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Chapter 13

Ozone injury symptoms on vegetation in an Alpine valley, North Italy

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Abstract

In recent years multidisciplinary surveys examining the impact of pollutants on forest ecosystems have been carried out in the Valtellina (Northern Italy, Alpine region). A large part of the activity of these surveys has involved the study of ozone and its distribution in the area, development of the exceedances maps (AOT40) and their validation by means of field observation of visible foliar symptoms in the indigenous and sensitive forest vegetation. The present paper reports the results of a field survey carried out in 1998 on the visible symptoms expressed by several native species (trees, shrubs and herbs). A non-systematic grid of 81 plots was assessed throughout the valley. Due to the high variability of the physical (altitude, slope, exposure, etc.) and vegetational (species assemblage, tree age, forest structure) features, the comparability among the plots was

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found to be very weak, so only the presence or absence of leaf injuries was assessed. Results do not show any correlation between the distribution of foliar symptoms in Valtellina and ozone levels. Rather, leaf injuries follow the same distribution of environmental modifying factors (such as depth and moisture of the soil) and tree sensitivity.

1. Introduction

High concentrations of ozone have been recorded in the transnational region between the north of Lombardy, Italy, and Ticino, southern Switzerland (Bacci et al., 1990; Staffelbach et al., 1997; Gerosa et al., 1999). This pollution is attributed to the influence of the wide urban and industrial area of Milan (Italy) and to the presence of the mountains (Alps and Prealps) that provide an obstacle to the spreading of the precursors to the north and enhance their accumulation in the area south of Alps, i.e., the Po plain (Staffelbach et al., 1997). On the other hand, the mountains lend the landscape a complex orography, and the distribution of ozone is irregular.

A research project, aimed at investigating the behaviour of ozone in Alpine areas, was carried out in a valley of Lombardy, the Valtellina (see Fig. 1(A)). Results were already partially reported by Ballarin-Denti et al. (1998a, 1998b) Dell'Era et al. (1998), and Gerosa et al. (1999).

Recently, a large part of the research activities was devoted to studying the distribution of ozone in the area. Fig. 1(B) (Mazzali, unpublished) shows the map of the exceedances for forests (based on the concept of AOT40, see Kärenlampi and Skärbi, 1996). Data were provided by a campaign with passive samplers from May to August 1998, and processed applying methods of spatial statistics (Cressie, 1991; Loibl et al., 1994). In synthesis, the AOT40 (May–August) levels estimated in a territory covering 80×42 km^2, ranged from 5000 to more than 25 000 ppb h, and most of the area showed levels higher than the critical threshold for forest vegetation (10 000 ppbh, see Fuhrer et al., 1997). The highest exposures were reached in the southern part of the valley, i.e., the northern slopes of the *Orobiche* Alps.

As part of the above-mentioned project, the distribution of the ozone-like symptoms on the foliage of sensitive native forest vegetation was also investigated. It is a well known fact that ambient concentrations of ozone in Canton Ticino (CH) may produce visible injuries (Skelly et al., 1987, 1998; Vander-Heyden et al., 2000).

The aim of this investigation was to answer the following questions:

- Is it possible to distinguish areas with different ozone exposures by monitoring symptoms in wild vegetation?

- What are some of the problems which may be connected to a spatial survey for O_3 induced injuries to vegetation in alpine and prealpine conditions?

1.1. Feasibility survey

The rationale of the survey in Valtellina was based on the open-top chamber experiments made in the Lattecaldo nursery, Canton Ticino in southern Switzerland (Skelly et al., 1998; VanderHeyden et al., 2000), where foliar symptoms were reproduced on several native plant species with ambient concentrations of ozone. The Lattecaldo nursery is located very close to Valtellina (Fig. 1); both sites are located in the same region subjected to the pollution from Milan (Gerosa and Ballarin-Denti, unpublished data), and show very similar ecological and vegetational features.

