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MICHIGAN AGRICULTURAL EXPERIMENT STATION

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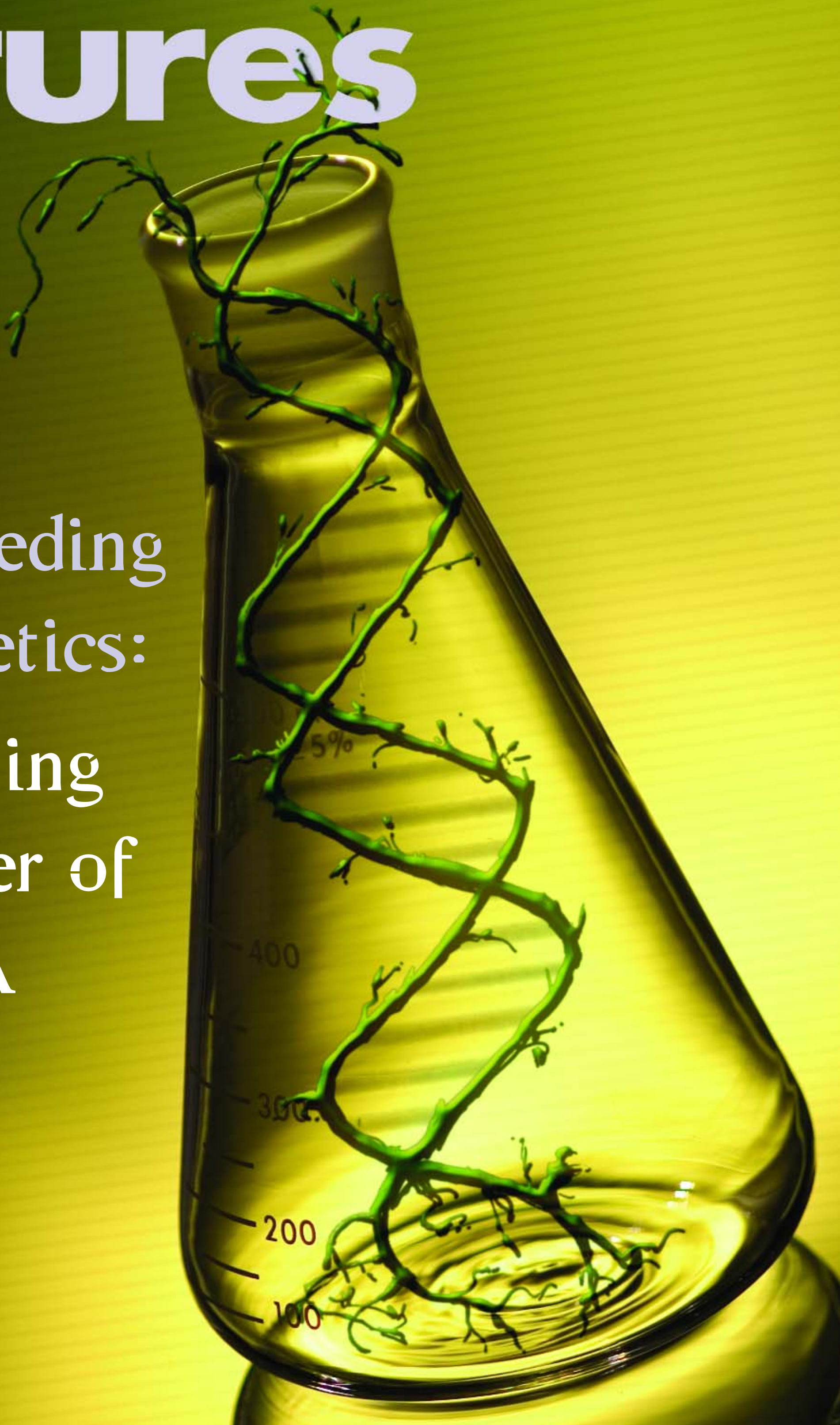
Plant Breeding and Genetics:

Harvesting the Power of DNA



looking into futures

Plant Breeding and Genetics

Since its creation, the Michigan Agricultural Experiment Station has been helping growers by developing new plant varieties and cultural techniques. Breeding and variety release are an outgrowth of the Hatch Act, passed by Congress in 1887, which created the MAES.

In 1877, William Beal established the first seed testing laboratory in the United States at what was then the Michigan Agricultural College. Beal was also the first person to cross-fertilize corn to increase yield through hybrid vigor. In 1940, Stanley Johnston, superintendent of the MAES field station at South Haven, made history by releasing the Redhaven peach variety, an early-ripening, red-skinned peach he had developed. Redhaven, the first commercial red-skinned peach, was one of 11 “Haven” peach varieties developed at MSU, and it went on to become the most widely grown cultivar in the world.

Michigan growers continue to need new varieties to remain competitive, and MAES plant breeders are working on developing even better, more prolific varieties. MAES plant geneticists and microbiologists also are creating new tools that plant breeders can use when developing these plants. In this issue of *Futures*, we feature just a small portion of the MAES-supported plant breeding and genetics research.

Biotechnology is used to improve plants and make food production more efficient and profitable. But because the science is difficult to understand and often poorly explained in the media, many people have fears about the technology and its use. The MSU Plant Transformation Center (PTC), one of nine such centers around the country, is helping to ease those fears by providing education and information about biotechnology. The PTC is a hub for biotechnology techniques at MSU, and one of its goals is to develop biotechnology methods for crops advantageous to Michigan agriculture, as well as provide services and training to MSU researchers.

Since 1915, MSU plant breeders, many of them supported by the MAES, have released more than 300 varieties of plants, from corn, wheat and alfalfa to zinnias, strawberries and spruce trees. Each breeder works closely with Michigan growers to improve the desirable traits in each crop while keeping yields high. Yet some in agriculture perceive that plant breeding is becoming the purview of private companies because many plant breeding positions at public universities are being eliminated. To address that issue, the Plant Breeding and Genetics Group at MSU organized an international conference on the topic, the first of its kind. With support from the MAES, the group was able to bring in experts from around the world, and participants were highly enthusiastic about the conference and its follow-up work.

Before plant breeders can develop a variety that is insect- or disease-resistant, they have to find a source of resistance, usually from a plant from the same or related species. Then the scientists have to determine how to cross-breed the plants or isolate the responsible genes and move them from one plant to the other. The MAES supports the work of a number of researchers who characterize themselves as “filling up the toolbox” of techniques for use by other scientists, such as plant breeders. Many times these scientists isolate genes or genetic pathways responsible for desirable traits and then develop new techniques to insert the genes into economically important agricultural crop plants.

The history of Michigan State University, the pioneer land-grant institution, is closely tied to the history of agriculture and natural resources. In honor of MSU’s 150th anniversary, each issue of *Futures* in 2005 will feature a special sesquicentennial article highlighting the intersection of MAES and MSU history.

We hope you enjoy this issue of *Futures* and that it helps you understand more about the MAES and the research it funds. If you have comments or questions or would like to subscribe to *Futures* (it’s free!), send correspondence to *Futures* Editor, 109 Agriculture Hall, Michigan State University, East Lansing, MI 48824-1039, or send an e-mail to depolo@msu.edu.

For the most current information about the MAES, I invite you to subscribe to the free MAES e-mail newsletter. Sign up by visiting the MAES Web site at www.maes.msu.edu/news.htm. Scroll to the bottom of the page and complete the subscription form.

::: Jamie DePolo

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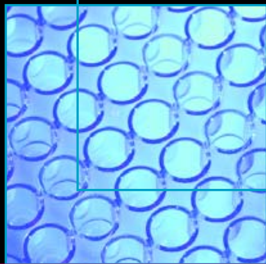
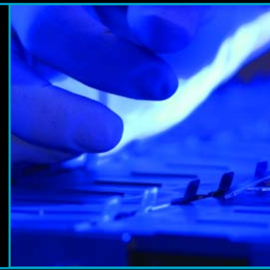
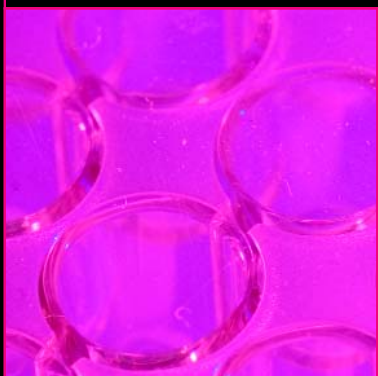
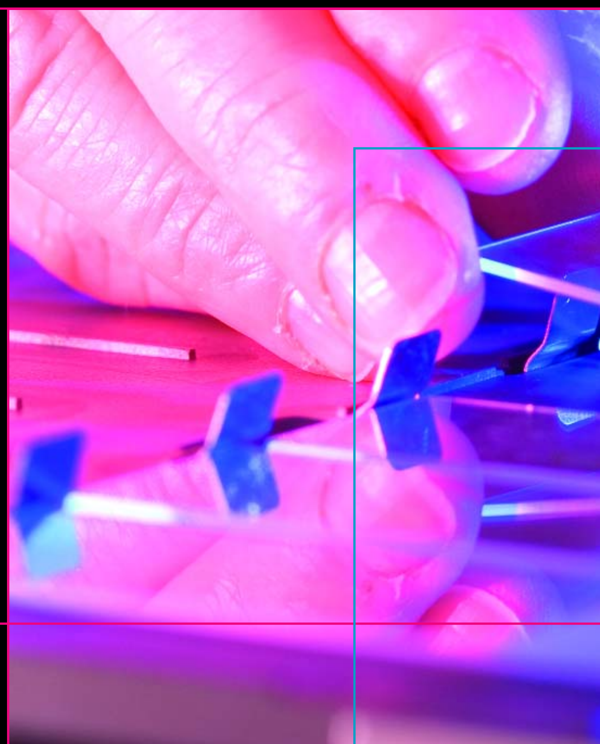




UNDERSTANDING THE OPPORTUNITI





Scientists who use biotechnology have the same goals as traditional plant breeders: making the food supply safer, less expensive, larger and more readily available to the world's growing population.

Biotechnology

ES AND THE RISKS

SCIENTISTS USE AGRICULTURAL BIOTECHNOLOGY

TO IMPROVE PLANTS AND FOOD PRODUCTION.

BUT THERE IS CONTROVERSY. . .

In 1996, only 21 percent of people knew what DNA is, according to a poll by the National Science Foundation. In 2003, 60 percent of people knew what DNA is, according to a Harris poll. The increase in knowledge is good, but it means that 40 percent of people still don't know what DNA is. *(If you're not sure, see the glossary on page 7.)*

When presented with the statement, "Ordinary tomatoes do not contain genes, while genetically modified tomatoes do," more than 60 percent of Europeans agreed, according to a 2002 survey by researchers from the London School of Economics. (Every single tomato in the world contains genes.) The survey also asked respondents to agree or disagree with this statement: "By eating a genetically modified fruit, a person's genes could also become modified." About half of the respondents agreed. (This statement is untrue.) ➢

"nothing at all" about genetically modified foods. More than 50 percent thought that chicken in the supermarket had been genetically engineered (this is untrue — poultry has not been genetically engineered using today's advanced technologies, though traditional breeding has gradually changed the bird's genome over time).

> "ALL THE RISKS NEED TO BE EVALUATED, BUT IN THE CASE OF COMMERCIALLY AVAILABLE BIOTECH CROPS, THESE HAVE BEEN STUDIED EXTENSIVELY — MORE THAN ANY CONVENTIONALLY BRED CROP."

Clearly, most people don't completely understand how genetics work. That fuzziness, coupled with the many terms surrounding the science — biotechnology, bioengineering, genetic engineering, genetic modification, gene splicing, etc. — has made the practice of improving plants using the science controversial to most and quite frightening to some people.

"People don't favor what they don't understand," said Wayne Loescher, MAES horticulture researcher and ad hoc member of the MSU Plant Transformation Center (PTC) Advisory Committee. "Science has sometimes dropped the ball in explaining biotechnology. That's why the educational component of the Plant Transformation Center is so important. We have to provide information and resources to people."

WHAT IS BIOTECHNOLOGY?

"You people in the developed world are certainly free to debate the merits of genetically modified foods, but can we please eat first?"

— Florence Wambugu, Kenyan plant breeder

Agricultural biotechnology is a collection of scientific techniques, including genetic engineering, that are used to improve plants, animals and microorganisms. Improving plants has been a goal of every recorded civilization on Earth. Farmers cultivated crops and chose seed from the best plants to ensure that next year's crop would be as good as or better than the past year's. This science of selection has given us broccoli, cabbage, cauliflower and brussels sprouts. An early relative, *Brassica oleracea*, grows wild in western and southern Europe; hundreds of years of careful selection led to these now common foods. Wheat is the result of three wild grasses being interbred. Nectarines are the result of crossing varieties of peaches and plums. In short, certain types of biotechnology have been occurring for thousands of years — as long as people have been growing crops and eating them.

All living things, including the fruits and vegetables we eat, contain genes that provide the instructions that tell the cells how to function. The information for many important traits is passed from generation to generation through genes, which are made of a large molecule called DNA. Every living thing contains DNA.

DNA is a strand of genes, much like a strand of pearls. And the amount of DNA is usually quite specific to a species. For purposes of this example, we'll say the necklace has 40 pearls in it.

In traditional plant breeding, a scientist crosses the original plant with another variety that has a desirable trait, such as resistance to a disease. But the scientist doesn't know which of the genes (pearls) from each parent plant are in the new off-

Wayne Loescher, MAES horticulture researcher, studies biosynthesis and the degradation of sugar alcohols in plants. He often speaks publicly about the risks and opportunities of biotechnology.

spring plant — all the genetic information gets mixed up at pollination, and the breeder has no control over which pearls from each parent make up the new necklace of the offspring. Although the new plant will have 20 pearls from one parent and 20 from the other, exactly which 20 from each is determined by a random process. The parent plant that has the desirable trait may also have some undesirable traits, such as lower yield. Again, the breeder has no idea which genes have come from each parent and must study the new offspring plant and see which characteristics it exhibits. If it is only a little more disease-resistant, then the breeder may cross the offspring plant with the disease-resistant parent to create another generation and then study it to see if it is any more disease-resistant. It could also have inherited the undesirable trait, which will have to be removed by backcrossing until the offspring contain mostly desirable genes. This is why it can take many, many backcrosses and 15 to 20 years to create a new plant variety.

Biotechnology eliminates much of the uncertainty. It allows a scientist to take the one gene that is responsible for the desirable trait and insert only that one into the offspring. This technique is known as gene splicing. Keeping with the example, a single pearl from one parent's necklace is inserted into the other parent's necklace to create the offspring. The researcher knows exactly which gene or genes have moved and can more quickly see if the offspring express the desirable trait.

The first food products of biotechnology — an enzyme used in cheese production and a yeast used for baking — appeared on the market in 1990. In 2001, the acreage planted in biotechnology crops (also known as GMOs — genetically modified organisms, transgenic crops or bioengineered crops) was more than 40 times larger than it was in 1996. An estimated 5.5 million farmers grew 130 million acres of biotech crops in about 15 countries, with the United States, Canada and Argentina leading the way. Nearly half of U.S. corn, 80 percent of U.S. soybeans and 75 percent of U.S. cotton now come from biotech seeds. In 2004, about 167 million acres of genetically modified crops were grown.

PLANT GENETICS PRIMER

CELLS

Cells are the fundamental units of every living thing. The instructions that tell a cell what to do are in the chemical DNA (deoxyribonucleic acid) within the cell.

DNA

Deoxyribonucleic acid (DNA) in all organisms is made up of the same chemical and physical components. The DNA molecule is a double helix — two spiral strands that wind around each other like a twisted rope ladder. DNA contains the four basic chemical units of life, known as nucleotide bases: adenine (A), guanine (G), cytosine (C) and thymine (T).

DNA SEQUENCE

The DNA sequence is the particular side-by-side arrangement of the nucleotide bases along the DNA strand. These base pairs form the rungs in the twisted rope ladder structure of the DNA. The order of the base pairs spells out the exact instructions required to create a organism with its own unique traits.

GENOME

The genome is an organism's complete set of DNA. Genomes vary greatly in size — the smallest is for a bacterium with about 600,000 base pairs. The human genome has more than 3 billion base pairs. The yeast genome has more than 12 million base pairs. The wheat genome has more than 15 billion base pairs, and the *E. coli* bacterium genome has 4.6 million base pairs.

CHROMOSOME

DNA is arranged into distinct chromosomes — physically separate molecules that range in length from about 50 million to 250 million base pairs.

GENE

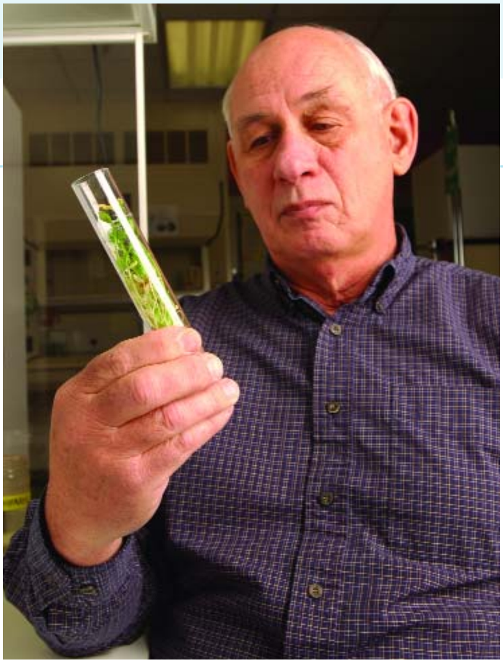
Each chromosome contains a number of genes, the basic units of heredity. Genes are specific sequences of bases that encode instructions on how to make proteins.

