

# futures

Michigan State University • AgBioResearch

SPRING/SUMMER 2013 • Volume 31, Nos. 1 & 2



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## PERENNIAL **POWERHOUSE:**

Plant research fuels new frontiers



## Gardening gene unfortunately skipped a generation



I must confess that I do not have a green thumb. I wish I did, but the trait has apparently skipped a generation. My mother is a fabulous gardener. There isn't a plant that doesn't thrive under her care. In her late 60s, she continues to enjoy countless hours deadheading flowers, concocting the perfect fertilizer cocktail and adding to her home's lush landscape. Her hydrangeas are simply out of this world, and the flowerbed at her mailbox has commanded knocks on the front door from strangers.

There was a time when I naively thought that I'd inherit my mother's gardening gene. In grade school, I recall easily growing all sorts of things from bean stalks from seed to saplings in paper cups for projects. I realize now that it had nothing to do with my genetic makeup and everything to do with my mother's help.

It finally dawned on me when my husband and I bought our first house the secret to a perfect garden is not approaching it as a chore. Instead it's about investing passion into your planting endeavors.

Michigan State University (MSU) is

certainly a mecca for green thumbs. The individuals featured in this issue of *Futures* are phenomenal plant scientists. They have devoted their lives to studying plants for various reasons — to help feed the world, in pursuit of a medicinal cure, to improve the environment. The one thing they share in common is a pure fascination with and passion for plants. These faculty members have all helped to make MSU a perennial powerhouse — a phrase typically reserved for sports, but in this particular case most definitely the plant world. The knowledge they generate and share with the world is nothing short of amazing.

When brainstorming themes for this magazine, I was surprised that we had not devoted an issue to plant research since spring 2005. These stories are long overdue. Much has happened since that last publication, including the beautiful construction of the new Plant, Soil and Microbial Sciences building (captured in the photo on the magazine cover).

I'd like to thank Michael Thomashow, director of the MSU Plant Research Lab, for inspiring the theme for this issue. During an interview last winter, he mentioned that the work of David Kramer and the Center for Advanced Algal Plant Phenotyping (see article on page 38) is a fine example of how MSU has become "an international destination point in plant research." Ultimately, Dr. Thomashow is responsible for planting the seed — pun intended! — in my mind that has truly grown into this very celebratory edition of *Futures*. There is absolutely no question that MSU, with its cutting-edge research and state-of-the-art plant facilities, is a leader in this field. And not surprisingly, MSU AgBioResearch

scientists are at the helm of many of these outstanding endeavors!

Although I don't have my mother's green thumb, I did inherit her love and appreciation for plants and their ability to add to the beauty of our surroundings, enhance our lives and generate economic prosperity for people here in Michigan and around the world. These tiny things are miraculous organisms — oftentimes objects of sheer beauty but also the primary source of food on our planet.

We've attempted to cover a lot of ground in this issue. Our aim was to shed light on a century of breakthrough achievements, share some modern-day discoveries and provide a glimpse of what lies on the horizon. We could not possibly cover everything that has happened or is happening at MSU in plant science, but we hope to give you a look at some of the examples under the MSU AgBioResearch umbrella. Let us know how we did!

I truly hope you enjoy the new look and feel of *Futures* magazine. Your feedback is always encouraged as we grow together. Feel free to contact me at [whetst11@anr.msu.edu](mailto:whetst11@anr.msu.edu). To learn more about AgBioResearch, be sure to find us on Facebook and follow us on Twitter at [@MSUAgBio](https://twitter.com/MSUAgBio).

Here's to a wonderful and prosperous growing season! 🌱

Holly Whetstone  
Editor



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Michigan State University  
**AgBioResearch** [AgBioResearch.msu.edu](http://AgBioResearch.msu.edu)



Futures is published twice per year by Michigan State University AgBioResearch. To receive Futures free of charge, write to: Futures Editor, 446 W. Circle Dr., 109 Agriculture Hall, MSU, East Lansing, MI 48824, email [info@AgBioResearch.com](mailto:info@AgBioResearch.com), or call (517)355-0123.

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**ON THE COVER:** New MSU Molecular Plant Sciences building at dusk.



# 'GREEN' with envy

Vast resources catapult MSU into an upper echelon of universities worldwide

**BY HOLLY WHETSTONE**

MSU AgBioResearch editor

By all accounts, the breadth and depth of plant science research at Michigan State University are enviable. The pioneer land-grant university has emerged in the past 50 years as one of the premier places worldwide to study plants, thanks in part to a host of researchers with diverse expertise and philosophies, and state-of-the-art facilities.

"I firmly believe we're in the top handful of plant science institutions in the world," said **Doug Buhler**, MSU AgBioResearch director and senior associate dean for research for the College of Agriculture and Natural Resources (CANR). "One of our strengths — and perhaps some of our uniqueness, particularly in the United States — is the breadth of our expertise, from very fundamental to quite applied research. It's something that I believe we're as good at, if not better, than anyone else."

Home to more than 200 plant scientists in areas from plant pathology to plant biotechnology, MSU has an impressive arsenal of knowledge that has played a critical role in improving plant production and food safety. It has also been instrumental in establishing other agricultural institutions in faraway places.

"Our outstanding plant science reputation is part of a much broader image we have

*Home to more than 200 plant scientists in areas from plant pathology to plant biotechnology, MSU has an impressive arsenal of knowledge that has played a critical role in improving plant production and food safety.*

worldwide because we've been in global international research for so long," said **Steve Pueppke**, former director of MSU AgBioResearch and now director of CANR Global and Strategic Initiatives. "Much of it started out in the development arena with MSU and other universities that look very similar to MSU going out and oftentimes helping to establish agricultural universities in developing parts of the world."

Many of the individuals instrumental in starting these institutes in other countries came to MSU to be trained and educated, many by AgBioResearch (then Michigan Agricultural Experiment Station) scientists. They eventually returned home to become faculty members at the new institutions. Pueppke, a Spartan alumnus who received his undergraduate degree in horticulture, said the university's reach is global.

"You can also go to Europe and Japan and very developed places such as Brazil, and you find faculty members or somebody else there who is doing a more basic plant science project, and very often the person they worked with was an MAES faculty member," said Pueppke, who is also MSU associate vice president for research and graduate studies. "That is a definite sign of our breadth. And those are some of the most fun conversations I get to have."

AgBioResearch is particularly instrumental because of its reach across seven colleges, two of which tie directly to plant studies — the CANR and the College of Natural Science.

"The broad reach of AgBioResearch gives us a mechanism to link researchers in collaborative ways to bring the latest tools of plant biology, genetics and bioinformatics to bear on real-world problems," Buhler said.

## **Project GREEN is model specimen**

Of all the plant collaborations taking shape at MSU, one program in particular has grown into a model specimen: Project GREEN (Generating Research and Extension to meet Economic and

Environmental Needs). Nearly 15 years after its beginning, Project GREEN has become a standard in effective partnership building. In fact, since taking his new post in January, CANR Dean Fred Poston has mentioned the desire and the need to establish more programs like Project GREEN.

A main reason for its success is the program's close relationship with the plant-based industry and the ability to respond rapidly to unexpected adversities. MSU's track record of offering solutions and assistance to growers and processors — sometimes as quickly as a day or two — is impressive.

"Responding to industry issues at a fairly rapid clip — a rate almost unheard of in our world — has really been a rallying point for a very diverse but very large and important industry here in Michigan," Buhler said. "Building the emergency fund and its flexibility into the model from day one was a very wise decision. We've worked hard and managed the budget such that we've always had a little money to respond to the urgent needs of the industry."

The solution could be hosting a grower meeting, providing insect traps or something more involved, such as pursuing federal grants for major issues.

Another key is that the endeavor goes both ways — the commodity partners invest time, effort and funding into the initiative. Annual meetings are held to review plans and gather feedback for future research priorities.

Word has spread about GREEN's success, resulting in the development of other programs. In fact, the Michigan Food and Agriculture Strategic Growth Initiative,

an outcome of the Governor's Summit on Production Agriculture in 2011, is being modeled after GREEN. Like GREEN, it will use a competitive grant process to fund research, education and technical assistance efforts.

Buhler said that Project GREEN will continue to be a valuable asset to leverage funding from beyond the university and respective industries to address long-term problems that pose significant threats.

"Project GREEN and our partnership with the industry set us up pretty well to give the researchers the opportunities to develop appropriate preliminary data, proof of concept data and things like that," he said. "We need to be able to set these researchers up to be very competitive, especially for federal grant programs."

Whether it's building relationships in state or helping feed people around the globe, Buhler is optimistic about the direction that MSU plant science is headed.

"Other universities might have more plant breeders or more this or more that, but there aren't many that have the philosophy and the history of groups working together that we have," he said. "I hope we're going to see a lot more of that in the future."

"We have a very strong international reputation, particularly in Africa. We have an opportunity to build on that and to bring more of our plant science expertise into the food security/food safety world that is really critical. I see a fuller integration of our plant sciences into our international portfolio. It's a great opportunity for us." 🌱



LEFT: Doug Buhler was named director of MSU AgBioResearch director in May. He also serves as senior associate dean of research for the College of Agriculture and Natural Resources. He previously was interim dean of the CANR and associate director of MSU AgBioResearch.

RIGHT: Steve Puepke served as director of MSU AgBioResearch from 2005-2013. He was named as director of global and strategic initiatives, a new position within the College of Agriculture and Natural Resources, in May.



## Project GREEN

Project GREEN (Generating Research and Extension to meet Economic and Environmental Needs) strives to develop innovative, integrated ways to address emerging and unexpected insect, disease, weather, regulatory and economic factors to benefit agriculture. The initiative fosters a strong partnership between MSU, the Michigan Department of Agriculture and Rural Development, and the state's plant commodity groups to work together to respond to grower needs and encourage integration and multidisciplinary programming in production management research, market research and value-added projects.

**Learn more about Project GREEN by visiting [green.msu.edu](http://green.msu.edu).**



# Deeply Rooted:

Beal study, legacy continues over 130 years later

**BY DOUG BUHLER**

Director of MSU AgBioResearch  
Senior Associate Dean of Research of CANR

William J. Beal started the Beal Botanical Garden on the MSU campus in 1873.

## Centuries-old seed experiment influences modern plant biology

**N**early 134 years ago, one of Michigan State University's (MSU) most influential botanists buried 20 glass pint bottles on a sandy knoll in a secret location on campus. Each was filled with moist sand and exactly 50 seeds from each of 21 common plant species.

With the intent of "learning something more" about seed viability, William James Beal accomplished this and more in 1879 when he began what is now the world's oldest continuing plant biology experiment.

Although well-known because of its mysterious pint glass excavations (now every 20 years) and extreme longevity, the Beal seed viability study is much more meaningful. It delves deeper than mere scientific curiosity — it serves as inspiration to countless researchers, including myself.

Long before I came to MSU, I studied how weedy plants responded to common agricultural practices. Much of my work involved seeds in the soil, an obvious connection to Beal and his novel approach to address a major challenge in agriculture.

For generations, farmers and gardeners have tried — almost always unsuccessfully — to eliminate weeds from their land. Further complicating the issue is the fact that new weed species often flourish as cultural and control practices evolve.

The basic understanding of these phenomena can be traced to Beal's recognition that seeds can lie dormant in the soil for extended periods of time, then suddenly spring to life under optimal conditions. Though longevity varied among species, this early finding prompted a multitude of valuable experiments and models that have shaped present-day thinking and management practices.

In a recent lecture, **Frank Telewski**, MSU professor of plant biology and curator of the MSU W.J. Beal Botanical Garden, noted one of Beal's most famous maxims: "Be a keen observer of the world around you." MSU continues to honor this charge by maintaining Beal's botanical garden, which he founded in 1873, as a "living laboratory."

Telewski speculated that Beal envisioned his work and its impact outliving him, and that he established the garden to facilitate collections-based research, teaching and outreach. Today Telewski works to ensure that those goals continue to be met.

As he explained, the W.J. Beal Botanical Garden forges people-plant connections. When visitors stroll through the garden, they are inspired to learn more about plants. Telewski, his staff and dedicated volunteers cater to that desire with interpretive labeling, beautiful displays, tours and educational programs.

Besides being a teaching tool, Beal's work is an example of MSU's impact as one of the first institutes to study agriculture. From the start, MSU has been fueled by researchers interested in understanding basic scientific principles that could be applied to real-world problems.

Since its founding as the Michigan Agricultural Experiment Station in 1888, MSU AgBioResearch has operated in the same vein. There are different challenges, technologies and techniques today, but, like Beal and the many MSU AgBioResearch scientists who have made significant research contributions over the years, we remain committed to using the best science to unearth the best solutions.

Beal was one of the first botanists to approach the problem of seed longevity in a scientific way. He innovatively explored challenging issues, contributing insights that continue to be referenced and celebrated to this day.

