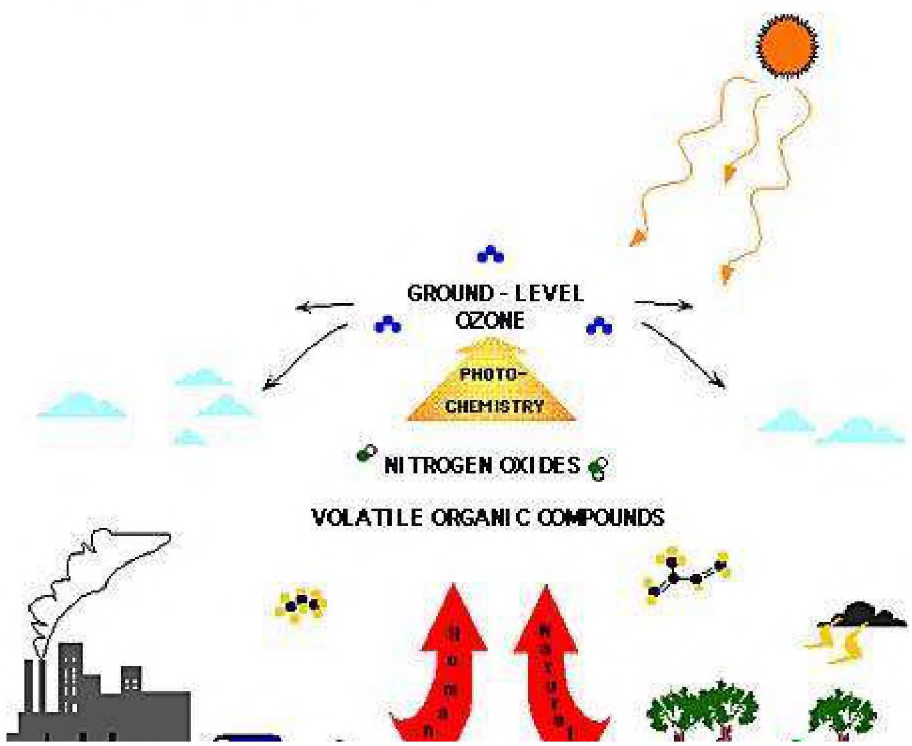
Effects of Ozone Air Pollution on Plants

Ambient ozone inury to sensitive and tolerant snap beans

Ozone injury in a pumpkin leaf

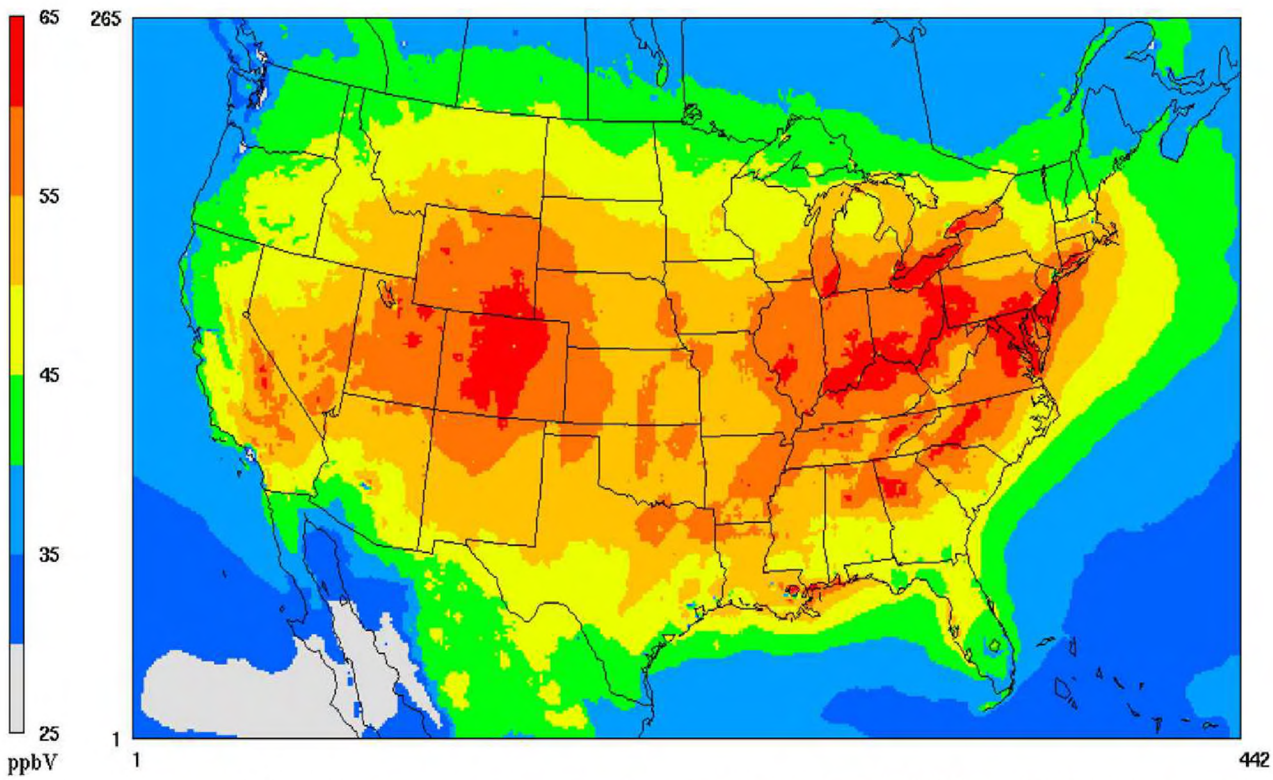
Ground-level ozone causes more damage to plants than all other air pollutants combined. This web page describes the ozone pollution situation, shows classical symptoms of ozone injury and shows how ozone affects yield of several major crops.



