

Keywords: clover, bioindicator, ozone, short-term, critical level, cumulative uptake of ozone (CUO)

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