Undoubtedly, the work of Professor Beal will inspire plant scientists for years to come. And as leaders in food, natural resources and energy research, MSU AgBioResearch scientists will continue to do the same. 🌱

Douglas Buhler received his bachelor's degree from the University of Wisconsin-Platteville and his master's and doctoral degrees — both in agronomy — from the University of Nebraska. His research and outreach activities have focused on the responses of weed populations to various crop and soil management practices, and have been used to develop and implement improved weed management systems.



### Next seed excavation: 2020

*Although well-known because of its mysterious pint glass excavations (now every 20 years) and extreme longevity, the Beal seed viability study is much more meaningful. It delves deeper than mere scientific curiosity...*

# Modern-day MILESTONES grow out of multidisciplinary endeavors

**BY ROSEMARY KEANE**

MSU AgBioResearch communications assistant

**W**illiam J. Beal, one of the most influential plant researchers in MSU history, is often quoted as saying, “Merely learning the name of a plant or parts of a plant can no longer be palmed off as valuable training.” His desire to fully understand the plant world, coupled with a drive to constantly push research in new directions, continues to inspire the entire MSU plant science community today.

Contributions range from breeding better fruit and vegetable varieties to using plants for pharmaceuticals, and from studying how climate change will affect ecosystems to how plants respond to stress and attack by pests. Collaboration through interdisciplinary partnerships enables plant scientists to more fully address issues related to the economy, including crop production, processing, packaging and bioenergy.

MSU AgBioResearch scientist **James ‘Jim’ Kelly** has been at the forefront of MSU bean breeding for more than 30 years. The first of its kind in the country, MSU’s bean breeding program has released more than 52 dry bean cultivars in 11 commercial classes and participated in the release of 85 germplasm lines. Forty of those varieties have been developed by Kelly, university distinguished professor of plant, soil and microbial sciences, since he became the fourth breeder in the program in 1980.

Through projects such as the Common Bean Coordinated Agricultural Project (BeanCAP) and the Legume Innovation Laboratory, Kelly and other MSU researchers have played critical roles in USDA program research and



ABOVE: MSU university distinguished professor James ‘Jim’ Kelly has accomplished extensive work on bean breeding for more than three decades. His work has benefited people around the world, including this predominantly agricultural region of northern Rwanda.

## MSU Plant Science milestones timeline

**Editor’s Note:** This is just a sampling of the numerous contributions MSU plant scientists have achieved. It is not intended to be a complete listing.

**1855:**

The Agricultural College of the State of Michigan (now MSU) is founded

**1857:**

College Hall becomes the first U.S. venue for teaching scientific agriculture

**1862:**

MSU becomes the pioneer land-grant university after President Lincoln signs the Morrill Act



**1865:**

Agriculturist Manly Miles teaches the first U.S. course in scientific agriculture

**1873:**

Botanist William J. Beal begins Beal Botanical Garden with more than 5,000 species and varieties

President Obama's Feed the Future Initiative. BeanCAP, the result of a grant from the USDA National Institute of Food and Agriculture, involves 26 researchers from 16 U.S. institutions. The aim of the project is to enhance and contribute to existing genomic research tools for beans and other legumes. Expanding knowledge of bean genetics will allow researchers to breed for desired traits such as increased yield, drought tolerance and key nutritional characteristics.

The Legume Innovation Laboratory (LIL) at MSU (formerly the Dry Grains Pulse Collaborative Research Support Program, or Pulse CRSP) has also provided opportunities for collaboration. Recently, LIL researchers received a \$24.5 million grant from the U.S. Agency for International Development to continue their work from the Pulse CRSP. Through this effort, MSU has been a critical contributor to President Obama's Feed the Future Initiative, and international collaborations have led to advancements in agriculture and economic success in many countries, such as Rwanda and Ecuador.

"Our research strengthens the local legume breeding programs in these countries, and we've had impressive results," said Kelly on his LIL-related work in Ecuador on disease- and drought-tolerant bean varieties with increased resilience to climate change. "Being able to work on the bean crops in the laboratory and in the field with other researchers and growers is a unique advantage that MSU offers. What might work in Michigan might not work in other places, so you need to be going to these other areas and communicating with the growers. Being able to see your research out in farmers' fields, seeing the product you developed come forward as a new variety – you get a sense that you've really achieved something."

MSU AgBioResearch scientist **Amy Iezzoni** has also contributed to MSU's plant breeding legacy by using genetic and genomics knowledge to improve disease resistance in tart cherries. The most costly disease affecting the industry is cherry leaf spot, which attacks the tree and causes defoliation, thereby reducing fruit quality and overall tree health. The MSU professor of horticulture identified a chromosomal region in a wild small-fruited cherry species that exhibits resistance to cherry leaf spot. By breeding this species with the Montmorency variety (the major tart cherry variety in Michigan), Iezzoni successfully transferred the disease resistance through three generations in a quest to develop disease-resistant varieties with excellent fruit quality.

Since joining MSU in 1981, Iezzoni also helped establish RosBREED, a \$14.4 million project funded by a combination of federal and matching funds through the USDA NIFA Specialty Crops Research Initiative. This noteworthy international collaborative effort involves scientists in 10 U.S. states and eight foreign countries, and provides a framework to expand research in plant breeding, genetics and genomics in Rosaceae crops — apples, peaches, sweet and tart cherries, and strawberries — to improve crop characteristics.

"The incredibly valuable cultivars that researchers have been able to develop have all been through traditional breeding," said Iezzoni, RosBREED director. "Imagine the types of varieties we could develop if we were using the full range of genetic breeding tools we have available to us."

For Iezzoni, the collaborative nature of the research community has been essential in meeting this goal.

"MSU has such a strong group in plant science research; the collaborators have been there when I've needed them," she said. "I've been able to just go across the street and talk to someone about a project I am pursuing where they can contribute valuable expertise. That type of communication has been invaluable."

**George Sundin**, MSU AgBioResearch scientist and professor of plant pathology, is working on disease management from a different angle – targeting the pathogen rather than the plant. Fire blight is one of the foremost concerns for the apple industry in Michigan, the third largest producer in the nation. The contagious disease is particularly devastating because it has the potential to kill the tree and even an entire orchard.

*The most costly disease affecting the industry is cherry leaf spot, which attacks the tree and causes defoliation, thereby reducing fruit quality and overall tree health.*

Sundin, also an MSU Extension specialist, is working with Christopher Waters, assistant professor of microbiology and molecular genetics, to find ways to genetically manipulate the pathogen. Waters successfully identified a chemical compound called ABC-1 (anti-bacterial compound 1) that inhibits biofilm formation in the laboratory. Fire blight infects the fruit and trees primarily through this type of biofilm, and Sundin hopes that ABC-1 can be developed to treat the disease on trees before doing serious damage.

**(Continued on page 42.)**

#### 1888:

Liberty Hyde Bailey establishes the first horticulture laboratory in the U.S.



#### 1890:

Robert C. Kedzie imports sugar beets from Germany and distributes them to farmers, resulting in the birth of a new industry

#### 1915:

Plant breeder F.A. Spragg releases the first navy bean variety, Robust

#### 1928:

Plant scientist E.E. Down introduces hybridized barley (Spartan) to the Michigan grain industry

#### 1933:

Scientists develop flash pasteurization of apple juice, which becomes an industry standard



**(Timeline continues on page 45.)**

# Winning battles in the



## Practical plant applications give growers ammunition they need

**T**he past several decades have witnessed a series of attacks on the Michigan agriculture community. Some of the state's most important crops have struggled against a myriad of threats, from devastating diseases and insects to damaging drought. Motivated by the people and the industries that rely on these plants for sustenance, MSU AgBioResearch experts diligently arm growers with solutions they need to wage war against disease, weeds, insects and other threats.

The foundational tactics developed in the research laboratory lay the groundwork for the strategies and actions deployed in the field. In the trenches alongside growers, Michigan State University (MSU) AgBioResearch scientists wield their knowledge as weapons in a battle against relentless foes.

**BY NATASHA BERRYMAN**

MSU AgBioResearch writer

# the field

## Devising strategic attacks

Helping growers outsmart evolving, destructive plant pathogens is a critical mission of MSU AgBioResearch. One such pathogen is *Pseudoperonospora cubensis* (*Ps. cubensis*), a fungus-like microorganism that causes cucurbit downy mildew. The cucurbit family includes pumpkin, cucumber, squashes, melons and gourds.

“Downy mildew is the No. 1 disease problem threatening vegetable production worldwide,” explained **Brad Day**, MSU AgBioResearch molecular biologist. The disease — characterized by leaf lesions, rapid defoliation, low crop yield and poor fruit quality — was first reported in the United States in 2004. When the disease arrived, it did so with ferocity.

“My lab confirmed downy mildew in Michigan; over the course of the 10 days that followed, we watched it spread from one side of the state to the other,” said **Mary Hausbeck**, MSU AgBioResearch plant pathologist and Extension specialist. “In this lab, it was all hands on deck.”

Hausbeck, a professor of plant pathology, and Day, an associate professor of molecular plant pathology, collaborate to understand the disease and to develop effective management tactics by combining insights from genomics, plant pathology and epidemiology research.

“It’s an interesting marriage of sorts,” Day explained. “Hausbeck monitors real-time occurrence of the pathogen in the field under various environmental conditions, and my lab develops 21st century, genomics-based resources to understand the pathogen, its biology and the impact of the disease on the world.”

And Hausbeck works with growers to tackle yield-limiting stressors.

“A big thrust in my lab is to identify the issues that limit production for Michigan vegetable and greenhouse growers and

then to solve those problems through research,” she said. “Our findings shape the management strategies used in the field, and the feedback from growers and industry drives my research program.”

To unearth the best solutions for growers, Hausbeck and Day work in coordination with each other.

“When Hausbeck and I talk about strategies for managing the disease, her research is absolutely critical — she’s the front line — the infantry,” Day said. “The long-term solution is going to be some component of breeding for resistance. I’m not a plant breeder, but my genomic research is important in helping breeders understand the fundamental mechanisms underlying the problem.”

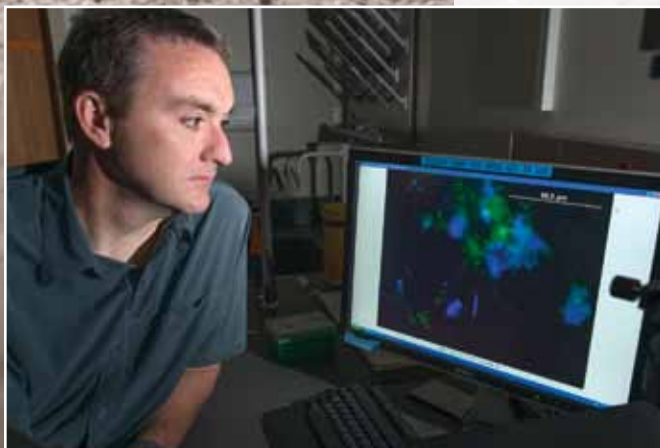
MSU has become a world leader in cucurbit downy mildew research, thanks to Hausbeck, Day and other MSU scientists. This has opened doors for collaboration with researchers from countries around the world, including China and Japan. In fact, MSU is set to host the international conference on Cucurbitaceae in 2014.

In addition to developing a draft genome sequence of *Ps. cubensis*, Day is also working to create advanced diagnostic tools that can be used in the field to better identify downy mildew and anticipate its pathogenicity.

“I’m working behind the scenes, developing a toolkit that ultimately supports outreach efforts,” Day said. “Every year, the target is moving; every year Hausbeck has to adapt very quickly to the virulence of the pathogen. If I can help her track the goalpost faster and with more precision, that’s where I want to be.”

“When you have a split appointment between research and extension like mine, it creates a continual loop between research and application,” Hausbeck added. “Now growers aren’t saying that downy mildew is going to force them into early retirement — that’s very different from what they were saying in 2005.

“For me, there is an emotional piece that’s tied to this research,” Hausbeck concluded. “There’s a level of trust that exists between myself and the industry. With that trust comes a great level of responsibility:



ABOVE: Brad Day, MSU AgBioResearch molecular biologist, conducts advanced genomics research to understand and combat *Ps. cubensis*, the pathogen that causes cucurbit downy mildew.



*“For me, there is an emotional piece that’s tied to this research. There’s a level of trust that exists between myself and the industry. With that trust comes a great level of responsibility...”*

— Mary Hausbeck

I feel charged with making their struggles manageable. Our work with downy mildew is a really good example of MSU responding to that demand.”

## Deploying the infantry

MSU AgBioResearch plant pathologist **Martin Chilvers** is also tackling diseases that threaten Michigan agriculture. The assistant professor of plant pathology and MSU Extension specialist works in close partnership with other scientists in the region, industry leaders and other Extension specialists to combat the spectrum of challenges that soybean growers face – from parasitic nematodes to crippling seedling diseases.

