Ozone

Title	Ozone effects on plants in natural ecosystems
Author Name	N. E. Grulke & R. L. Hea
Journal Name	Plant Biology
Year	2019
Volume and Issue	---
Pages	---
Abstracts	Tropospheric ozone (O_3) is an important stressor in natural ecosystems, with well- documented impacts on soils, biota and ecological processes. The effects of O_3 on individual plants and processes scale up through the ecosystem through effects on car- bon, nutrient and hydrologic dynamics. Ozone effects on individual species and their associated microflora and fauna cascade through the ecosystem to the landscape level. Systematic injury surveys demonstrate that foliar injury occurs on sensitive species throughout the globe. However, deleterious impacts on plant carbon, water and nutrient balance can also occur without visible injury. Because sensitivity to O_3 may follow coarse physiognomic plant classes (in general, herbaceous crops are more sensitive than deciduous woody plants, grasses and conifers), the task still remains to use stomatal O_3 uptake to assess class and species' sensitivity. Investigations of the radial growth of mature trees, in combination with data from many controlled studies with seedlings, suggest that ambient O_3 reduces growth of mature trees in some locations. Models based on tree physiology and forest stand dynamics suggest that modest effects of O_3 on growth may accumulate over time, other stresses (prolonged drought, excess nitrogen deposition) may exacerbate the direct effects of O_3 on tree growth, and competitive interactions among species may be altered. Ozone exposure over decades may be altering the species composition of forests currently, and as fossil fuel combustion products generate more O_3 than deteriorates in the atmosphere, into the future as well.
Keywords	Tropospheric ozone (O_3); microflora; drought; nitrogen deposition; competitive interactions; Ozone exposure

Title	**The effects of elevated CO_2 and elevated O_3 exposure on plant growth, yield and quality of grains of two wheat cultivars grown in north India**
Author Name	Achchhelal Yadav, Arti Bhatia, Sudesh Yadav, Vinod Kumar & Bhupinder Singh
Journal Name	Heliyon
Year	2019
Volume and Issue	5, 8
Pages	---
Abstracts	Global food security is challenged by increasing levels of CO_2, O_3 and temperature trough their impacts on production and grain quality of wheat, one of the major C_3 crops and staple food across the world. The present study was conducted to assess the effects of elevated levels of CO_2 (EC; 550 ppm) and tropospheric O_3 (EO; 70 ppb) as well as of combined interactive treatment [EC X EO; ECO] on plant growth, yield and grain quality of two wheat cultivars (HD-2967 and C-306) grown during 2016-17 and 2017-18 using free air ozone and carbon dioxide enrichment (FAOCE) facility under field conditions. Individually, EC, increased leaf area index (LAI; 15.9-28.2%), photosynthetic rate (Pn; 11.4-20.3%) and yield (8.2-20.9%) whereas EO declined LAI (5.1-12.5%), Pn (2.8-11.8%) and yield (2.2-14.2%) over ambient conditions (Amb: 405.2 ppm CO2 and 30.7 ppb O3). Under ECO condition, EC increased LAI (2.2-17.1%), Pn (2.8-17.6%) and grain yield parameters (4.4-24.3%) across the cultivars in both years, but reduced the positive effects of EO on quality as compared to Amb. Dilution effect of increased yield under EC condition have reduced total protein, micro- and macro-nutrient concentrations whereas EO increased them notably compared to Amb. Starch in grains increased under EC but reduced under EO as compared to Amb. AOT40, the sum of averaged difference of O_3 h^{-1} concentration beyond 40 ppb for 7 hours (31233 ppb h^{-1}) in FAOCEs rings during the crop growth period led to reduction in average grain yield of HD-2967 and C-306 by 11.6 and 8.5% or by 1.6 and 1.3% yield loss per ppb increase of O_3, respectively. The growth, yield and quality parameters of both wheat cultivars responded similarly but to different extent to all treatments. EC was able to offset the negative effects of EO on yield and yield components only, but not those concerning the quality of grains. To stabilize global food security, precursor gases forming tropospheric ozone must be constrained.
Keywords	tropospheric O_3; leaf area index; photosynthetic rate; wheat cultivars; global food security