PROTEIN

Proteins perform most of life's functions — including cell growth, repair, digestion and aging — and make up almost all cell structures. Proteins are large, complex molecules made up of smaller units called amino acids. The chemical properties of these amino acids make the protein chains fold up into specific three-dimensional structures that define their function in the cell. Many proteins are enzymes, which can trigger or speed up chemical reactions. Other proteins are transporters, such as hemoglobin, which takes oxygen from the lungs to cells in the body.

PROTEOME

The collection of all proteins in a cell is called its proteome. The genome is relatively unchanging, but the proteome changes from minute to minute in response to tens of thousands of signals from within and outside the cell.



MAES horticulture researcher Ken Sink directs the Plant Transformation Center (PTC). The PTC provides reliable biotech services to MSU plant scientists and other groups.

1877

William Beal established the first seed testing laboratory in the United States at the Michigan Agricultural College (MAC). Beal was the first person to cross-fertilize corn to increase yield through hybrid vigor.

(Other biotech products include pharmaceutical products such as human insulin and human growth factor, consumer products such as biodegradable laundry detergent, stone-washed jeans and towels, and contact lens cleaner. Almost anything with enzymes in it is likely a biotech product.) Virtually all of the biotech crops on the market today were developed to reduce crop damage caused by weeds, insects and diseases. In the future, scientists hope to develop crops that can be used to create new materials or energy sources, provide more nutrients, treat diseases or serve as vaccines to prevent diseases.

Scientists who use biotechnology have the same goals as traditional plant breeders:

- Making the food supply safer for consumers and the environment.
- Making food less expensive to produce.
- Increasing the food supply to support a growing population in the face of decreasing tillable land resources.

According to statistics from noted agricultural researcher Norman Borlaug, who won the Nobel Peace Prize in 1970 for his work on preventing starvation in less developed parts of the world, food production in the United States went from 252 million tons per year in 1960 to 650 million tons per year in 2002 with 25 million fewer acres of farmland. The average U.S. farmer in 1940 fed 19 people: today each farmer feeds 129 people, and less than 2 percent of people in the United States are farmers. Less than 2 percent of the population is feeding the other 98 percent. No wonder biotechnology is controversial — a small group applies the technology and a large group may be affected by something they have little or no understanding of or control over.

POTENTIAL RISKS AND OPPORTUNITIES

As technology advances, it is important that scientists and regulatory agencies assess the impacts of both new and existing technologies for farmworker and consumer safety and for any environmental effects on plants, animals and water systems.

"Some of the issues associated with biotech crops include the emergence of 'superweeds' that we won't be able to control, genetic pollution — the idea that the genes from biotech crops can move into other plants — and horizontal transfer — that the biotech crop genes will move into people or bacteria," Loescher said. "People are also concerned that biotechnology will affect the biodiversity of plants. All these risks need to be evaluated, but in the case of commercially available biotech crops, these have been studied extensively — more than in any conventionally bred crop."

There are two main ways that the risks of new technology are approached. One is known as the precautionary principle — the technology is not used until it's possible to prove there is no risk. The other is to compare the new technology with current practices to see if using it reduces risk.

Loescher used the biotech crop Bt cotton as an example. Traditional cotton plants are susceptible to a number of pests and require numerous applications of pesticides to control them and make the crop viable. The "Bt" in "Bt cotton" stands for *Bacillus thuringiensis*, a naturally occurring bacterium that is harmless to people and animals but kills certain pest insects. When researchers created cotton that manufactures its own Bt, the amount of chemicals used to control cotton pests was dramatically reduced.

"Similar comparisons should be made when new biotech crops are introduced," Loescher said. "We need to take into account current practices and their associated risks. Statistics show that in Australia, growers who plant Bt cotton use 45 percent fewer pesticides. An article in *Science* said that pesticide poisonings in China have been reduced by 75 percent because of Bt cotton. In the United States, data from the National Center for Food and Agricultural Policy show that use of Bt corn reduced pesticide application by 46 million pounds in 2001."

The U.S. Food and Drug Administration (FDA), the Environmental Protection Agency (EPA) and the U.S. Department of Agriculture (USDA) have established regulations that govern the production and consumption of biotech foods. These agencies work with university scientists and other individuals to ensure that the regulations are based on sound science. All the available evidence to date shows that foods from biotech crops are as safe as foods from non-biotech crops. There have been no reports documenting illness from biotech foods. This country's food supply is the safest in the world, but that doesn't mean it is 100 percent safe — outbreaks of illness from contamination or spoilage of traditionally produced foods still occur.

People who don't want to eat biotech foods have that choice. They can buy food products that meet certified organic standards. These standards do not allow the use of genetically engineered foods or processing aids.

"I think there are definite advantages to biotechnology," Loescher said. "It offers expedient solutions that take advantage of the science we now have available to us. Biotechnology is not going to replace traditional methods — it augments them. It does allow us to create crops that can be produced in more environmentally friendly and sustainable ways.

"It's understandable that many people are concerned about biotechnology," he continued. "Many people are unfamiliar with the technology and are unaware of the safeguards that are in place to protect the public and the food supply. There is a mistrust of the industry; the public needs a strong assurance of safety and, unfortunately, the scientific community has not addressed the public's concerns nor effectively communicated the value of this technology. We hope the Plant Transformation Center can help with that."

NOTHING IS RISK-FREE

"Everything we eat is a poison; it is the dosage that makes it poisonous!"

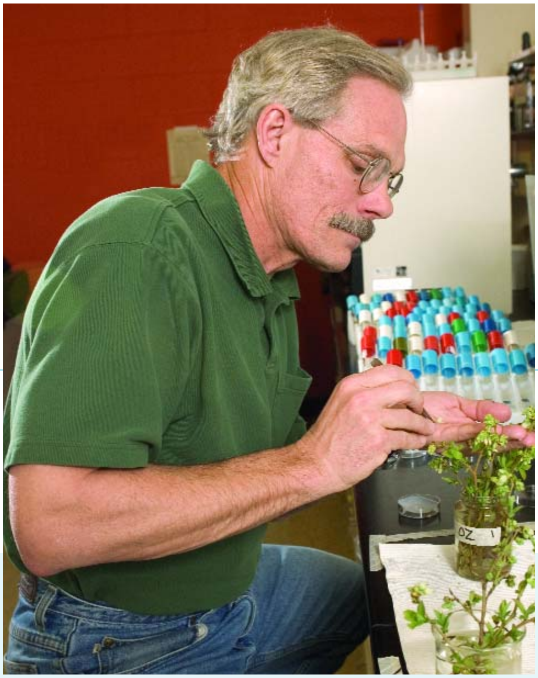
— Paracelsus (1493-1541), Swiss medical scholar who is considered the father of therapeutic medicine

Much of the concern about biotechnology revolves around science's inability to guarantee absolutely that it is 100 percent safe. Because biotechnology is new, people are unsure what an acceptable level of risk for it is. For something familiar, such as crossing the street, people accept a slight risk because they are comfortable with the action. But the risk that they could be hit by a car still exists, even if it is incredibly small.

> "BIOTECHNOLOGY IS NOT GOING TO REPLACE TRADITIONAL METHODS — IT AUGMENTS THEM. IT ALLOWS US TO CREATE CROPS THAT CAN BE PRODUCED IN MORE ENVIRONMENTALLY FRIENDLY AND SUSTAINABLE WAYS."

"There is no zero risk," Loescher said. "We consume about 10,000 natural toxins daily. Roasted coffee has about 1,000 chemicals. Of 27 tested, 19 were carcinogens. Similarly, potatoes, celery, kidney beans, peach seeds, cassava and wheat all have toxins in them. But we're comfortable with the old and natural and anxious about the new and synthetic."

The safety data required by the USDA, EPA and FDA are extensive — much more data are required



MAES scientist Jim Hancock, who breeds blueberries and strawberries, looks to the Plant Transformation Center when he wants to know if a specific gene is available.

on biotechnology crops than on traditionally bred crops, though the outcomes might be the same. A partial list includes:

- Product description (crop and species names; intended technical effect; intended compositional changes; food use: fresh and/or processed, feed use; source of the gene and history of its use; gene function).
- Molecular characterization.
- Toxicity studies.
- Effects of antibiotic resistance marker genes (analysis of potential horizontal gene transfer in humans; analysis of potential horizontal gene transfer in the environment).
- Nutritional data (nutrients, proteins, amino acids, calories, vitamins, ash, moisture content, crude protein, crude fat, crude carbohydrates).
- Other safety studies (substantial equivalency with parental variety, literature review and background, allergenicity, natural toxicants, anti-nutritional effects, protein digestibility).
- Environmental aspects (field trials at multiple sites, four replicates/site plus isogenic line[s] plus parental variety plus other varieties to establish a range of values, biology of the crop analysis, outcrossing and gene flow study, gene flow to same species, gene flow to related and wild species, disease and insect resistance changes).

THE MSU PLANT TRANSFORMATION CENTER: TECHNOLOGY FOR MICHIGAN

Michigan is the country's No. 1 producer of minor or specialty crops – basically, anything that isn't corn, soybeans, wheat or cotton. Though cherries, blueberries, squash, geraniums and cucumbers might be considered minor when compared with the millions of acres devoted to the field crops, these high-value specialty crops are hugely important to Michigan agriculture and the state's economy.

Because private companies don't make as much money from specialty crops, research on biotechnology techniques has focused on the big, money-making crops. To help Michigan's diverse agricultural industry benefit from biotechnology, the MAES in 2002 created the MSU Plant Transformation Center (PTC), one of nine such centers around the country. The PTC's goals are to develop biotechnology methods for crops advantageous to Michigan agriculture, as well as provide biotech services and training to faculty members and graduate students, and serve as an educational resource on biotechnology for the public.

"MSU is one of the top universities in the country in plant biology," said Ken Sink, MAES horticulture scientist who serves as PTC director. "We have a lot of good people here, and there are many biotechnology opportunities for important Michigan crops."

Part of the center's mission is to provide reliable biotech services to campus plant scientists and other groups. So, for example, if a researcher developing a new asparagus variety doesn't have the expertise or facilities to do tissue culture in his or her lab, the PTC can do the work on a fee-for-service basis.

"In Michigan, we have a lot of potential for nutraceuticals or functional foods [foods that have a health benefit beyond basic nutrition]," Sink explained. "But our immediate attention is on controlling weeds through biotechnology. This will allow growers to reduce pesticide applications, which is better for the environment and more cost-effective."

As director, Sink employs a postdoctoral researcher in the PTC lab and works with a rotating advisory committee whose members represent the broad areas of biotechnology.

"There is a lot of molecular genetics work on campus," said Jim Hancock, MAES small fruit breeder and PTC Advisory Committee member. "People are interested in the biology but not the application of the work. The PTC can do contract work to get a certain gene into a specific crop — herbicide resistance into strawberry, for example. Then that strawberry germ plasm is another tool that plant breeders can use. The PTC also serves as a clearinghouse of available non-patented genes. If you want to know if a gene is available, you can ask the PTC."

"Having a central location on campus for biotechnology work is good," said Dave Douches, MAES potato breeder who is also a PTC Advisory Committee member. "It gives everyone a place to go for training or to get work done and helps to foster collaborations between scientists. Wherever there is a need in biotechnology, the PTC will try and fill it."

- Germination and flowering studies.
- Ecological impact (changes in soil degradation; variations from traditional products; change in farming practices; effects on non-target insects; residual effects on subsequent crops; resistance management program; crop safety study; produce quality; yield studies; and impact on non-target organisms such as earthworms, microorganisms, non-target arthropods, grazing birds and mammals).

"To me, biotechnology today is similar to the railroad in the 1830s," said Mariam Sticklen, professor of crop and soil sciences, who has been using biotechnology since 1978 and doing genetic transformation since 1987. "In 1838, President Andrew Jackson received a letter from concerned citizens demanding that he stop railroad technology. They wrote to the president that railroads were allowing trains to move with a breakneck speed of 15 miles per hour, setting crops on fire, scaring women and livestock, destroying farm fields and creating other problems. People were scared of these big, noisy machines that, yes, occasionally had little problems. I think that's where we are today with genetic engineering. The genetic engineering system appears to be moving very quickly, but we're still improving and refining it. We need to be proactive and improve this very promising technology."

::: Jamie DePolo

1880s

Liberty Hyde Bailey, MAC horticulturist, established the first horticulture laboratory in the United States at MAC. He urged that horticulture could be advanced by cross-breeding, hybridization, the "chance growth of seedlings" and selection from wild species.

Left to right: **Brian Hughes, toxicologist with the Michigan Department of Agriculture; Kirk Heinze, director of Communication and Technology Services for the College of Agriculture and Natural Resources; and Jim Hancock, MAES small fruit breeder, all serve on the PTC Advisory Committee. Public education about biotechnology is a big part of the PTC mission.**

"We have a very big public education mission," added Richard Allison, MAES plant biology and plant pathology scientist. "This component is just as important as the on-campus technical work. I believe that Michigan can truly benefit from biotechnology. With education, we can turn any criticisms around and help people see the value of the technology to the state."

As part of its initial education and outreach efforts, the PTC is working with the Michigan Association of Science Teachers to provide information on biotechnology in general and the center in particular.

"We know that people don't know a lot about biotechnology," said Kirk Heinze, director of Communication and Technology Services for the College of Agriculture and Natural Resources, who is also on the PTC Advisory Committee and oversees the center's outreach efforts. "There's no better target than young people for this information. One of the things we want to demonstrate to them is biotechnology's role in sustainable agriculture."

The PTC also maintains close contact with the Michigan Department of Agriculture (MDA). MDA toxicologist Brian Hughes serves on the Advisory Committee and believes it's appropriate for MSU to take the lead in educating Michigan residents about biotechnology.

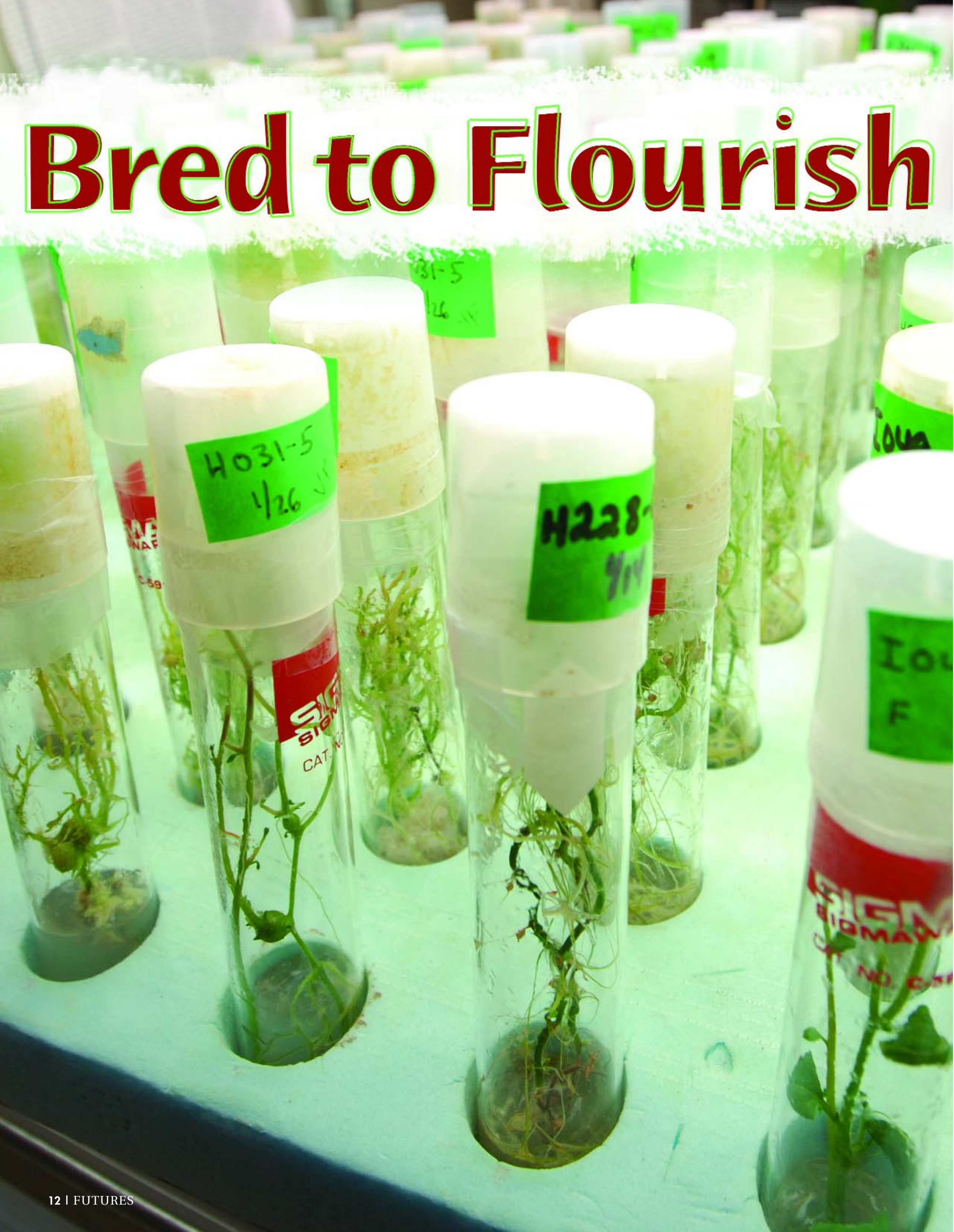
"MSU is a leader and a credible source of information on biotechnology research and education," he said. "The MDA's role is to track changes in federal biotechnology regulations and the development of new crops, to ensure their accessibility and proper use, and to make sure the integrity of non-biotech crops is maintained."

