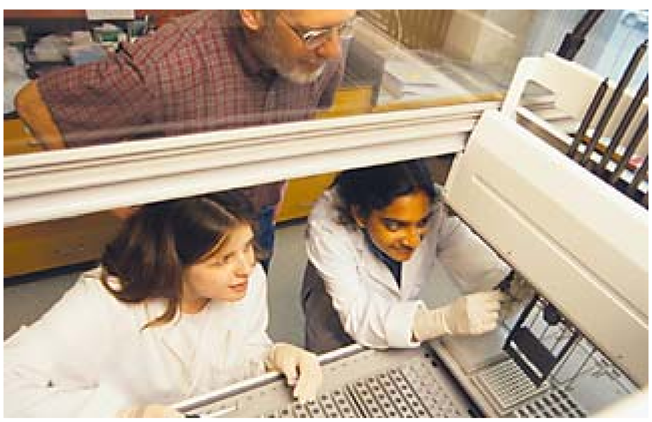
Cornell scientists use genetic tools in a race to feed the world's hungry

By Susan Lang

In Cornell's Biotechnology Building, Ray Wu, a molecular biologist, and his colleagues are making use of insect-resistant genes from potato plants and salt- and drought-hardy genes from barley plants by transferring them to rice plants to improve the tolerance of the plants to insects, salt and drought stresses.

Two floors down in the Biotechnology Building, Stephen Kresovich of the Institute for Genomic Diversity is working with international researchers to understand genetic diversity to improve yields and hardiness of two of the developing world's most vital crops, cassava and millet.



Stephen Kresovich, above, director of Cornell's Institute for Genomic Diversity, works with, from left, lab technician Amber Carmon, a senior majoring in biological sciences in the College of Agriculture and Life Sciences, and Ramya Rajagopalan, a junior biology major in the College of Arts and Sciences. They are setting up DNA amplifications on the liquid-handling workstation in the institute's lab in the Biotechnology Building. *Frank DiMeo/University Photography*

And across campus, plant breeders Steven Tanksley and Susan McCouch are working to unlock the genetic treasures in the germplasm of wild, often inedible, species to enhance the nutritional value, yields and disease resistance of edible crops in the developing world.

Feeding the hungry Third World

This flurry of research depends on the latest tools of genetics in an effort to feed the world's hungry people and to do so before the pressures of population on crops become so great that starvation reaches catastrophic levels. It is research in which Cornell has a large and growing stake.

"Future productivity increases will require raising the genetic yield potential of crops, and the only way to do that is with sophisticated genetic engineering and biotechnology techniques," said Tanksley, Cornell's Liberty Hyde Professor of Plant Breeding and Biometry.

But Cornell researchers like Tanksley, McCouch and Wu can't do this alone, and increasingly they are turning to the opportunities for interdisciplinary research that Cornell offers. Because genomics sits at the intersection of biology/genetics and computational science/bioinformatics, the opportunities for cooperative research on campus are wide.

The plant geneticists are able, for example, to work with colleagues in the Center for Bioinformatics and Comparative Genomics, established at Cornell a year and a half ago by the U.S. Department of Agriculture, where they can explore and compare information about the genome structure and function of agricultural plants. Or researchers can consult the center's databases, Demeter's Genomes named for the Greek goddess of the harvest to look for specific information on such areas as DNA maps and markers and beneficial traits in crops, contributed by plant scientists worldwide.

Further emphasizing the depth of information and technology resources in plant genetics available at Cornell are the powerful computers at the Cornell Theory Center (CTC), known as the Velocity complex. These systems support genome and related databases, as well as advanced research in computational molecular biology and genomics.

Much essential information is provided through CTC's Parallel Processing Resource for Biomedical Scientists, funded by the National Center for Research Resources, where the focus is on developing interdisciplinary approaches to molecular structure focused on revealing the relationship between structure and function of proteins, the products of genes.

New faculty members frankly admit that these resources are among the research outlets that attracted them to Cornell. "The expertise and information available in bioinformatics and the gene databases will be particularly helpful to me," said Walter De Jong, who came to Cornell as assistant professor of plant breeding in February. The researcher, who is genetically characterizing resistance to a highly destructive cyst nematode of potatoes, said, "I hope to begin conducting microarray analyses soon, looking at the expression of thousands of genes simultaneously in potatoes."

The need for this interdisciplinary cooperation is critical.

"Millions of people in the Third World are facing food insecurity and malnutrition," said McCouch, an associate professor of plant breeding. "Is it ethical for the well-fed people of the West to use biotechnology to prolong their own lives through bio-engineered pharmaceuticals and ignore the potential of biotechnology to better feed the undernourished world?"

Today's population of 6 billion is expected to reach 8 billion by 2030 and the demand for food is expected to double over that same period. Yet, as the world population grows by 250,000 a day, land, fresh water and other natural resources needed to produce staple crops are declining.

McCouch, Wu and Tanksley and other Cornell researchers are acutely aware that the most effective strategy for staving off starvation is to enable people to grow their own food but to grow crops that have better nutritional value, higher yields, greater disease resistance and higher tolerance to drought and saline soils than in the past.