Preliminary inspections enabled us to recognize in the native vegetation of the Valtellina region the same kind of symptoms recorded in Lattecaldo (Cozzi et al., 2000). These symptoms were further validated by means of microscopic observations (Gravano et al., 2000). The main symptomatic species recorded were: *Ailanthus altissima* (Mill.) Swingle, *Corylus avellana* L., *Fraxinus excelsior* L., *Laburnum alpinum* (Mill.) Berchtold & J. Presler, *Parthenocissus quinquefolia* (L.) Planch., *Prunus avium* L., *Robinia pseudoacacia* L., *Rubus* spp., *Ulmus glabra* Hudson and *Vitis vinifera* L.

Other important features of the study area were: scattered plants with visible symptoms, seedlings and young trees most severely affected, visible symptoms generally affecting only some plants in a population and even only some leaves on an individual plant. Finally the species assemblage varied with the altitude, with the broadleaved trees in the lower areas and mainly conifers at higher elevations.

1.2. Survey design

The survey was performed at the end of the summer 1998 on 81 observation plots distributed throughout the whole area (Fig. 1(B)), but depending on the conditions of accessibility. The first problem was the comparability between the plots. This problem has usually been solved by choosing areas with similar ecological conditions, with similar species assemblage and of a similar age; however this was not possible in this specific case. In fact, the Alps are characterized by a great variability in the physical properties of the landscape over short distances (altitude, slope, exposure, previous soil use, soil conditions and forest management); consequently the conditions of the vegetation (species composition, intra-specific genetic variability, tree age) are quite variable, so each plot was representative only of its specific conditions and no between-plots comparison were possible. For these reasons we chose to determine only the “presence” or “absence” of symptoms on any species (trees and shrubs) without any further discrimination. That meant that we were unable to find any relationship between the severity of the symptoms and the AOT40 levels, but only the possible minimum exposure thresholds for the presence of the symptoms.

2. Results

Foliar symptoms were detected on 52 of 81 plots (64%) and were distributed fairly evenly throughout the study area (Fig. 1(B)). Symptomatic plants were to be found at all altitudes: relatively rare at the lower elevations (28% of plots between 200 and 400 m asl); more frequent at intermediate levels (between 62 and 66% of plots between 400 and 1000 m asl); and their frequencies decreased again at altitudes above 1000 m asl (50%). Other morphological and topographical parameters (exposure, position) did not appear to affect the distribution of symptomatic plots.

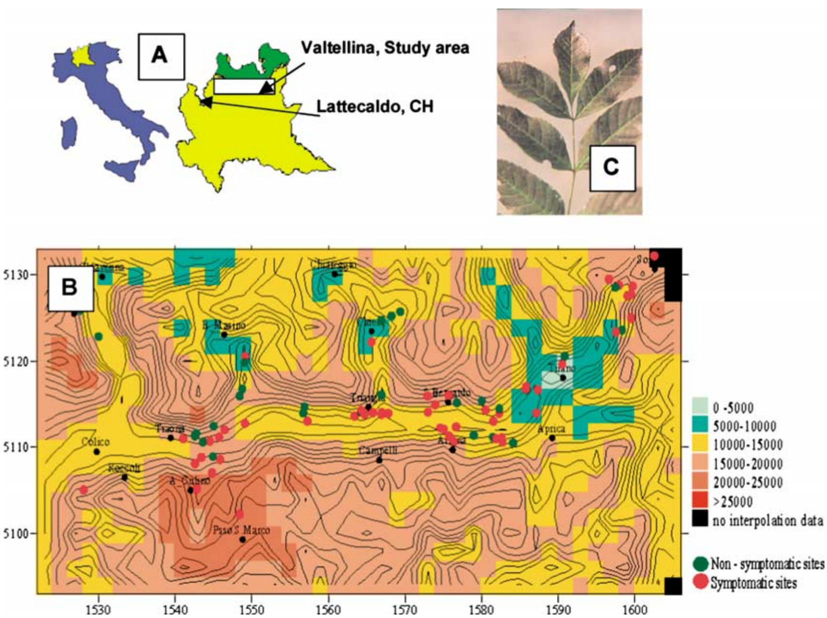

Figure 1. (A) The location of the study area; (B) Map of the exceedances (May–August 1998) and location of symptomatic and non-symptomatic plots. The values are expressed as ppbh; (C) Typical symptoms on *Fraxinus excelsior* leaves.

