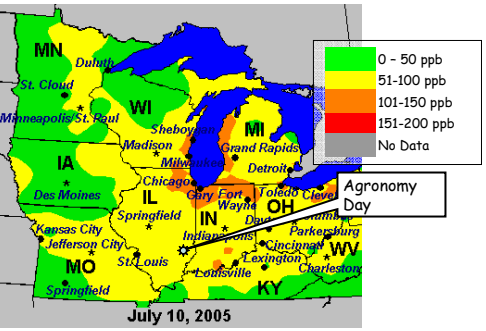
The Air Pollutant Ozone in Central Illinois Decreases Soybean Yields by 20% and may become worse. What is being done to solve this?

Elizabeth Ainsworth, Andrew Leakey, Timothy Mies, Patrick B. Morgan, Randall Nelson, Don Ort, Stephen Long.
Departments of Crop Sciences and Plant Biology, Institute of Genomic Biology.



Environmental Protection Agency Ozone Monitoring

The air pollutant ozone has risen steadily in the rural Midwest since the 1960s. Daytime summer concentrations in central Illinois average 50 – 60 parts per billion (ppb). Soybean is one of the most sensitive crops to ozone, showing yield decreases when levels exceed 30 ppb. Studies in chambers suggest that current levels in Illinois lower soybean yields by about 10%. However, until now this has not been tested in fields in the open air. SoyFACE has provided the first "real-world" test of these losses. The facility raises the ozone level, 20% background, from planting to harvest.

Soybean yields and ozone – findings in SoyFACE

In 2002 the background daytime ozone concentration was 60 ppb, the current average for Central Illinois, and an increase to 72 ppb, the mean level expected for 2030 – 2050, decreased yield by 15%. This not only confirms the expectation from chamber studies of a yield loss, but shows even more damage. In 2003 mean ozone concentration was low at 50 ppb. Increasing this by 20% raised the concentration to the 60 ppb, the average for typical of Central Illinois summers today, and lowered yield by 25%. 2003, as a low ozone year, showed the yield loss that the crop suffers in an average year today while 2002 showed the further loss that will occur, if we do not find a solution. Ozone is low in S.America so developing ozone tolerant soybean will be critical to maintaining the competitiveness of the Midwest crop. Although varieties vary in their response to ozone, all show some yield loss and there is no connection between release date and degree of yield loss. That is, varieties selected under the higher ozone levels of the last decade appear no more resistant than those of 100 years ago.

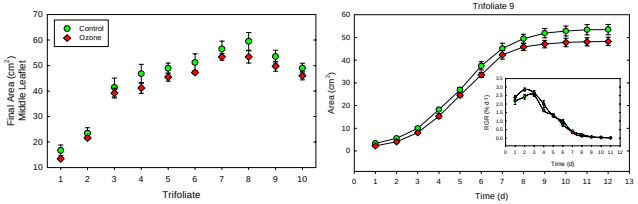
So there is a problem. What are we doing about it in SoyFACE?

Defining what germplasm is more resistant to ozone and how.

1) Characterizing how ozone decreases leaf growth (see middle panel)
2) Determining the network of genes involved in soybean response to ozone, and those which may increase tolerance by up-regulation (see panel on right).

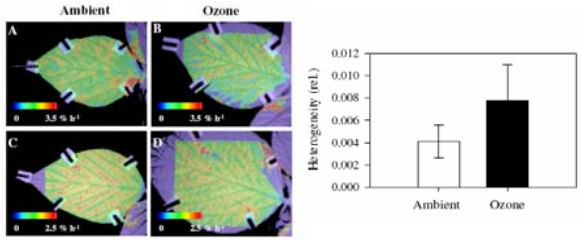
Effects of elevated ozone on development of leaf area and dynamics of leaf growth

• Development of leaf area was tracked throughout the growth season by taking digital images of leaves.



• Final leaf area was lower in plants grown at elevated ozone, despite little change in the relative growth rates of individual leaves.

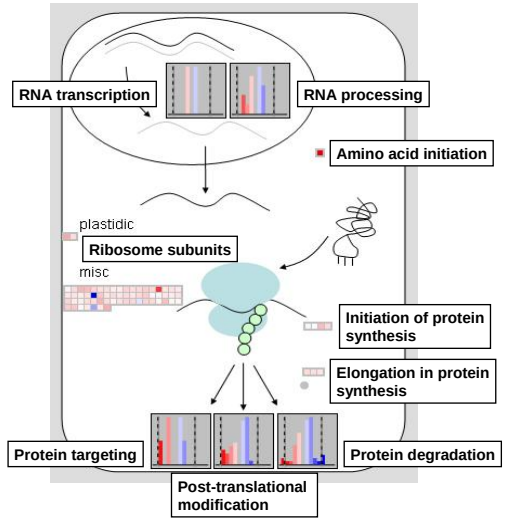
• We are using digital image sequence processing to investigate the fine scale spatial and temporal patterns of leaf growth.



• Preliminary results suggest growing leaves exposed to elevated ozone have increased spatial heterogeneity in growth rates.

Microarray analysis revealed that at elevated ozone gene expression for the machinery to synthesize protein was inhibited in soybeans

• Each box below (■) represents a unique transcript associated with an enzyme or structure in soybean leaves.
• The color signifies the ratio of abundance in elevated ozone compared to ambient ozone.
• Darker red = fewer transcripts in elevated ozone.
• Darker blue = more transcripts in elevated ozone.



• Gene expression to produce the ribosomes and enzymes needed to synthesize protein was inhibited at elevated ozone
• This may be a key part of the molecular mechanism that leads to accelerated senescence at elevated ozone and reduced photosynthesis and crop yield