What Beans Reveal about Ozone Impact on Plants in the Northeast

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Every summer on Long Island, NY, ozone reaches high enough concentrations to cause visible foliar injury in sensitive plants. While regulations have resulted in a reduction in vehicular emissions, which are an important source of precursors for the formation of ozone by the action of uv radiation, there has been an increase in the number of vehicles. Ozone is more toxic to plants than other common air pollutants. Plants generally are more sensitive to ozone than people. Injury includes stippling and bronzing, which can lead to leaf death. Leaves without acute injury may also die prematurely because ozone induces accelerated senescence of leaves that involves many of the genes involved in natural senescence.

Presumably injury and senescence induced by ambient ozone affects the productivity of plants; however, determining this impact is challenging. Assessing impact necessitates having plants not affected by ozone to compare with plants that are affected. The main method that has been used entails growing plants outdoors in specialized chambers with charcoal-filtered air next to plants grown in similar chambers with non-filtered air. A disadvantage of this system, aside from the cost, is the fact that the environment inside is different from that outside the chamber where the plants normally grow and this could have a confounding effect.

An alternative method for investigating ozone impact has been identified that entails comparing two lines or clones of a plant that differ in sensitivity to elevated ozone but have similar productivity when ozone levels are low. A system with snap bean was developed for assessing ozone impact. The two bean clones are grown outdoors in the ground. Both fresh market and mature yield are measured by removing pods from some plants every week as they reach size for fresh market consumption and removing pods once they have dried from the other plants. Since beans reach maturity in just 12 weeks, two to three successive planting times are needed to cover the entire summer growing period.

Ambient ozone on Long Island has been demonstrated to have an impact on plant productivity using the bean system at Cornell University's research facility in Riverhead. This work has been on going for several years. During growth periods when ozone levels measured at this location were low, which was sometimes in the spring and other years during fall, the ozone-sensitive and tolerant plants did not differ significantly in the number or weight of bean pods produced. This documents these pairs do produce similarly when ozone is low, providing validity to the system. Leaves of the sensitive bean have exhibited bronzing, which often has been sufficiently severe to result in the leaves drying up and dropping off the plant. Images of the injury are posted at http://www.longislandhort.cornell.edu/vegpath/photos/ozone_beans.htm. Impact of episodes of high ozone on productivity of bean has been extremely high. Weight of beans harvested immature for fresh market was reduced as much as 62%. There were up to 56% fewer bean seeds in mature pods. And the average weight of those seeds was up to 42% lower.

A simple relationship has not been found between ozone concentrations that plants were exposed to and the subsequent impact measured. This partly reflects the fact the dose of ozone that gets inside of plants depends on stomatal conductance and other aspects of flux. If plants are water stressed when ozone is high, stomates will be closed, and thus ozone dose will be lower than for well-watered plants. Sometimes an acute exposure (several days of very high ozone concentrations) can result in severe leaf injury that is more detrimental to plant productivity than moderate high ozone levels on all the other days during the growth period. For example, ozone exceeded 80 ppb on 6 of 7 days during 15 – 21 July 2007 with hourly average reaching 120 -128

ppb three times. Very severe ozone injury was observed on 25 July, which was 6 days before the first harvest of fresh market pods in the second planting that year. High ozone events in Riverhead have varied from year to year since 1996. The yearly highest 1-hour ozone concentration recorded has ranged from 104 ppb to 168 ppb. The date that this has occurred has varied from 7 June to 9 August. Ozone has been at least 80 ppb for as few as 40 hours on 8 days during a growing season and as many as 184 hours on 31 days. This research continues to further document the impact of ground level ozone on plant productivity and to elucidate the relationship between ozone exposure and impact.

Ozone injury has been observed in vegetable crops growing on Long Island, in particular pumpkin and potato. Premature senescence of leaves may also be occurring. Consequently these crops may also be sustaining yield reduction due to ozone. Images of injury are posted at http://www.longislandhort.cornell.edu/vegpath/photos/index.htm.

Ozone also reaches high levels in New England; consequently, plant productivity may also be affected there. For example, during 2006 – 2011, while the 1-hr highest ozone concentration in Riverhead ranged from 90 to 167 ppb, it was 96 to 129 ppb in New Haven, CT, 89 to 146 ppb in East Hartford, CT, 109 to 144 ppb in Danbury, CT, 86 to 106 ppb in East Providence, RI, 66 to 81 ppb in Boston, MA, 87 to 119 ppb in Adams, MA, 83 to 128 ppb in Truro, MA, 83 to 136 ppb in North Amherst, MA, 73 to 92 ppb in Manchester, NH, 71 to 84 ppb in Bennington, VT, 78 to 120 ppb in Portland, ME, 80 to 99 ppb in Kennebunkport, ME, 55 to 76 ppb in Presque Isle, ME. Concentrations above 40 ppb are considered potentially injurious to sensitive plants. Ozone concentrations can be high far from major urban areas due to air currents moving the ozone and additionally, ozone concentrations tend to decline more quickly in urban areas because vehicles and other sources of precursors for ozone formation are also sources of compounds involved in breaking down ozone. There is concern that ozone pollution could increase in the future as a result of deep natural gas well drilling using hydraulic fracturing (aka fracking) as a means of natural gas extraction.