Title	Ozone Toxicity and Remediation in Crop Plants
Author Name	Annesha Ghosh, Aditya Abha Singh, Madhoolika Agrawal & S. B. Agrawal
Journal Name	Environmental Science and Pollution Research
Year	2018
Volume and Issue	25,9
Pages	Pages 8181–8189
Abstracts	Seedlings of durum wheat [Triticum turgidum subsp. durum (Desf.) Husn] were exposed to zinc nutrition and to ozone (O3) in a factorial combination: adequate (+Zn treatment) or no Zn (−Zn) in the nutrient solution, followed by exposure to either ozone-free air (filtered air, FA) or to 150 nL L−1 ozone (O3) for 4 h. Although omitting Zn from the nutrient solution failed to impose a genuine Zn deficiency, −Zn*FA durum wheat seedlings showed a typical deficiency behaviour, i.e. Zn mobilisation from root to shoot. Such inter-organ Zn redistribution, however, did not occur in −Zn*O3 plants. Exposures to each stress singly decreased the activity and the protein amount of foliar plasma membrane H+-ATPase, but not stress combination, which even increased the H+-ATPase expression with respect to control. In the −Zn*O3 plants, moreover, the foliar activities of the plasma membrane-bound NAD(P)H-dependent superoxide synthase and of Cu, Zn-superoxide dismutase, and the transcripts abundance of the luminal binding protein and of the protein disulphide isomerase, were also stimulated. It is proposed that, even in the absence of actual Zn starvation, the perception of deficiency conditions could trigger changes in redox homoeostasis at the plasma membrane level, helpful in compensating an O3- dependent oxidative damage.
Keywords	Zinc; Surface ozone; Plasma membrane; Redox activation; Durum wheat; Triticum turgidum subsp. durum (Desf.) Husn

Title	Exposure- and flux-based assessment of ozone risk to sugarcane plants
Author Name	Barbara Baesso Moura, Yasutomo Hoshika, Rafael Vasconcelos Ribeiro, Elena Paolettib
Journal Name	Atmospheric Environment
Year	2018
Volume and Issue	176
Pages	252-260
Abstracts	Ozone (O3) is a toxic oxidative air pollutant, with significant detrimental effects on crops. Sugarcane (Saccharum spp.) is an important crop with no O3 risk assessment performed so far. This study aimed to assess O3 risk to sugarcane plants by using exposure-based indices (AOT40 and W126) based on O3 concentrations in the air, and the flux-based index (PODy, where y is a threshold of uptake) that considers leaf O3 uptake and the influence of environmental conditions on stomatal conductance (gsto). Two sugarcane genotypes (IACSP94-2094 and IACSP95-5000) were subjected to a 90-day Free-Air Controlled Experiment (FACE) exposure at three levels of O3 concentrations: ambient (Amb); Amb x1.2; and Amb x1.4. Total above-ground biomass (AGB), stalk biomass (SB) and leaf biomass (LB) were evaluated and the potential biomass production in a clean air was estimated by assuming a theoretical clean atmosphere at 10 ppb as 24 h O3 average. The Jarvis-type multiplicative algorithm was used to parametrize gsto including environmental factors i.e. air temperature, light intensity, air vapor pressure deficit, and minimum night-time temperature. Ozone exposure caused a negative impact on AGB, SB and LB. The O3 sensitivity of sugarcane may be related to its high gsto (~535 mmol H2O m−2 s−1). As sugarcane is adapted to hot climate conditions, gsto was restricted when the current minimum air temperature (Tmin) was below ~14 °C and the minimum night-time air temperature of the previous day (Tnmin) was below ~7.5 °C. The flux-based index (PODy) performed better than the exposure-based indices in estimating O3 effect on biomass losses. We recommend a y threshold of 2 nmol m−2 s−1 to incorporate O3 effects on both AGB and SB and 1 nmol m−2 s−1 on LB. In order not to exceed 4% reduction in the growth of these two sugarcane genotypes, we recommend the following critical levels: 1.09 and 1.04 mmol m−2 POD2 for AGB, 0.91 and 0.96 mmol m−2 POD2 for SB, and 3.00 and 2.36 mmol m−2 POD1 for LB of IACSP95-5000 and IACSP94-2094, respectively.
Keywords	Tropospheric ozone; PODy; Stomatal conductance; Ozone FACE; Air pollution; Sugarcane

