Elevated carbon dioxide changes soil microbe mix below plants

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A detailed analysis of soil samples taken from a forest ecosystem with artificially elevated levels of atmospheric carbon dioxide (CO_2) reveals distinct changes in the mix of microorganisms living in the soil below trembling aspen. These changes could increase the availability of essential soil nutrients, thereby supporting increased plant growth and the plants' ability to "lock up," or sequester, excess carbon from the atmosphere. The research will be published online this week in the journal *Environmental Microbiology*.

"These changes in soil biota are evidence for altered interactions between trembling aspen trees and the microorganisms in the surrounding soil," says Daniel (Niels) van der Lelie, a biologist at the U.S. Department of Energy's (DOE) Brookhaven National Laboratory, who led the research. "This supports the idea that greater plant detritus production under elevated CO_2 has altered microbial community composition in the soil. Understanding the effect these microbial changes have on ecosystem function, especially via effects on the cycling of essential elements, will be important for evaluating the potential of forests to act as a natural carbon sink in mitigating the effects of rising CO_2."

Atmospheric CO_2, the most abundant "greenhouse gas," has been increasing since the start of the industrial age, and is one of the main contributing factors associated with climate change. Since plants take in CO_2 and convert it to biomass during photosynthesis, much research has focused on the potential of forests to sequester excess carbon and offset the rise in CO_2.

Various studies have demonstrated increased plant growth under elevated CO_2, but there is no consensus on many of the secondary effects associated with these plant responses. The goal of this study was to investigate the composition and role of microbial communities, which help to regulate the cycling of carbon and nitrogen in terrestrial ecosystems.

The study was conducted on soil samples collected at an experimental trembling aspen forest in Rhinelander, Wisconsin. That forest is outfitted with a series rings made of large pipes that can pump a controlled amount of carbon dioxide (or other gases) into the air to artificially mimic expected environmental changes in an otherwise open-air environment. This and other similar "free-air carbon dioxide enrichment" (FACE) facilities around the world were developed by the Department of Energy to help estimate how plants and ecosystems will respond to increasing CO_2. Before FACE, much of what scientists knew about plant and ecosystem responses to rising CO_2 came from studies conducted in enclosures, where the response of plants is modified by their growth conditions.

In this study, the scientists compared the microbial content of soil taken from three FACE rings receiving ambient levels of CO_2 (about 383 parts per million, as of January 2007) with that from soil taken from three FACE rings that have been receiving elevated CO_2 (560 parts per million) - a level expected to be ambient on Earth in the year 2100 if the current rate of CO_2 increase remains constant at 1.9 parts per million per year.

The scientists first isolated the genetic material from each soil sample. They then used molecular genetics techniques to isolate regions of genetic material known to be highly species-specific, sequenced these regions, and compared them with genetic sequence libraries of known bacteria, eukaryotic microbes (those with nuclei, such as fungi and protozoa), and archaea, a group of microbes that are genetically distinct from bacteria and often dwell in extreme environments.

Main findings

There were no differences in total abundance of bacteria or eukaryotic microbes between ambient and high CO_2 soil samples. But elevated CO_2 samples showed significant changes in the composition of these communities, including:

-- an increase in heterotrophic decomposers - microbes that rely on an external food source and break down organic matter to recycle carbon and nitrogen

-- an increase in ectomycorrhizal fungi - which gain nutrients by living in association with plant roots and help to provide the plants with essential minerals

-- a decrease in fungi that commonly cause disease in plants - perhaps because increased plant growth stimulated by CO_2 makes the plants less hospitable/susceptible to the fungi.

-- a significant decrease in nitrate-reducers of the domain bacteria and archaea potentially implicated in ammonium oxidation.

The increased plant growth associated with elevated CO_2 environments has often been observed to be temporary because of the progressive depletion of the element nitrogen from the soil. Such a limitation has not yet been observed at the Rhinelander FACE site.

"Overall, the changes we observed support previously reported increases in biomass turnover rates and sustained availability and translocation of the essential nutrients required for increased plant growth under elevated CO_2," van der Lelie said.

Source: Brookhaven National Laboratory