Tropospheric Ozone Pollution

Ozone is formed in the troposphere when sunlight causes complex photochemical reactions involving oxides of nitrogen (NOx), volatile organic hydrocarbons (VOC) and carbon monoxide that originate chiefly from gasoline engines and burning of other fossil fuels. Woody vegetation is another major source of VOCs. NOx and VOCs can be transported long distances by regional weather patterns before they react to create ozone in the atmosphere, where it can persist for several weeks.

Seasonal exposures at low elevations consist of days when ozone concentrations are relatively low or average, punctuated by days when concentrations are high. Concentrations of ozone are highest during calm, sunny, spring and summer days when primary pollutants from urban areas are present. Ozone concentrations in rural areas can be higher than in urban areas while ozone levels at high elevations can be relatively constant throughout the day and night.



Seasonal mean of ambient ozone concentrations between 09:00 and 16:00 h over the continental United States from 1 July to 31 September 2005 (Tong et al. 2007Atmos. Environ. 41:8772). Areas shown in brown, orange and red can experience significant crop yield loss and damage to ecosystem function from ambient ozone.

Description of Ozone Injury

Ozone enters leaves through stomata during normal gas exchange. As a strong oxidant, ozone (or secondary products resulting from oxidation by ozone such as reactive oxygen species) causes several types of symptoms including chlorosis and necrosis. It is

almost impossible to tell whether foliar chlorosis or necrosis in the field is caused by ozone or normal senescence. Several additional symptom types are commonly associated with ozone exposure, however. These include flecks (tiny light-tan irregular spots less than 1 mm diameter), stipples (small darkly pigmented areas approximately 2-4 mm diameter), bronzing, and reddening.

Ozone symptoms usually occur between the veins on the upper leaf surface of older and middle-aged leaves, but may also involve both leaf surfaces (bifacial) for some species. The type and severity of injury is dependent on several factors including duration and concentration of ozone exposure, weather conditions and plant genetics. One or all of these symptoms can occur on some species under some conditions, and specific symptoms on one species can differ from symptoms on another. With continuing daily ozone exposure, classical symptoms (stippling, flecking, bronzing, and reddening) are gradually obscured by chlorosis and necrosis.