In the near future, Sink hopes to develop commercial products for the university that can be licensed and use those funds to help support the center.

"We want to reduce pesticide applications, which helps the environment and makes agriculture more sustainable," he said. "We believe we have a role to play, and we have a vision. Our work supports Michigan agriculture."

::: Jamie DePolo

Bred to Flourish



Michigan growers need new varieties to remain competitive.

MAES plant breeders have developed some of the most popular and prolific selections and are working on even better ones.

Breeding and genetics have allowed plant agriculture to become more productive, more economical and more environmentally friendly. Ancient farmers used a form of genetic engineering as a tool long before it was a science. By selecting seeds from the strongest and most disease-resistant plants in their fields and cross-breeding those plants with plants of other varieties, they gradually improved their crops.

The science began to evolve in 1865 when Gregor Mendel, an Austrian botanist and monk, identified what he called "hereditary factors" — now known as genes. Three years later Friedrich Miescher, a Swiss biologist, unknowingly discovered DNA — deoxyribonucleic acid. In 1876, Charles Darwin conducted experiments in breeding and published *Cross and Self Fertilization in the Vegetable Kingdom*. A year after that, William Beal, a renowned horticulturist at Michigan Agricultural College (later Michigan State University), established the first seed testing laboratory in the United States and was the first person to cross-pollinate corn to increase yields. His research demonstrated to farmers the advantages of hybrid vigor.

Today, MAES plant breeders continue to work closely with industry and commodity group representatives around the state to ensure that their breeding programs meet the needs of growers. From Christmas trees to potatoes to cherries to blueberries to soybeans and other field crops, the scientists strive to create crops tailored to the state's conditions.

"I think all the breeders on campus would say their primary goal is to develop varieties for Michigan needs," said MAES horticultural researcher Jim Hancock who breeds blueberries and strawberries. "Each crop has different traits that are desired by our growers, and we work closely with them to make sure we meet those needs."

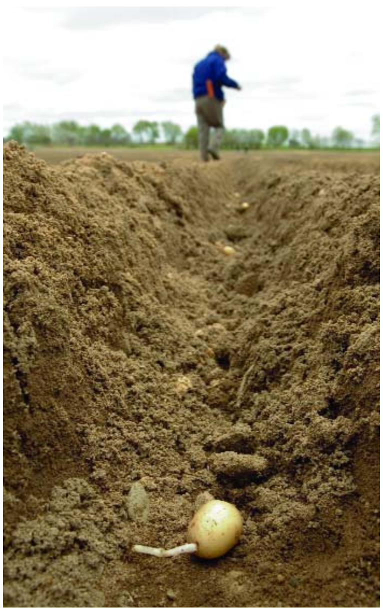
"New varieties are important to farmers — they need them to stay competitive with other states in terms of yield and costs," said Randy Judd, manager of the Michigan Crop Improvement Association (MCIA). The MCIA promotes the use of and provides certified seed to Michigan growers for field crops such as corn, wheat, oats, soybeans and dry beans. Since 1996, potato growers have had their own association, the Michigan Seed Potato Association, that certifies potato seed.

"MSU is a major source of new material for the MCIA; the university is critically important to our members," Judd said. "We definitely want to encourage the university to continue to release varieties."

BLUE CHIP POTATO STOCKS

When Dave Douches came to MSU in 1988, he was a newly minted genetics Ph.D. from the University of California-Davis and had done potato research at the International Potato Research Center in Peru. By combining traditional crossing programs and biotechnology, Douches has released several varieties over the past 17 years (it takes 10 to 12 years to develop a new potato variety) that have good processing traits, more uniform size and disease resistance.

"We have a very active breeding program," Douches said. "Our pipeline is primed and we're in the process of releasing new varieties. Because it takes a while to develop a new variety, we tend to have things happening simultaneously. We'll continue to have new releases over the coming years."



Douches conducts much of his research on potatoes at the Montcalm Research Farm, an MAES field research station, in Lakeview. Here, seed potatoes are being planted.

MAES scientist Dave Douches strives to create potato varieties with traits desired by growers, such as excellent storage ability, low sugar content, and resistance to bruise, late blight, scab and Colorado potato beetle.

Michigan, the No. 1 producer of chipping potatoes in the country, produced more than 15 million hundredweight of potatoes in 2003, which added more than $105 million to the state's economy, according to the Michigan Agricultural Statistics Service. Chips are made from round white potatoes, and processors want very specific traits in these potatoes.

"They want low sugar content, bruise resistance, a high level of solid material and excellent storage ability, with few or no defects — no marks, spots or holes," Douches explained. "So we start with that. Growers want potatoes that are resistant to late blight and scab [two diseases that dramatically reduce the yield and marketability of potatoes] and the Colorado potato beetle [a voracious insect that eats potato plant leaves and significantly reduces the yield]. Combining all those things in one potato would be the Holy Grail of traits. We're not quite there yet, but we're starting to combine disease resistance with the chipping properties. And a high yield per acre is a given. Growers won't even consider a potato if it doesn't have good yield."

This last point underscores one of Douches' challenges — because insects and diseases can be controlled with chemicals, growers may continue to grow potatoes that are susceptible to these pests because the potatoes are high quality and high yielding.

"We need to have the resistance properties in a high quality potato," he said.

In 2001, Douches and his team released Liberator, a scab-resistant, chip processing round white potato. Another scab-resistant, chip-processing variety, known as MSG227-2, and a late blight-resistant variety, MSJ461-1, are also being considered for release.

Michigan also has a viable table stock potato industry — potatoes sold directly to consumers in grocery stores or other markets.

These true potato seeds were extracted from potatoes grown in Douches' research greenhouses. The seeds are the beginning of a new breeding cycle.

"We have an emerging niche market for table stock potatoes," Douches said. "People want better tasting, locally grown gourmet potatoes — they're looking for specialty varieties, not the ones you can get anywhere."

To meet these demands, Douches released Michigan Purple and Jacqueline Lee, both in 2001. Michigan Purple, as its name suggests, has purple skin and white flesh. Douches described it as a good all-purpose potato for mashing, pan-frying, boiling, baking and microwaving.

"We've heard that some growers have been successfully marketing the Michigan Purple in combination with red and white potatoes, but it also does quite well alone. It's a good-looking potato and gives people options for presenting potatoes as part of a meal. People like the taste and its utility in the kitchen."

Jacqueline Lee, named for Douches' daughter, is a yellow-flesh potato with late blight resistance. It has a bright, smooth skin and is good for all types of home cooking.

"It has an excellent taste quality, very similar to Yukon Gold potatoes," Douches said.

Because storage ability is such an important trait for chip processors, Douches works with the Michigan Potato Industry Commission (MPIC) to provide

This striking purple-fleshed potato is a new selection in the MSU potato breeding program. Douches says the potatoes will be sold at farm markets and used for specialty potato chips.

storage demonstrations to Michigan growers and processors.

Most commercial storage facilities house about 10,000 hundredweight of potatoes. If the spuds on the bottom of the pile are going to succumb to pressure bruises, everyone involved wants to know before the variety is grown.

"About five years ago, the MPIC funded the construction of the B.F. Cargill Demonstration Storage Facility next to the Montcalm Research Farm [the MAES field research station that specializes in potatoes]," Douches explained. "Before that, we just had some small storage bins. This is truly a partnership between the growers, the processors and the university. The facility allows us to simulate how potatoes are really stored so the farmer doesn't have to take the risk. Processors won't buy bruised potatoes. Storage drives the releases. If a variety doesn't store well, it won't work."

BUILDING BETTER BEANS

As one of the nation's top producers of dry beans, Michigan has somewhat of a reputation to uphold in bean breeding. MSU scientists, many of them affiliated with the MAES, released 40 varieties of beans in the 20th century. The program began in about 1910, so that means MSU released a variety just about every other year — quite an accomplishment when it takes about 10 years to develop a new bean variety.

Frank Spragg was the first plant breeder hired by MSU, and he released the first navy bean variety, Robust, in 1915. Though it was superior at that time, Robust was a vine-type bean that was susceptible to white mold, mosaic virus and anthracnose, diseases that significantly reduce yield. In 1956, MSU bean breeders E.E. Down and Axel Anderson developed the Sanilac navy bean, the first bush-type navy bean. It set the standard for bean varieties by getting the beans up off the ground. This meant fewer problems with mold and disease. It was a high quality bean as well.

For the next 30 years, MSU bean breeders kept improving on the Sanilac model, releasing navy bean varieties that incorporated resistance to various diseases (Gratiot), zinc tolerance (Saginaw) and improved productivity (Mayflower). In 1968, MSU breeders logged another milestone when they released the Seafarer navy bean. Also a bush-type bean, Seafarer is an early-maturing variety. The fact that Seafarer beans could be harvested before other navy beans was an advantage to growers. The fact that the Seafarer variety was still being grown in 1997 indicates its quality and sustainability. Not many varieties last 30 years — the average is about four to seven.

In 1974, MSU released the Montcalm dark red kidney bean, which was resistant to halo blight, another problematic disease for growers.

"A quarter century after its release, Montcalm is still the most widely grown dark red kidney bean variety, sought by growers for its halo blight resistance and by processors for its superior canning quality," said Jim Kelly, MAES crop and soil scientist and dry bean breeder.

In 1989, MSU released its first pinto bean, Sierra, to help Michigan growers take advantage of consumers' preferences for nachos, burritos and other southwestern and Mexican dishes using these beans.

Dry bean breeding continues to match the needs of growers and consumer preferences with beans that will grow well in Michigan. The latest variety, Redcoat, was released in 2004. A list of bean varieties in various market classes released since 1982 can be found at www.css.msu.edu/bean/.

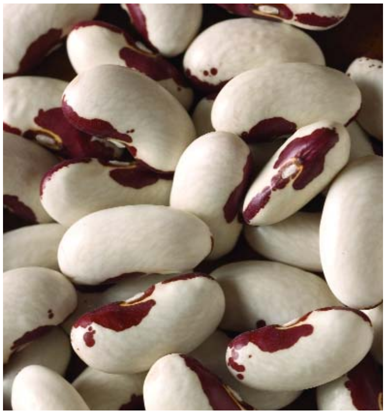
MAES crop and soil sciences researcher Jim Kelly has been breeding dry beans at MSU for more than 25 years. His most recent release is Redcoat, a soldier bean.

Redcoat is a large-seeded, splotchy red-and-white bean that may appeal strongly to those who are choosey about how their food looks as well as how it tastes. Redcoat's development caused

1908 **Frank Spragg, MAC scientist, collected grain from many sources, grew each separately, selected the most productive strains, identified the best seeds and multiplied them. Spragg's most famous grain variety was Rosen rye, which outyielded conventional varieties two to one at the time. Spragg founded the Michigan Crop Improvement Association.**

Kelly and his bean breeding team to go to Texas and back and delve into DNA to unravel its mystery.

"The opportunity to commercialize a mutant bean that we never would have worked on directly is a nice surprise, given that bean variety development is usually a 10-year program," Kelly said.



The Redcoat bean's distinctive coloring is due to a random genetic mutation. The bean has a red kidney bean's valuable attributes.

The Redcoat bean is a Soldier bean. Soldier beans are so named because their red markings look like the uniforms worn by 18th century European soldiers. In 1999, MAES scientists obtained seeds for basic red kidney beans from a Texas supplier. Researchers planted the seeds in northern Michigan, and most of the plants did, in fact, produce the expected red beans. A small fraction, however, produced beans with striking white splotches.

The researchers first suspected that the coloring had an ordinary explanation — perhaps stray seeds from white bean plants had gotten mixed in with the seeds in Texas — or maybe the beans had cross-pollinated with fields of white bean plants nearby.

But when the MAES team searched the area in northern Michigan where the new red and white beans turned up, they found no cross-pollination suspects. And when they infected the plants with two common bean diseases, the Redcoat beans behaved more like other red kidney beans than white or Soldier beans.

Over the years, red kidney beans have been bred to resist mosaic virus and anthracnose. Redcoat proved immune to infection as well, even though these diseases are often lethal to other Soldier bean varieties.

"Redcoat has the best yield potential of any Soldier bean," said Greg Varner, research director of the Michigan Dry Bean Research Board, who worked with Kelly.

What about the possibility of a mix-up in Texas? The scientists inquired and learned that the Texas supplier had hand-picked the beans sent to Michigan. The entire batch contained nothing but beans with the familiar, uniform red coloring.

It's true that most living organisms carry two copies of each gene. With other explanations ruled out, the scientists began suspecting that one copy of the bean color gene had mutated. They thought that the other gene had remained normal and still contained instructions for making red beans. Often, one normal gene is enough to mask the effects of a mutation. This would explain why all the Texas seeds were red.

Random mutations, changes in DNA structure in the cells of a living organism, happen all the time. Most mutations have no effect on the organism or its offspring; some prove harmful to the organism. Only a small fraction of mutations turn out to be advantageous. In this case, the big advantage is for bean lovers who might see an unusually attractive red and white bean in their local markets within the next few years.

It took several years' work in campus greenhouses, but Kelly finally confirmed his suspicions: the new coloring was indeed the result of a rare beneficial mutation of a single gene in the bean's DNA.

"The single gene mutation of seed coat color pattern means that an entirely new class has the same valuable attributes present in the commercial red kidney bean class that breeders have worked on for more than 100 years at MSU," Kelly said. "It's somewhat ironic that one of the most successful bean varieties in the history of Michigan agriculture is the Sanilac navy bean, developed through mutation breeding on the MSU campus. Redcoat is the result of a natural rare mutation that proved to be beneficial."

1928 **Eldon Down, MAC plant scientist, introduced hybridized Spartan barley to Michigan's grain industry.**

A BEVY OF BLUEBERRIES

The work of MAES blueberry breeder Jim Hancock came to glorious fruition in 2002. He released not one, not two but three blueberry varieties that year. Before that, the last blueberry variety released from MSU was in 1977 — a gap of 25 years.

"These blueberries were developed specifically for Michigan needs," Hancock explained. "Michigan growers get the most money for their blueberries at the end of the season because we're the last state that has berries left. So one of our goals was to develop varieties that were late-maturing. We also wanted to make sure they stored well."

Until Hancock's releases, Michigan blueberry growers had one late-maturing variety, Elliott. Elliott produced very high yields, but it wasn't very flavorful and could be sour. Growers also had one major midseason-maturing variety, Bluecrop, which had average fruit quality but didn't store very well.

Hancock's three new releases are:

- Liberty — named after groundbreaking Michigan Agricultural College horticulturist Liberty Hyde Bailey, the man who established the first horticulture lab in the United States (Hancock said he also likes the patriotism of the name). Liberty matures slightly earlier than Elliott (about five days) but is still considered a late variety. It also has much better fruit quality.
- Aurora — a name suggested by Hancock's wife, Ann, manager of the MSU Delapa Perennial Garden, after *Aurora borealis*, the northern lights. Aurora matures about five days later than Elliott and can be stored longer. It also has better fruit quality than Elliott.
- Draper — named after highly acclaimed USDA blueberry breeder Arlen Draper. Draper matures during the early midseason, a little ahead of Bluecrop. But it has much better fruit quality and flavor and can be stored much longer than Bluecrop.

The three are the first major varieties released in 10 years and will grow well everywhere blueberries are grown now, including all parts of the United States, South America and Europe.

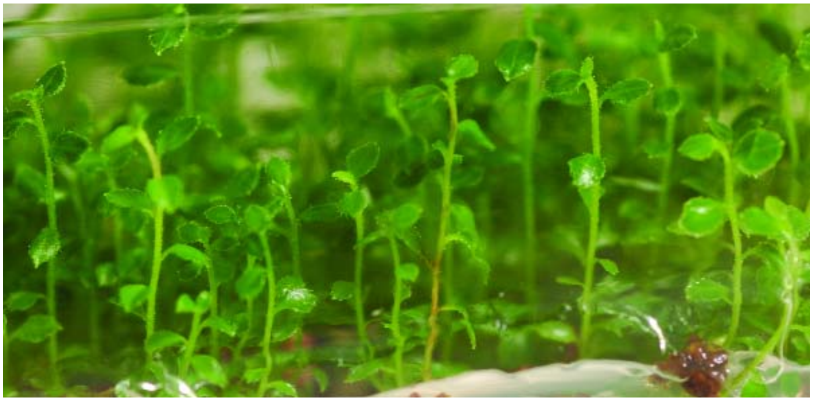
Licensing agreements have been drawn up through the MSU Office of Intellectual Property and the varieties are being sold around the world. But everyone at MSU emphasized that the needs of Michigan producers were considered first.

