

Plant stress

Adding ethylene to injury

Mike Unsworth

OZONE is a gas about which environmentalists are equivocal. Most atmospheric ozone is formed and resides in the stratosphere (12–40 km) where it is generally agreed to be beneficial because it absorbs otherwise harmful ultraviolet light. Consequently, substances that destroy stratospheric ozone, such as chlorofluorocarbons used in refrigerators and aerosol sprays, are viewed with concern. But ozone is also formed in the lower atmosphere from reactions involving pollutants such as nitrogen oxides and hydrocarbons. In hot, sunny weather these reactions proceed rapidly and, if there is little wind, ozone concentrations can become large enough to damage sensitive plants. It is difficult to assess the importance of this ozone as a plant stress because it often occurs simultaneously with other stresses such as drought. On page 417 of this issue, Mehlhorn and Wellburn propose that ethylene, known to be emitted from stressed plants, determines the susceptibility of plants to injury by ozone. If they are correct, this could be an important unifying concept for explaining ozone/stress interactions.

Plants produce ethylene, an important growth regulator, during normal metabolism. Ethylene production increases rapidly following trauma caused by chemicals, temperature extremes, drought, disease and insect damage. This enhanced production of 'stress ethylene' can accelerate the abscission of leaves or fruit damaged by stresses. Stress ethylene has often been used as a measure of ozone injury, but it does not seem to have been suggested previously that ethylene biosynthesis is a necessary condition for ozone injury to occur.

Mehlhorn and Wellburn find that leaves of pea seedlings grown for three weeks in clean air are severely damaged by only one exposure to ozone, and release large amounts of stress ethylene. In contrast, seedlings exposed every day to ozone produce very little ethylene and have no leaf injury after three weeks. To test the hypothesis that rates of ethylene emission influence the amount of leaf injury caused by ozone, the authors sprayed seedlings grown in clean air with an inhibitor of ethylene biosynthesis and exposed them to ozone. Compared with unsprayed controls, the seedlings that could not synthesize ethylene had substantially less injury. Finally, to test whether exposure to a second pollutant could increase stress ethylene production and so increase the ozone-mediated injury, they exposed seedlings to nitric oxide (NO) and

nitrogen dioxide (NO₂) as well as ozone. In each case, injury was greater than in ozone alone, and there was more ethylene emitted. Interestingly, exposure to NO or NO₂ without ozone did not lead to injury, but did increase ethylene emissions, and the authors speculate that the plants would therefore be susceptible to subsequent ozone exposure.

These results led Mehlhorn and Wellburn to suggest that plants are more susceptible to ozone injury if high ozone concentrations (or other stressing factors)

occur infrequently, because the capability for stress-ethylene production would be greater in such plants than in plants that had been continually stressed. Ozone undoubtedly does occur in this episodic fashion, and if this mechanism turns out to be generally correct, the value of the long series of growth experiments in which crops are exposed every day to ozone (Heck W.W. *et al. J. Air Poll. Control Ass.* 32, 353–361; 1982) becomes decidedly dubious. But other evidence makes the case unproven at this stage.

Although it is possible that ethylene emission is no more than an indicator of biochemical processes that are disrupted by ozone, Mehlhorn and Wellburn favour the more exciting interpretation — that reaction between ozone and stress ethylene causes the observed injury. P.M

Survey of UK ozone distributions

THE figure displays the daily maximum ozone concentrations (hourly mean values) recorded in 1978 in Devilla forest, Scotland. Also shown diagrammatically and tentatively are contributions from major ozone sources, as reviewed in a recent report*. Prolonged exposure to levels above 50 parts per billion (p.p.b.) damages many species of trees and plants, whereas short-lived episodes of concentrations above 100 p.p.b. are also deleterious (see the accompanying article by Mike Unsworth). There seems to be a rising trend in tropospheric ozone levels around the globe but a lack of consistency between experimental monitoring stations renders it hard to arrive at a definitive verdict.

A principal source of ozone in the lower atmosphere is the photolysis of nitrogen dioxide by solar ultraviolet radiation, although downward transport from the stratosphere can be at least as important. A balance is struck as ozone reacts with the photolytically generated nitric oxide or is taken up at the surface. But other agents such as photochemically degraded hydrocarbons can also oxidize nitric oxide and thereby leave ozone levels enhanced.

The report provides a timely survey of ozone distributions in the United Kingdom and of the means by which people are try-

ing to account for them, including a striking (if idealized) depiction of the inter-linked roles of meteorological and man-made chemical processes in an imaginary parcel of air passing over an isolated town in the early daytime.

The parcel picks up nitric oxide and hydrocarbons which are mixed within the lowest kilometres by surface heating and turbulence. Within an hour the most reactive hydrocarbons (olefins) are photochemically oxidized and, in the presence of nitrogen oxides, start to enhance ozone levels as outlined above. The parcel moves away from the town and ozone levels increase over the next 10 hours or so, as aromatic hydrocarbons followed by olefins of medium reactivity make their presence felt. Ozone production declines after sunset, but the chemical destruction or deposition of the gas is hindered, if the circumstances are particularly unfavourable, by its being trapped above a nocturnal temperature inversion layer. On subsequent days the hydrocarbon-associated processes continue so that ozone levels only start to decline once hydrocarbon oxidation is complete several days later.

Such an episode is particularly likely to occur in summer, when typically low wind speeds allow the build up of precursor chemicals while reaction rates are enhanced by sunlight and by higher temperatures. Philip Campbell

*Ozone in the United Kingdom by the UK photochemical oxidant review group, available from Department of the Environment, Victoria Road, South Ruislip HA4 0NZ, UK, price £10.

