Ozone's Impact On Soybean Yield: Reducing Future Losses

URBANA, ILL.

People tend to think of ozone as something in the upper atmosphere that protects the earth's surface from UV radiation. At the ground level, however, ozone is a pollutant that damages crops, particularly soybean.

Lisa Ainsworth, a University of Illinois associate professor of crop sciences and USDA Agricultural Research Service plant molecular biologist, said that establishing the exposure threshold for damage is critical to understanding the current and future impact of this pollutant.

"Most of my research is on measuring the effects of ozone on soybean, determining the mechanisms of response, and then trying to improve soybean tolerance to ozone so that we can improve soybean yields," she explained.

Ozone is highly reactive with membranes and proteins and is known to damage the human lung. It also harms plants, slowing photosynthesis and accelerating senescence. As a result, they take in and fix less carbon, reducing yield. Ainsworth said that ground level concentrations of ozone are already high enough to damage crop production.

"Ozone reacts very quickly once it enters the leaf through the stomata," she explained. "It can form other oxygen radicals and also hydrogen peroxide. Then a series of cascading reactions causes a decrease in photosynthesis, reducing stomata conductance."

The plant's response to ozone mimics a hypersensitive response to a pathogen attack. "At quite high concentrations of ozone, you can get leaf bronzing, stippling of the leaves, and necrotic spots," Ainsworth said. "At really high concentrations, you get cell death." The metabolic changes then feed forward to affect plant productivity.

Ainsworth's group conducted a two year study in 2009 and 2010 at the Soybean Free Air Concentration Enrichment (SoyFACE) facility at the U of I South Farms. It was the first dose-response experiment to look at ozone and soybean under completely open-air conditions.

They investigated the responses of seven different soybean genotypes to eight ozone concentrations. The plants were exposed to ozone concentrations ranging from ambient levels of 38 parts per billion up to 200 parts per billion. "This is quite high, but unfortunately, those kinds of concentrations are what very polluted areas of China and India are looking at today," Ainsworth said.

The researchers found that any increase above the ambient concentration was enough to reduce seed yield: roughly half a bushel per acre for each additional part per billion.

"This is significant," Ainsworth said. "Especially considering that background concentrations of ozone today vary year to year, anywhere from about 38 to 39 parts per billion to about 62. That can be 15 bushels per acre from one year to the next that farmers are losing to ozone."

The researchers compared the results of this study, which used modern genotypes, with results from experiments conducted in controlled environments in the 1980s. They found that the responses of the modern genotypes were similar to those of the older genotypes.

"Breeders haven't inadvertently bred for ozone tolerance in more modern lines," Ainsworth said. "They're still sensitive to ozone, which means that farmers are still subject to these yearly variations in ozone and are losing yield accordingly."

Potential increases in background ozone are predicted to increase soybean yield losses by 9 to 19 percent by 2030. Levels were particularly high during this year's growing season because most days were sunny and warm, and thus they were favorable for ozone formation. Peaks on many days exceeded 80 parts per billion, twice the known sensitivity threshold.

The research was recently published online in Plant Physiology and can be accessed at http://www.plantphysiol.org/content/early/2012/10/04/pp.112.205591.abstract. Amy Betzelberger, Craig Yendrek, Jindong Sun, Courtney Leisner, Randall Nelson and Donald Ort are co-authors. Δ