"We are very sensitive to Michigan growers' concerns," Hancock said. "We want to make sure we're giving them what they need."

"Our first duty is to Michigan taxpayers, the university and the inventors to ensure that inventions are commercialized at a reasonable rate of return," said Tom Herlache, licensing associate in the Office of Intellectual Property. "And we also take into account the needs of our local businesses and producers."

Hancock said that Michigan blueberry nurseries are projecting more than $1 million in sales of the new varieties over the next several years, which is a good sign of the acceptance of the new varieties. Because it takes 6 to 8 years for a blueberry plant to establish itself and reach full maturity, blueberry growers are understandably reluctant to take out large number of older fruit-bearing plants.

"Michigan has quite a few 70-year-old blueberry plantations," Hancock said. "The growers are getting a modest return from them, and it's very expensive to start over."



These tiny plants are microshoots of Draper blueberries in tissue culture. This procedure allows for rapid propagation of thousands of shoots in a few months.

After his triple success in 2002, Hancock isn't resting on his laurels. He's continuing to work on creating an even better blueberry.

"What do I do for a follow-up?" he asked rhetorically. "My goal is to replace these varieties eventually. I want to develop more varieties with Draper's storage capabilities. Liberty and Aurora have some flaws that can be improved upon. I'm continuing to make crosses and have some selections that are going into replicated trials."

Hancock also has a fourth selection that is almost ready for release. The variety, as yet unnamed, matures early in the season, even earlier than Duke, which is the most popular early blueberry variety. The unreleased variety has excellent fruit quality and good storage capability, though not as good as Draper's.

Like much of the plant breeding work on campus, creating new blueberry varieties takes time. Hancock made the crosses for Draper 13 years ago, and the ones for Aurora and Liberty about 11 years ago. The work is considered fast by blueberry standards — normally a variety takes 20 years of work or more before it's ready for release.

Hancock noted that the blueberry industry is expanding about 10 percent per year and is projected to keep growing at that rate. As more people join the industry, more varieties will be needed to keep up with growers' and consumers' demands.

One trait that Hancock would like to improve in the berries, which would also meet a growing consumer demand, is the level of antioxidants. Blueberries are known to have high levels of antioxidants, plant compounds that may help reduce cancer risk, slow down destructive cell aging processes and boost the immune system.

Flowers from an Aurora blueberry plant, ready for pollination. To make crosses, scientists emasculate and hand pollinate the flowers.

"Liberty has very high levels of antioxidants, and by making crosses with it to create new varieties, we may be able to develop several new varieties with these high levels," he said.

Hancock also runs a strawberry breeding program and hopes to have some releases ready in three or four years.

Michigan grows more than 1,000 acres of strawberries each year and the fruit occupies an important niche market for farm stand and u-pick operators.

This yellow powder is pollen from a Liberty blueberry plant ready to be used in crosses. Scientists collect the pollen by rolling open flowers between the thumb and forefinger.

Hancock's focus is on producing high quality berries with excellent flavor and aroma, as well as breeding in some resistance to black root rot. Much of his effort focuses on capturing genes from wild-type strawberries and breeding them into elite lines that other breeders could use in their work.

CONSUMMATE CUCURBITS

Michigan is the country's No. 1 producer of pickling cucumbers — the 181,000 tons produced in 2003 added more than $36 million to the state's economy. Like many cucurbit (pumpkin, squash and gourd) crops, cucumbers can suffer severe yield losses from the fungus-like organism *Phytophthora capsici*. In cucumber fields, the vines can look excellent, but the fruit located underneath the vines can be infected. Dark, water-soaked lesions develop first, followed by a distinctive layer of spores that look like powdered sugar on the surface of the fruit. Fruit infection may occur days before the symptoms become visible, and the fungus can spread rapidly through warm, wet fields. Rebecca Grumet, MAES horticulture researcher, and Mary Hausbeck, MAES plant pathologist, have been searching for natural resistance to *Phytophthora*.

In cucurbit crops such as melons, only female flowers make fruit. Ethylene appears to play a role in the development of female flowers — research has shown that plants engineered to make more ethylene make more female flowers.

"Unfortunately, our screening of varieties and wild relatives has not identified a source of resistance that can be used for breeding," Grumet said.

Because the leaves and stems aren't infected, Grumet is looking into whether changing the architecture of the plant might work to limit the disease by making conditions less favorable for the fungus to grow. The researchers hypothesized that if they could open up the canopy of the plant and at the same time get the fruit up off the ground, they might be able to reduce plants' susceptibility to disease.

"There also seems to be an age effect — as the cucumbers get older, they're not as susceptible," Grumet said. "We want to find out why and whether those changes can be used to help make more resistant cucumbers."

In melons, Grumet is studying how the hormone ethylene may help cantaloupe growers produce more fruit from plants.

Cucurbit crops have separate male and female flowers. Only female flowers make fruit, and plants usually make male flowers first — probably because it takes more energy to make fruit, Grumet suggested. Because the female flowers appear later on the plant, it takes more time for the plants to produce fruit, which means a longer growing season for producers.

"In cucumbers, there is a gene for femaleness," Grumet explained. "This allows for a shorter growing season and more uniform fruit set. But there's not an equivalent gene in melons. The gene in cucumbers causes the plant to make more of the plant hormone ethylene. We wanted to see whether we could cause a similar effect in melons."

To test her theory, Grumet inserted a gene into the cantaloupe plants that cause them to produce more ethylene. The plants had more female flowers and set fruit earlier. Grumet is now studying how to direct the gene specifically to the flowers so the plant is not always making extra ethylene.

In celery, Grumet is again working with Hausbeck to tackle fusarium yellows, a fungal disease. Fusarium yellows, a long-time problem for celery growers, threatened to wipe out the celery industry in Michigan and California 15 years ago. The disease can't be controlled with chemicals, and crop rotation and other cultural practices don't seem to help much, either.

MAES horticulture researcher Rebecca Grumet studies cucumbers, melons and other cucurbit crops, and celery. In celery, she is working to develop varieties resistant to fusarium yellows, a fungal disease.

Working with former MAES plant pathologist Mel Lacy, Grumet used a combination of tissue culture and traditional breeding to produce some fusarium-resistant celery lines, but the plants had short stalks, a less than desirable trait in current markets. Grumet and Hausbeck are trying to introduce increased height into the resistant varieties.

"I think we'll probably be able to release two breeding lines in a couple years that will have good resistance and quality," Grumet said. "The lines we are working with have two sources of resistance, which is good in case the fungus overcomes one of them. Some of the lines seem to lose their resistance after a few years. We're hoping ours won't."

1933 **Michigan became the leading state in the production of processed apple juice after scientists discovered that apple juice could be clarified with pectinol A, an enzyme. MAC scientists developed the procedure for flash pasteurization of apple juice, which became the accepted standard.**

THE CHERRY CHALLENGE

As the only publicly supported cherry breeder and geneticist in the entire United States, MAES scientist Amy Iezzoni balances an incredible amount of work on her slender shoulders. In addition to conducting a tart cherry breeding program (which is the top priority), she searches for and evaluates dwarfing rootstocks for sweet cherries, and provides genetics and genomics expertise for both sweet and tart cherries.

"Breeding tart cherries is so important because the entire tart cherry industry in the country is based on one variety: Montmorency, a 400-year-old variety from France," Iezzoni explained. "Since Michigan produces 75 percent of the nation's tart cherries, the state would benefit greatly from new varieties."

The industry's vulnerability because of its dependence on Montmorency was harshly underscored on the night of April 21, 2002. Temperatures plummeted, freezing cherry flowers and reducing production to only 2 percent of what it normally is, the lowest level since 1945. The industry was devastated.

To see if more diversity would have prevented such dramatic losses, Iezzoni headed up to the MAES Northwest Horticultural Research Station in Traverse City early the next morning to check on her tart cherry research plots. Of 21 other tart cherry varieties, Iezzoni found that all but one was much less damaged than Montmorency by the freeze.

Cherry blossoms are sometimes hand pollinated when temperatures below freezing are predicted. The trees then start the fruit-making process before any blossom damage occurs.

"This suggested that the nearly complete crop loss that producers experienced in 2002 would have been greatly reduced if the industry had been growing an array of varieties," Iezzoni said. "The goal of my program is to take the risk out of cherry production for growers and increase their profits."

When Iezzoni came to MSU in 1981, she had to create a tart cherry breeding program from scratch. After evaluating the tart cherry cultivars available for breeding, Iezzoni was quickly disappointed. There was nothing better than Montmorency available to breed with. If she didn't have superior germ plasm (genetic material), she couldn't develop an improved variety. Thus began her 15-year quest to collect quality tart cherry germ plasm and bring it back to her lab.

MAES horticulture scientist Amy Iezzoni is the only publicly supported cherry breeder and geneticist in the United States. Here she hand pollinates her test plots at the Northwest Michigan Horticulture Research Station in Traverse City.

"What this superior germ plasm was and where it would be found, I didn't know," she said. "But in the spring of 1983, I set out to find it and bring it to the United States."

After determining that eastern Europe — including Bulgaria, Romania, Hungary, Poland, the former republic of Yugoslavia and Russia — was the best place to find the germ plasm, Iezzoni mapped out her collection trips. The search was complicated by the Cold War and U.S. quarantine restrictions (the quarantine period for wood ranges from 3 to 8 years), but Iezzoni nonetheless managed to collect pollen and seed (which did not face quarantine restrictions) to build her program.

Today, Iezzoni is using that germ plasm to breed new cherry varieties that have traits desired by Michigan growers.

"We're breeding for a late flower bloom to avoid frost damage — if the flower isn't there, it can't be damaged," she explained. "We also want consistent production and resistance to cherry leaf spot."

Caused by a fungus, cherry leaf spot is the No. 1 disease problem in tart cherries, both in cost and decreased production. The disease is extremely difficult to control during wet spring months.

Other characteristics that Iezzoni wants to incorporate include firmer fruit (because tart cherries are mechanically pitted, firmer fruit means higher fruit grade and quality after pitting, which means more money for growers) and fruit with deep red color similar to that of Montmorency. She would also like to develop varieties with different ripening times so growers can spread out their costs and equipment and not have to harvest everything at the same time. Earlier ripening times would also mean that the fruit could be harvested before cherry fruit flies hatch and start looking for an orchard on which to feast.

To offer the industry some genetic diversity, Iezzoni released Balaton, a Hungarian tart cherry, in the United States in 1984. Balaton is a dark burgundy cherry (skin, flesh and juice are dark red) that is firm with a sweet-tart taste. Balaton cherries are used to make cherry port, sold fresh, and preserved in Mason jars and sold as a "glass pack."

"Balaton's fruit is great, but it does have some flaws," Iezzoni explained. "The yields aren't as high as we'd like; they're lower than Montmorency yields, which makes some producers hesitant to grow it."

One of Iezzoni's multiple research projects is exploring whether fruit set is the weak link in yields. Initial results suggest that bees are pollinating Balaton flowers with pollen from the earlier-flowering Montmorency and sweet cherry trees. This suggests that providing an earlier-flowering pollen source may increase fruit set in Balaton.

"By the time a variety goes to growers, it can't have any Achilles' heels," Iezzoni said. "It has to be complete and be able to be integrated into their systems.

"It takes about 20 years to develop a new cherry variety," Iezzoni explained. "With the superior germ plasm we are using, the question is not whether you do it but how will you fund it. My disappointment is that the new varieties will be in the second generation of the crosses I've made, not the first. Accolades go to the industry for hanging in there with me. I am very lucky — everyone has been very supportive."

In Iezzoni's lab, graduate student Audrey Sebolt extracts pollen from cherry flowers. Iezzoni hopes to release new varieties from the second generation of crosses she's made.

Sclerotinia Initiative, a consortium of federal and state university scientists that includes 10 land-grant universities (including Michigan State) and five crop commodity groups.

Partial resistance to white mold has been found in some germ plasm. Wang is trying to put all the partial resistance into one plant so the resistance level is the highest it can be. He anticipates that a high-yield soybean variety with some white mold resistance will be released this year.

Soybean rust, a fungal disease, is probably the disease most feared by soybean growers. It is caused by not one but two pathogens:

- *Phakopsora pachyrhizi*, or Asian rust, is the more destructive pathogen and poses the biggest threat to U.S. soybeans. The name is somewhat misleading — it has been found in Australia, Africa, South America and Hawaii as well as Asia. This pathogen is most commonly associated with soybean rust.
- *Phakopsora meibomiae*, by contrast, is less aggressive and is not reported to cause severe yield loss in soybeans.

STRENGTHENING SOYBEANS

Ask soybean growers what they fear the most, and soybean aphids, soybean rust and white mold will probably be at the top of everyone's list. Dechun Wang, MAES soybean breeder and geneticist, knows this and is working to breed resistance to these troublesome pests into new varieties of soybeans.

"Soybean aphids were first found in the United States in 2000, and now they're the No. 1 most damaging pest in soybeans," Wang explained.

The pale yellow creatures are less than 1/16 inch long, but they caused an estimated $120 million in losses for U.S. soybean growers in 2003.

Wang is the first breeder in the country to identify aphid-resistant germ plasm that could be grown in northern climates. However, the varieties, from China where the aphid has long been a pest, are low-yielding varieties that need to be crossed with higher yielding varieties to make them practical for Michigan growers.

"It takes about 8 to 12 years to develop a new variety of soybean," Wang said. "We can get something promising in 4 years, but we need to do long-term, widely replicated field trials to make sure there are no surprises for growers. High yield is still the No. 1 trait that everyone wants in a variety. We always start with a high-yield variety and then try to add other desirable traits to it."

White mold, also known as sclerotinia stem rot, is caused by a fungus whose spores can be spread by wind. It affects growers in the upper Midwest and East. Though the disease has been in the United States since 1946, it has become more widespread recently, causing increasingly significant yield losses. The disease affects 408 species of seven crops: soybeans, sunflowers, canola, edible dry beans, chickpeas, lentils and dry peas. It has become such a problem that in 2002 the USDA-Agricultural Research Service (USDA-ARS) developed the National

As part of his soybean breeding program, MAES scientist Dechun Wang has found some germ plasm that shows promising resistance to soybean rust.

"Soybean rust can reduce yields by 80 percent," Wang said. "It is highly mobile, and the spores are blown up from the South each year. But because Michigan is so cold, it will not be able to overwinter and is not here — yet. We fear its arrival and are working to educate farmers about how to control it."

At the end of 2004, the disease was discovered in Missouri, South Carolina, Tennessee, Florida, Arkansas, Louisiana, Mississippi, Georgia and Alabama. In addition, rust was also found on kudzu growing near the infected field in Florida. Researchers suspect that rust spores reached the United States via Hurricane

Ivan in September 2004.

According to Wang, computer models project losses of up to 40 percent in major U.S. soybean regions if the disease becomes established. The disease is expensive to control and requires application of fungicides at precisely the right time — otherwise they won't be effective.

"The disease is also hard to identify early," Wang explained. "It starts as tiny spots on the bottom side of the plant's lower leaves. It can look like other diseases, such as brown spot, bacterial pustule or bacterial blight. By the time you see soybean rust on the tops of the leaves, it's too late."

Wang has been working for the past 2 years to find natural resistance to soybean rust in soybean plants. Before 2005, the disease was subject to quarantine and regulated in the United States, so his research could only be done abroad.

"With the potential for loss, you can certainly understand why bringing rust into the United States — even for research — was strictly prohibited," Wang said. "There was only one extremely secure USDA facility that is conducting limited testing."

So Wang was screening germ plasm for soybean rust resistance by collaborating with researchers in China. He selected soybean germ plasm based on the plants' ability to do well in Michigan and then evaluated the germ plasm in two rust nurseries in China for rust resistance.

"We found some promising germ plasm in 2004," he said. We need to conduct more tests in 2005 to confirm the resistance. But it's very exciting."

DEDICATED TO IMPROVING CROPS

The Michigan Crop Improvement Association (MCIA) has a long history of association with Michigan State. The MCIA was founded by Michigan Agricultural College researcher Frank Spragg in 1908, and until 1968, the manager of the MCIA was an MSU employee. The organization also was housed at the university until the mid-1970s, when it built new facilities and moved out to Jolly Road in Okemos. From the start, its mission has been to provide farmers with sufficient amounts of certified seed for field crops such as corn, soybeans, wheat, oats, barley and dry beans. Potatoes were included until 1996, when the potato growers formed their own association, the Michigan Seed Potato Association, to certify potato seed.

Randy Judd, MCIA manager, says the organization looks to the university for new varieties to keep Michigan growers competitive.