In 2010, Michigan growers saw unprecedented levels of soybean sudden death syndrome (SDS), a two-phase fungal disease that causes premature defoliation and root rot. The disease had not been identified as a significant issue in Michigan until 2009. Once it emerged, Chilvers worked to map and monitor the progression of outbreaks in the state. Unfortunately, he found that the disease



appeared to be moving north as it spread east and west.

“When the threat of disease isn’t present, breeders focus on increasing soybean yield – no one had been breeding for resistance to this pathogen. When it came into the state, thousands of acres were affected,” he explained. “Since we confirmed it in Michigan, we’ve worked with breeders to identify genes for resistance.”

Chilvers also developed a real-time diagnostic tool to help growers confirm the presence of SDS in their fields – an important tool because SDS is often misdiagnosed. This phenotyping instrument also enables Chilvers to ask foundational epidemiology questions critical to applied research and SDS management.

Equally important is the potential impact of the disease on another Michigan crop: dry beans.

“Most of the dry bean-producing areas are up in the Thumb region,” Chilvers noted. “With time, we will see more virulent SDS in that area – how will that affect dry beans?”

In collaboration with fellow MSU AgBioResearch dry bean breeder Jim Kelly, Chilvers has been monitoring the foliar and root symptoms of several dry bean varieties under SDS pressure in field and greenhouse trials.

“If we do find that SDS causes damage to dry beans, we have to work with the dry bean breeders now as a preemptive strike,” he stated. “We also need to begin developing management practices to use in

the field.”

“There is a continuum between fundamental research and applied research,” Chilvers concluded. “Some of the questions we ask are basic but have very direct, applied outcomes. It’s difficult to know what to do if you don’t know what you’re up against.”

## Engaging the enemy within

Major threats to crop yield and sustainability don’t always come in the form of microscopic organisms. **Christy Sprague**, MSU AgBioResearch weed scientist and MSU Extension specialist, works with growers to overcome the challenges that herbicide-resistant weeds pose to fellow plants.

“Glyphosate-resistant weeds, or weeds that are resistant to Roundup, are a huge concern because we are heavily dependent on that herbicide for weed management in many Michigan crops,” she explained.

Over the past decade, many producers have been planting varieties engineered to be unaffected by glyphosate treatments. These are commonly referred to as “Roundup-Ready crops.”

“With sugar beets, especially, there are very few herbicide options that are effective,” Sprague explained. “So when the switch occurred to breeding Roundup-Ready plants, it gave growers a very effective means of controlling weeds.”

Even though producers benefit from using Roundup as their primary herbicide, Sprague and others have intentionally



OPPOSITE PAGE LEFT: Mary Hausbeck, MSU AgBioResearch plant pathologist and MSU Extension specialist, partners with growers to effectively manage disease outbreaks in Michigan vegetable and floriculture crops.

OPPOSITE PAGE RIGHT: Christy Sprague, MSU AgBioResearch weed scientist and MSU Extension specialist, develops diversified management strategies as she helps Michigan growers contend with aggressive, herbicide-resistant weeds.

LEFT: Sieg Snapp, MSU AgBioResearch agronomist, develops multi-purpose cover crop systems for Michigan growers and Malawian growers who are concerned about yield and climate change.

developed and emphasized the use of diversified management strategies to avoid encouraging glyphosate resistance in weeds.

“Taking these measures helps, but unfortunately it hasn’t completely precluded us from having glyphosate-resistant weeds in Michigan – some of these weeds came into the state already resistant to key herbicides,” Sprague explained.

One such weed is Palmer amaranth, a type of pigweed that is both non-native to the state and characterized by resistance to multiple classes of herbicides.

“As I’ve talked about glyphosate-resistant weeds over the years, I used Palmer amaranth as an example – now growers are seeing it firsthand in their fields,” Sprague said. “My Extension work for the past several years has focused on communicating the urgency of the issue. Research in the area has focused on understanding how it got here, how it behaves biologically in a northern climate and how we can deplete its seed bank.”

Sprague collaborates with industry leaders and other MSU scientists to address a wide range of weed science challenges, from the effects of weeds on conventional and organic cropping systems to the effect of desiccation treatments on the color retention of black beans.

“The key is to look at questions growers have, find those answers and then communicate the findings,” she concluded. “The outreach component goes hand-in-hand with the research component – it’s extremely important that they do.”

## Fostering lasting change

Beyond overcoming the threat of pathogens and weeds, growers around the world must also respond to the long-term effects associated with monoculture farming systems. Reduced soil quality is of particular concern. **Sieg Snapp**, MSU AgBioResearch agronomist based at the W.K. Kellogg Biological Station, has devoted much of her career to exploring multipurpose cover crops as a means of contending with this concern.

“Cover crops improve agriculture by building soil resources,” Snapp explained. “Because of climate change, we have to pay particular attention to improving our soil organic matter and to protecting water and soil quality.”

Cover crops – which are planted to fix nitrogen in the soil and to prevent nutrient leaching and soil erosion – are also known as “accessory crops.”

Though many growers are aware of the benefits of incorporating cover crops into their farming portfolios, only some can afford to invest in them – it can take three to 10 years before a grower sees a return.

“Through my work with economists and social scientists, we’ve realized that we have to make sure there are immediate returns from cover crops in addition to the long-term benefits,” Snapp said.

This need shaped two of her primary projects. One has applications for Michigan; the other has applications for countries in Africa.

“One long-term project is to develop a

whole new type of crop for Michigan farmers: perennial wheat,” Snapp said.

Snapp is hopeful because perennial wheat can be sold in an already existing market, or growers can have livestock graze in the spring. In both cases, growers reap an immediate return and have the added benefit of gaining from its long-term impact: large root systems that improve soil organic matter, carbon sequestration and water quality.

*Though many growers are aware of the benefits of incorporating cover crops into their farming portfolios, only some can afford to invest in them...*

Her second project focuses on helping growers in Africa overcome nutrition and economic challenges by planting multipurpose cover crops.

“Because Africa’s climate is tropic, growers can incorporate pigeonpea into their cash crops; it’s a shrub that will grow for one to three years,” Snapp said. “After it’s harvested, growers can cut it back and use the vegetative material as fodder for livestock or to improve soil fertility; they can sell the peas for profit or use them as a protein-rich food for their families.”

Snapp said that more than 10,000 northern Malawian families have already benefited from incorporating pigeonpea into their farming systems. These families also benefit from Snapp’s second recommendation:



LEFT: Martin Chilvers, MSU AgBioResearch plant pathologist and MSU Extension specialist, uses an intricate multi-state network to help soybean growers battle a variety of diseases that compromise yield and production.

BELOW: An array of cups containing soybean seedling samples; the samples will be screened for the presence and pathogenicity of *Pythium*, a family of disease-causing oomycetes.



fertilizer and noted healthy weight gain by their children.

Cover crops have the potential to help growers respond to evolving climates and increasing populations, changes that countries all over the world are projected to experience.

“All of the models predict that Michigan will experience more intense rainfall events with more dry spells in between,” Snapp said. “The total amount of rainfall may remain consistent with past seasons, but when and how it’s distributed is changing. Having plants such as perennial wheat grow over a longer time period can help farmers cope because the crop is well-established and better equipped to survive dry spells.”

Snapp explained that growers in Africa are trying to meet the demands of a growing middle class while still meeting the nutritional demands of their own households.

“Some of the farmers I work with in Africa are on the edge of survival,” she concluded.

“By growing these types of multiple-use crop systems, they can survive and eventually begin to sell more legumes. This creates opportunities for them to invest in irrigation or their children’s school fees.”

Time and change encourage competition and the evolutionary struggles that accompany the fight to be the fittest. Although crop-covered plains may appear harmonious, history adequately notes the relentless battles waged in fields all over the world – it also describes the triumphant rallying of research-based brigades that have overcome challenges and laid a strong foundation for continued victory in the future.

Though they may be unable to anticipate every battle, when one does arise, MSU AgBioResearch scientists eagerly fight on the front lines, partnering with growers and using their expertise to advance the agriculture industry and the plants that fuel it. 🌱

*“There is a continuum between fundamental research and applied research. Some of the questions we ask are basic but have very direct, applied outcomes. It’s difficult to know what to do if you don’t know what you’re up against.”*

— Martin Chilvers

# BUILDING SUCCESS:

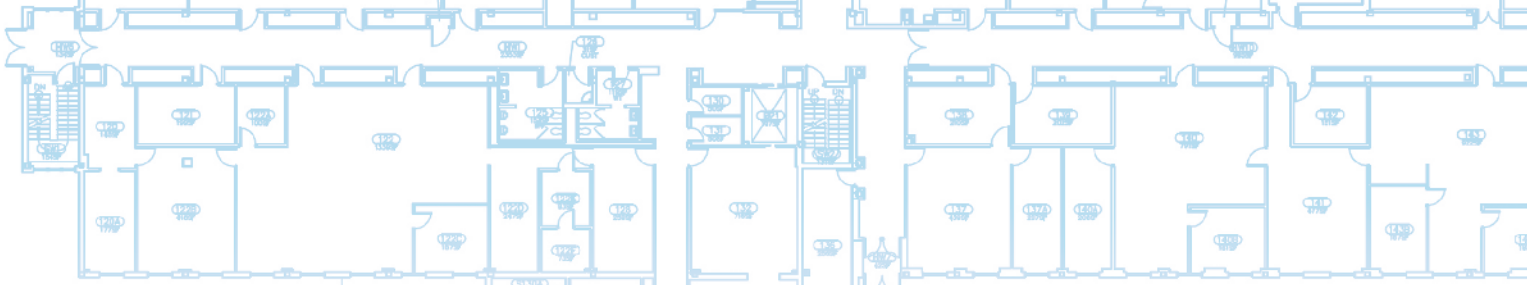
New structure unites plant researchers on campus

**T**he glass gleams and the stainless steel shines. Flower gardens and other plants adorn the entrances, and a year after its official opening, the Molecular Plant Sciences (MPS) building still smells new. However, it is all just window dressing for more symbolic changes in plant research at Michigan State University.

**BY JANE L. DEPRIEST**

MSU AgBioResearch contributing writer

The atrium in the new MSU Molecular Plant Science building serves as a gathering place for students and faculty, as well as a venue for meetings.



**James J. Kells**, professor and chair of the Department of Plant, Soil and Microbial Sciences, said that the new structure has helped unite two distinct groups of plant researchers on campus.

“Plant and Soil Sciences houses researchers involved in more applied aspects of plant research – that’s a strong component in dealing with plant-related agriculture,” he said. “Plant Biology has researchers with a more fundamental research focus. Now, the new MPS building physically connects the applied scientists and the fundamental scientists and helps to strongly position MSU to continue to be a national leader in plant research.”

**Richard Triemer**, professor and chair of the Department of Plant Biology, agrees that the building has helped strengthen the plant programs.

“MSU has been highly ranked nationally for its plant research,” he said. “With this new building and the emphasis on interdisciplinary research, we hope to move even higher in the national rankings.”

Although Plant Biology had been in close proximity to Plant and Soil Sciences, researchers had a tendency to stay in their own buildings. That isn’t the case anymore.

“Now with the new MPS connecting our buildings, I have seen Jim [Kells] more in the past 12 months than in the 10 years prior,” Triemer said. “It’s easy to walk between the buildings, no matter what the weather, and there are more opportunities to talk with faculty members.”

### Open labs encourage multidisciplinary research

The three buildings are home to more than 65 MSU AgBioResearch scientists. Researchers from the departments of Plant Biology; Plant, Soil and Microbial Sciences; Horticulture; and Biochemistry and Molecular Biology have moved into the new laboratory spaces on three floors of the building.


“The new lab spaces use a modern, open floor layout that is unlike lab space in our older buildings, where investigators had

individual labs,” Kells explained. “There are no walls or partitions in the new lab space. This is intended to encourage more interaction and collaboration among scientists who have different but complementary expertise and to facilitate interdisciplinary research.”

Each open lab accommodates up to five principal researchers and the technicians, graduate students and postdocs associated with their research programs. There are lab benches and space for individual equipment, but researchers also share commonly used equipment such as hoods and specialized instruments, as well as conference and lunch rooms.

Ultimately, the new building symbolizes the future of plant research.

“The really difficult problems in plant research are not going to be solved by one person,” Kells said. “They are going to be solved by interdisciplinary teams that are working together effectively on more complex scientific questions, and that’s where a building like this increases our



*The structure takes advantage of green technology — part of its roof is carpeted with sedum and herbaceous perennials and grasses.*



capacity to address these big problems.”

Funding sources have also changed in a similar way.

“If you look at the major funding sources in the United States today, the big grants are collaborative grants,” Triemer said.