Title	**Fertilizer efficiency in wheat is reduced by ozone pollution**
Author Name	Malin C. Broberg, Johan Uddling, Gina Mills & Håkan Pleijel
Journal Name	Science of the Total Environment
Volume and Issue	607 - 608
Year	2017
Pages	876–880
Abstracts	Inefficient use of fertilizers by crops increases the risk of nutrient leaching from agro-ecosystems, resulting in economic loss and environmental contamination. We investigated how ground-level ozone affects the efficiency by which wheat used applied nitrogen (N) fertilizer to produce grain protein (NEP, N efficiency with respect to protein yield) and grain yield (NEY, N efficiency with respect to grain yield) across a large number of open-top chamber field experiments. Our results show significant negative ozone effects on NEP and NEY, both for a larger data set obtained from data mining (21 experiments, 70 treatments), and a subset of data for which stomatal ozone flux estimates were available (7 experiments, 22 treatments). For one experiment, we report new data on N content of different above-ground plant fractions as well as grain K and P content. Our analysis of the combined dataset demonstrates that the grain yield return for a certain investment in N fertilizer is reduced by ozone. Results from the experiment with more detailed data further show that translocation of accumulated N from straw and leaves to grains is significantly and negatively affected by ozone, and that ozone decreases fertilizer efficiency also for K and P. As a result of lower N fertilization efficiency, ozone causes a risk of increased N losses from agroecosystems, e.g. through nitrate leaching and nitrous oxide emissions, a hitherto neglected negative effect of ozone. This impact of ozone on the N cycle implies that society is facing a dilemma where it either (i) accepts increased N pollution and counteracts ozone-induced yield reductions by increasing fertilization or (ii) counteracts N pollution under elevated ozone by reducing fertilization, accepting further yield loss adding to the direct effect of ozone on yield. (C) 2017 Elsevier B.V. All rights reserved.
Keywords	O3; Nitrogen; Phosphorus; Potassium; Triticum aestivum; Nitrogen translocation

Title	Tropospheric ozone pollution in India: effects on crop yield and product quality
Author Name	Aditya Abha Singh & S. B. Agrawal
Journal Name	Environmental Science and Pollution Research
Volume and Issue	24,5
Year	2017
Pages	4367–4382
Abstracts	Ozone (O3) in troposphere is the most critical secondary air pollutant, and being phytotoxic causes substantial losses to agricultural productivity. Its increasing concentration in India particularly in Indo-Gangetic plains is an issue of major concern as it is posing a threat to agriculture. In view of the issue of rising surface level of O3 in India, the aim of this compilation is to present the past and the prevailing concentrations of O3 and its important precursor (oxides of nitrogen) over the Indian region. The resulting magnitude of reductions in crop productivity as well as alteration in the quality of the product attributable to tropospheric O3 has also been taken up. Studies in relation to yield measurements have been conducted predominantly in open top chambers (OTCs) and also assessed by using antiozonant ethylene diurea (EDU). There is a substantial spatial difference in O3 distribution at different places displaying variable O3 concentrations due to seasonal and geographical variations. This review further recognizes the major information lacuna and also highlights future perspectives to get the grips with rising trend of ground level O3 pollution and also to formulate the policies to check the emissions of O3 precursors in India.
Keywords	Crop productivity; Ethylene diurea; India; Oxides of nitrogen; Ozone; Quality; Yield