"We've always had a close relationship with MSU," said Randy Judd, MCIA manager, who has been with the organization for 21 years. Judd is an MSU alumnus and has served as manager for the past 10 years. "Now we're a nonprofit organization funded through user fees, seed sales, certification tag fees and field inspection fees. We receive no state or university money."

Certified seed is a quality control program. If seed is certified, it means that it has met certain standards set by the Michigan Department of Agriculture for that crop. Though the United States has no law that requires the use of certified seed, many other countries, including Canada, do require certified seed, so growers who want to export their crops must use certified seed.

At one time, Michigan had two organizations connected with certified seed. In 1997, the MCIA merged with the Michigan Foundation Seed Association (MFSA) and took on its mission of working with researchers and breeders to ensure there was enough certified seed available to growers, as well as promoting the use of certified seed among producers.

"When the MCIA and MFSA started, our main goal was to get improved seed stock to farmers," Judd said. "Now we get the seed to growers and promote its use."

The process of providing certified seed to farmers begins several years before a variety is released. Once a promising new variety is identified by a plant breeder, a small amount of prebreeder seed is increased for two to three generations to obtain adequate seed supplies. The crop grown from the prebreeder seed produces breeder seed, which then produces foundation seed. The foundation seed is used to produce the certified seed.

"We usually start the process of increasing seed about 3 years before the variety is released so there is enough foundation seed available to meet the needs of the industry," Judd explained. "Because we work so far ahead, sometimes we do an initial increase on a variety and then the variety isn't released. That seed is used as grain and we start over again."

Judd said the MCIA looks to MSU for new varieties that will keep Michigan farmers competitive with growers in other states.

"We look to the university to develop crops that have better quality traits and more disease resistance," he said. "We are always looking for new varieties to get to Michigan growers. Farmers know that Michigan certified seed will do well here and they know that the breeders are working on problems that are specific to the state. MSU is a major source of new material for us. I think we have an excellent relationship with the university."

NURTURING WHEAT

MAES wheat breeder Rick Ward, the son of a cereal geneticist, is about to have somewhat of a wheat baby boom on his hands.

"We're poised to release four soft winter wheat varieties," he said. "One has red grain and the others have white grain."

Ward works mainly with soft white wheat, which is used as whole grain or

In addition to developing new varieties, MAES wheat breeder Rick Ward has helped add more than 540 marker proteins to the wheat genome.

heavy bran in breakfast cereals. The flours of both red and white varieties are used for crackers, cookies, pastries and many other products.

Michigan primarily grows winter wheat — the crop is planted in the fall and then harvested the next summer. About 40 to 50 percent of the wheat grown in Michigan is white wheat, partly because of the large cereal company located in Battle Creek.

"Growers want a wheat that has good grain quality and would like it to be resistant to some of the 10 diseases that wheat succumbs to — scab is seen as the biggest threat," Ward said. "We're moving to release a white wheat that is more resistant to scab. There is no such thing as a white wheat that is totally resistant to scab."

Also known as fusarium head blight, scab is caused by several species of fungi. Rain around the time of wheat flowering is one of the main causes — the fungi like the damp, warm conditions. The organisms that cause scab are the same ones that rot cornstalks left in the field.

"We have a lot of scab in Michigan and much of the Midwest because there is so much corn stubble in the fields," Ward said. "The fungi stay in the fields on the stubble and then infect the next crop. The East has no areas that are safe from scab."

Besides reducing yield and grain quality, scab also leaves behind mycotoxins, which can cause diseases in animals and may be harmful to humans. Wheat must be tested for mycotoxins. If they are found, its value drops dramatically.

Ward is also looking for a breeding solution to sprouting, another problem identified by growers. Sprouting happens when rainy weather occurs just before or after harvest. The starch and protein in the wheat start to break down and can significantly reduce the quality of the grain.

"Almost all white wheat varieties are susceptible to sprouting if it rains," Ward explained. "On the other hand, most red varieties resist sprouting. We are actively using sprout resistance genes in our breeding program and now have them in advanced lines, including one poised for release."

As part of his breeding work, Ward runs the state variety trials for his crop. Each year he compares all the entered varieties and posts the results online and also distributes them through Michigan Farm Bureau so growers and seed producers have a guide to yields and disease resistance. Because most Michigan wheat is planted in the fall and harvested the next summer, it's imperative that Ward gets the results to growers quickly.

"We publish the variety trial results in August, and growers are planting what we just analyzed in September," Ward said. "We can analyze the data about a half-hour after cutting so growers can make the decisions right away.

"The state was dominated by two varieties, Frankenmuth and Augusta [also developed at MSU] until about 1990," he continued. "Now we have much greater diversity and better yields. Interestingly, varieties from Kentucky and Virginia do well here. It's a win for growers; it's opened up a huge diversity for them."

Ward is also studying the genomic structure of wheat, which has one of the largest genomes of any living thing. At about 16.9 billion base pairs, the wheat genome is nearly five times the size of the human genome. As scientists work to characterize this enormous collection of genetic material, the first step is to map out where so-called marker proteins go along the sequence.

It's somewhat akin to looking at a road map. If you were going to travel on I-75, you would need to know the order of the exits and where and how far apart they are before you could figure out where to stop. Adding more markers to the wheat genome map makes it easier for scientists to orient themselves as they seek to identify genes responsible for specific traits.

"As you make the marker map denser, there's a greater likelihood you'll find genes," Ward explained.

Ward and his colleagues Perry Cregen, of the Beltsville Agriculture Research Center, and Bikram Gill, of Kansas State University, have added more than 540 markers to the map — a dramatic increase over the fewer than 2,000 markers that were known when they began their work. All their markers begin with the letters "BARC," which stand for Beltsville Agricultural Research Center, where the markers were generated. The labs of Ward and Gill had the task of discovering the position of BARC markers.

"The BARC markers closed many gaps in the previous wheat maps, and the denser map is enabling scientists around the world to identify the position of performance-critical wheat genes," Ward

Michigan produces mainly winter wheat, which is planted in the fall and harvested the next summer.

1938-42 **Donald Cation, Michigan State College (MSC) plant pathologist, conducted research on fruit tree disease control. Cation was the first to demonstrate virus transmission through soil, and he established virus indexing procedures and the use of virus-free clones and their distribution to nurseries.**

said. "I'm very proud to have had this opportunity. I doubt I will ever make another contribution this big to wheat genetics."

UNDERSTANDING WHAT MAKES TREES TICK

Compared with most agricultural crops, trees grow in a different way — out as well as up.

"Trees have secondary growth — trunk width growth — as well as primary growth," said Kyung-Hwan Han, MAES forestry geneticist and tree breeder. "We want to understand the molecular mechanisms of secondary growth. Knowing this has economic implications for the wood products industry, as well as fruit growers. There is also an environmental angle. Trees can hold huge amounts of carbon; if we know the gene that controls trunk growth, we can breed trees that will hold more."

As part of this work, Han has learned that the body weight of the trunk is an environmental cue that tells the tree if it has enough support and is able to meet the water needs of the canopy. A signaling molecule tells the trunk to make more wood tissue if the tree's needs aren't being met.

"It's logical, but it's never been proven in an experiment before," he said.

As part of the international team that sequenced the genome of *Populus trichocarpa*, a poplar tree, Han is at the forefront of forestry genetics research. The poplar was the first tree genome to be sequenced, and it may help scientists pinpoint the genes that cause the tree to go dormant in winter and become active in the spring, another of Han's research projects.

"We're trying to understand the genes that trigger trees' annual growth cycle — move it in and out of dormancy," Han said. "Day length plays a role, as does temperature. We want to know which specific genes control dormancy and hope to identify them in about 2 years."

This work, too, will have economic and environmental implications, especially for the Michigan tree fruit industry. By giving the trees even a 1- or 2-week longer dormant period, researchers may be able to prevent severe damage and loss from spring frosts and freezes, like the one that devastated the state's cherry industry in 2002.

"We're also curious about how trees will respond to global warming," Han added. "If the temperature changes but day length doesn't, how will the trees respond?"

Han also hopes to help make the winter holidays a little greener for some tree growers.

According to statistics from the Michigan Department of Agriculture, the 2.5 million to 3 million Christmas trees harvested each year contribute about $41 million to the state's economy. Michigan has about 830 Christmas tree growers and more than 54,000 acres of Christmas trees. Michigan grows eight varieties of trees, including the traditional scotch pine, eastern white pine, Colorado blue spruce and Douglas fir. Michigan ranks third in the nation in the number of Christmas trees grown and second in acreage devoted to the growing of Christmas trees.

Christmas trees also play a role in environmentally friendly land use and farmland preservation. Tree farmers plant trees for a holiday season 7 to 10 years in the future. For every tree harvested, up to three are planted. As Christmas trees grow, they produce oxygen and clean water and provide wildlife habitat. After the holidays, trees can be recycled by chipping and used in landscaping, recreational trails, playgrounds or mulch. Whole trees can be recycled for erosion and pollution control projects.

"We've surveyed growers to learn the traits that were most important to them," Han said. "Herbicide resistance was their overwhelming response. They want to be able to reduce their costs and use one type of herbicide, regardless of variety. The growers face intense competition from artificial trees, so we want to help them as much as we can."

Han is also studying how to create an "on-demand" tree. By identifying the genes responsible for a tree's characteristics, such as height and shape, he could genetically engineer a tree to grow to only a certain height and have a certain number of branches — a designer tree to meet the needs of today's very particular consumers.

"But that's down the road a little bit," Han said. "It's not available yet. But once we have the technology, we'll be able to do it."

::: Jamie DePolo and Geoff Koch

Kyung-Hwan Han, MAES forestry geneticist and tree breeder, helped sequence the genome of the poplar tree and hopes to produce new varieties of Christmas trees with traits desired by Michigan growers.

1939 **MSC scientists bred apricot varieties that could be grown in Michigan. Until this time, 90 percent of the U.S. crop was grown in California.**

WHO WILL TRAIN THE PLANT BREEDERS OF THE FUTURE?

In an article in the Feb. 6, 2003, issue of the British science journal *Nature*, molecular biologist Jonathan Knight profiles how public-sector research into classical crop breeding is withering and being supplanted by "sexier" high-tech methods. But without breeders' expertise, molecular genetic approaches might never bear fruit.

"Breeding positions at public universities are often not being refilled or are being replaced by molecular biologists," said Jim Hancock, MAES horticultural scientist and small fruit breeder. "It's happening worldwide, and everyone is starting to wonder where the new breeders will come from as current breeders retire."

Members of the Plant Breeding and Genetics Group at MSU decided to tackle the question head-on and organized a symposium, "Plant Breeding and the Public Sector: Who Will Train Plant Breeders?", March 9-11 on campus.

"This is the first time the question has been addressed in a forum like this," Hancock said. "We wanted to bring together international breeders, U.S. university scientists, industry and government organizations, and other funders to develop an action plan. The MAES provided the seed money to make it happen, and that allowed us to invite the best speakers. We were able to secure exactly the people we wanted. We received a lot of positive comments. I was very pleased with the symposium."

This shift to hiring molecular biologists instead of traditional breeders is being fueled by the notion that private industry breeding programs are sufficiently meeting the world's needs. Also, university funding cuts have resulted in less support for applied field programs, which has pushed current public plant breeders to focus their work on more basic research that can be supported by federal grants and the private sector.

"The field has changed so much," said Karolyn Terpstra, a doctoral student in plant breeding and genetics. Her work focuses on incorporating improved resistance to white mold into dry beans. "There are so many more tools now, and plant breeders graduating from universities now are expected to know traditional plant breeding as well as genomics. The universities are looking for people who can do research in molecular biology because that's where the money is, while industry may be looking for someone with strong training in traditional breeding."

According to Hancock, the loss of plant breeding programs is of great concern to both the domestic plant breeding industry and the international community. A large number of plant breeders in developing nations were trained at U.S. universities, and almost all the private North American breeders attended land-grant universities.

"The bottom line is that we must find a way to keep a critical mass of applied geneticists and plant breeders at public institutions in the United States and around the world, if we want to maintain our training programs in plant breeding," Hancock said. "Once all the breeders retire, who will be left to train the new students?"

The five invited symposium speakers and their topics were:

- P. Stephen Baenziger, Eugene W. Price distinguished professor at the University of Nebraska: Plant Breeding Training in North America
- Fred Bliss, senior director of research and development special projects, Seminis Seeds, and former Will W. Lester endowed chair at the University of California: Plant Breeding in the Private Sector of North America.
- Gurdev Khush, former head of plant breeding at the International Rice Research Institute and recipient of the World Food Prize in 1996: Plant Breeding Training in the International Sector.
- Michael Morris, senior economist at the World Bank and former director of the economics program for Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT): Building Capacity for International Plant Breeding: What Roles for the Public and Private Sectors?
- Elcio Guimaraes, senior officer for cereal/crop breeding for the United Nations Food and Agriculture Organization: Assessment of National Plant Breeding and Biotechnology Capacity Worldwide.

At the symposium, participants worked on three major questions: what type of training do plant breeders need, how will minor/specialty crop varieties be provided, and how can public and private entities work together to train new breeders? Terpstra and other plant breeding and genetics graduate students served as recorders for the break-out groups and are also doing the bulk of the report writing.

"Our goal now is to issue the proceedings of the symposium and the reports of the break-out groups," Hancock said. "We hope to have them done in about 8 months. We're also developing an action plan and will make recommendations about how to train plant breeders using Hatch funds. MAES scientist Rebecca Grumet is spearheading this initiative."

"At the conference, the government officials and private company officials and university scientists were grappling with the same questions that we're discussing in our graduate seminar," Terpstra said. "It was gratifying to see that these well-respected and intellectual people had the same concerns. It made me feel like our opinions were valuable and our comments were well-received. A lot of great ideas came out of the symposium. Of course, the challenge is implementing them. But I left the symposium very excited about the field and about what we can accomplish."

Anyone interested in the topic who did not attend the symposium but would still like to be involved can e-mail Hancock at hancock@msu.edu. Copies of the symposium's presentations and reports are online at www.hrt.msu.edu/PBSymp/.

::: Jamie DePolo

Mike Thomashow, MAES microbiologist and molecular geneticist, found the genetic pathway that controls freezing tolerance in Arabidopsis. His work may lead to crops that can tolerate lower temperatures.

Filling Up the Toolbox

MAES scientists are creating biotechnology tools to help other scientists improve crops and the environment

BEFORE MAES POTATO BREEDER DAVE DOUCHES CAN DEVELOP A POTATO VARIETY THAT is resistant to scab, either he or another scientist has to find a plant that is already resistant to the disease. Then scientists have to determine how to cross-breed a potato plant with the resistant plant. They might try to determine the gene or genes responsible for the resistance, isolate them and then try to insert them into a potato plant through a variety of methods. At Michigan State University, the MAES supports the work of a number of scientists who characterize themselves as “filling up the toolbox” of biotechnology techniques for use by other scientists, such as plant breeders.

“I use biotechnology to attempt to solve problems that are either impossible or close to impossible to solve through traditional plant breeding,” said Mariam Sticklen, professor of crop and soil sciences, who has been using biotechnology since 1978. She has developed systems to genetically engineer crops such as potatoes, rice and turfgrasses to improve their resistance to insects and diseases as well as their tolerance to salt and drought. By boosting resistance to pests and drought, biotechnology allows producers to reduce the amount of pesticides and irrigation water they apply, which helps the environment and saves money.

CAN A CORN PLANT BECOME A MINI ETHANOL PLANT?

One of Sticklen's current projects is attempting to engineer corn leaves to make the enzymes needed for ethanol production. Ethanol can be made from any plant material that contains enough sugar or materials that can be converted into sugar, such as starch or cellulose. Corn grain contains starch that is relatively easy to convert into sugar. To produce ethanol, corn is ground and then its starch is converted into sugar. The sugar is then fermented into ethanol. However, corn as grain or starch is already valuable.

"I wanted not only a scientific but also an economic challenge, so I started working on corn," Sticklen said. "I felt that corn farmers weren't getting the benefits they deserve. Corn prices are low and I wanted to find a way to add value to corn. There is so much biomass [stalks and leaves] left over when corn is harvested, I started thinking about ways we could use that and make it more valuable. A few other scientists were thinking of buying expensive enzymes to add to corn biomass to convert into sugar and then into ethanol. My goal has been to produce a corn variety that produces its own enzyme, so after harvest one could chop it and convert it into alcohol sugars."

Sticklen thought that developing corn with higher levels of the enzymes needed for ethanol production would make the excess biomass more valuable.

"Ethanol production from plant biomass requires cellulase enzymes," she explained. "We have already produced one of these enzymes in corn. We have made the corn leaves and stems produce high levels of the enzyme. This will be an extremely lucrative market for corn growers. Imagine selling corn crop biomass for alternative fuel production."

Sticklen has also started studying how corn leaves could be engineered to make a protein that has the potential to help stop the transmission of the virus that causes AIDS.

"HIV/AIDS is not transmissible through saliva because there is a protein in saliva that kills the virus," Sticklen said. "A company in California has found the gene for making that protein."

The company has been able to produce small quantities of the protein, which retails at an extremely high price — $500 per microgram. Because the protein is so expensive, no large-scale studies have been done on its ability to prevent or control the spread of HIV. But Sticklen and other scientists are intrigued.