“Though there is still a place for individual investigator grants, the big research questions will require collaborative efforts incorporating the expertise of many scientists from multiple universities. “

MSU AgBioResearch biochemist **Christoph Benning** was the first faculty member to move his lab from the Biochemistry Building, across the street, into the new building.

“I like the lab layout,” said Benning, a professor of biochemistry and molecular biology. “It’s designed for interaction with other researchers and with the students, technicians and postdocs who work in the lab. One example of this is that another professor [Eva Farre] and I are co-mentoring a graduate student who does work with both of us.”

## Expanding an essential tool of plant research

The MPS building also expanded the capacity for growth chambers, which are instrumental in plant research.

“MSU has a total of nearly 5,000 square feet of growth chamber space,” Kells said. “These growth chambers are spread across a number of buildings. The new building added to that capacity, and there is room to add more.”

Growth chambers, which resemble large refrigerators, provide controlled environmental conditions for plants.

“You can control temperature, light intensity, humidity and CO<sub>2</sub> levels,” Kells explained. “Researchers can create very controlled environmental conditions to study how plants respond to different environments. Greenhouses are great for doing some research, but we cannot control the temperature and light as well there because greenhouses are affected by the weather. Growth chambers are expensive,

*“Now, the new MPS building physically connects the applied scientists and the fundamental scientists and helps to strongly position MSU to continue to be a national leader in plant research.”*

— Jim Kells

FAR LEFT: Brad Rowe, professor of horticulture, inspects succulents planted on the green roof atop the new atrium.

CENTER: (From left) James J. Kells, chair of the department of plant, soil and microbial sciences, and Richard Triemer, chair of the department of plant biology, believe that the new building brings together applied and fundamental plant research. They are shown here on the walkway that connects the second floor of the Plant Biology building with the Molecular Plant Science building.

BELOW: The new auditorium serves as a lecture hall for various classes and an interactive facility for students to collaborate on projects.



but researchers can control precisely the conditions that they need.”

Triemer pointed out that environmental factors such as global warming and drought will affect Michigan's growing conditions and ultimately determine what plants can be grown successfully. Growth chambers can simulate varying conditions and can help predict how plants respond to environmental changes.

### New features attract students and faculty members

The new building has not only increased research capacity but also classroom capacity. The structure includes a teaching auditorium that can accommodate more than 200 students, and it has many modern technology features including full Wi-Fi access, multiple screens for viewing information, and plenty of electrical outlets for laptops and other electronic devices. It also serves as a learning center where students can work together.

The structure also takes advantage of green technology — part of its roof is carpeted with sedum and herbaceous perennials and grasses. MSU AgBioResearch horticulturist **Brad Rowe** was instrumental in getting the green roof installed. It reduces heat

energy transfer and can retain and slow stormwater runoff.

“When we started doing green roofs 13 years ago, no one really knew what a green roof was,” said Rowe, a horticulture professor. “You can plant almost any type of plant on a roof. However, the majority of the roofs, like the one on MPS, have a lot of succulents such as sedum, which can go for months without water.”

The atrium on the first floor was designed for student use but has become a place for poster sessions, receptions, and other types of meetings and gatherings.

“The atrium and the entire building are valuable tools for recruiting the best of the best, including undergraduate and graduate students and new faculty members,” Kells said. “They can see the state-of-the-art facilities and get a better understanding of the quality of plant research that MSU is doing.”

Kells and Triemer, along with other researchers, said they appreciate the priority that the university puts on plant science research.

“It's not just lip service,” Kells said. “The university made a huge investment in this building to support plant science, so it's very clear that MSU has set plant science as one of its key institutional priorities.” 🌱



ABOVE: The new Molecular Plant Science building is helping to renew and advance MSU's history of plant research.

BELOW: Spacious research laboratories provide room for up to five research groups on each of three floors. The open labs are intended to foster more interaction and collaboration among research groups with different but complementary expertise.





**Building:**

Molecular Plant Sciences

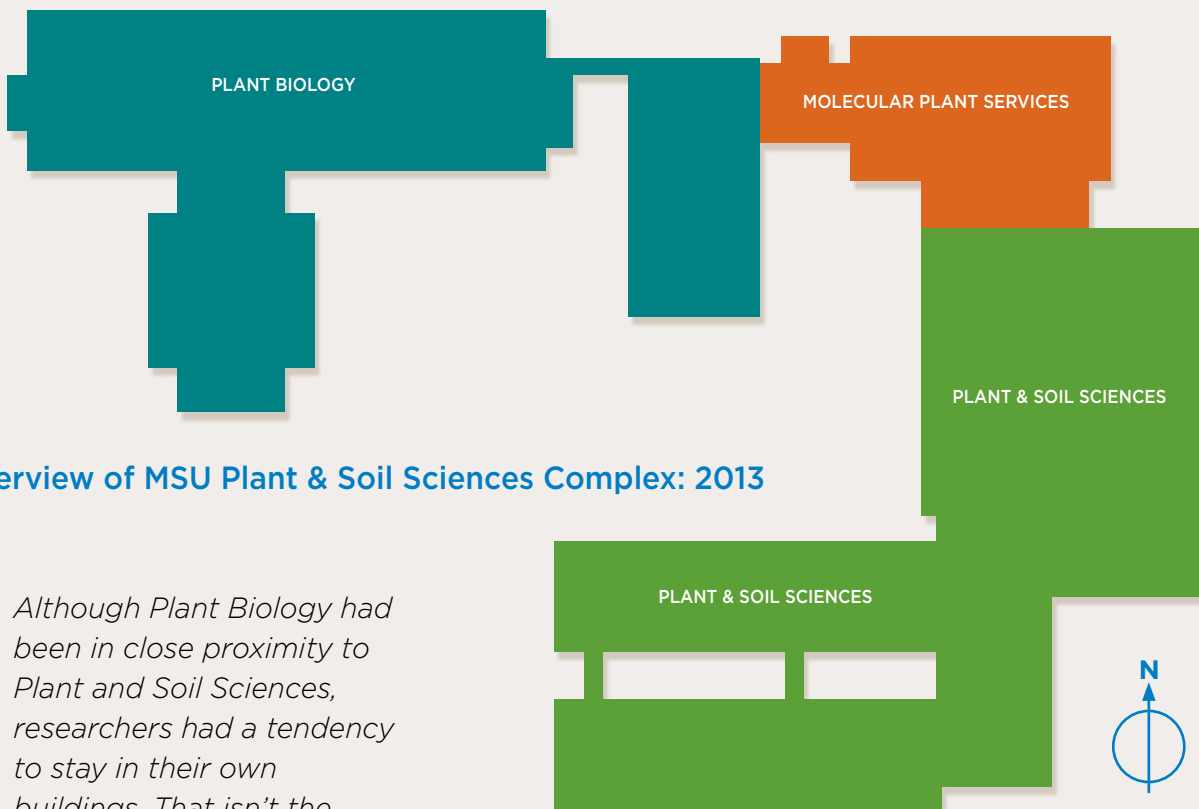
**Cost:** \$43 million

**Opened:** April 13, 2012

**Size:** 90,000 square feet  
(four floors)


**Special features:**

Joined two buildings (Plant Biology and Plant and Soil Sciences) into one large plant complex; three floors with open lab space able to support up to 15 research groups; expanded space for growth chambers; new auditorium and classroom space



**Overview of MSU Plant & Soil Sciences Complex: 2013**

▶ Although Plant Biology had been in close proximity to Plant and Soil Sciences, researchers had a tendency to stay in their own buildings. That isn't the case anymore.

A photograph of Sheng Yang He, a molecular biologist, in a greenhouse. He is wearing a blue and white striped button-down shirt and glasses. In the foreground, there are several black trays containing young green plants growing in soil. The background shows the structure of the greenhouse with translucent panels and metal frames.

Sheng Yang He, MSU AgBioResearch molecular biologist, is unearthing insights about how pathogens affect the photosynthetic efficiency of plants.

# THE GREEN HOUSE EFFECT

## Plant Research Lab fuels new frontiers

**B**y 2022, the United States must meet a cellulosic biofuel blending mark of 16 billion gallons — a staggering figure that is more than 1,000 times greater than the current mandate. The requirement, passed by Congress in 2007, is one example of the great pressure in the United States to improve the production of renewable fuels. In response, the U.S. Department of Energy (DOE) has committed to developing efficient solutions that leverage domestic energy supplies; their efforts rely heavily on scientific insight from pioneering researchers.

**BY NATASHA BERRYMAN**

MSU AgBioResearch writer

Michigan State University (MSU) AgBioResearch scientists from the MSU-DOE Plant Research Laboratory (PRL) are fueling the charge with insights into improving energy crop production and unraveling the intricate mechanisms by which plants — the root of all biofuels — capture, convert and deposit energy.

## Building a basis for biofuel

The PRL was established in 1965 as a joint venture between MSU and the DOE to increase basic knowledge of photosynthetic organisms and to train graduate and postdoctoral students.

“For many years, the PRL charge had been to conduct high-quality plant biology research with the idea that this fundamental knowledge would be important to energy research in the long term,” said MSU AgBioResearch molecular geneticist and PRL Director **Michael Thomashow**.

Researchers experienced great success as they worked to fulfill the primary mission. But the DOE recently approached the PRL and proposed a shift in focus. Because the researchers had been so successful in understanding plant biology processes, the DOE asked them to conduct more research on the complex processes of photosynthesis and growth.

“This is both a challenge and an exciting opportunity for the PRL to develop creative, forward-thinking research goals and programs that continue to capture the interest of the DOE,” Thomashow said.

As scientists strive to meet this challenge, the main objective — to address fundamental research questions in plant biology — still stands, but the work now includes several research programs that concentrate on understanding how biotic (e.g., pathogens and insects) and abiotic (e.g., drought and freezing) stressors affect photosynthetic efficiency and plant growth.

“Even though one might look at a basic question such as ‘How do plants survive freezing and drought?’ and wonder how it relates to energy, the fact that we rely on plant biomass to create biofuels makes it

clear,” Thomashow said. “If we can improve the ability of plants to withstand abiotic stresses such as freezing and drought — one area of my research — then this will lead to increases in biomass, a result that has direct applications in energy production.”

Past insights from PRL researchers who didn’t have this goal remain critical to meeting the DOE objectives.

“Ken Keegstra (MSU AgBioResearch plant biologist) was the PRL director for 13 years and directly preceded me; a major element of his research program was to understand how plants synthesized their cell walls,” Thomashow explained. “Much of the carbon on the planet is locked up in plant cell walls as energy-rich molecules. Keegstra and his colleagues wanted to get their hands on the key enzymes and genes responsible for building these molecules.”

Thomashow noted that Keegstra’s work was important not only because of its relevance to the energy research of the time but also because it helped MSU become a partner in the formation of the Great Lakes Bioenergy Research Center (GLBRC) (see page 34 for more about this facility), a joint University of Wisconsin/DOE-supported facility that was established to explore renewable bioenergy solutions.

“A chief component of the GLBRC’s focus areas is cell walls and modifying them — Keegstra’s work in that area has played an important role in that group’s success,” he explained.

## Unlocking plants’ full potential

**Federica Brandizzi**, a professor of plant biology and newly appointed MSU AgBioResearch plant biologist, is a PRL researcher whose work complements Keegstra’s. Brandizzi is using advanced fluorescent imaging technology to study the dynamics of secretory membrane traffic in plant cells — specifically, the Golgi apparatus and the endoplasmic reticulum.

“These two organelles are manufacturers of all the food that we eat — directly and indirectly,” Brandizzi, who is also a GLBRC investigator, explained. “For plants to



ABOVE: Equipment from the MSU-DOE Plant Research Lab, established in 1965 to further fundamental knowledge of photosynthetic organisms and to train students.

build the entire plant cell. If you don’t have the plant cell, then you don’t have plants and you definitely don’t have cows that eat plants. They’re equally important when we talk about biofuel.”

The walls of plant cells are mostly made of cellulose, hemicellulose and pectins, Brandizzi explained. Cellulose is produced at the cell plasma membrane by enzymes that are synthesized in the endoplasmic reticulum; they travel to the Golgi apparatus and then to the plasma membrane through the secretory pathway. Hemicellulose is synthesized in the Golgi apparatus and is eventually deposited in the cell wall.

“Understanding how cellulose and hemicellulose are synthesized holds a very strong promise for the production of sugars that can eventually be used to make biofuels,” she noted. “By understanding what enzymes make up the Golgi apparatus, you can understand more about the transport of cellulose machinery and hemicellulose machinery.

“We’ve also observed that plants that have a lot of the proteins responsible for making hemicellulose grow much bigger than those that do not have these proteins,” she continued. “Can you imagine the effect this kind of information could have when we’re breeding plants for biofuel production? If we can identify more and more of these genes that improve the yield of biomass, we can produce better energy crops in the future.”



Gregg Howe, MSU AgBioResearch biochemist and molecular biologist, is unraveling the complex process of carbon allocation in plants and the effect insect attacks have on it.