Title	Effects of Ozone on Japanese Trees
Author Name	Makoto Watanabe , Yasutomo Hoshika, Takayoshi Koike, Takeshi Izuta
Journal Name	Air Pollution Impacts on Plants in East Asia
Year	2016
Pages	73-100
Abstracts	The effects of ozone (O3) on tree species in Japan have been studied since the 1970s. Based on the results from O3 fumigation studies, current ambient levels of O3 have negative impacts on the growth and physiological functions of Japanese forest tree species, although there is a big variation of O3 sensitivity between species. Stomatal O3 uptake is one of the key factors that can explain the differences in O3 sensitivity between species and modeling of this factor has been intensively studied during the past decade. Although O3 generally induces stomatal closure, less efficient stomatal control, so-called stomatal sluggishness, is also induced by chronic exposure to O3. These opposite phenomena result in complex responses of stomata to O3. Detailed gas exchange analysis has revealed that O3-induced reductions in the photosynthetic rate of Japanese forest tree species were mainly due to a biochemical limitation in chloroplasts, but not due to stomatal closure. Risk assessments of the O3 impact on Japanese forest tree species, based on the results of experimental studies, national monitoring data of air pollutant concentrations, and vegetation surveys, indicate that the areas with high O3-induced reduction in growth do not necessarily correspond to the areas with relatively high O3 exposure. Free-air O3 fumigation systems in Japan were developed in 2011. Studies with this novel technology have clarified differences in leaf O3sensitivities between canopy positions, and have estimated the effects of O3 on whole-canopy carbon budgets. As future perspectives, not only we need clarification of the physiological mechanisms of O3 impact, but we also need clarification of the effects of interactions between trees and other biotic factors such as diseases, herbivores, and symbiotic microbes.
Keywords	Ozone Japanese; forest tree species; Growth Physiological functions; Stomatal function

Title	**How do increasing background concentrations of tropospheric ozone affect peatland plant growth and carbon gas exchange?**
Author Name	Jennifer L. Williamson, Gina Mills, Felicity Hayes, Timothy Jones ,Chris Freeman
Journal Name	Atmospheric Environment
Year	2016
Volume and Issue	Volume 127
Pages	133–138
Abstracts	In this study we have demonstrated that plants originating from upland peat bogs are sensitive to increasing background concentrations of ozone. Peatland mesocosms from an upland peat bog in North Wales, UK were exposed to eight levels of elevated background ozone in solardomes for 4 months from May to August, with 24 h mean ozone concentrations ranging from 16 to 94 ppb and cumulative AOT024hr ranging from 45.98 ppm h to 259.63 ppm h. Our results show that plant senescence increased with increasing exposure to ozone, although there was no significant effect of increasing ozone on plant biomass. Assessments of carbon dioxide and methane fluxes from the mesocosms suggests that there was no change in carbon dioxide fluxes over the 4 month exposure period but that methane fluxes increased as cumulative ozone exposure increased to a maximum AOT 024hr of approximately 120 ppm h and then decreased as cumulative ozone exposure increased further.
Keywords	Tropospheric ozone; Methane; Peatlands; Wetlands; Senescence

