

Change and the Heartland

How Climate Change Will Affect the Midwest

Big issues, bite-sized lessons



How Will All That Extra CO₂ Affect Crops?



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Imagine that the atmosphere is a buffet for plants, one that provides the carbon dioxide (CO₂) they use to produce sugars. What if every day that buffet served up a little bit more CO₂ for plants to eat? Would the plants grow faster, become larger? Or is it possible for plants to overeat or overheat?

A unique experiment at the University of Illinois is answering this question. The Soybean Free-Air Gas Concentration Enrichment experiment (SoyFACE—soyface.illinois.edu) is growing soybeans and corn at concentrations of CO₂ expected for the year 2050.

The soybeans and corn are grown according to standard agricultural practices and are not isolated from other environmental factors such as rainfall, sunlight, and insects.

Soybean Yields May Increase 15%

SoyFace has provided the unprecedented ability to investigate yield responses of soybean and corn grown at high CO₂ under real field-scale conditions. The results so far have been clear and consistent: elevated CO₂ at levels anticipated for 2050 improves soybean yields by 15% and has no effect on corn yields.

Both Corn and Soybeans May Be More Drought-Resistant

Both crops have improved soil moisture when grown at elevated CO₂, suggesting that they might be more drought-tolerant in the future.

Increased Ozone and Pests May Negate CO₂ Benefits

The SoyFACE story about changing climate is not completely rosy. An unexpected result from the experiment done by Evan

Key Term

Carbon Fertilization

A common trick in greenhouses is to give plants extra carbon dioxide. Some plants can use that extra CO₂ to produce extra food and grow faster. This is known as carbon fertilization.

Now, as cars, factories, and powerplants pump CO₂ into the atmosphere of “greenhouse Earth,” CO₂ is fertilizing plants on a global scale.

CO₂ fertilization doesn’t affect all plants equally. In general, this global increase in CO₂ will give a boost to trees and shrubs, but not to some grasses. For crops, CO₂ fertilization may boost soybean yields, but it will probably not affect corn yields.

DeLucia’s laboratory is that plants grown in elevated CO₂ are preferred by insects. Beetles eat more leaves, live longer, and have more offspring when feeding on leaves grown at high CO₂.

This is true for two reasons. Soybeans grown at elevated CO₂ have higher sugar content, and they shut down a key natural insect defense pathway. So not only are insects attracted to the tastier leaves, it appears that the leaves don’t put up a fight while they’re chewed.

In addition to rising CO₂, ozone (O₃) concentrations at the ground level are increasing, and SoyFACE is studying this change. Ozone at ground level is generated when smog reacts with sunlight. Unfortunately,

Corn and Beans Changing the Air They Eat

ozone does not always form where the smog is produced. Smog can travel hundreds of miles before it reacts with sunlight, which effectively increases the concentration of ozone in rural areas, including much of the midwestern corn belt.

Ozone will react with any living tissue to cause oxidative damage and, in plants, ozone decreases photosynthetic carbon gain.

In the SoyFACE experiment, elevated ozone concentrations have caused an average 17% reduction in soybean seed yield. Therefore, while future elevated CO₂ levels alone might increase yield, increased herbivory and elevated levels of atmospheric ozone will decrease yield and possibly negate benefits derived from rising CO₂.

Why Does Extra Carbon Dioxide Improve Yields for Beans But Not Corn?

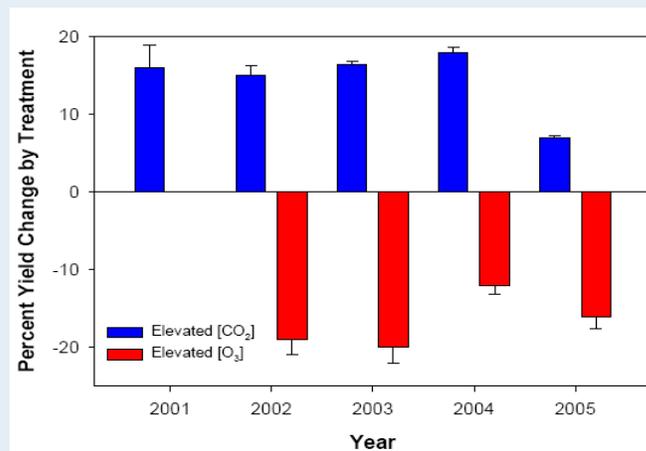
The impact of rising atmospheric carbon dioxide on plant and crop growth and production has been a major research interest around the world because plants use atmospheric CO₂ to build the carbon-based molecules that humans and all other animals rely on for growth. Additionally, climate change factors such as rising temperature and increasing drought stress will reduce future crop yields, while rising CO₂ has been considered a potential silver lining of global climate change.

How different crops respond to rising CO₂ depends on the process of photosynthesis. Plants convert CO₂ and water into sugar molecules and oxygen in the presence of light. Our world's entire food web depends on photosynthesis for the basic building blocks of life.

This is why plant physiological response to climate change is a focus of research. For many plants, including soybeans (referred to as C3 plants), the first step in photosynthetic carbon fixation involves an enzyme called Rubisco (ribulose 1,5 carboxylase/oxygenase). Corn and many other grasses (called C4 plants) rely on a different enzyme (phosphoenolpyruvate carboxylase) to take up CO₂ before releasing it in specialized cells for uptake by Rubisco.

Even though Rubisco is the most abundant enzyme on earth, it is currently running under capacity in C3 plants because atmospheric CO₂ levels are not high enough to maximize the rate at which R can convert CO₂. Increasing the supply of CO₂ to C3 plants will increase the rate of Rubisco's reaction and the subsequent production of sugars.

Ozone Negates CO₂ Benefits



Blue: Extra CO₂ boosted soybean yields 15%

Red: Extra ozone decreased soybean yields 17%

“CO₂ fertilization” did not significantly boost corn yield

In C4 plants, CO₂ is concentrated in specialized cells that contain Rubisco. This concentration mechanism means that rising atmospheric CO₂ won't directly benefit C4 photosynthesis. Thus, C4 crops such as corn and sorghum are predicted to be less responsive to rising CO₂ than C3 crops, which include wheat and soybean.

Why Does Extra CO₂ Increase Drought Resistance?

Increased access to CO₂ can have a significant influence on drought tolerance in both C3 and C4 crops. Leaf surfaces in both types of plant are covered in tiny pores, called stomata, which open and close to allow CO₂ to diffuse into the leaf.

When these pores are open, water vapor escapes. Plants grown with elevated CO₂ do not need to open their stomata as much to satisfy CO₂ needs, so less water is lost. This increases whole-plant water use efficiency and allows both C3 and C4 crops to maintain higher photosynthetic rates during times of drought.

About the Researchers

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