Not all plants will thrive in 'greenhouse'

With atmospheric carbon dioxide levels likely to double over the next 100 years, many climate analysts forecast a sunny future for green plants, which harvest the gas for their growth. But some plant ecologists now say the prospect for plants in a future "greenhouse" climate looks partly cloudy at best. Three research groups reported potentially mixed blessings at the American Institute of Biological Sciences meeting in Toronto earlier this month.

Plants respond to carbon dioxide doubling with a significant increase in photosynthesis — the rate at which green plants absorb carbon dioxide. But Chantal D. Reid and Boyd R. Strain at Duke University in Durham, N.C., find this response does not necessarily flag a positive adaptation. Sugar maples, they report, increase photosynthetic carbon dioxide uptake by 20 percent (per unit weight) when grown in 650 parts per million (ppm) carbon dioxide instead of the 350-ppm level representative of ambient conditions. Beech trees increase their carbon dioxide absorption just half as much under carbon dioxide enrichment. In terms of growth, however, only the beech benefited from an increase.

Green plants also "exhale" some carbon dioxide. The Duke experiments, which Reid describes as the first to precisely measure a plant's below-ground release of carbon dioxide, show that maple and beech trees lose five times more carbon dioxide from roots than from leaves. And under carbon dioxide enrichment, maples increased this loss to compensate for the higher photosynthetic rate. As a result, Reid says, these trees "surprisingly" grew no faster than counterparts raised under ambient carbon dioxide levels. The beech, however, grew 50 percent faster under carbon dioxide enrichment. Reid says this suggests beeches may have a selective advantage over maples in the future.

Dennis F. Whigham and his colleagues at the Smithsonian Environmental Research Center in Edgewater, Md., found a similar species-specific growth adaptation to carbon dioxide enrichment in a salt marsh. Field studies comparing grasses with grass-like sedges showed that the sedges received no growth benefits from a carbon dioxide doubling. Sedges, Whigham explains, belong to a class of plants using a different ("C4") photosynthetic pathway, and so would not be expected to take advantage of the extra fertilization.

In contrast, marsh grasses grown in plastic-covered, carbon-dioxide-enriched field sites grew about 20 to 30 percent more than those breathing ambient carbon dioxide. Their tissue also showed carbon enrichment, which Whigham says may make it decompose more slowly. This suggests such grasses could transform salt marshes into net carbon "sinks," or storage sites, he says.

Carbon dioxide increases are not the only predicted climate change of the future. If stratospheric ozone continues to thin — as many scientists think it will — increased levels of biologically damaging ultraviolet light will bathe Earth's surface. Ecologists at the University of Maryland in College Park are investigating how higher ultraviolet levels might affect plant growth.

In one ongoing study, they irradiate loblolly pines with ultraviolet levels characteristic of a 25 percent thinning in stratospheric ozone — which could occur by the middle of the next century. Now in its third year, the study shows most irradiated pines growing about 10 percent slower than pines grown at ambient levels. And this year, the growth changes are beginning to affect tree height and general architecture, reports physiological ecologist Joe H. Sullivan, who says the trees appear "more shrubby."

In another experiment, the group irradiated wheat, rice and soybeans with similar ultraviolet increases. Compared with plants grown at ambient ultraviolet levels, all three suffered reductions in photosynthetic capacity of 5 to 10 percent. When the same species instead confronted a combination of ultraviolet increases and doubled carbon dioxide levels, all stepped up photosynthesis. But these increases were as much as 40 percent smaller than those of identical plants grown in high levels of carbon dioxide but ambient levels of ultraviolet.

The take-home message, Sullivan says, is that the higher growth seen in plants raised under enriched carbon dioxide levels may lead to an overly optimistic view of the future. — *J. Raloff*

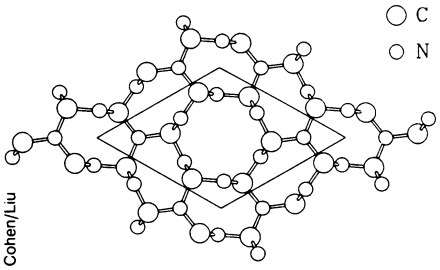
Dreaming up crystals that outdo diamond

After envisioning their dream house and drawing up blueprints, a couple can assemble the dream into a reality. Following a similar course, scientists with a theoretical bent have used a supercomputer to draw up molecular plans for crystalline materials that, if actually made, could surpass the world-record hardness of diamond.

Harder-than-diamond materials would outperform diamond at the jobs it does now, such as protecting the surfaces of drill bits and other cutting tools. The superhard materials might also enable engineers to machine diamonds into intricate shapes — a feat beyond any existing material — for electronic and exotic applications.

Using a simple mathematical model of material hardness and supercomputer calculations of physical features of simulated crystals, physicist Marvin L. Cohen and graduate student Amy Y. Liu of the University of California, Berkeley, predict in the Aug. 25 SCIENCE that new solids made of carbon and nitrogen could prove at least as hard as all-carbon diamond.

"We feed in some information about the atoms, and then go through a long computer calculation to get out the information about the solid," Cohen says. But before committing to expensive calculations, Cohen uses a simple equation he developed earlier that describes how a material's compressibility relates to its constituent atoms and the length of the bonds connecting them. The equation indicates that the shorter the distance between the atoms and the more equally, or covalently, the atoms share their bonding, or outermost, electrons, the harder the solid.



Cohen/Liu

View of the C_3N_4 crystal structure. Parallelogram shows crystal's basic unit.

Covalent solids made of carbon and nitrogen might be superhard, Cohen says, because carbon-nitrogen bonds are shorter than the carbon-carbon bonds in diamonds. The tougher task involves figuring out which of the many possible crystal structures will yield superhard solids. After ruling out simpler but unstable structures, Cohen and Liu used a supercomputer to analyze a possible carbon-nitrogen structure based on a real crystal made of hexagonally arranged silicon and nitrogen atoms in a 3:4 ratio.

The calculations suggest that a carbon version of the real crystal, once formed, would have enough cohesive energy to remain intact. They also indicate the crystal would be just shy of diamond hardness, though Cohen suspects even harder carbon-nitrogen arrangements exist. Berkeley experimentalist Raymond Jeanloz has begun preliminary attempts to realize the dream crystal by squeezing carbon and nitrogen ingredients at high pressures in a diamond anvil press while heating them with lasers. — *I. Amato*