## Balancing the scales

The work of MSU AgBioResearch scientists **Gregg Howe** and **Sheng Yang He** also holds great promise for directing plant breeding.

“He and Howe are working closely together because they’re focusing on similar things,” Thomashow explained. “Howe works with insects; He works with pathogens. The idea is that, if you know more about basic plant mechanisms for defense against insects and pathogens, you’ll be better able to prevent loss and get more biomass.”

Howe, an MSU professor of biochemistry and molecular biology, has been using tomato and *Arabidopsis* plants as model systems to study plant-insect interactions and their effects on photosynthesis and plant growth.

“It turns out that tomato is very well-endowed in its ability to defend itself against insects and pests,” Howe explained. “It uses a few different defense strategies: ‘constitutive defense strategies,’ which are engaged at all times; and ‘inducible defense strategies,’ which are turned on when a plant is attacked but turn off when they’re no longer needed.”

His work in exploring plants’ ability to flip these responses on and off helped him better understand a defense hormone called “jasmonate,” which initiates the production of several defense compounds in intact plant tissue.

▶ *“We’re interested in knowing more about this allocation of carbon between growth and defense.”*

— Gregg Howe

Howe noted that many of the compounds that plants use to protect themselves are carbon-based and are ultimately derived from the carbon dioxide that plants naturally fix during photosynthesis. When plants make these carbon-based defense compounds, they’re diverting resources away from growth processes.

“We’re interested in knowing more about this allocation of carbon between growth and defense,” Howe stated. “It seems that there’s a tipping point that changes during the course of the day depending on the environmental inputs that plants gauge and respond to.

“There’s a fine balance,” he explained, “And we’re now learning that plant hormones such as jasmonate prioritize where carbon goes. The actual mechanism we don’t understand very well, but we think it’s important information to have to answer questions about photosynthesis and carbon fixation.”

## Safeguarding the green

He, a Howard Hughes Medical Institute and Gordon and Betty Moore Foundation investigator, is exploring pathogen-plant interactions and their effect on photosynthesis.

“Pathogens affect photosynthesis dramatically,” said the university distinguished professor of plant biology, microbiology and molecular genetics. “Exploring this has great potential to actually improve the photosynthetic capability of plants.”

He explained that plants do not experience maximum photosynthetic efficiency in nature because they must devote some energy to respond to threats, a few of which he has shed light on.

“One of the most important findings of my

lab was the needle-like syringe that some bacteria use to inject proteins into plant cells and cause disease,” He explained. “Ten years ago, we didn’t know what these proteins did once they were in the cell. Now we know that one of their primary functions is to suppress cells’ basal immune responses.”

Another interesting finding from He’s lab is that plant stomata — the tiny orifices in plant epidermis that are important for photosynthesis and through which water and gases are exchanged — do not passively allow pathogens to enter plants. His group found that stomata are actually one of the plant’s first lines of defense — when they recognize harmful bacteria, they close.

The insight He gained from these discoveries has important implications not only for general plant biology and human health — bacteria such as *E. coli* and *Salmonella* use the same syringe system to infect human cells — but for energy research.

“Many pathogen infections lead to chlorosis, which is caused by the degradation of chlorophyll in plants,” He said. “It’s a normal process of disease development that renders plants very low in photosynthetic capacity. By understanding how pathogens influence or disrupt chlorophyll production, and thus photosynthesis, we will learn a lot about normal photosynthesis regulation.

“The conditions in which photosynthesis occurs in a lab are often very different from the conditions that trigger it in the real world,” he said. “Take a look outside — there are constant changes in temperature, sunlight, precipitation, insect presence and pathogen presence. By understanding how plants respond to these varying conditions and how they affect photosynthesis, we can use the information to make plants more resilient so that even when they are under stress, they will not become chlorophyll-deficient.”

## Investing in the future

The PRL is going through a process of subtle reinvention — sticking closely to its founding purpose but shifting some

research to address a current challenge. Several new scientists with extensive research relevant to energy processes have been hired to help achieve this goal.

Thomashow explained that Brandizzi was one such hire; David Kramer, MSU AgBioResearch biochemist and Hannah distinguished professor (featured on page 38); Danny Ducat, assistant professor of biochemistry and molecular biology; and Cheryl Kerfeld, Hannah distinguished professor of structural biology, were also recently hired. Their knowledge in transformative instrumentation development, carbon dioxide fixation and structural biology will work to further the MSU-DOE Plant Research Laboratory’s position as an international leader in plant biology and energy research.

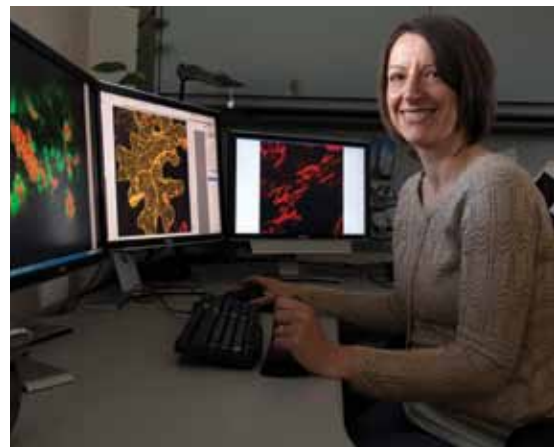
“It’s been a bit of a challenge for us to adjust our charge,” Thomashow concluded. “But we’ve been highly successful in our past endeavors as a department, and this is another opportunity for us to demonstrate that we can continue to contribute important, energy-relevant research.”

The general consensus among scientists and researchers is that there are so many puzzling questions and areas of interest to explore that choosing one is sometimes difficult. The MSU AgBioResearch scientists who work to advance the PRL have allowed their work and pursuit of knowledge to be guided by real-world problems in need of viable solutions. They have combined their interests and expertise to address these challenging questions and to play a key role in helping the United States produce clean, renewable energy. 📈

*For more about how MSU AgBioResearch scientists are collaborating to address the nation’s biofuel challenges, visit [AgBioResearch.msu.edu](http://AgBioResearch.msu.edu) and search “biofueling the future.”*



TOP: Michael Thomashow, MSU AgBioResearch molecular geneticist and director of the MSU-DOE Plant Research Laboratory, is guiding the PRL through a subtle shift in focus as he ensures that the department continues to meet its founding goals.



ABOVE: Federica Brandizzi, MSU AgBioResearch plant biologist, uses advanced imaging technology to elucidate the intricate dynamics of key organelles found in plant cell walls.

*“By understanding how plants respond to these varying conditions and how they affect photosynthesis, we can use the information to make plants more resilient so that even when they are under stress, they will not become chlorophyll-deficient.”*

— Sheng Yang He

A middle-aged man with glasses and a grey beard, identified as William Kirk, PhD, is smiling at the camera. He is wearing a light blue tweed jacket over a white button-down shirt and a blue and red plaid kilt with a large silver belt buckle and a black sporran. He is holding two small, round, golden-brown potatoes in his hands. He stands in a room with metal shelving units filled with large clear plastic bags of brown powder, likely coffee. In the background, white lab coats hang on a rack.

**William Kirk, PhD**

▶ **BEST VACATION:**

Puerto Rico to visit my son, his wife and their new baby.

## William "Willie" Kirk

**TITLE:** MSU associate professor of plant pathology

**EDUCATION:** Doctorate in potato crop physiology from Scottish Crop Research Institute in the United Kingdom

**AREA OF EXPERTISE:** Potatoes; potato late blight

**JOINED MSU:** 1995

**HOMETOWN:** Born and raised in the seaside town of Kirkcaldy, Scotland

**MUSE:** My wife, Rosalind — of course! [They've been married 37 years and have three grown children.]

**FAVORITE FOOD:** If I can't get authentic Scottish fare — which is very difficult to find in the U.S. — it's Indian food. But my first choice is Scottish haddock with fresh potatoes (of course!) and peas with mint.

**BOOK I'D RECOMMEND:** I'm an avid reader, particularly of crime fiction. Scottish authors Christopher Brookmyre and Ian Rankin are a couple of my all-time favorites.

**COOLEST GADGET:** Computer.

**BEST INVENTION:** Bicycle.

**WORST INVENTION:** Too many to mention, but the gun and bullets are a mixed blessing.

**ON MY BUCKET LIST:** The "Bike End-to-End" tour that spans Great Britain from Land's End to John o' Groats, an 874-mile trek that takes most cyclists 10 to 14 days to complete.

**PERSON(S) I'D LIKE TO MEET:** I'd like to say "hello again" to Gordon Brown — a former U.K. prime minister whom I knew as an adolescent. We were in Scouts together for 10 years, from ages 6 to 16.

**BEST VACATION:** Puerto Rico to visit my son, his wife and their new baby.

**ON A SATURDAY AFTERNOON, YOU'LL LIKELY FIND ME:** Walking my three dogs. They're great companions and they help keep me fit.

**MAJOR RESEARCH BREAKTHROUGH OF THE NEXT DECADE:** It's more of a change in perception rather than a scientific breakthrough. I hope that people eventually change their perception of food and energy and how they're produced. Agriculture is not a business that is evil. Instead, it's a way in which we can feed an increasing world population that is facing real issues with starvation. I'd like see an acceptance of mainstream agriculture — particularly the acceptance of new technologies in food and energy production. It's something I can't do myself, but I'd like to help enable these technologies to be used. Specifically, I'd like to see more done with disease- and drought-resistance. 🍌

*You might be surprised when you meet one of the more than 300 AgBioResearch scientists. Our world-renowned researchers (from the MSU colleges of Agriculture and Natural Resources; Communication Arts and Sciences; Engineering; Natural Science; Social Science; and Veterinary Medicine) are as likely to be sunburned or frostbitten as they are to be wearing lab coats and safety goggles. More often than not, their laboratory is the outside world where science rolls up its sleeves and gets to work with unpredictable, wonderful life.*

*Read more about Kirk and other MSU AgBioResearch scientists at [agbioresearch.msu.edu/spotlight](http://agbioresearch.msu.edu/spotlight).*





LEFT: As part of an MSU research team working on a grant from the Gates Foundation, Jim Hancock, a professor of horticulture known for his work in breeding blueberries and strawberries, helps African researchers understand and use plant biotechnology improvements to alleviate hunger and nutrition problems in their countries.

# THE RESEARCH PERSPECTIVE:

Plant technology advancements maximize productivity, opportunities

*Technological advancements in the plant world have transformed and revolutionized plant production over the past two decades. Plant biotechnology has increased the food supply to support a growing population in the face of shrinking land resources.*

Technology is a driving force in medicine, engineering and science. Most advances are accepted, even embraced, by consumers as part of 21st century life. Some examples are cellphones that expedite communication and new medical procedures that prolong life.

Technological advancements in the plant world have transformed and revolutionized plant production over the past two decades. Plant biotechnology has increased the food supply to support a growing population in the face of shrinking land resources. Technology also has helped to significantly reduce pesticide use. There have also been secondary effects, such as reduced tillage or plowing of the soil, and decreased microtoxin contamination and pesticide poisonings in developing countries. Researchers around the world also can quickly and efficiently find solutions to diverse production and postharvest problems using these advances in technology.

Some consumers have difficulty accepting these changes, however, especially when the technology is applied to plants grown for food. They're concerned that genetically engineered (GE) plants pose health risks. The U.S. Food and Drug Administration (FDA), health professionals and health organizations say that foods from genetically engineered crops are as safe as those from

traditionally bred plants. Researchers maintain that genetic engineering can contribute to higher quality foods grown in more ecologically sustainable ways.

## One 'tool' for plant researchers

In the United States, the FDA, the Environmental Protection Agency (EPA) and the U.S. Department of Agriculture (USDA) coordinate the regulation of foods and food ingredients produced through biotechnology to ensure the safety of the U.S. food supply. Because plants have been modified through breeding and selection for thousands of years, regulatory agencies use the term "genetically engineered" for plants modified using modern technology to distinguish them from those modified through traditional breeding.

The first genetically engineered microorganism was developed about 40 years ago. Soon afterward the technology to genetically engineer plants was developed. Food products made from GE microbial and plant sources have been in the food supply since the 1990s. Cotton, corn and soybeans are the most common GE crops in the U.S., according to the U.S. Department of Agriculture. Most of these plants are genetically engineered to ward off pests or to tolerate herbicides. There are also new varieties of several other foods, such as

**BY JANE L. DEPRIEST**

MSU AgBioResearch contributing writer



LEFT: MSU professor Dave Douches and his staff and students plant potatoes at the MSU AgBioResearch Lake City Research Center near Cadillac, Michigan.

squash and papayas, which are from plants engineered to resist plant diseases.

MSU AgBioResearch plant breeder **Jim Hancock** teaches a five-week course in fundamental plant breeding for horticulture and other plant science majors. He covers genetic engineering in the class and calls it “one tool in a plant researcher’s toolbox.”