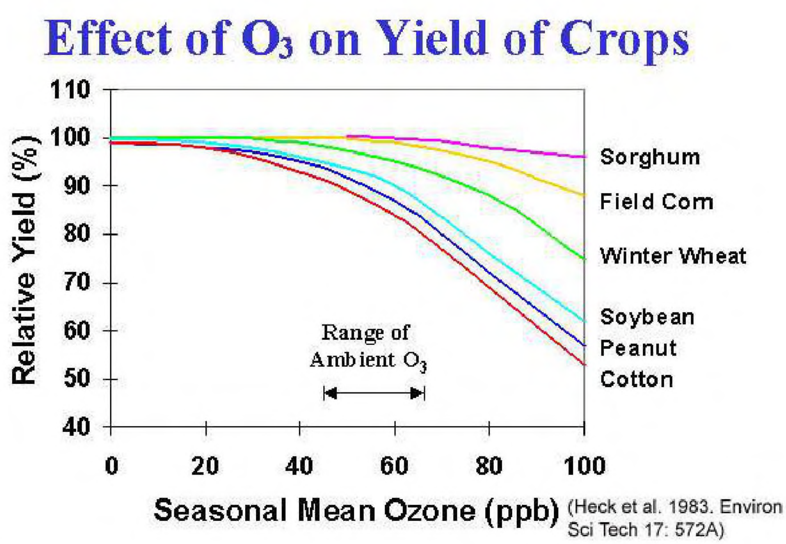


Studies in open-top field chambers have repeatedly verified that flecking,stippling, bronzing and reddening on plant leaves are classical responses to ambient levels of ozone. Plants grown in chambers receiving air filtered with activated charcoal to reduce ozone concentrations do not develop symptoms that occur on plants grown in nonfiltered air at ambient ozone concentrations. Foliar symptoms shown on this web site mainly occurred on plants exposed to ambient concentrations of ozone.

Yield Loss Caused by Ozone

Field research to measure effects of seasonal exposure to ozone on crop yield has been in progress for more than 40 years. Most of this research utilized open-top field chambers in which growth conditions are similar to outside conditions. The most extensive research on crop loss was performed from 1980 to 1987 at five locations in the USA as part of the National Crop Loss Assessment Network (NCLAN). At each location, numerous chambers were used to expose plants to ozone treatments spanning the range of concentrations that occur in different areas of the world. The NCLAN focused on the most important agronomic crops nationally.

The strongest evidence for significant effects of ozone on crop yield comes from NCLAN studies (Heagle 1989). The results show that dicot species (soybean, cotton and peanut) are more sensitive to yield loss caused by ozone than monocot species (sorghum, field corn and winter wheat).



Monitoring ground-level ozone from space
Agricultural Research Magazine, August 2011

Breeding Plants for a High-Ozone World
Agicultural Research Magazine, July 2011.

References

Ainsworth EA, A Rogers, ADB Leakey. 2008. Targets for crop biotechnology in a future high-CO_2 and high-O_3world. Plant Physiology, 147: 13-19.

Bell, JNB and M Treshow. 2002. Air Pollution and Plant Life. 2nd ed. Cinchester:John Wiley & Sons, Inc. 465 pp.

Booker, FL, R Muntifering, M McGrath, KO Burkey, D Decoteau, EL Fiscus, W Manning, S

Krupa, A Chappelka, DA Grantz. 2009. The ozone component of global change: Potential effects on agricultural and horticultural plant yield, product quality and interactions with invasive species. Journal of Integrative Plant Biology 51:337-351.

Fiscus, EL, FL Booker, KO Burkey. 2005. Crop responses to ozone: uptake, modes of action, carbon assimilation and partitioning. Plant, Cell and Environment 28:997-1011.

Fishman, J, JK Creilson, PA Parker, EA Ainsworth, GG Vining, J Szarka, FL Booker and X Xu. 2010. An investigation of widespread ozone damage to the soybean crop in the upper Midwest determined from ground-based and satellite measurements. Atmospheric Environment 44:2248-2256.

Heagle, AS. 1989. Ozone and crop yield. Annual Review of Phytopathology 27:397-423.

Heck, WW, AS Heagle, DS Shriner. 1986. Effects on Vegetation: Native, Crops, Forests. In: Air Pollution. 3rd Ed., Vol. VI. Supplement to Air Pollutants, Their Transformation, Transport and Effects. AC Stern, ed., pp. 248-333. Academic Press, New York, NY.

Krupa, S, MT McGrath, C Andersen, FL Booker, KO Burkey, A Chappelka, B Chevone, E Pell, B Zilinskas. 2001. Ambient ozone and plant health. Plant Disease 85:4-17.

Matyssek, RH Sandermann, G Wieser, FL Booker, S Cieslik, R Musselman, D Ernst. 2008. The challenge of making ozone risk assessment for forest trees more mechanistic. Environmental Pollution 156:567-582.