Symptomatic plots were especially distributed in areas with considerable anthropogenic disturbance or those with irregular forest structures (in these conditions no asymptomatic plots were found at all), where we can find more frequently ruderal sensitive species (*Ailanthus altissima* or *Rubus* spp.) or small trees, more sensitive than the big ones. As far as the stand features are concerned, the main parameter linked to the presence of symptoms was soil depth (73% of the symptomatic plants were found more frequently on deep and moist soil).

The species that was most frequently found to be symptomatic was *Fraxinus excelsior* (26 plots), followed by *Ailanthus altissima* (19), *Prunus avium* (7) and *Rubus* spp. (5). The other species display symptoms with less frequency. The typical symptoms of ozone injury on ash leaves are presented on Fig. 1(C).

Symptomatic sites were scattered throughout the whole area, and no relationship was found with any of the estimated AOT40 values.

3. Discussion

It is usually recognized that the occurrence of foliar symptoms, as well as any physiological injury, does not depend totally on the environmental concentrations of ozone, but rather on the stomatal uptake of this pollutant (Matyssek and Innes, 1999). Thus, factors limiting stomatal gas exchanges are also believed to reduce the harmful effects of ozone. Among these factors those considered most important in the scientific literature are:

- Soil moisture (Schaub et al., 1999). In field conditions symptoms are less evident because water constraints and dry soils enhance stomatal closure (Davison and Barnes, 1998);
- The age of the trees (Kolb et al., 1998). Seedlings and young trees usually have a greater stomatal conductance than mature trees. Aging induces a loss in the efficiency of water transport (Magnani et al., 2000);
- The genotype. Bennett et al. (1992) and Ferdinand et al. (2000) have shown that sensitive individuals of *Fraxinus pennsylvanica* and *Prunus serotina* have a more mesophytic foliar structure than the tolerant individuals: a greater amount of intercellular spaces enhances the effectiveness of gas exchange;
- Structure of vegetation. Canopies provide an obstacle to the deposition and circulation of ozone within forest ecosystems (Dell'Era et al., 1998), so only the individuals in open areas are fully exposed to the action of ozone; and finally
- The different sensitivity of the various tree species and their assemblage according to the ecological conditions markedly influences the distribution of symptoms.

The influence of the factors mentioned above is confirmed by the results of the present survey. In fact the distribution of the symptoms does not follow any AOT40 gradient, but it is influenced by the distribution (according to an altitudinal gradient) of species with different sensitivity (at the higher altitudes we found only coniferous trees, which are less sensitive) and by the distribution of the "modifying" ecological factors, such as soil moisture and canopy structure.

On the other hand, we can observe that the AOT40 levels across the entire study area are high enough to cause visible symptoms; in fact, the sensitive species show foliar injuries with levels of AOT40 less than 10 000 ppb h (VanderHeyden et al., 2000). The lack of differences along the estimated AOT40 gradient may also be due to the period of the survey (late summer). In late summer the response is "flattened" (since each plot has received a sufficient exposure) and the more severely damaged leaves have been shed. To enhance the differences of ozone exposure, it is probably more suitable to detect the symptoms at their onset, assessing the sample trees several times from the beginning of the summer to the onset of the symptoms.

4. Conclusions

The alpine environment is characterized by marked variability of territorial and vegetational features. In these conditions the most important problem in conducting ozone-foliar injuries surveys is to obtain a homogeneous sample, evenly distributed across the investigated territory. Without such a sample (as in the present investigation), only qualitative observations are possible. Moreover, in field conditions the distribution and intensity of leaf injuries doesn't follow a gradient of ozone concentration but, rather, symptom patterns follow the distribution of the sensitive species and the environmental "modifying" factors which are related to a greater or lesser extent to the uptake of ozone.

Probably, more information can be obtained with same-species-trees and shrubs (belonging to the native vegetation) planted in plots distributed according to the AOT40 gradient (*trend plots*, see Chappelka et al., 1999).

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