"When the protein is manufactured, it loses its shape, so the company has to go back in and reshape it, which is very expensive and contributes to the protein's high cost," Sticklen said. "We're attempting to put it into corn, and we think that it will keep its shape there. Just to be sure, we're adding another bit of genetic material that will help."

The techniques that Sticklen develops could potentially be used to add value to any crop with a relatively large amount of biomass that is thrown away as waste. Several other scientists are working on various aspects of the research. Hesham Oraby, a doctoral student from Egypt, is attempting to insert the genes that produce the enzymes necessary for ethanol production into rice.

"In developing countries, rice is a huge crop," he explained. "Nothing can be done with the rice straw after harvest, so much of it is burned. This contributes to the high levels of asthma and air pollution. I've experienced it in Egypt — there's just a haze everywhere when rice straw is burning. It stings your eyes and makes it hard to breathe."

Regulators are starting to notice. In California, it is illegal to burn rice straw.

"If we could use the rice straw for something useful, then there would be a market for it and growers wouldn't have to burn it — they could sell it," Oraby added.

> "I make tools that other people use. I want to understand what limits plants' ability to thrive."

STRESS RELIEF FOR PLANTS

When MAES microbiologist and molecular geneticist Mike Thomashow came to MSU in 1986, he wanted to know how plants evolved mechanisms to withstand stresses such as cold and drought. His goal was to improve stress tolerance in plants.

"I make tools that other people use," Thomashow said. "I want to understand what limits plants' ability to thrive."

Almost 20 years later, after being elected a member of the National Academy of Science and receiving the Alexander von Humboldt Foundation Award (the most prestigious award for agricultural research in the United States), Thomashow is internationally recognized for his work on the molecular mechanisms of cold acclimation in plants.

Environmental stresses such as temperature and water availability are the main limiters of the geographic boundaries of crops. Michigan's comparatively short growing season and harsh winters are why the state doesn't have a thriving citrus industry.

1957 **Eldon Down, MSU plant scientist, produced the Sanilac navy bean, an important Michigan variety. It was the first variety produced from parent beans that had been irradiated to create a plant that matured earlier.**

By understanding how plants evolved specific mechanisms to tolerate environmental stresses, specifically cold, Thomashow hoped to be able to find the genes responsible. He succeeded, brilliantly.

"We found the CBF cold-response pathway in *Arabidopsis* [a small plant in the mustard family]," Thomashow said. "This is the genetic pathway that controls freezing tolerance."

The CBF cold-response pathway is a small family of cold-responsive genes. Within 15 minutes of a plant being exposed to low but non-freezing temperatures, these CBF genes are turned on. After about two hours, the CBF genes turn on other genes that make up a regulatory element, the CBF regulon. After a few days of the CBF regulon genes being turned on, the plant's freezing tolerance increases. The CBF regulon genes also increase the plant's tolerance to drought and high salt concentrations. When Thomashow and his colleagues created plants that had their CBF genes turned on all the time, they found that the plants had better freezing tolerance.

Plant breeders at universities and private companies are now working to use this pathway as a type of master control switch to control a suite of genes responsible for dehydration stress, which can be caused by drought, freezing and high salinity.

"Now we want to optimize the expression of the genes and see if we can influence various plant species and create improved varieties," Thomashow said. "There are a number of plants that are freezing tolerant, such as wheat and canola. In those we're trying to increase the tolerance now that we know what the pathway is."

But other plants, such as tomatoes, rice and potatoes, have no freezing tolerance. These plants pose new questions for Thomashow and his research team. Do these plants even have a CBF pathway? Do they have parts of one? If they have a CBF pathway, is it defective? Is that why the plants have no freezing tolerance? Could it be fixed?

"We're now looking at those plants," Thomashow said. "In the tomato, we've found that it has a complete CBF pathway, but the CBF regulon is very simple. It has only 10 genes. We want to know why it is so simple — is there a mutation in another regulatory gene? Does it mean that the regulatory system sits in front of only a few genes?"

Thomashow also wondered if there were any other cold-response pathways that controlled hydration and perhaps worked in partnership with the CBF pathway. He found one. Called ZAT12, this pathway activates a much smaller suite of genes. If just the ZAT12 genes are turned on, the freezing tolerance increase is also smaller. He continues to look for other pathways, but so far the genes that turn on the most after cold exposure are in the CBF pathway.

"Our challenge is to take the knowledge we have of the system and use it to improve our strategies," Thomashow said. "Can we ratchet up the genes that turn on the CBF main switch and improve cold tolerance?"

Unknowingly, breeders were selecting for varieties that had their CBF genes turned up before anyone knew the CBF pathway existed.

"When we looked at cold-tolerant plants, we found their CBF systems are turned up very high," Thomashow explained. "Which makes sense. Growers want plants that are more cold-tolerant, so those are the ones that are selected for the next season.

"When I came to MSU, we didn't know any of this stuff," he added. "It's been fun to learn and discover it. The MAES deserves credit for supporting my ideas. There's still a lot to be learned about this pathway and any other pathways that may act in parallel to it."

Scientist Mariam Sticklen has developed systems to genetically engineer crops such as potatoes, rice and turfgrass to improve their resistance to insects and diseases.

A MASTER SWITCH FOR PLANT GENES

To create its hugely successful line of Roundup-Ready crops, including corn, soybeans and canola, the Monsanto Company identified and patented a specific sequence of DNA called a promoter. Promoters sit in front of genes and tell the plant when to turn on the expression of the gene. The promoter that Monsanto patented, the 35S promoter, is known as a general promoter and is on all the time. Monsanto inserted it into crops and the promoter basically told the plants to turn on the genes that made them tolerant to Monsanto's herbicide Roundup. So growers could use Roundup to kill weeds without harming their crops.

Because Monsanto owns the promoter, the company controls who gets to use it. Scientists can use the promoter free of charge in experimental attempts to improve crops, but use of the 35S promoter in commercial varieties is controlled by Monsanto.

After several years of research, MAES plant biologist Richard Allison identified a new promoter that functions in a similar way to the 35S promoter. Like Monsanto's 35S promoter, Allison's promoter was derived from a virus. In this case, the promoter came from a virus infecting a Michigan blueberry crop.

"This promoter is like a switch," Allison explained. "You put it in front of any gene and it tells the gene to turn on. It would allow us to bypass the 35S promoter that Monsanto owns. Because MSU would have the patent on this new promoter, it would allow

MAES plant biologist John Ohlrogge wants to create plants that produce more oil or oil with special properties to give farmers the opportunity to grow higher value crops.

scientists here to use it to develop new crop varieties."

Through the MSU Office of Intellectual Property, he filed for a patent on it in March 2004. He expects to have the patent in about 2 years.

"There has been a lot of interest in this by MSU researchers," said Tom Herlache, licensing associate in the Office of Intellectual Property. "We haven't started advertising the licensing process outside yet."

Allison is also working on a new way to transform plants. Though the work is extremely promising and he's very excited about it, Herlache cautioned him not to say much because the patent application for it has not yet been published.

"Large-seeded legumes, such as dry beans and soybeans, both of which are an important part of Michigan agriculture, are difficult to transform with the techniques that we now have," Allison said. "We've refined a promising approach for the introduction of foreign genes into these crops. It would put MSU in a nice position with the intellectual rights to this technology."

A third tool that Allison is just beginning to work on is somewhat similar to his promoter work. But instead of having a virus resistance gene turned on all the time, that gene would turn on only when the virus entered the cell. Then the resistance gene would turn on and kill the cells around the virus and lock the virus in the dead cells.

"The plant is basically the same, except if it contracts a virus," Allison said. "The mechanism of having the virus turn on the gene is what I'm working on. We think this type of plant might be more acceptable to people who are opposed to biotechnology because it's different only if and when the virus enters."

CREATING INDUSTRIAL PLANTS

With gas prices firmly parked above $2 per gallon, many consumers are revisiting the idea of alternative fuels. As gas prices go up, so does public discussion about ways to power vehicles and machinery with something other than crude oil products. MAES plant biologist John Ohlrogge has never stopped talking about alternative oil products. His research career is focused on genetically engineering oilseeds to create products for the chemical industry, including plastics, polymers and oils.

"If we can create plants that produce more oil or oil with special properties, it gives farmers more options — a chance to grow a higher value crop," Ohlrogge explained. "It provides alternatives to crude oil."

Ohlrogge passionately believes that these plant oils will help increase income for farmers all over the world.

Many of the larger chemical companies are interested in using crops to produce chemicals that have traditionally been made as byproducts of crude oil. Polyurethane, for example, can now be made from plant oils. Currently, conventional soybean oil with no genetic engineering is being used to make polymers.

"With some genetic modifications, we could make that process better and easier," Ohlrogge said. "We can create a plant that does some of the chemical reactions in the plant, so the chemical company doesn't have to do it. This reduces the amount of refining the company has to do, which makes it more cost-effective. The profit margin for commodity chemicals is tiny, so if we can make an oil that is less expensive or more attractive, companies will use it because it can now compete with crude oil. In a sense we're replacing industrial plants with green plants."

The genetic modifications that Ohlrogge refers to involve making the oil molecule more reactive. To do this, he is working to isolate genes from natural plant systems that already do the chemistry. For example, the *Sterculia foetida* tree, also known as kapuh or kelumpang, is a large tropical tree with orange-red flowers that produce red seed pods. The flowers don't smell very nice, but the seeds are rich with oil and Ohlrogge thinks one of the fatty acids in the seeds could be very valuable.

"We have isolated the genes that make this fatty acid and are working toward introducing these genes to oilseed crops that can be grown in Michigan," he explained. "We're not introducing

> "We can create a plant that does some of the chemical reactions in the plant. The potential markets in the chemical industry are enormous."

them into crops grown for food — we're looking at specialty crops that aren't used for food, such as crambe and flax and possibly tobacco. Crambe might be similar to canola agriculturally."

The fatty acid in *Sterculia foetida* is unusually reactive, Ohlrogge said, and he thinks it would be used in lubricants and plastics. It is just one of the fatty acids that Ohlrogge's lab has worked on over the years.

"Isolating the genes is the easy part," he said. "Getting them to work efficiently in plants and producing a new type of crop is the difficult part. It may require about 10 more years before we will see large-scale commercial production. However, the potential markets in the chemical industry are enormous."

Polymers and plastics made from plants not only offer farmers higher value for their crops, they are often biodegradable, so using and disposing of this type of oil would be far less taxing on the environment than a non-biodegradable product. Ohlrogge thinks that in the future, outboard motor oil, snowmobile oil and chainsaw oil will be based on plant oils to protect the environment.

"There are some biodegradable chainsaw oils available now," he said. "They are now required in some places — mainly in Europe. In the future, Michigan might require that only biodegradable oil can be used on state forest and park land to keep our water and forests clean."

TECHNIQUES FOR MICHIGAN CROPS

When scientists use biotechnology to transform plants, they transform only a small number of cells. The challenge is to create the conditions that allow only those transformed cells to grow and not the others.

The standard way to do this is to use a selectable marker — an antibiotic-resistant gene or a herbicide-resistant gene, for example. Then when the antibiotic or herbicide is applied to the culture, the non-transformed cells are killed.

"Almost all these selectable marker genes are patented, however, and the patents are owned by chemical companies," explained MAES horticulture scientist Wayne Loescher, who has long studied the molecular mechanisms for biosynthesis and the degradation of sugar alcohols in plants. "If I want to use those patented genes, the companies that own them want a cut, which is understandable. This is a particular problem for horticultural crops because their acreage is much smaller than that of corn, wheat and soybeans. There is no economic incentive for the companies to do this work themselves. And it is especially an issue in Michigan because many of these comparatively smaller horticulture crops are important to the economy."

In his research, Loescher worked out the metabolic pathways for mannitol (a type of plant sugar) synthesis and identified and sequenced the genes involved. One of the genes may be able to be used as a selectable marker.

"It would be very nice to have a selectable marker that MSU could own and use and not have to worry about paying a big company for," Loescher said. "So far, we have dramatic results in tobacco, but we want to see if it works in Michigan crops."

Loescher has placed the similar genes in *Arabidopsis*, a plant commonly used in biotechnology research. The plant then began to make mannitol, which it doesn't normally make, and the mannitol enhanced the salt tolerance in the plant. This may have worldwide implications.

Dry beans and soybeans, important crops in Michigan, are difficult to transform with current techniques. Richard Allison, MAES plant biologist, is working on a new way to transform these crops and has filed a patent application for it.

"Having to use brackish water for irrigation is a global problem," Loescher explained. "Farmers are relying on irrigation more and more to improve productivity. Sometimes the only water they can get has high salinity."

Biotechnology is also important for Michigan growers.

Loescher said that biotechnology will ensure that the horticultural crops important to Michigan, such as cherries, blueberries and cucurbits, have good regeneration procedures.

"There is a long list of crops that don't have good, consistent techniques because they're smaller than corn or rice or soybeans," he said. "*Arabidopsis* and tobacco are easy to do, but they're not biologically similar to most horticultural crops. We can't predict how specific plants will respond to the various procedures. We have to use the models we have and then move beyond them to develop techniques for crops that are important for Michigan. [MAES scientist and Plant Transformation Center director] Ken Sink is doing this type of work. These techniques are turning out to be different for each crop. We're not going to be able to convince people in Iowa to work on blueberries. There is no value for them there. MSU has to do this type of work for our growers."

::: *Jamie DePolo*

1958 **MSU horticulturists Shigemi Honma and O. Heeckt successfully hybridized snap and lima beans. This hybridization transferred the early germination ability and early maturity of the snap bean to the lima bean so it could be planted earlier.**

MICHIGAN STATE UNIVERSITY

SESQUICENTENNIAL

A History of Good Varieties

Michigan State University is celebrating its 150th anniversary in 2005. MSU is the pioneer land-grant institution, and its history is closely tied to the history of agriculture, natural resources and rural communities in the state. The Michigan Agricultural Experiment Station was founded on Feb. 26, 1888 — 33 years after MSU was founded — and the MAES has played a significant role in shaping MSU's research legacy and its priorities for the future. Each issue of Futures *in 2005 will feature a special sesquicentennial article highlighting the intersection of MAES and MSU history.*

Advancing Knowledge. Transforming Lives.

1855-2005

In 1940, Stanley Johnston, superintendent of the MAES field station at South Haven, made history by releasing the Redhaven peach variety, an early-ripening, red-skinned peach he had developed. Redhaven, the first commercial red-skinned peach, was one of 11 "Haven" peach varieties developed at MSU, and it went on to become the most widely grown cultivar in the world.

Though not a geneticist, Johnston knew that Michigan peach growers needed an early-ripening variety to invigorate the industry. His Haven peaches joined a long list of MSU-developed crops that offered economic advantages to growers and nutritious and plentiful food to consumers.

The corn variety trial at MSU celebrates its 70th anniversary in 2005. Former MAES corn breeder Elmer Rossman developed more than 45 hybrid varieties and more than 40 inbred varieties for Michigan growers.

Breeding and variety release are an outgrowth of the Hatch Act, passed by Congress in 1887, which created the Michigan Agricultural Experiment Station and allocated $15,000 per year for agricultural research in each state. Today the MAES budget exceeds $78 million and covers a wide variety of research, from production practices to environmental quality and food safety.

Keith Dysinger, research assistant at the MSU Agronomy Farm, oversees the corn variety trials. He's been working on them for 33 years and has seen almost half the trials.

Growers have always needed new varieties to remain competitive, and in the 117 years since the founding of the experiment station, MAES plant breeders have been helping growers do just that. MSU has released more than 300 varieties of crops — from apples, blueberries and peaches to wheat, dry beans, petunias and snapdragons. Though none has approached the wide popularity of the Redhaven peach, many have been extremely important and beneficial to growers.

Many of the same MAES scientists who conduct breeding research also oversee variety trials of the same crops they breed. This work is also extremely important to growers.

"The trials are unbiased sources of information that let everyone know how each variety performs in various locations around Michigan," said Keith Dysinger, a research assistant at the MSU Agronomy Farm, who oversees the corn variety trials. "MSU produces publications each year for a multitude of crops that growers can use as a guide."

Seed companies pay a fee to have their varieties in the trial. The number of varieties in each year's trial varies from crop to crop. Corn usually has about 300, wheat has about 85, and soybeans had more than 200 varieties in the 2004 trial.

One of the oldest trials, the corn variety trial celebrates its 70th anniversary in 2005. Dysinger has been working on the corn trials for 33 years, so he's seen just about half of them.

"The history of Michigan agriculture has strong ties to corn," Dysinger said. "In 1887, Professor Beal first cross-pollinated corn to create hybrid vigor. Dr. Elmer Rossman developed more than 45 hybrids and 40-plus inbred varieties suitable for Michigan between 1948 and 1989. MSU started the corn trials in 1935, just at the point when hybrids were starting to make their mark by out-producing the open pollinated lines used at the time."

The corn hybrid variety trials helped Michigan corn growers choose the best varieties for their growing conditions and made a large impact on the amount of corn grown in the state. In 1950, about 1.7 million acres were planted in corn. In 1982, it was 2.83 million acres. At the same time, yields were increasing. The new hybrids doubled the average corn yield in less than 20 years.

