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altered for an increase in the amino acid lysine.

Indeed, protein-improved produce may be just around the corner. Five years from now, predicts the workshop's nutrition group, people will be eating protein-enhanced beans, corn, soybeans and wheat, and livestock will chow down on altered corn, soybeans, wheat, alfalfa, rapeseed and sunflower.

Any risks posed by these crops would vary depending both on the plant host and on the source of each new protein. And although scientists have few actual examples on which to base safety predictions, they say they suspect that plants receiving a gene for a well-characterized protein from a known source will pose little if any health risk.

Scientists find themselves handicapped not only by the lack of experimental data but also by their incomplete understanding of genetic expression in plants. This makes it difficult to predict how a given manipulation will affect the plant's other genes, says food scientist John E. Kinsella of Cornell University. In addition, gene transfer technology has yet to reach the point where scientists can control where in a plant's genome a new piece of DNA will insert itself, notes Stephen H. Howell, Boyce Thompson's director of plant molecular biology.

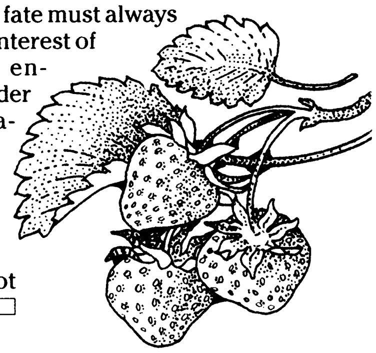
However, because genetic engineering results in a well-defined genetic change — as opposed to an unknown alteration later selected as an observable trait, as occurs in plant breeding — it theoretically introduces fewer unknowns into the product. Thus, genetic engineering should ultimately enable scientists to predict more accurately whether a new gene will affect a plant's overall health and its usefulness as food.

As the technology advances, genetic engineering should provide a much more efficient way to endow plants with agriculturally and nutritionally important traits than is possible with conventional breeding. With genetic engineering, scientists would need to isolate a gene only once in order to use it on subsequent occasions without much additional work. Moreover, by linking beneficial genes to marker genes, they could more easily detect the presence of the desired gene in the transgenic plant and follow it through subsequent generations. And because genetically engineered plants would have more predictable properties, researchers could more easily identify plants with the desired traits, Falco says.

Some food scientists and policymakers worry that plant geneticists might engineer crops with traits that improve processing and yield at the expense of good nutrition. Plant breeders have already contributed to such "nutritional erosion" by endowing tomatoes with genes for uniform ripening, "self pruning" and other commercially beneficial traits that significantly decrease vitamin C content, Doyle says. He wonders: "Where are the priorities, and who's going to set them?"

Many believe that genetic engineering will, on balance, promote better health by enhancing plants' nutritional value and even ridding some foods of natural toxins. Nonetheless, scientists must first ensure that potential risks will not cast a shadow over the technology's budding blessings.

Warns Kinsella, paraphrasing advice from Albert Einstein: "Concern for man himself and his fate must always form the chief interest of all technical endeavors, in order that the creations of our minds — and, I would add, our laboratories — shall be a blessing and not a curse." □



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Surveys slash away at forest estimates

Two new studies indicate Earth's forests may hold far less vegetation than commonly believed — and therefore may be much less able to store the carbon dioxide emitted by human activities, primarily fossil-fuel burning. These findings, reported last week at the American Institute of Biological Sciences' annual meeting in Toronto, could complicate scientific and political efforts to balance the planet's carbon budget and to slow a climate-altering buildup of atmospheric carbon dioxide.

Green plants inhale carbon dioxide, exhale oxygen and harness carbon for growth. To gauge how much of the world's carbon dioxide emissions such plants can absorb, scientists need an accurate tally of vegetative mass, or biomass. However, maintains Daniel B. Botkin of the University of California, Santa Barbara, until now "there have been no statistically valid estimates of biomass for any large area of the Earth."

Two years ago, Botkin began surveying North America's boreal forests — the largely coniferous woodlands running from the Arctic tree line down through Canada and dipping into the northern United States. His statistically representative sampling of 760 circular plots, each 10 meters in diameter, indicates they contain a mean biomass of 4.2 kilograms per square meter (kg/m^2). Botkin says that adds up to 1.9 billion metric tons of stored carbon within the roughly 5 million km^2 boreal forest he surveyed — only one-third the total indicated by most previous assays of that forest.

He attributes most overestimates to ecologists' practice of trekking into known mature forests, measuring what's there and then multiplying those values by the presumed area of the forest. He thinks the "same casual [survey] techniques" have probably exaggerated biomass estimates for all other ecosystems. In contrast, Botkin randomly surveyed all regions able to support forests. This enabled him to identify not only existing forest but also areas cleared for agriculture, burned, logged or covered by bedrock or water.

Forest ecologist Sandra Brown of the University of Illinois at Urbana-Champaign reports that accepted biomass figures for tropical woodlands may be similarly exaggerated. As recently as 1980, she says, "we thought we knew what the biomass of the tropical forest was" — generally about 35 kg/m^2. But she says she and other researchers had obtained those estimates by averaging values from about a dozen places worldwide, using a total sampling of less than 30 hectares (0.3 km^2). Having recently tapped into "statistically sound" forestry inventories conducted for economic reasons and stored at the United Nations Food and Agricultural Organization, she says she's now finding that tropical biomass values vary regionally — from about 5 to 55 kg/m^2. And because of "rampant" cutting and degradation of tropical woodlands, she says the average of 35 kg/m^2 is no longer valid in many places.

For years, policymakers in industrial nations have pressured developing nations in the tropics to preserve their trees from overexploitation because forests play such an invaluable role in the global environment, notes Charles A.S. Hall at the State University of New York at Syracuse. Hall thinks Botkin's data hint at some hypocrisy in that stance by intimating that "we in the United States and Canada are also chopping down our forests as fast as we can."

Together, Botkin's and Brown's studies suggest the world's forests "have been degraded more than we had thought," says Sandra Postel, a natural resource analyst with the Worldwatch Institute in Washington, D.C. If so, she says, "there's even more reason to step up reforestation rates — not just to recapture the carbon we've lost, but also to regain the ecosystem services [such as erosion protection and water-holding capacity] that we're obviously losing." *— J. Raloff*