Title	Effects of Ozone on Chinese Trees
Author Name	Zhaozhong Feng , Pin Li
Journal Name	Air Pollution Impacts on Plants in East Asia
Year	2016
Pages	195-219
Abstracts	This chapter reviews the effects of elevated ozone on tree species in China, based on the results of studies in the past two decades. The high ozone concentration in summer in most parts of China has induced typical ozone symptoms in urban and mountain forest tree species. In experiments using open-top chambers, elevated ozone affected the growth, gas-exchange rate, foliar microscopy, antioxidant systems, and biogenic volatile organic compound (BVOC) emissions in trees. The effects of ozone on biomass accumulation depended on the ozone concentration, tree species sensitivity, and exposure duration. The ozone uptake of individual tree species was also investigated by the sap flow technique. Further studies were conducted on the interactions between O3 and other environmental change factors, such as increasing CO2 concentrations, increased nitrogen deposition, and drought. Future needs for research include the development of an O3 flux model for the most widely used tree species and the assessment of ozone removal by urban forests on a regional and a national scale.
Keywords	Biomass; Elevated CO_2; Forest tree species; Gas exchange; N deposition ozone Senescence

Title	**Leaf traits and photosynthetic responses of Betula pendula saplings to a range of ground-level ozone concentrations at a range of nitrogen loads**
Author Name	Harry Harmens, Felicity Hayes, Katrina Sharps, Gina Mills, Vicent Calatayud
Journal Name	Journal of Plant Physiology
Year	2016
Volume and Issue	Volume 211
Pages	42–52
Abstracts	Ground-level ozone (O3) concentrations and atmospheric nitrogen (N) deposition rates have increased strongly since the 1950s. Rising ground-level O3 concentrations and atmospheric N deposition both affect plant physiology and growth, however, impacts have often been studied in isolation rather than in combination. In addition, studies are often limited to a control treatment and one or two elevated levels of ozone and/or nitrogen supply. In the current study,three-year old Betula pendula saplings were exposed to seven different O3 profiles (24 h mean O3 concentration of 36–68 ppb in 2013, with peaks up to an average of 105 ppb) in precision-controlled hemispherical glasshouses (solardomes) and four different N loads (10, 30, 50 or 70 kg N ha−1 y−1) in 2012 and 2013. Here we report on the effects of enhanced O3 concentrations and N load on leaf traits and gas exchange in leaves of varying age and developmental stage in 2013. The response of leaf traits to O3 (but not N) vary with leaf developmental stage. For example, elevated O3 did not affect the chlorophyll content of the youngest fully expanded leaf, but it reduced the chlorophyll content and photosynthetic parameters in aging leaves, relatively more so later than earlier in the growing season. Elevated O3enhanced the N content of senesced leaves prior to leaf fall, potentially affecting subsequent N cycling in the soil. Enhanced N generally stimulated the chlorophyll content and photosynthetic capacity. Whilst elevated O3 reduced the light-saturated rate of photosynthesis (Asat) in aging leaves, it did not affect stomatal conductance (gs). This suggests that photosynthesis and gs are not closely coupled at elevated O3 under-light saturating conditions. We did not observe any interactions between O3 and N regarding photosynthetic parameters (Vc,max, Jmax, Asat), chlorophyll content, gs, N content in senesced leaves and leaf number. Hence, the sensitivity of these leaf traits to O3 in young silver birch trees is neither reduced nor enhanced by N load.
Keywords	Air pollution; Chlorophyll content; Leaf age; Nitrogen content; Photosynthetic capacity; Stomatal conductance

Title	**Removal of Ozone by Urban and Peri-Urban Forests: Evidence from Laboratory, Field, and Modeling Approaches**
Author Name	Carlo Calfapietra , Arianna Morani, Gregorio Sgrigna, Sara Di Giovanni,Valerio Muzzini, Emanuele Pallozzi, Gabriele Guidolotti, David Nowak and Silvano Fares
Journal Name	American Society of Agronomy
Year	2016
Volume and Issue	Volume 45,1
Pages	224-233
Abstracts	A crucial issue in urban environments is the interaction between urban trees and atmospheric pollution, particularly ozone (O3). Ozone represents one of the most harmful pollutants in urban and peri-urban environments, especially in warm climates. Besides the large interest in reducing anthropogenic and biogenic precursors of O3 emissions, there is growing scientific activity aimed at understanding O3 removal by vegetation, particularly trees. The intent of this paper is to provide the state of the art and suggestions to improve future studies of O3 fluxes and to discuss implications of O3 flux studies to maximize environmental services through the planning and management of urban forests. To evaluate and quantify the potential of O3 removal in urban and peri-urban forests, we describe experimental approaches to measure O3 fluxes, distinguishing laboratory experiments, field measurements, and model estimates, including recent case studies. We discuss the strengths and weaknesses of the different approaches and conclude that the combination of the three levels of investigation is essential for estimating O3 removal by urban trees. We also comment on the implications of these findings for planning and management of urban forests, suggesting some key issues that should be considered to maximize O3 removal by urban and peri-urban forests.
Keywords	Anthropogenic ; biogenic precursors; peri urban ; Senescence

