Effects of ozone on vegetation are modified by nitrogen and factors of climate change

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- **Tropospheric ozone has been identified as the most damaging air pollutant to vegetation.**
- **The impacts of ozone in a future nitrogen polluted and changing climate depend on the ozone sensitivity of plant species and the respective concentration and intensity by which the climate change factors interact with ozone.**
- **While both elevated CO_2 and nitrogen input offered some protection from ozone damage, drought stress can exacerbate the negative effects of ozone.**

Background and aims

Tropospheric ozone (O_3) is considered the most significant phytotoxic air pollutant negatively affecting plant growth, development and productivity. In the context of the Convention on Long-Range Transboundary Air Pollution (CLRTAP) critical levels for O_3 to protect vegetation have been derived for different types of vegetation and they are continuously developed on the basis of present scientific knowledge.

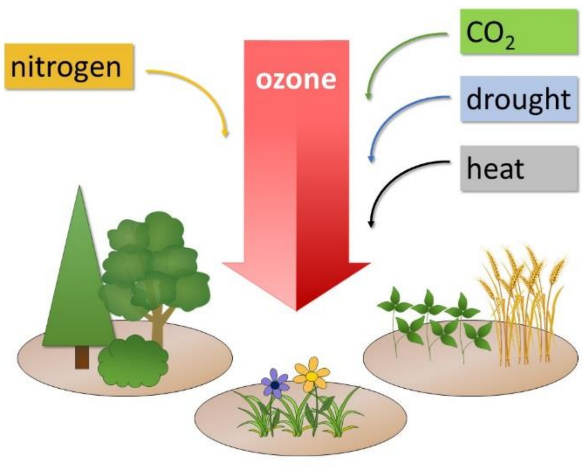
Critical levels are used to estimate the O_3 risk for vegetation in the current and future pollution situation in Europe as a basis for mitigation measures in the European air pollution control policy. The derivation of O_3 critical levels is based on many years of research on the impact of O_3 on vegetation by means of experiments in which plants were exposed to different levels of O_3, mostly under otherwise optimal growth conditions. However, it is known that the effects of O_3 in the field can be significantly modified by a number of other environmental and anthropogenic factors.

The objective of the project was to review the available literature and to summarize the current knowledge on how factors of climate change, including temperature and drought stress, nitrogen input and increased CO_2 concentrations influence or alter the responses of plants to O_3 (Figure 1). The study therefore aims to contribute to a more realistic estimation of ozone risks for vegetation in a future climate.

Approach

A systematic literature search was performed using Web of Science™ (Core Collection, Biological Abstracts, CAB Abstracts) encompassing reviewed papers, book chapters, or research reports starting with the year 1990 and describing results of factorial experiments in which plants have been subjected to exposures of different levels of O_3 in combination with treatments where N, CO_2, temperature, or soil moisture was manipulated. Focusing on crops, forest trees and grassland species, the available literature was analyzed with respect to assess the current knowledge about how temperature and drought stress, N input, and elevated CO_2 concentration can modify growth, yield and gas exchange responses to O_3.

Figure 1: Ozone impacts on vegetation in a future nitrogen polluted and changing climate



Source: Thünen Institute/Elke Bergmann

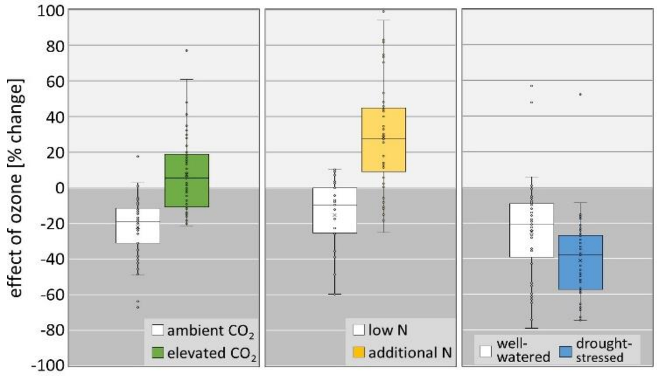
Results

A total of 315 literature references were evaluated which described interactive effects of O_3 with either elevated CO_2, drought stress, temperature, or N input for 65 species. The study shows that, to varying degrees, these other factors may exacerbate or ameliorate the effects of O_3. In principle, elevated CO_2 and N as "fertilizers" have positive effects on plant growth. Although our analysis revealed a great variability in responses to combined exposures with O_3, both factors reduce adverse O_3 effects or even cause a net positive effect in the majority of the experiments (Figure 2). However, the extent of this net effect appears to depend on the concentration of O_3, the O_3 sensitivity of the plant species, the concentration of CO_2 or the amount of N, respectively, and the response parameter considered. This means, for example, that high O_3 exposure levels may also significantly limit the positive growth effects of CO_2 and N.

The lower magnitude of negative O_3 effects at elevated CO_2 were often associated with a lower flux of O_3 into the leaf due to lower stomatal conductance at elevated CO_2. Similarly, drought stress may limit O_3 flux into the leaf as stomata close to prevent water loss. However, when plants are simultaneously exposed to O_3 and soil moisture deficit we found that in some studies drought reduced symptoms of O_3-induced leaf injury (mainly in grassland species), but drought stress tended to exacerbate O_3 effects on growth and biomass in crops and young trees (Figure 2), suggesting that drought stress dominated over the O_3 stress in these studies.

There have been very few experiments that manipulated both O_3 and elevated temperature. A general conclusion on the combined effect is difficult to derive, although critical growth stages such as anthesis are sensitive to both stresses.

Figure 2: Box-Plots of the effect of ozone alone and in combination with elevated CO_2, additional nitrogen and drought stress on plant biomass, calculated as percentage change from an O_3 unpolluted control. The underlying data come from experiments with crops, trees and grassland species.



Source: Thünen Institute/Elke Bergmann

Further Information

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