“When students learn that genetic engineering is just another breeding technique, it takes away the mysticism,” Hancock said. “After I go through the regulatory structure and all of the testing that has to be presented to get approval of a genetically engineered crop, students are surprised at how much oversight there is. I believe consumers also may not understand what genetically engineered or modified crops are and the oversight that goes into them.”

### Difference in terminology

Professor of plant, soil and microbial sciences **David Douches**, who combines traditional breeding programs and biotechnology, has developed and released numerous potato varieties during his 25 years at MSU. Although there are no GE potatoes on the market, Douches believes it’s only a matter of time.

“Making crosses means pollinating a plant with pollen from an alternative parent,” the MSU AgBioResearch scientist explained. “That’s what conventional plant breeding is – crossing two individual plants that have complementary traits and then looking for progeny that best combine these traits.” There is a lot of uncertainty in this method,

however, and one cross seldom yields the desired result. Numerous crosses are typically required and can take up to 15 years to accomplish.

“Genetic engineering is inserting a specific gene with a known trait into a plant to get some type of effect from that gene,” Douches explained. “It could mean silencing the gene or expressing a novel protein or feature.”

Genetic engineering also expands opportunities to affect traits that might be difficult to change through traditional breeding and can speed up the breeding process. The technology used has changed over the years.

“It used to be that we were inserting genes from other plant species into plants we wanted to develop,” Douches said. “Now we are inserting genes from the same species. That’s reflected in the terms we use. ‘Genetic engineering’ used to be synonymous with ‘transgenic’, meaning that genes derived from another species were inserted into the plant. Now if you are taking a native gene from a potato variety and inserting it into another potato variety, we use the terms ‘intragenic’ and ‘cisgenic.’ Both mean that the genes are derived from the original plant species.”

Hancock, who specializes in breeding blueberry and strawberry varieties, is using other plant technology methods to further his breeding program.

“For the specific traits that I am most interested in improving, I don’t need to use the genetic modification technologies,” he said. “What I am involved in is molecular marker technology. I use this to find DNA

markers for specific genes from the same species I am working with.”

One example involves the development of strawberries that produce berries all summer long instead of just one crop in June.

“There are wild strawberry plants that carry the ever-bearing characteristic,” Hancock explained. “So, we can identify markers for specific genes in those wild strawberry varieties.”

Hancock then uses those markers to breed and make crosses to efficiently move the desired characteristics into strawberry plants for the commercial market. A new gene is not added to the plant.

“It’s the same technique that they use in forensics to figure out who done it,” Hancock said. “Instead of ‘who done it,’ we are interested in ‘who’s got it.’”

### Sequencing gives valuable options

**Rebecca Grumet**, a professor of horticulture who works with cucumbers and melons, also recognizes the monumental impact of plant technology.

“What we can do now versus 10 years ago is phenomenal,” said the MSU AgBioResearch scientist. “Technology now provides huge amounts of sequencing data that has had a tremendous impact. For example, we are able to sequence RNA, which are messages that indicate what genes are active at a given time. So, we have been able to use that information to understand what happens as a cucumber fruit grows and develops.”

Grumet is particularly interested in an age-related resistance to an important cucumber



disease, *Phytophthora capsici*.

“When the cucumber fruits are very young, they are highly susceptible to this disease,” she explained. “Then they go through a phase of very rapid growth and become resistant to the disease. We want to understand what kinds of changes in gene expression happen in that transition from susceptible to resistant.”

The other change that has come about because of technology is the ability to sequence whole genomes.

“About four years ago, the first cucumber genome sequence became available and additional ones since then,” Grumet said. We can use that information to pinpoint genes of interest. So, if we are looking for genes that have a specific trait – disease resistance, food quality or the capacity to develop the age-resistant characteristics – we can use the genomic information together with genetic analyses to begin to pinpoint which regions of the genome may be affecting the trait of interest.”

Trying to figure out why the *Phytophthora* pathogen is not able to infect the fruit at a certain stage could lead to clues to genetically engineer resistance.

“But another way is to find resistance genes in other cucumber genomes and do conventional crosses or use the information to design targeted chemical treatments, depending on what causes the resistance,” Grumet said.

Finding cures for plant disease is only one part of a researcher’s job.

“Farmers and processors are interested

in disease resistance, but they also want cucumbers that perform well in harvesting, processing and brining and have the taste consumers want,” Grumet said. “The final product has to have all of these traits.”

Grumet is also involved in programs that look at biosafety and risk assessment of plant technology, including research, teaching and outreach. She added that not only have government agencies approved the agricultural and environmental safety of GE crops, but numerous national and international organizations – including the National Academy of Sciences, the American Medical Association, the World Health Organization and Food and Agriculture Organization of the United Nations, and the European Food Safety Association – have examined the technology and do not consider it to have greater risks than those associated with conventional breeding.

### Developing countries have specific needs

MSU AgBioResearch horticulturist **Wayne Loesch** focuses his research on how plants respond to abiotic stresses – extremes of heat and cold, drought and salt. He sees biotechnology augmenting traditional methods in developing plants that can better withstand abiotic stresses.

“We look at various kinds of plants that are tolerant to these extremes and investigate what characteristics make them that way,” explained Loesch, a professor in the MSU Department of Horticulture. “We need to identify the genes involved, what metabolic pathways are used and what control

mechanisms are part of the stress tolerance response. Using modern biotechnology, we can more intelligently go after those genes and use them for crop improvement.”

He is working with MSU AgBioResearch bean breeder **James ‘Jim’ Kelly** on a project examining drought tolerance in beans.

*“The big point I make is that, by increasing crop productivity, we decrease the impact of agriculture on the environment. It takes less land to grow the same amount or more of a crop.”*

— Wayne Loesch

“This is critically important in developing countries where beans are the primary protein source in most people’s diets,” said Loesch, who visited Ecuador in May for the project. “Drought due to insufficient and unpredictable rainfall patterns is one of the major constraints to continuing or expanding bean production in some countries. Besides providing the main protein source, beans are an important source of iron and zinc, the lack of which causes nutritional problems in some parts of the world. So it is important that growers in these countries are able to grow sufficient supplies of beans.”

Loesch often makes presentations to farmers and consumers about biotechnology. “The big point I make is that, by increasing crop productivity, we decrease the impact of agriculture on the

OPPOSITE PAGE: Rebecca Grumet, a professor of horticulture who works with cucumbers and melons, has been pro-active in developing programs that examine biosafety and risk assessment of plant technology. She discusses biotechnology and biosafety with African university professors who came to MSU in May.

RIGHT: MSU horticulture professor Wayne Loescher (left) evaluates bean plants with Ph.D. horticulture student Jesse Traub.



environment,” he said. “It takes less land to grow the same amount or more of a crop.”

In addition, insect- and pathogen-resistant crops have significantly reduced the amounts of pesticides used to grow them.

“In some countries, the results of this are significant,” said Loescher, who pointed out that, unlike their counterparts in the United States, farm workers in other countries often sprayed pesticides without protective gear. “In China, for example, human pesticide poisonings have been reduced by about 75 percent since the introduction of insect-resistant cotton.”

## Ideas become plants

After the experimental breeding and testing is complete, the final step in bringing new plants to the commercial market is rapidly multiplying plant material to produce a large number of identical progeny plants. Much of that work is done through the MSU Plant Biotechnology Resource and Outreach Center (PBROC).

“Figuring out the technology to take a segment of stem or leaf and then produce many whole plants that have the new characteristics developed by researchers can be a bottleneck,” explained **Vance Baird**, director of the PBROC and professor and chair of the MSU Department of Horticulture. The center uses the plants designed by researchers and provides a large number of small plants called microshoots. It’s an important component in developing a new variety for the marketplace.

*(Continued on page 46.)*

## Second plant biotechnology symposium slated this October

To encourage training opportunities for graduate students in plant biotechnology, the MSU College of Natural Sciences will again host the Symposium on Plant Biotechnology for Health and Sustainability Oct. 25-26.

The conference, held for the first time last fall, is part of an interdisciplinary effort organized by MSU AgBioResearch scientists Christoph Benning (professor of biochemistry and molecular biology), Tim Whitehead (assistant professor of chemical engineering and materials science) and Gregg Howe (professor of biochemistry and molecular biology).

Topics of discussion include:

- ▶ Research on plant and algal metabolic pathways and its role in production of pharmaceuticals and biofuels.
- ▶ Enhancement of human nutrition.
- ▶ Sustainability of modern agriculture.

“With all the emerging technologies, particularly genomic technologies, we’re able to gain deep insights into what makes plants tick and what allows them to produce many of the interesting compounds that they do,” Howe said. “If we’re talking about the kinds of compounds that are made in plants and made nowhere else, we’re talking thousands, if not tens of thousands of novel natural products.”

Because scientists from both academia and industry attend, the symposium gives graduate students and postdoctoral students the opportunity to broaden their perspectives on how plant biotechnology can foster human well-being and resource sustainability. It also provides a venue for students to interact directly with plant scientists working in the industry.

This year’s event is being coordinated by **Robert Last**, MSU AgBioResearch scientist and professor of biochemistry and molecular biology, along with Whitehead, Benning and Howe. It is expected to become an annual university event.

“The networking opportunities afforded by the symposium are invaluable – they allow us to interact and collaborate with scientists from both academia and the industry,” Howe said. “The graduate students are being exposed to a variety of research ideas, and the scientists are getting to engage the next generation of plant biotechnologists in meaningful dialogue.”



Robert Last

Endeavor in  
medicinal therapy  
provides important  
data to the world

# Casting vital **LIGHT** on understudied plants

For centuries, people have used plants to treat medical conditions of all types. Now, a group of Michigan State University (MSU) AgBioResearch scientists has helped shed important light on a select group of medicinal plants that could improve pharmaceuticals, make them more readily available and reduce costs. Working with researchers from six other institutions across the nation, they have generated a massive dataset that is being mined by scientists around the globe.

**BY HOLLY WHETSTONE**

MSU AgBioResearch editor



MSU assistant professor of horticulture Cornelius Barry was responsible for supplying *Atropa belladonna*, also known as deadly nightshade, for the Medicinal Plant Consortium (MPC) experiments. The plant is used to make the drugs atropine and scopolamine, which have many medicinal uses including easing motion sickness and dilating pupils.

## Half-trillion base pairs of DNA captured

In 2009, four MSU AgBioResearch scientists joined colleagues from six other institutions to study how the genes of 14 plants contribute to the production of various medicinally important chemical compounds. The plants, prized for their therapeutic potential, were largely a mystery because little was known about how they produced the medicinal compounds and what genes were responsible.

The scientists embarked on an endeavor, funded by the National Institutes of Health (NIH), called the Medicinal Plant Consortium (MPC). The objective: develop a collection of public data that would aid in understanding how plants make chemicals — a process known as biosynthesis.

University distinguished professor of biochemistry and molecular biology **Dean DellaPenna**, MPC co-project coordinator, who coordinated the work at MSU, and his lab extracted the DNA from the plants. The project generated 500 billion base pairs of DNA, enough to stretch across nearly two football fields, in just over two years.

“The goal wasn’t to make new medicines or understand how pathways are made. Instead, we set out to develop a worldwide resource,” he said. “The information is not just for us, it’s in the public domain for everyone to use, much like the human genome sequence. The next phase will be to use that information to go in and understand how targeted medicinal compounds are made in plants.”

The resulting DNA sequence data is empowering endeavors to discover new drug candidates and increase the efficacy of existing ones.

“For a plant, a genome is the instruction diagram or the wiring diagram for things like knowing how to germinate from the seed, to photosynthesize and to reproduce, and knowing when that seed should germinate again,” said **C. Robin Buell**, MSU professor of plant biology. “By doing the sequence you obtain those instructions and try to figure out how they work together to make a plant.”

Eventually scientists will use biotechnology — the process of putting genes into a target plant — to alter the amount of the medicinal compounds produced by the plant. In some cases, it might even result in novel medications.

“The concept is this: if they actually knew the exact pathway and they had the genes to convert compound A to compound B to compound C, then they could move that out of the plant and into a different organism, like yeast, to have yeast produce it in a larger quantity,” Buell explained.

Researchers will also be able to look at variation in the genome to determine if it is associated with a specific trait, which allows for more targeted breeding.

“For example, right now, to make a potato cultivar that farmers would actually grow takes over 15 years,” she said. “But if you could identify regions of the genome that are important in your cultivar, you could speed up the process. Having a genome today isn’t going to change the farmer tomorrow, but you’re going to change the pipeline of development for new cultivars and new varieties.”

### A key starting point

Although several institutions were involved in the project, MSU plant scientists played leading roles.


