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Editorial

Impacts of Ozone on Forest Plants and Ecosystems

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Globally, tropospheric ozone is one of the most important air pollutants and greenhouse gases, with adverse effects on forest trees and the function of ecosystems. High levels of ozone are frequently measured in developing and densely populated regions, particularly in Asia and in many parts of southern Europe. Chronic long-term exposure to high ozone concentrations can cause considerable yield and production losses and have a negative impact on the biodiversity of forest ecosystems. Although the responses of forest trees to ozone have been studied for decades, more knowledge and assessment is required to understand the acclimation and adaptation capacity and mechanisms of trees, as well as the interactions between ozone and other climatic, soil and stress factors, to devise better strategies for climate change mitigation and adaptation.

This Special Issue comprises six papers by authors from Italy, Japan and South Korea, representing areas suffering from high ozone concentrations. The papers expand our knowledge about the environmental factors and interactions behind the ozone responses of trees and further impacts on ecosystems.

First, Watanabe et al. [1] studied the impacts of elevated ozone on nitrogen use efficiency (NUE) of Siebold's beech (*Fagus crenata*) seedlings growing at three fertilization levels in a chamber fumigation facility in Japan. Against their expectations, elevated ozone did not decrease the seedling level NUE, although previous studies with this experiment confirmed the negative impacts of ozone on growth and photosynthetic activity of these seedlings. However, leaf level photosynthetic nitrogen use efficiency (PNUE) was decreased by ozone, indicating different responses between seedling and leaf scales. The paper suggests that more research with various tree species is needed to understand the mechanisms and interactions between ozone and soil N supply on the nitrogen use efficiency parameters of trees.

The study by Hoshika et al. [2] conducted at an ozone FACE facility in Italy was able to demonstrate the relationship between the appearance of ozone-induced visible injuries, exposure-based index (AOT40) and flux-based index (POD_y) in three cool–temperate deciduous tree/woody species, *Alnus glutinosa*, *Sorbus aucuparia* and *Vaccinium myrtillus*. The results showed that the timing of the onset of visible injuries was determined by the amount of stomatal ozone uptake. The impact of ozone on the plant injury index (PII) was better explained by the flux-based index (POD_y) compared with the exposure-based index (AOT40), but there were species-specific differences in ozone sensitivity and injury development determined by ecophysiological traits and the developmental stage. For example, in *V. myrtillus*, the plants showed enhanced ozone sensitivity during the flowering and fruiting phase.

The study by Lee at al. [3] focused on leaf mustard (*Brassica juncea* L.), which is an important species in forest ecosystems in many areas of East Asia. They studied the effects of elevated temperature and elevated ozone on the growth, physiology and the accumulation of reactive oxygen species (ROS) in mustard leaf. The results showed that ozone reduced photosynthetic rates, while elevated temperature may enhance ozone damage due to increasing stomatal conductance and ozone uptake by the leaves, accumulation of ROS and reductions in carotenoid and ascorbic acid levels.

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The study by Masui et al. [4] investigated the impact of ozone on profiles of biogenic volatile organic compounds (BVOVs) emitted from birch (*Betula platyphylla*) growing in an ozone FACE facility in Japan. The study was linked with Y-tube insect preference tests with alder leaf beetle *Agelastica coerulea*. The results demonstrated that the leaf beetles were attracted to BVOCs, but the emissions profiles were altered by ozone, leading to less attractive mixtures of BVOC emissions. Therefore, the authors assume that high ozone concentrations can disturb the plant–insect interactions and the orientation of herbivorous insects towards food sources.

Paoletti et al. [5] measured whole-tree transpiration of mature *Fagus sylvatica* and *Picea abies* trees exposed to ambient and twice-ambient ozone regimes in Kranzberg Forest in Germany. The results showed that elevated ozone amplified short-term water loss from mature beech trees by slowing stomatal dynamics, i.e., by causing stomatal sluggishness. However, long-term exposure to ozone led to reduced steady-state stomatal conductance rates, mitigating the water loss and nullifying the impact of ozone on transpiration. Interestingly, there were no differences between the sun and the shade leaves in stomatal responses to ozone. The study demonstrated that stomatal functioning and hydrological parameters are important factors to consider in the ozone risk assessment of forest trees, particularly during high ozone and drought episodes.

Finally, the review paper by Marzuoli et al. [6] analysed the relationships between visible foliar symptoms and plant growth reduction based on the available literature on forest tree species exposed to ozone in different experimental systems. The authors concluded that the appearance of visible injuries and negative growth responses are consequences of separate physiological processes such as various compensatory, detoxification and repair processes, increased respiration, defoliation and closure of stomata, leading to ozone avoidance. Therefore, the authors suggest that the concept of ozone "sensitive" or "resistant" species should be re-considered when used in an ecological context.

Conflicts of Interest: The author declares no conflict of interest.

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