"Hundreds of millions of hungry people need these crops now because the crop losses to insects, drought and increasing salinization of soils are devastating," said Wu, professor of biochemistry, molecular and cell biology, and leader of an international team that splices genes from other plant species into rice.

Mining wild rice

Tanksley sees the best hope for meeting the developing world's food needs through mapping wild varieties in order to pick out the best characteristics of each.

"Owing to the advent of molecular mapping and our ability to scan the genomes of wild species for new and useful genes, we can now mine wild inedible species for previously undiscovered genes and harness them for human food production," he said.

Tanksley, McCouch and their colleagues, for example, have systematically used molecular markers to map genes of the tomato and rice and have identified specific genes or loci known as the quantitative trait loci that can boost production. Before the use of molecular markers, breeders had no way of identifying specific genes that controlled complex (or quantitative) traits in any species.

"Rice will be the first crop plant in the world to be completely sequenced, and this provides us with an opportunity to look at the entire genetic repertoire of this important species," said McCouch. "As rice geneticists, we try to understand how the genome is structured, how it evolved and how it functions. In other words, we want to understand how genetics contributes to the biology of the rice plant in its natural environment and how specific genes contribute to agriculture by driving higher grain yields, pest resistance, etc. We also study the repetitive, non-coding portion of the genome to understand how the whole organism works."

In a Cornell greenhouse, Ray Wu, left, professor of molecular biology and genetics, sophomore biology major Joan Lee and Ajay Garg, a postdoctoral student in molecular biology and genetics, study an example of genetically modified rice that is insect-, salt- and drought-tolerant. *Nicola Kountoupes/University Photography*

This work is aimed at tapping the potential of genetic maps, which allow McCouch and others to identify and move genes for high yield, for example, from wild rices into widely eaten cultivated varieties. New lines are being tested in China that are expected to produce 15 to 20 percent more than the best Chinese rice hybrids.

McCouch also is working on developing high-yielding inbred rice varieties because they "breed true," meaning that their seeds serve both as food and as the source of new plants for the next generation. Varieties now being developed in collaboration with researchers from throughout the rice-growing world are expected to generate increased yields of 3 percent to 5 percent a year for the next 20 years. The beauty of inbreds, McCouch said, is that they keep the seeds in the hands of the farmers at no additional cost.

McCouch not only gets this information out to researchers around the world but also trains undergraduate students as future plant scientists. Presidential Research Scholar Vincent Lee, a sophomore in the College of Agriculture and Life Sciences (CALS) whose major is biology, with a focus on molecular biology and bioinformatics, works on computational approaches to genome analysis to try to better understand how sequence information can be used to predict biological function.

McCouch also looks ahead to recruiting junior and high school students. For example, Presidential Research Scholar Chris Maher, a junior in CALS, works with McCouch and Margaret Corbit at the Cornell Theory Center on developing multi-user virtual worlds on the Internet that involve learning about transposable elements in rice and maize as after-school activities for high school and junior high school students. The science outreach program is supported by the Cornell Theory Center, the USDA the National Science Foundation.

Improving cassava and millet

Cornell researchers are now applying what McCouch and Tanksley have learned in tomatoes and rice to cassava and millet, staple foods in some developing countries. Much of this work is now under way at the Institute for Genomic Diversity at CALS where researchers apply of state-of-the-art genomics and bioinformatics to solve problems affecting global food security and the conservation of biodiversity. Researchers such as institute director Kresovich and his colleagues work closely with scientists from around the world to improve vital crops, such as cassava and millet.

One of the regular visitors to the institute is Nigerian scientist Martin Fregene of the International Center for Tropical Agriculture (CIAT) in Cali, Colombia, a research organization dedicated to alleviating hunger and preserving natural resources in developing countries. Fregene is working to improve cassava, a crop that more than 500 million people in the developing world depend on for their food and livelihood (the crop also is known as manioc; in the United States it is more familiar as tapioca). Cassava provides more than half the daily calories for 200 million people in sub-Saharan Africa and provides significant amounts of protein.

"Pests and poor agronomic practices can cut production in half," said Fregene, noting that in 1998, Africa lost 60 percent of its cassava crop, the region's largest source of calories, to the mosaic virus.

Now, with Kresovich's help, Fregene is trying to develop cassava with higher yields, starch content and disease resistance.

"We help him through understanding genetic diversity of the crop so that he can genetically modify cassava to resist pests and diseases that can wipe crops out in Latin America and Africa," said Kresovich. "We've also been involved with Fregene's work to boost the carotene, iron, zinc content of the roots, improving dry foliage yield."

Cornell also is helping improve millet, a staple grain for millions in Asia and Africa and considered the seventh most important cereal grain in the world. Pearl millet, for example, is one of the most important food crops in the arid and semi-arid tropics. Tom Hash, who was a visiting fellow at the Institute for Genomic Diversity and now is at the International Center for Crops Research in the Semi-Arid Tropics in Andhra Pradesh, India, is trying to improve drought resistance in millet and to shorten the crop's lifecycles so plants can escape late-season drought. He also is trying to make varieties more disease resistant. He and his colleagues have made significant progress incorporating genes that foster resistance and boost production, and they are field testing a variety of new cultivars in India.

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