MSU professor of biochemistry and molecular biology **A. Daniel Jones** conducted the chemical analysis of the plant tissue. Jones and his team detected thousands of chemical compounds known as specialized metabolites and attempted to connect them to their respective genes. A tool called a liquid chromatograph/time-of-flight mass spectrometer is used. The instrument first sorts the molecules by their solubility in water. As the compounds exit the separation, they receive a charge (either positive or negative) that allows them to be easily moved. Heavier molecules move more slowly than lighter molecules, and their speeds are measured to determine their molecular weights with exquisite accuracy. (Weight is one of the most defining features.) The amounts of each kind of molecule are also measured in the process.

“Most scientists have a streak of being a control freak in them,” Jones said. “For people who do chemical analysis, we literally like to make molecules jump through hoops for us because that’s how we find out what they are.”

The levels of approximately 10,000 compounds in the 14 species were measured.

“The curious part of this story is that we have no idea what the vast majority of the compounds are,” Jones said. “We can measure them and we can say here’s something we know about the molecule, but we don’t know its exact identity. We hope that just knowing that something is there — and not knowing what it is — will be enough impetus for other researchers to say, ‘Oh, this looks like something that may be relevant.’”

The information is without question a fundamental step in figuring out how the plants make the compounds. The next step is to identify the plant genes responsible for making these compounds.



*The scientists embarked on an endeavor, funded by the National Institutes of Health (NIH), called the Medicinal Plant Consortium (MPC). The objective: develop a collection of public data that would aid in understanding how plants make chemicals — a process known as biosynthesis.*

“Think of the information as a gigantic parts list for a car,” DellaPenna said. “It doesn’t tell you how to make it or tell you how to go fast, but at least you have the parts.”

Organizing the massive amount of data was the primary job of Buell. She and her lab technicians were responsible for the bioinformatics — developing methods for storing, retrieving, organizing and analyzing the massive amount of biological data.

“My lab did all of the bioinformatics to

figure out the transcripts these genes do in the cell,” she said. “Essentially, the transcripts are just a proxy for the gene. It’s too difficult to sequence the genome (because it’s so large), so we essentially cheated and just took the transcripts.”

High throughput transcriptome sequencing provides straightforward access to the genes in organisms with large genomes. It also facilitates identification of candidate genes pertinent to the pathway of interest by using bioinformatics techniques to search for traits such as protein databases.

## The unusual plant suspects

With production of new pharmaceuticals derived from chemical compounds dwindling over the past decade, scientists are increasingly turning to natural resources such as plants. MPC focused on a group of 14 medicinal plant species, many of which are actually poisonous.

“Mother Nature has already made all of these compounds – they’re actually not medicines, we use them as medicines – they’re made and retained in evolution because they have a beneficial impact for the plant,” DellaPenna said. “Most of them can be toxic, and that’s one of the reasons they’ve evolved and have been maintained in evolution — they keep the plants from being eaten. At the right levels, one person’s toxin is another person’s medicine.”

MSU assistant professor of horticulture **Cornelius Barry**, an MPC plant

collaborator, was responsible for supplying *Atropa belladonna*, also known as deadly nightshade, for project experiments. The plant, whose foliage and berries are extremely toxic, is used to make the drugs atropine and scopolamine, which have many uses in medicine, including easing motion sickness and dilating pupils.

“Although deadly nightshade and related species have been used for centuries for medicinal applications, the biosynthetic pathways for the bioactive medicinal compounds aren’t fully elucidated,” Barry said. “NIH selected the plants we worked on and, luckily for me, one of those was a member of the Solanaceae family, which is a plant family that I’m specifically interested in.”

Other plants studied range from foxglove (*Digitalis purpurea*), which gives the cardiac muscle stimulant digoxin, to periwinkle (*Catharanthus roseus*), which offers a source for the widely used chemotherapy drugs vincristine and vinblastine. Each of the plants on the list had already been in NIH clinical trials and shown potential for either producing anti-cancer drugs or affecting human health in some way.

Compounds extracted from Mexican yam (*Dioscorea mexicana*) are used to make progesterone, commonly used in birth control. The MPC project sequenced wild yam (*Dioscorea villosa*), which produces diosgenin, which is converted into estrogen. Some of the drugs are extremely expensive, costing hundreds of thousands of dollars

per gram, and are produced by only a few plants in very small quantities. For example, a purified kilogram of the drug from periwinkle, which can only be extracted from the plant leaves, costs \$20 million.

“One reason we want to understand how they’re made is to take those genes and put them into a cheaper, easier, more efficient system and to produce larger quantities at a lower cost to make the medicine more widely available to more people,” DellaPenna said.

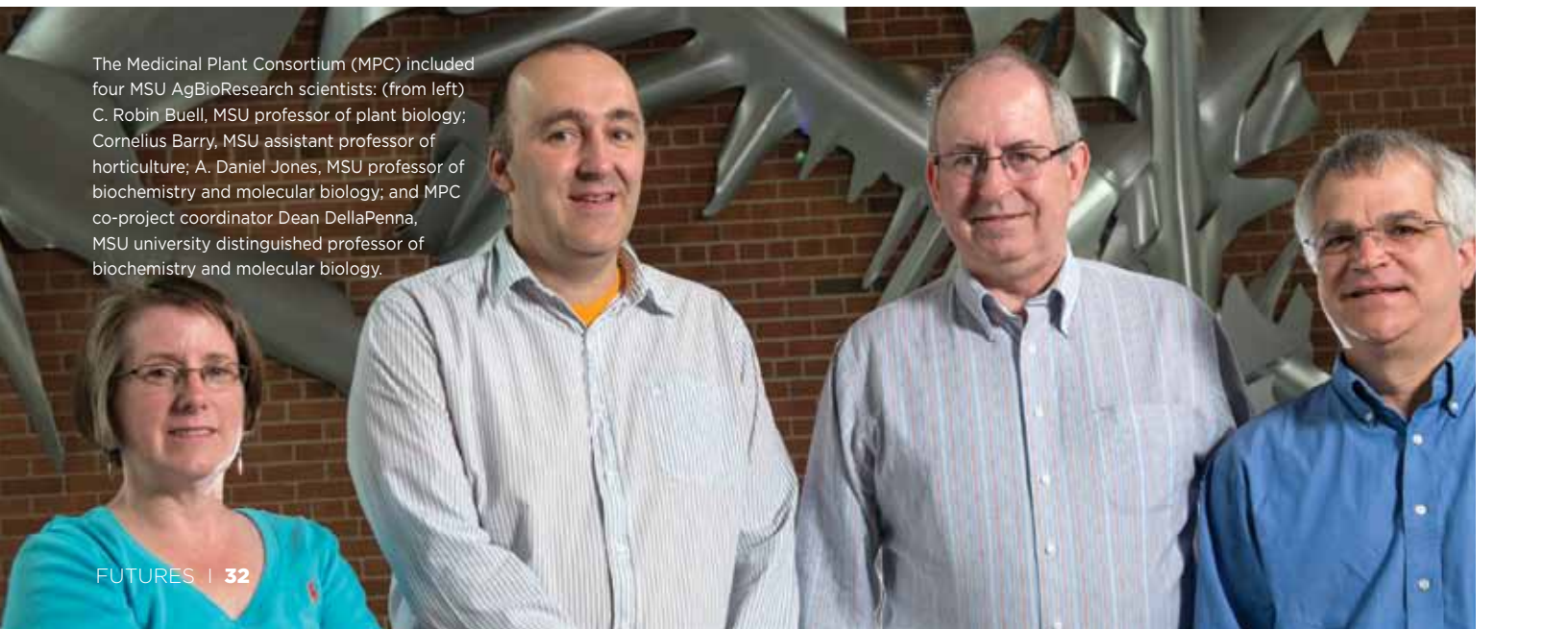
Jones knows from personal experience how expensive the drugs can be. Several years ago, his father was diagnosed with kidney cancer, and one medication costs \$10,000 per month.

“There is a need now to extend the diversity of the chemicals that are the basis for the next generation drugs,” Jones said. “There are many approaches one can take, but what we’re trying to do is to use what nature has already provided as a starting point.”

## Sprint to the finish

Many scientists and plant biologists around the world are analyzing the MPC database online. Like many other plant biologists, Barry has already made some discoveries.

“From my point of view, MPC was really successful because we have been able to mine the data and identify several new genes in the biosynthetic pathway for the medicinal compounds of deadly



The Medicinal Plant Consortium (MPC) included four MSU AgBioResearch scientists: (from left) C. Robin Buell, MSU professor of plant biology; Cornelius Barry, MSU assistant professor of horticulture; A. Daniel Jones, MSU professor of biochemistry and molecular biology; and MPC co-project coordinator Dean DellaPenna, MSU university distinguished professor of biochemistry and molecular biology.

nightshade,” Barry said. “We’ve been very fortunate in that the tools [Buell] developed were very robust, and we’ve been able to make tremendous progress in identifying missing pieces of the puzzle.”

The researchers agree that it is only a matter of time before a major drug discovery.

“Now it becomes a question of who is more clever and smarter,” DellaPenna said. “We’re all starting out with the same information. What it really comes down to is experiments, experimental design and educated guesses – knowing from experience what may or may not be a likely candidate for the gene enzyme you’re looking for.”

The work of MPC has opened many new areas of research for people coming up through the scientific ranks. Groups in Canada are doing similar types of work, but their data are not publicly available, DellaPenna said.

“I think NIH and NSF believe that making data accessible is the way that you really spur on science in the United States or science in another country,” he added. “Ultimately, it benefits all of us. I think many believe now is a very good time to plow these fields that have never been plowed before scientifically, mainly because there are cost-effective ways of doing it now.”

MSU AgBioResearch scientists Jones, Buell and DellaPenna have already applied for a follow-up grant to focus on two plants (whose identity the researchers wanted to keep private until funding is announced) from the MPC project.

“Through the MPC project, we provided the groundwork for building the next generation of rationally designed or engineered or modified compounds for some of the biggest problems out there,” DellaPenna said. “I believe that down the road the main impact will be on the next wave of cancer drugs that come along. And the discoveries won’t come just from plant biochemists alone. They will be group efforts between chemists, animal researchers and animal model systems.” 🌱

## Medicinal Plant Consortium

## Partners:

University of Kentucky  
Michigan State University  
Purdue University  
University of Mississippi  
Texas A&M University  
Iowa State University  
Massachusetts Institute of Technology

## Lead PI:

Joe Chappell, University of Kentucky

**Plant species studied:** (Not pictured: *Camptotheca acuminata*, *Hoodia gordonii*)



*Atropa belladonna*



*Cannabis sativa*



*Catharanthus roseus*



*Digitalis purpurea*



*Dioscorea villosa*



*Echinacea purpurea*



*Ginkgo biloba*



*Hypericum perforatum*



*Panax quinquefolius*



*Rauwolfia serpentina*



*Rosmarinus officinalis*



*Valeriana officinalis*



*MSU AgBioResearch scientist Jonathan Walton mixes many cocktails in his lab, but they're not the kind you want to drink. A fungal biologist, he combines various fungal enzymes that are helpful in converting lignin in plants into free sugars.*

LEFT: Jonathan Walton, professor of plant biology, points out that finding adequate biofuels for the future spans many sectors of the economy and the research establishment and that the GLBRC brings people together to increase collaborations.

# Taking a 'field to fuel' approach

Great Lakes BioEnergy Research  
Center marks five years of success

**BY JANE L. DEPRIEST**

MSU AgBioResearch contributing writer

The United States needs alternatives to fossil fuels, and more than 400 researchers – faculty members, postdoctoral research associates, technicians and students – affiliated with the Great Lakes BioEnergy Research Center (GLBRC) are working to discover usable options.

**Kenneth Keegstra**, MSU AgBioResearch plant biologist and GLBRC scientific director, said there are two major issues with fossil fuels.

“First, they’re a finite resource,” he said. “We may not run out of them for 100 years, but we’re eventually going to. Secondly, it’s a one-way street of carbon from something that is in the ground to something that is in the air. Natural gas is better than oil; oil is better than tar sands, but they all boil down to taking carbon out of the ground, burning it and releasing CO<sub>2</sub> into the atmosphere. In my opinion, the evidence is overwhelming that this is causing climate problems.”

The GLBRC was formed in 2007 as a partnership between the University of Wisconsin-Madison and Michigan State University. It’s one of three national centers funded by the U.S. Department of Energy (DOE). (The DOE recently renewed \$125 million in funding for another five years.) Rather than focus on designing one biomass crop or a single conversion platform, GLBRC takes a holistic, field-to-fuel approach that evaluates the energy efficiency, sustainability and economic viability of several technologies.

“This approach allows farmers or fuel producers in various parts of the country to select the pieces of our technology that work best for their crops, climate or fuels,” said Keegstra, a university distinguished professor of plant biology and biochemistry and molecular biology.

The GLBRC is organized into four major research areas: plants, biomass processing, fuel synthesis and sustainable bioenergy practices. Each focuses on a critical step in the conversion of plant biomass to bioenergy.