"In terms of acreage and cash value, corn remains Michigan's No. 1 crop," Dysinger said. "Though Michigan has many other crops that rank in the top five nationally. Michigan growers continue to use MSU variety trial information to help them make choices about which varieties to plant. We have a good reputation, and our challenge is to keep presenting quality data. We're now working with other states in our region to standardize the data and are conducting joint trials. This makes it easier for growers and seed companies to compare data from several states."

::: Jamie DePolo

1958 **Harry Murakishi, MSU plant pathologist, studied the effect of tobacco mosaic virus (TMV) — a virus that attacks vegetables — on the survival rate of tomato cells from resistant and susceptible varieties. His work offered a way to screen thousands of cells for TMV resistance.**

The following is the most complete listing of varieties developed at MSU that has been compiled so far.

CROP	VARIETY	YEAR RELEASED
Alfalfa	Hardigan	1920
	Webfoot	1989
	Big Ten	1990
Apple Rootstock	MARK	1982
Apricot	Goldcot	1967
	Traverse	1978
Barley (Spring)	Michigan Black Barbless	1918
	Michigan Two Row	1918
	Spartan	1918
	Bay	1945
	Coho	1969
	Bowers	1975
Barley (Winter)	Michigan Barley	1914
	Cass	1969
	Lakeland	1969
	Norwind	1972
	Odin	1973
Begonia	Spartan Beauty	1993
Black Bean	Domino	1981
	Black Magic	1981
	Blackhawk	1988
	Raven	1993
	Phantom	1999
	Jaguar	2000
	Condor	2004
Blueberry	Keweenaw	1951
	Bluehaven	1967
	Northland	1967
	Tophat	1977
	Bluejay	1978
	Aurora	2002
	Draper	2002
	Liberty	2002
Broccoli	Spartan Early	1960
Carrot	MSU 1558	1963
	MSU 3489	1963
	Spartan Bonus	1969
	Spartan Sweet	1969
	Spartan Delite	1971
	Spartan Fancy	1971
	MSU 1558A	1971
	MSU 1558B	1971
	MSU 5986B	1971
	Spartan North	1972
	Spartan Classic	1976
	Spartan Premium	1976
	Spartan Winner	1976
	MSU 872A	1976
	MSU 872B	1976
	MSU 5988C	1976
	Spartan Delux	1977
	Spartan Bonus 80	1981
	Spartan Classic 80	1981
	Spartan Delite 80	1981
	Spartan Delux 80	1981
Carrot	Spartan Fancy 80	1981
	Spartan Premium 80	1981
	Spartan Winner 80	1981
Cauliflower	Green Ball	1971
	Self-Blanche	1973
	White Empress	1979
	Stovepipe	1980
Celery	Michigan Golden	1933
	Michigan State Green Gold	1951
	Spartan 162	1958
	Golden Spartan	1974
Corn (Open-pollinated)	Duncan	1920
	M.A.C. Yellow Dent	1922
	Polar Dent	1927
Corn (Inbreds)	MS 24	1954
	MS 206	1954
	MS 109	1957
	MS 111	1957
	MS 121	1957
	MS 125	1957
	MS 126	1957
	MS 24A	1958
	MS 12	1958
	MS 116	1961
	MS 211	1961
	MS 1334	1962
	MS 4	1963
	MS 106	1963
	MS 107	1963
	MS 132	1963
	MS 213	1963
	MS 214	1963
	MS 57	1969
	MS 80	1969
	MS 92	1969
	MS 93	1969
	MS 100	1969
	MS 140	1969
	MS 142	1969
	MS 141	1970
	MS 68	1972
	MS 153	1972
	MS 145	1972
	MS103	1972
	MS 70	1975
	MS 71	1975
	MS 72	1975
	MS 74	1979
	MS 200	1979
	MS 221	1988
	MS 222	1988
	MS 223	1988
	MS 224	1988
	MS 225	1988
Corn (Hybrids)	Michigan 561 (T)	1936
	Michigan 1218 (T)	1936
	Michigan 21A (T)	1939
	Michigan 20D	1943
	Michigan 29D	1943
Corn (Hybrids)	Michigan 250	1951
	Michigan 350	1951
	Michigan 480	1952
	Michigan 570	1953
	Michigan 160	1955
	Michigan 420	1955
	Michigan 430	1955
	Michigan 475	1955
	Michigan 300	1958
	Michigan 370	1960
	Michigan 425	1960
	Michigan 490	1960
	Michigan 620	1960
	Michigan 400	1962
	Michigan 270	1963
	Michigan 550	1965
	Michigan 402-2X	1965
	Michigan 280	1966
	Michigan 500-2X	1966
	Michigan 463-3X	1967
	Michigan 200	1967
	Michigan 275-2X	1968
	Michigan 568-3X	1968
	Michigan 510-2XHLHT	1969
	Michigan 555-3X	1969
	380-3X	1970
	511-3X	1971
	572-3X	1971
	396-3X	1971
	333-3X	1972
	410-2X	1972
	560-2X	1972
	407-2X	1974
	575-2X	1974
	2013	1975
	2833	1975
	2853	1975
	3093	1975
	5443	1975
	3102	1976
	4122	1976
	5802	1976
	5922	1979
	477	1980
Cranberry Bean	Michigan Improved Cranberry	1969
	Cardinal	1982
	Coral	2005
Cucumber (Pickling)	National Pickle	1929
	Spartan Dawn	1963
	Spartan Champion	1964
	Spartan Reserve	1964
	Spartan Progress	1967
	Spartan Advance	1968
	Spartan Valor	1968
	Spartan Salad	1972
	Spartan Jack	1973
	MSU 305 M	?
	MSU 183 C	1973
	Spartan Magic	1981
	Spartan Pride	1981
	Spartan Spirit	1981
	Spartan Wonder	1981
Grasses	Wintergreen Chewings Fescue	1969
	Tetrelite Annual Ryegrass	1969
	Beaumont Meadow Fescue	1969
Great Northern Bean	Alpine	1992

CROP	VARIETY	YEAR RELEASED
Great Northern Bean	Matterhorn	1998
Kalanchoe	Michigan State	1942
Kidney Bean (Dark Red)	Charlevoix	1961
	Montcalm	1974
	Isles	1993
	Red Hawk	1997
Kidney Bean (Light Red)	Manitou	1967
	Mecosta	1974
	Isabella	1981
	Chinook	1991
Kidney Bean (White)/Alubia	Beluga	1998
Lettuce	Great Lakes	1942
	Tendergreen	1955
	Spartan Lakes	1968
	Chesibb	1969
	Domineer	1972
	Superbib	1980
Lima Bean	Spartan Freezer	1968
Muskmelon	Superb Golden	1939
	Spartan Rock	1958
	MSU 1C	1969
Navy Bean	Robust	1915
	Michelite	1937
	Sanilac	1956
	Seaway	1960
	Saginaw	1961
	Gratiot	1964
	Seafarer	1968
	Tuscola	1973
	Swan Valley	1981
	Neptune	1981
	C-20	1982
	Laker	1983
	Mayflower	1988
	Huron	1993
	Newport	1994
	Mackinac	1997
	Seahawk	2003
Oats	Alexander	1911
	College Success	1916
	Wolverine	1916
	Worthy	1917
	Huron	1938
	Eaton	1945
	Kent	1947
	Bonham	1947
	Jackson	1954
	Coachman	1964
	AuSable	1964
	Heritage	1976
	Pacer	1988
	MI-88-0-30	1995
	Ida	1997
	Ruby	1997
Onion	Michigan Sweet Spanish	1945
	Spartan	1957
	Spartan Era	1963
	Spartan Gem	1963
	Spartan Banner	1966
	Spartan Bounty	1966
Onion	Spartan Sleeper	1974
	Spartan Banner 80	1980
	Sweet Sandwich	1982
	Spartan Supreme	1997
Peach	Halehaven	1932
	Kalhaven	1938
	Redhaven	1946
	Fairhaven	1946
	Richhaven	1955
	Sunhaven	1955
	Suncling	1961
	Cresthaven	1963
	Glohaven	1963
	Jayhaven	1976
	Spartancling	1976
	Sweethaven	1976
	Newhaven	1978
	MSU II 7(26)	1999
Pear	Spartlet	1972
Pepper	Spartan Emerald	1964
	Spartan Garnet	1968
	Frommage	1972
	Sonnette	1974
	Spartan Ruler	1976
Petunia	Mary Michie	1993
Pinto Bean	Sierra	1989
	Aztec	1992
	Kodiak	1998
Pink Bean	Sedona	2005
Popcorn	Michigan Popcorn No. 1	1958
	Michigan Popcorn 1-A	1958
Potato	Pontiac	1939
	Onaway	1956
	Tawa	1957
	Arenac	1961
	Emmet	1961
	Russet Arenac	1965
	Saginaw Gold	1988
	Michigold	1989
	Spartan Pearl	1991
	Jacqueline Lee	2002
	Michigan Purple	2003
	Liberator	2002
	Boulder	2003
	Beacon Chipper	2005
Raspberry	Early Red	1951
Red Bean	Merlot	2003
Rye	Rosen	1912
	Wheeler	1970
Snap Bean	Spartan Arrow	1963
	Spartan Pride	1974
	Green Ruler	1976
	Spartan Ruler	1976
	Golden Ruler	1979
Snapdragon	Spartan Bronze	1952
	Spartan Rose	1952
Snapdragon	Tahiti White	1952
Soldier Bean	Redcoat	2004
Soybean	Dimon	1989
	Felix	1990
	Apollo	1992
	Olympus	1993
	Titan	1998
	Skylla	2004
Spruce Tree	Spartan Spruce	1982
Strawberry	Scarlet	1978
Sugar Beet	USH20	1971
	USH23	1981
	SR80	1993
	SR97	2003
Tomato	Victor	1941
	Early Chatham	1943
	Spartan Hybrid	1943
	Spartan Red 8	1961
	Spartan Pink 10	1962
	Moto-Red	1968
	Droplet	1971
	Rapids	1971
	Mini-Spartan	1980
Wheat	Red Rock	1913
	Berkeley Rock	1922
	Baldrock	1932
	Ionia	1969
	Tecumseh	1973
	Frankenmuth	1979
	Augusta	1979
	Hillsdale	1983
	Chelsea	1992
	Lowell	1993
	Mendon	1993
	Ramrod	1996
	Bavaria	1998
	MSUD6234	2003
	MSUD8006	2004
Zinnia	Spartan Rainbow	1993

Research *in the news*

Project GREEEN Awards Research Dollars for 2005

Project GREEEN (Generating Research and Extension to meet Environmental and Economic Needs), Michigan's plant agriculture initiative at MSU, awarded grants for 28 new research projects for fiscal year 2005. Almost $1.7 million was available in Project GREEEN grant money this funding cycle, of which $850,000 was appropriated to new projects. The remaining dollars were directed toward projects that started in 2003 or 2004. All projects target priority issues affecting Michigan's plant agriculture industries.

A total of 75 new project proposals and 30 continuation proposals requesting approximately $3.3 million were received for consideration in this year's selection process.

Research projects were funded in the categories of basic research, applied research and extension/education/demonstration. New projects were funded across the spectrum of Michigan's plant agriculture industries, on topics ranging from restoring community landscapes devastated by the emerald ash borer and developing market-ready, shelf-stable products to enhance profitability of the state's tree fruit industries to integrating endangered species protection with agricultural commodity production. Other research topics funded by Project GREEEN in 2005 include developing new weed control systems for soybeans and corn, strategies to limit *Phytophthora* disease in vegetables and more frost-tolerant bedding plants for Michigan's greenhouse industry.

"The research and outreach projects selected for Project GREEEN funding address industry-identified priorities and have met the rigors of scientific peer review," said Doug Buhler, coordinator of Project GREEEN and acting associate director of the Michigan Agricultural Experiment Station. "These research and outreach projects reflect the partnership and cooperative relationship that exists between the plant industry groups, agribusiness, the Michigan Department of Agriculture and Michigan State University."

"Project GREEEN has meant a great deal to Michigan's agriculture and natural resources since its inception," said Dan Wyant, former director of the Michigan Department of Agriculture. "It's truly a unique model of industry, government and university working together to identify needs and produce tangible results. From helping develop tools that sustain food safety and address exotic pests to efforts that protect Michigan's environment and adapt to rapidly emerging issues, Project GREEEN is key to helping keep Michigan agriculture successful and local communities and economies strong for generations to come."

A complete listing of 2005 newly funded and continuing Project GREEEN research projects can be found at www.greeen.msu.edu/newspage.htm.

1978 **Cisplatin, an anti-cancer agent developed by MSU biophysicist Barnett Rosenberg, was approved by the FDA after several years of testing. It was lauded as the most effective anti-cancer drug in 20 years. Cisplatin resulted from experiments Rosenberg conducted with electric currents and bacteria growing in culture.**

Water Cooling Research Proactive Step for Cherry Industry

As water conservation and regulation gain attention, Michigan fruit growers and processors are looking for ways to be proactive about reducing water use. Most notably, Michigan's $80 million tart cherry industry is looking at developing new strategies to maximize water efficiency while increasing profitability for both growers and processors.

"There's no question that a lot of water is used during the cherry harvest and handling process," said Phil Korson, director of the Cherry Marketing Institute.

Cherries are harvested by machine and plunged into a cool bath of well water to cushion their entry into the holding tank and remove field heat. The cherries are flushed with more water to clean and cool them, and additional water is used during transporting, processing and handling. Most of the water used then flows into on-site holding ponds from which it is released back into the soil or distributed via surface irrigation.

Within the past decade, a trend has developed among some cherry producers and processors to cool cherry fruit in chilled water (below average well water temperature of 48 to 50 degrees F) by using refrigerated water chillers. Their use can both reduce the amount of water used and improve fruit quality.

Korson said chilled water allows the fruit to cool to a lower temperature more quickly, making the cherries firmer and better able to withstand the pitting process. The chilled water can also be recirculated so that less total water is used.

Dan Guyer, MAES biosystems and agricultural engineering researcher, is studying both the economic and the environmental advantages of using chilled water.

"Many cherry growers and processors have said that using chilled water results in a firmer, higher quality cherry, but there is limited data to back up the anecdotal evidence," he said. "We're looking at four main research questions. First, does using chilled water reduce the amount of water used? Second, does fruit quality actually improve? Third, does it result in greater overall net returns to producers? And lastly, does it reduce the challenges associated with water disposal?"

Guyer said that during data collection last summer, researchers looked at temperature profiles within several tanks with well water and mechanically chilled water.

"We found greatly varying temperatures throughout the chilling tanks even after several hours of chilling," he said. "It led us to ask a lot more questions about how much water at what temperature works best. For example, what temperatures and flow rates will best chill the cherries to the desired temperature within a time frame that is practical for the producer? Should the cherries be rapidly cooled and held, or cooled gradually over the time of holding? And what are the impacts of these protocols on cherry quality?"

For now, Guyer said, whether an operation should implement mechanical chilling and water recycling depends on many factors, including the rate of return on investment, actual improved fruit quality and the size of the fruit operation. Guyer hopes to determine guidelines for these topics as research progresses.

"Ultimately, our objective is to make sure the cherry industry is sustainable in the future, both economically and from an environmental stewardship perspective," Guyer said.

"This research is a big deal for the industry," Korson added. "It's definitely a proactive step forward. We know there is a need to conserve water, and this research is addressing it before it becomes a problem."

Researchers Investigating Using Animal Composting at Meat Packaging Plants

Restrictions in the use of animal byproducts in animal feed and other products have created a new set of concerns for meat processors. Historically, a rendering truck would pick up the unwanted animal tissue and bones. At one time the processors were paid for the material, but today the render service has become an increasing expense. In some cases, processors don't have an outlet, regardless of the costs, so the material ends up in landfills.

To help processors address this concern, Dale Rozeboom, MAES animal science researcher, has conducted an on-site demonstration project with Jones Farm Meats of Saranac to study the feasibility of composting meat processing byproducts. Rozeboom, who also studies dead animal composting on farms, believes there is a place for composting at the meat processing plants as well.

"We hope to show that a small meat processing business can use composting to effectively, safely and economically convert inedible byproducts into a product that can be used beneficially by crop and plant growers," Rozeboom said. He estimated that there are 100 to 200 small meat-processing plants in Michigan that may benefit from this project if it leads to changes in the Bodies of Dead Animals Act (BODA).

At this time Michigan law (the Bodies of Dead Animals Act and the Natural Resources and Environmental Protection Act) requires that processors must obtain a special permit to compost. Jones Farm Meats was granted permission to compost as a demonstration facility.

"The last time we paid a renderer it cost us $15,000 a year," said Karl Jones, owner of the meat plant. "At one point in the 1970s, renderers paid us around $40,000 a year — it was what we lived on." Jones and his family have been in the meat packing business since 1883.

The demonstration at Jones Farm Meats began in January 2004. Rozeboom and private consultant Howard Person designed a composting facility to handle the 600,000 pounds of byproducts generated at the plant each year.