Title	**Responses of a tropical tree species to ozone: visible leaf injury, growth, and lipid peroxidation.**
Author Name	Essica C. Cassimiro, Regina M. Moraes
Journal Name	Environmental Science and Pollution Research
Year	2016
Volume and Issue	Volume 23, 8
Pages	8085–8090
Abstracts	The Brazilian native tree species Astronium graveolens was indicated as sensitive to ozone in a fumigation experiment. Thus, the objective of this study was to evaluate how sensitive A. graveolens is to ozone under realistic conditions in the field.Eighteen saplings were exposed to ozone in a contaminated area and in a greenhouse with filtered air during two exposure periods of approximately 63 days each (March–May 2012 and September–October 2012). Leaf injury was analyzed by means of its incidence and severity, the leaf injury index (LII) and the progression of leaf abscission. These variables were monitored weekly, whereas growth and lipid peroxidation were monitored monthly. Plants exposed to ozone showed significant growth decrease and visible leaf injury increase, but lipid peroxidation and leaf abscission remained unchanged. These results indicated that plants subjected to ozone possibly diverted energy from growth to the production of antioxidants necessary to cope with ozone-induced oxidative stress.
Keywords	Air pollution; Ozone; Tropical tree species; Ozone-induced injuries; Astronium graveolens

Title	**Current ambient concentrations of ozone in Panama modulate the leaf chemistry of the tropical tree Ficus insipida**
Author Name	Gerald F. Schneider,Alexander W. Cheesman, Klaus Winter,Benjamin L. Turner, Stephen Sitch, Thomas A. Kursar
Journal Name	Chemosphere
Year	2016
Volume and Issue	Volume 172
Pages	363–372
Abstracts	Tropospheric ozone (O3) is a major air pollutant and greenhouse gas, affecting carbon dynamics, ecological interactions, and agricultural productivity across continents and biomes. Elevated [O3] has been documented in tropical evergreen forests, the epicenters of terrestrial primary productivity and plant-consumer interactions. However, the effects of O3 on vegetation have not previously been studied in these forests. In this study, we quantified ambient O3 in a region shared by forests and urban/commercial zones in Panama and found levels two to three times greater than in remote tropical sites. We examined the effects of these ambient O3 levels on the growth and chemistry of seedlings of Ficus insipida, a regionally widespread tree with high stomatal conductance, using open-top chambers supplied withozone-free or ambient air. We evaluated the differences across treatments in biomass and, using UPLC-MS-MS, leaf secondary metabolites and membrane lipids. Mean [O3] in ambient air was below the levels that induce chronic stress in temperate broadleaved trees, and biomass did not differ across treatments. However, leaf secondary metabolites – including phenolics and a terpenoid – were significantly downregulated in the ambient air treatment. Membrane lipids were present at lower concentrations in older leaves grown in ambient air, suggesting accelerated senescence. Thus, in a tree species with high O3 uptake via high stomatal conductance, current ambient [O3] in Panamanian forests are sufficient to induce chronic effects on leaf chemistry.
Keywords	Ozone; Tropical forest; Open-top chamber; Secondary metabolite; Senescence; Stomatal conductance