Probing Ozone Exposure Effects on Different plant species with THz Imaging

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Abstract: This study evaluates Terahertz (THz) imaging for early detection of ozone (O_3)-induced plant damage. Exposure to increasing O_3 concentrations reveals that THz imaging is efficient in detecting subtle ozone-induced physiological changes, providing a promising tool for monitoring plant health and climate-related stress adaptability.

Ozone (O_3) pollution poses a significant threat to plant health, affecting physiological processes and water dynamics. One of the primary physiological effects of O_3 exposure is stomatal sluggishness, which alters water regulation and carbon assimilation, ultimately influencing plant water use efficiency (Paoletti, 2005). Non-destructive techniques such as THz spectroscopy and imaging have emerged as powerful tools for assessing plant stress, offering high sensitivity to water content changes (Rawson and Sunil, 2022).

Here, we investigated ozone (O_3)-induced plant damage using THz continuous-wave imaging through two distinct experimental studies.

The first study (Pagano et al., 2024) focused on two European hornbeam species, *Carpinus betulus L.* (CB) and *Ostrya carpinifolia Scop.* (OC), with the aim of assessing whether THz imaging could identify leaf damage induced by ozone exposure. Experiments were conducted in the field at the O_3 Free-Air Controlled Exposure (FACE) facility in Sesto Fiorentino, Italy, where plants were exposed to three ozone levels: ambient air (AA), 1.5 ×AA, and 2.0 ×AA.

In this experiment, ozone damage was detected by identifying localized spots in THz leaf images appearing as transparent regions. These areas exhibited intensity values comparable to the background, indicating that the leaf tissue was effectively transparent to THz radiation in those points. Such features were interpreted as damaged zones associated with ozone stress. The analysis revealed a higher occurrence and extent of these damaged areas in OC compared to CB, indicating a greater sensitivity of OC to ozone exposure.

The second experiment was performed on *Zelkova serrata*. with the objective of determining whether ozone-induced damage could be detected earlier in the THz range

than in the visible region. THz measurements were carried out before ozone exposure and after one, two, and three months of treatment under the same ozone conditions (AA, 1.5 ×AA, and 2.0 ×AA). The results showed a progressive increase in THz-detected damage over time for all exposure levels. Importantly, clear differences were already observable after two months of exposure, when visual symptoms were still weak or barely detectable, as also shown in figure 1.

Overall, these results demonstrate that THz imaging is an effective tool for the early identification of ozone-induced leaf damage, allowing discrimination between species sensitivity and revealing stress effects before they become evident in the visible domain.

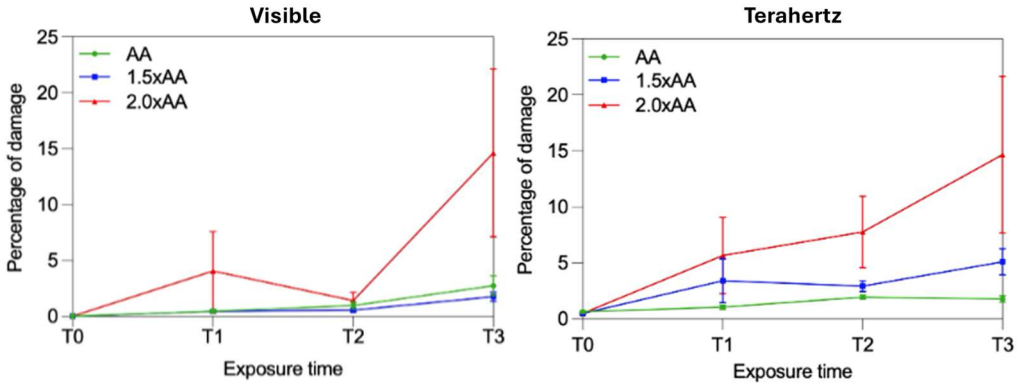

Fig.1 | Percentages of ozone damage as a function of the Ozone exposure time.

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