The composting process requires an optimum carbon to nitrogen ratio for proper decomposition. Maintaining the right balance of organic matter and bulking material is critical to proper composting. To help speed up the composting time, the byproducts are run through a grinder so everything is broken into 3-inch or smaller pieces. The byproducts are then moved to the composting site.

When new byproduct material is added to the compost pile, dried sawdust or other organic material is also added as a carbon source. Jones Farm Meats is located across the road from a large dairy operation, which supplies used sawdust bedding for use along with dried sawdust.

As microbial decomposition takes place, the pile is turned or moved to allow for proper aeration. The piles are turned when compost temperatures drop below 100 degrees F for a week or two. Compost is aerated at least once a month and may be turned two or three times a month. A layer of dry material is put down under the compost pile to absorb any leachate. If runoff develops or the pile begins to slip, it is pushed back into the bin.

Rozeboom said that under the current BODA, compost piles containing animal tissues need to be covered. Part of this project was to evaluate possible runoff from an unroofed structure. All bins slope in toward one another to prevent runoff out of the bins.

After at least three months of active composting, the compost is removed from the bin and piled elsewhere for curing. At this point the material, which is similar in texture to dairy manure, could be applied to farm fields. Curing makes the compost a potential potting medium or mulch for the greenhouse industry.

Rozeboom and Person have been monitoring gases produced during active composting. They have found very low levels if a biofilter cap or fresh layer of sawdust is kept over the pile during composting.

Controlling animals, especially rodents, around the area was an initial concern, but they have found that fencing around the area and keeping an adequate level of sawdust over the pile have prevented problems with insects and animals in the area. Rozeboom said the piles stay too hot for rodents and fly larvae.

Rozeboom and the owners of Jones Farm Meats are pleased with the first-year results. The plant owners are saving money in rendering expense and may at some point see an income source from the compost. This type of composting may have a place at small meat processing plants.

MAES Scientist Named Crop and Soil Sciences Acting Chair

Jim Kells, MAES weed scientist, was appointed acting chairperson of the Department of Crop and Soil Sciences in April. Former chairperson Doug Buhler is now serving as acting associate director of the MAES and acting associate dean for research for the College of Agriculture and Natural Resources (CANR).

Kells has been a faculty member in the Department of Crop and Soil Sciences since 1982. In addition to his teaching and MAES appointments, he also serves as an MSU Extension project leader, and he has served as associate chair of the Department of Crop and Soil Sciences since 2003. He has worked in leadership roles with both the Weed Science Society of America and the North Central Weed Science Society, and he has served on numerous professional review committees.

Kells' program excellence has been recognized with the MSU Outstanding Extension Specialist Award and the Michigan Association of Extension Agents Specialist of the Year Award, among others. He is a double graduate of MSU, with

1982 **Dennis Fulbright, MAES plant pathologist, used biotechnology to isolate a virus that helped save the American chestnut from Chestnut blight, a fungal disease that nearly wiped out the species. Foresters see Chestnut blight as the worst ecological disaster in North American history. The virus makes the fungus less virulent so it does not kill the trees it infects.**

both a bachelor's degree in crop and soil sciences and a doctorate in weed science. He received his master's degree in weed science from the University of Kentucky.

"I am very pleased that Jim has agreed to take on this responsibility," said Jeffrey Armstrong, dean of the CANR. "I am looking forward to working with him in this leadership capacity."

MAES Acting Director Featured in Detroit Free Press

An editorial by John Baker, MAES acting director, on how President Bush's proposed budget cuts to agricultural research funding would harm Michigan was featured in the Detroit Free Press May 3. To read Baker's comments, visit www.freep.com/voices/columnists/ebaker3e_20050503.htm.

High Fidelity Keeps Human DNA Assembly Line Humming

It turns out that building cars and building life have a lot in common – success all comes down to quality control.

MAES scientists have made a major discovery about the inner workings of genetic coding, mapping out the mechanisms of one of life's most elemental functions: RNA synthesis. Their work has crucial implications for understanding how a normal cell forms a tumor and how a virus runs amok.

The work was published in the May 13 edition of the scientific journal *Molecular Cell*.

Behind the basic research is a story that melds exquisite nanotechnology in living systems and cutting-edge biochemistry and molecular biology with a system of checks and balances.

"RNA synthesis is at the hub of human genetic control. It's important for understanding cancers, viral infections and normal human development," said Zachary Burton, MAES biochemistry and molecular biology scientist. "If you want to understand and control things such as viral infections and tumors, this fundamental process has to be understood in every detail. This is basic science, but it's basic science with practical application."

Burton and his team study how RNA is made from a DNA template. DNA is the genetic material that holds the blueprint for life. DNA dictates orders to RNA to make the proteins that give a cell its identity. Mistakes in RNA synthesis can lead to cancer or can support the life cycle of an invading virus. Researchers consider control of RNA synthesis to be a huge issue in human health. It is also the foundation of how living systems function.

In the world of molecular biology, much attention has been given to how RNA is made. Burton explained that it is similar to an industrial assembly line, with DNA being a conveyer belt to load building blocks, or bases, called nucleoside triphosphates (NTPs) to hook up with a growing strand of RNA.

Burton's insight was to discover that the NTP bases preload to the DNA template several steps before they are added to the growing RNA chain.

This idea contradicts the prevalent view of how RNA and NTP bases hook up. Preloading of NTPs hints at a previously unknown quality control station to maintain accuracy of RNA synthesis. If an NTP doesn't match up properly with DNA, the system stalls – and even backs up to correct the error.

"We're able to show how an error will be sensed and corrected," Burton said. "The quality control system checks NTP loading several ways. If it doesn't match the criteria, it gets booted out."

In addition to better understanding how errors are prevented, Burton's research team also learned ways that errors are corrected during rapid RNA synthesis. To learn about error correction, Burton's team stalled the DNA conveyer belt. They did this using a deadly mushroom toxin, alpha-amanitin.

Finding evidence of quality control gives some perspective to the elegance of cell creation. Burton said it does not mean mistakes never occur. The assembly line analogy holds up there. The human system has an acceptable level of error required to allow for the speed at which cells must reproduce.

"RNA polymerase is one of nature's great designs," Burton said. RNA polymerases are found in bacteria, yeast, plants and humans. The design has endured because of this fidelity mechanism for RNA synthesis. "This is a tried and true design, and our study explains why this is an enduring design."

Other co-authors of "Dynamic Error Correction and Regulation of Downstream Bubble Opening by Human RNA Polymerase II" are research associates Xue Gong and Chunfen Zhang, in Burton's lab, and Michael Feig, MSU assistant professor of biochemistry and chemistry.

MSU Receives $5.9 Million Kellogg Grant for Land Use Policy Research and Education

The W.K. Kellogg Foundation has announced a $5.9 million investment over three years in the Michigan State University Land Policy Program to support land use policy research, education and innovation to be done in partnership with Public Sector Consultants (PSC), a Lansing-based public policy research firm.

"This grant continues the foundation's commitment to increase awareness of important land use issues in Michigan through people and land programming," said Rick Foster, Kellogg Foundation vice president of Food System and Rural Development. The principal partner in implementing the grant will be the MSU Land Policy Program (LPP), directed by Soji Adelaja, John A. Hannah distinguished professor in land policy and MAES affiliated researcher.

The people and land (PAL) programming idea has received substantial credit for helping to change the Michigan landscape. The PAL approach focuses on educating citizens and policy-makers about land use issues, informing them of innovative policy tools and alternative options, and convening organizations to understand various perspectives and implement appropriate land use agendas.

Through PAL grant making, municipal leaders have gained easier access to valuable training and information to help them in making land use decisions. Cities have been given tools to establish standards showing that they are ready for redevelopment — helping them to

1984-85 **Jack Preiss, MAES biochemist, and his colleagues discovered that bacterial genes could increase a plant's rate of starch production.**

remove barriers to redevelopment while promoting collaboration between public and private sectors. As a result of dialogues facilitated by PAL, diverse partnerships have been established to help sustain Michigan's agriculture industry and rural character by promoting local farmland preservation programs and green infrastructure planning.

Bill Rustem, the president of Public Sector Consultants, who directed previous PAL work, will serve as co-director of the Phase III PAL work with Adelaja.

"PAL's accomplishments have been second to none in raising the awareness of land use issues in the state," Rustem said. "But much more needs to be done. MSU's Land Policy Program is positioned to take the lead in demonstrating how an engaged university and creative faculty members can support Michigan communities and government with research-based information as they work to make smarter land use decisions."

"PAL III funding will allow us to establish a sustainable land use change infrastructure that will compete nationally in attracting resources to implement effective land use solutions in Michigan," Adelaja said.

"We at Michigan State University are excited to have the generous support of the Kellogg Foundation to enhance our work with the people of Michigan to find innovative solutions to one of the most critical issues affecting both quality of life and economic competitiveness," said MSU President Lou Anna K. Simon. "In the spirit of a 21st century land-grant university, we will build on our partnership through PAL and will align our research and engagement priorities to bring new knowledge to bear on the important issues of land use and land use policy."

Land Policy Program goals under Phase III of PAL include delivering focused, timely and relevant research to land use stakeholders, engaging university faculty members to provide appropriate expertise to Michigan communities and governments, leveraging Michigan resources to attract competitive national funds and reshaping the university's Extension outreach activities to empower land use decision makers.

Cooperative Brings Nutritious Food Choices, Opportunities to Urban Community

An effort to refurbish a defunct farmers' market to help revitalize a neglected urban area is turning a roadblock into an opportunity.

A new cooperative, called Branches of the Vine Food Buyers Cooperative, is making fresh produce available to low-income residents in an east Detroit neighborhood who are without a nearby grocery store.

The farmers' market initiative was launched nearly three years ago by the Michigan Coalition of Black Farmers (MCBF) when the group approached Mike Score, Washtenaw County MSU Extension agricultural agent and MSU Product Center for Agriculture and Natural Resources innovation counselor, about creating a link between agriculture and urban consumers. The MCBF hoped to refurbish the Chene & Ferry Municipal Public Market — a fixture in the neighborhood for more than 40 years before it was converted into a recycling collection center that closed permanently in 1988 — into a market where the neighborhood's low-income residents could buy fresh produce and other horticultural products. Until recently, the community's only source for groceries within a 7-mile radius was a convenience store located near the market.

The MCBF, with help from Score and the MSU Product Center, reopened the new Chene-Ferry Farmers' Market last September. Under the original plan, Score and local groups would manage the market and the MCBF would act as the go-between with produce wholesalers. After about 13 weeks, however, organizers realized that they had underestimated the amount of time and money needed to make the facility suitable for delivering goods to the community.

The site may eventually be converted to a full-scale market, but Score estimated that it would cost nearly $2 million to bring the facility up to code and make it completely functional.

"There was no place to store produce that we didn't sell," Score added. "A second obstacle was that people from outside the neighborhood were uncomfortable coming to the area."

It was at this point that the MCBF initiated discussions with Branches of the Vine Food Buyers Cooperative, a local food organization managed by Peacemakers International Ministries.

Now area residents can place their grocery orders at the Peacemakers International Ministries on Chene Street from Monday through Thursday and pick them up on Friday. The cooperative, completely staffed by volunteers, buys its food in bulk from a wholesaler to fill the orders, which are sorted and packaged for each customer.

"Members of the community are very excited about the cooperative," Score said. "Some residents have even talked about starting urban gardening projects to help fill orders for the local community."

The cooperative will purchase wholesale as much produce and as many horticultural products as it can from farms in Washtenaw and Lenawee counties. Food that cannot be grown locally will be shipped in from farms in neighboring regions.

"The cooperative supports community agriculture," Score said. "The goal of this initiative is to provide local residents with access to wholesome, nutritious food for less than what it would cost them to purchase similar products at the grocery store."

The cooperative's organizers are willing to share their business plans with other community leaders so that the idea can be replicated in other neighborhoods. So far, several other Detroit communities and the southeastern Michigan cities of Ypsilanti and Adrian have received copies of the business plan.

"Besides providing fresh food, this program is also an opportunity to educate people about agriculture, health and nutrition, and enlighten them about all the jobs involved in agriculture — agricul-

1985 **Neogen Corporation, a Lansing biotechnology company, marketed a kit developed with biotechnology techniques by MAES scientist Jim Pestka to screen for aflatoxin B-1, a poison produced by a fungus that can contaminate spices, corn, small grains, cottonseed, peanuts and dairy products. The kit is used by grain elevator operators and dairy product distributors to detect aflatoxin before it gets to consumers.**

ture is not just about the food delivery system, it has a role in many jobs and careers," said Ralph King, executive director of the MCBF. "If this program is successful, I think it could lead to a renaissance in the area."

The Chene-Ferry Farmers' Market project and urban revitalization efforts have been supported by a number of programs, including Project GREEEN, the MCBF, MSU Extension, the MSU Product Center for Agriculture and Natural Resources, the MSU Land Policy Program, the C. S. Mott Group for Sustainable Food Systems at MSU and Peacemakers International Ministries.

Michigan's Tourism Industry Projected to Rebound in 2005

After four consecutive difficult years, Michigan's tourism industry will experience modest growth this year, if a forecast presented at the Michigan Tourism Outlook and Legislative Conference proves to be correct.

A research team headed by Don Holecek, MAES scientist and director of Michigan State University's Tourism Resource Center, projects that the number of Michigan travelers in 2005 will increase by 2 to 3 percent over last year's numbers, and travelers' spending will increase by a similar amount. In preparing their forecast, the team reviewed trends in a multitude of factors known to influence travel activity in Michigan and surveyed industry leaders across the state.

The projected growth for Michigan's tourism industry is slightly below the average registered over the past 20 years and would not be enough to recoup losses registered since 9/11 and the subsequent economic recession.

Holecek noted that many of the economic variables that the research team considers are less favorable for industry growth than they were at this time last year. For example, rising interest rates and oil prices are combining to slow economic growth in the United States. The unemployment rate in Michigan remains the highest in the nation. So, if not the economy, then what forces do the MSU researchers believe will boost tourism in 2005?

"An aging population with more leisure time and disposable income whose taste for travel is growing provides a base that is fueling long-term growth in demand for travel," Holecek said. "Weakening current economic conditions will only partially offset this overall long-term travel growth trend."

A Michigan vacation will remain a relative bargain in 2005 despite a projected increase in prices, other than for gasoline, of about 3 to 4 percent. The higher price of gasoline is not expected to significantly influence Michigan's overall tourism industry, largely because positive impacts, such as encouraging trips of shorter distance, will offset negative impacts, such as some reduction in total number of trips taken.

Even more important in the team's projection is the weather factor. Michigan's prime tourist attraction is its abundance of natural resources. These are most attractive when weather conditions are favorable for outdoor recreation activities.

Unfavorable and abnormal weather conditions persisted in late spring and across much of the summer travel season in Michigan last year. This depressed performance of the industry in 2004. A return to more normal weather conditions, assumed in MSU's forecast, supports the conclusion that the tourism business will be better this year than last year, especially in areas of the state and among businesses that cater to outdoor enthusiasts.

Project GREEEN Garden Offers Fresh Food, Educational Opportunities for School Children

When Project GREEEN research funding was awarded to the Department of Horticulture to perform its winter baby leaf salad greens production research at the MSU Horticulture Teaching and Research Center four years ago, few would have imagined the ripple effect it would have on local elementary school students.

"Project GREEEN funding combined with sustainable agriculture research funding provided us with a means to experiment with growing salad greens year round in unheated greenhouses — and the results led to grants from the W.K. Kellogg Foundation and the USDA Higher Education Challenge Grant Program to start the MSU Student Organic Farm [SOF] and opened the door for a lot of other projects," said John Biernbaum, MAES researcher and SOF faculty coordinator. Among these other projects was an opportunity in 2003 to partner with Lansing's Gunnisonville School to expand its children's garden to include a greenhouse.

"With the original garden, we were able to harvest the salad greens only before summer break, and then by fall the frost would get everything," explained Laurie Thorp, MSU director of the Residential Initiative on the Study of the Environment, who has worked closely with Gunnisonville School over the past five years. "Now we are able to have multiple harvests in both the spring and fall — and the cafeteria has access to fresh, locally produced food that it can serve to students."

Biernbaum reported that last summer's completion of the greenhouse, funded by a North Central Sustainable Agriculture Research and Education (SARE) program grant, resulted in fresh salad ingredients for the entire 200-plus student body by the second week of December last year.

"Kids do eat vegetables if you offer them something with flavor," Biernbaum added. "Kids will eat spinach, radishes, carrots — all kinds of things — if they're fresh and have flavor."

In addition to offering more variety in the cafeteria, Thorp and graduate student Emily Reardon worked with teachers at Gunnisonville to develop creative lessons on horticulture and science that satisfy the state-mandated curriculum.

"The garden and unheated greenhouse provide a living classroom that makes learning more meaningful to students," she said. "The students take ownership of it, and it makes their learning more tangible."

1992 **Chris Sommerville, MAES researcher, used genetic engineering techniques to make a plant produce a biodegradable plastic in its tissue. Sommerville combined genes of *Alcaligenes eutrophus*, a bacterium that makes tiny amounts of natural plastics called biopolymers, with a gene of the mustard plant, *Arabidopsis thaliana*.**

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