“It is the only one of the three DOE-funded research centers that has sustainability as a major part of its portfolio, and we’ve had multiple successes in that area,” Keegstra said.

Two other areas where MSU researchers have contributed significantly over the past five years are producing oils in the vegetative parts of plants and modifying plant cell walls for use in the production of ethanol.

“Our two major goals for the next five years are overcoming the things that are preventing biofuels from being economical — sustainable production of crops with desirable biofuels characteristics and energy-efficient conversion of biomass into fuels and chemicals,” Keegstra said.

### A bottleneck moving forward

One of the major bottlenecks in using biomass for energy production is the difficulty of degrading the major constituents of plant cell walls. Most ethanol that is produced comes from corn starch, which is easily broken down to glucose and subsequently converted to ethanol.

“The polymers in plant cell walls are also made of sugars, but breaking them down is difficult; and one of the reasons is the polymer in plant cell walls called lignin,” Keegstra explained. “It blocks access to the sugar-containing polymers, thereby creating a bad feature called recalcitrance, which means it is difficult to break down the biomass to fermentable sugars.”

Lignin is essential to the plant and therefore difficult to extract.

“You can get sugars out of plants without breaking down the lignin, but that’s what makes it difficult. It would be much easier if you could get rid of the lignin first and then break down the sugars,” he said. “It will be a decade before the improved plants that we’re working on are ready, so any efforts to make cellulosic ethanol or cellulosic biofuels will have to deal with the lignin for now.”

### A search for enzymes in fungi

MSU AgBioResearch scientist **Jonathan Walton** mixes many cocktails in his lab, but they’re not the kind you want to drink. A

fungal biologist, he combines various fungal enzymes that are helpful in converting lignin in plants into free sugars.

“Enzymes extracted from fungi are specific, nondestructive and environmentally benign – using them is much different from using strong acids, which destroy valuable sugars and create waste problems,” said Walton, a professor of plant biology.

He improves mixtures of fungal enzymes using a process called “bioprospecting,” looking at hundreds, even thousands of fungi simultaneously to see if they have better enzymes.

“Just like real prospecting, you can look for a long time and not find anything. It takes hundreds of enzymes to break down a complex plant cell wall efficiently, so we’re not looking for a single enzyme,” Walton said. “We’re looking for new enzymes that are not in current mixtures.”

Much of the work is done by “mining” DNA sequences.

“If there is one thing that has had an impact on this work over the past few years, it is DNA sequencing becoming less expensive,” Walton explained. “We can sequence fungi that have moderately small genomes at a very rapid rate.”

BELOW: Kenneth Keegstra, university distinguished professor of plant biology and biochemistry and molecular biology, is scientific director of the Great Lakes Bioenergy Research Center (GLBRC).



The mixtures are created by using a liquid-handling robot that can precisely fill vials with various mixtures all day long without tiring. The robot designs various enzyme combinations, and researchers analyze which combinations work best in degrading cellulosic materials. This process is important in the development of an economically viable lignocellulosic ethanol industry that doesn't compete with crops used for food or livestock feed.

## New avenues to create biofuels

MSU AgBioResearch lipid biochemists **Christoph Benning** and **John Ohlrogge** were initially the “odd people out” at GLBRC because others were primarily focused on making ethanol from crop residues and cell walls. They wanted to synthesize oil in vegetative tissues for use as a biodiesel fuel or other products.

“Now our oil project is distinguishing the GLBRC from other bioenergy research centers,” said Benning, professor of biochemistry and molecular biology. “Because we showed proof of concept, vegetative oils were one of the examples that led to the refunding of the project. Ethanol is still the biggest biofuel out there, but the possibilities for using plant oils, especially for biodiesel products, are now an accepted part of the biofuels research.”

During the first five years of research, the work focused on demonstrating that a plant could be engineered to produce oil in leaves and stems. The researchers used the lab plant *Arabidopsis* – commonly used as a model to test concepts but not grown commercially.

Ohlrogge, a university distinguished professor of plant biology, has spent years studying oilseed crops to help create products for the chemical industry. In 2010, he and a research team isolated a gene from the seeds of the burning bush plant (*Euonymus alatus*) that they thought might be useful for new sources of oil to use in diesel engines.

To test the concept, an algal gene was inserted into *Arabidopsis* to boost oil levels in the leaf tissue. To confirm that the engineered plants contained oil, researchers

*“Because we showed proof of concept, vegetative oils were one of the examples that led to the refunding of the project. Ethanol is still the biggest biofuel out there, but the possibilities for using plant oils...are now an accepted part of the biofuels research.”*

— Christoph Benning

fed the plant leaves to caterpillars. Those fed the engineered plant leaves gained more weight than caterpillars fed regular leaves.

“It’s a proven concept that can now be used to boost a plant’s oil production for biofuel use, as well as improve the nutrition level of animal feed,” Benning said.

Meanwhile, Ohlrogge has been working with a plant called camelina, a member of the mustard family and a distant relative of canola. He inserted the same oil-producing gene from the burning bush plant into camelina and grew it in a greenhouse.

“Camelina grows well on dry, marginal lands, which means that it is not competing with land for food crops,” Ohlrogge said.

“We genetically engineered the plant so that the oil we get has a low melting point and low viscosity which is better for diesel engines. It won’t clog fuel lines, a problem with other biodiesel formulas.”

Now the researchers are excited to try the concept in the field. A 2-acre test crop of camelina was planted in May. The U.S. Department of Agriculture has reviewed and approved the use of the plant in a field trial. Researchers hope to get at least a hundred gallons of oil from the crop to test in diesel engines.

“We believe this oil will burn directly in an engine that uses No. 4 diesel fuel, which is the type of engine used in trains, ships, generators and power plants,” Ohlrogge said. “It is not the type used in a car or truck, but we’re moving in that direction.”

Meanwhile, Benning is looking at other crops that might produce oil.

“We’re putting some of the technology we developed into corn because it’s the most productive biofuel crop that we have at this point,” Benning explained.

If the research proves positive, the oil would come from the vegetative parts of the corn plant, not the kernels.

“I work on a variety of strategies and systems because I am not sure which one will work best and there are justifications for several systems because one thing will not be the cure-all,” Benning said.

## Putting high priority on sustainability

The sustainable bioenergy practices area includes researchers with diverse backgrounds – agronomists, entomologists, zoologists, ecologists, economists, foresters and microbial ecologists. They examine a number of sustainability issues including agronomics, or how the bioenergy crop fits into the agricultural scheme on the farm, as well as environmental, economic and biodiversity questions.

MSU AgBioResearch ecosystem scientist **G. Phillip Robertson** is the GLBRC leader for this area.

“We’ve had considerable success defining key pieces of the sustainability puzzle during the first five years, particularly with respect to climate mitigation, water use, biodiversity benefits and the economics of biofuel production,” said Robertson, a faculty member at the MSU W. K. Kellogg Biological Station and a university distinguished professor of plant, soil and microbial sciences. “All of these together help to provide a holistic picture of how we can design the best mix of biofuels for providing multiple environmental benefits.”

During the next five years, the research team expects to further refine sustainability issues.

“We especially want to explore how biofuel crops might be grown successfully on marginal lands – land not now used for food production,” Robertson said. “This would help to avoid the food-fuel debate and provide significant conservation benefits.”

MSU AgBioResearch agronomist **Kurt Thelen** has dealt with sustainability issues, but the GLBRC casts them in a different light.

“Sustainability questions have always been there, but with the GLBRC we are looking at them in a different context. We’re working with bioenergy crops instead of the conventional crops that we are used to,” said Thelen, a professor of plant, soil and microbial sciences, who works on bioenergy production systems.

One project is consolidated bioprocessing — analyzing the benefits of harvesting and processing the whole corn plant together as a cellulosic plus starch feedstock to make ethanol.

“By doing this, we realize some improvement in sustainability because you go through the field only once, and it might be a way to significantly reduce the corn acreage needed for making ethanol,” Thelen explained. “The current U.S. Renewable Fuel Standard mandates 36 billion gallons of ethanol by 2022 with 21 billion gallons coming from cellulosic feedstocks. This policy enables 15 billion gallons annually of ethanol production from corn grain. Our research shows that, by utilizing the whole corn plant instead of just the grain fraction, you’d reduce by 40 percent the corn acreage needed to get the 15 billion gallons. This approach could potentially free significant acreage for food production or other uses.”

Researchers in the sustainability area also work with scientists in other GLBRC areas to make sure that what they’re planning is sustainable.

“For example, one researcher was working with rutabaga, which might hold potential as an oil crop, but when you look at root crops in general from a sustainability viewpoint, it takes more energy to get a belowground plant harvested than an aboveground plant,” Thelen explained. “There are also fundamental issues with soil erosion and compaction. So from a sustainability viewpoint, root crops are at a disadvantage compared with perennial aboveground crops because of environmental issues.”

## Looking at progress

GLBRC accomplishments are not always



measured in major breakthroughs.

“Science is very incremental. Someone adds on and someone else adds on more, that’s the way progress is made,” Walton said. “For example, if a researcher has developed a new thermochemical pretreatment, perhaps I can come up with enzymes that will work well with that pretreatment. We end up 10 percent ahead of where we were.”

Despite advancements, the researchers realize transitioning to biofuels will be a long process.

“We’re going to need liquid transportation fuels of various kinds for as long as our society exists in its current form,” Keegstra said. “Biofuels are important because they are renewable and because they help alleviate CO<sub>2</sub> problems. However, they are not the only solution. I am a firm believer that we need to create wind, solar and hydroelectric energy, but we also need biofuels as part of the energy picture.” 📌

TOP: Kurt Thelen, professor of plant, soil and microbial sciences who works on sustainability issues with bioenergy crops, emphasizes that there is not going to be one bioenergy crop that grows well in Michigan’s diverse ecosystems.

CENTER: (From left) John Ohlrogge, university distinguished professor of plant biology, and Christoph Benning, professor of biochemistry and molecular biology, have worked to get a proof of concept that oil could be synthesized in vegetative tissues for use as a biodiesel fuel.

RIGHT: G. Phillip Robertson, university distinguished professor of plant, soil and microbial sciences and a faculty member at the MSU W. K. Kellogg Biological Station, is the GLBRC leader for the sustainability area, a key area in finding the best mix of biofuels with multiple environmental benefits.



# EXPLORING PHOTOSYNTHESIS at a feverish pace

**New tools help make plant process more robust and efficient**

**P**hotosynthesis — the process by which plants convert sunlight into energy — was first recognized as a vital process for life in the 19th century. Today, MSU Hannah distinguished professor of biochemistry and molecular biology David Kramer is finding ways to increase the efficiency of photosynthesis by inventing new ways to view and access the process as it occurs in terrestrial plants and algae.

**BY HOLLY WHETSTONE**

MSU AgBioResearch editor

MSU Hannah distinguished professor of biochemistry and molecular biology David Kramer oversees the Center for Advanced Algal Plant Phenotyping (CAAPP). He and his team are focused on finding ways to increase the efficiency of photosynthesis in terrestrial plants and algae.

"There was a time when many people lost interest in photosynthesis," said the MSU AgBioResearch scientist **David Kramer**. "They thought it was already explained, but now photosynthesis is an essential component to any effort to improve food production as well as fuels for biological systems."

To supply food and fuel for the next century, Kramer said there is a need to increase the efficiency with which photosynthesis captures solar energy. It is also important to deal with the impact of climate change, he added, because photosynthesis is particularly sensitive to fluctuations in environmental conditions. Kramer is working not only to increase the efficiency of photosynthesis but to make it more robust.

Kramer began studying photosynthesis 20 years ago, then working on isolated bits of biochemical machinery. But to really understand how photosynthesis operates, he needed to see all the parts work together in living organisms. He realized that the techniques and equipment needed to do this were not available, so he started crafting the instrumentation himself.

"Some people may wonder, 'Why is a biophysicist building growth cabinets?'" Kramer said. "I respond by saying, it's the next logical step."

## Harnessing dangerous light energy


As he strives to understand the biophysical machinery of photosynthesis, Kramer is particularly fascinated by how plants supply the right amount of energy without self-destruction. It's a careful equation that teeters between life and death.

"Photosynthesis involves the highest energy intermediates of biology — it's dangerous," he said. "You know what happens when you take a house plant outside that's been in your room forever — it will die. That's because photosynthesis in plants like those you grow in your house cannot deal with high light; the reactions back up and they end up making toxic reactive oxygen."

Plants shed as much as 90 percent of

the energy that strikes them in full sun. Increasing photosynthetic efficiency even slightly, Kramer said, will pay off in terms of improved biofuel and food production.

"Photosynthesis is important because that's where all the energy comes from, but also because it has to be regulated by the plant," he said. "This regulation basically responds to the physiological and metabolic state of the organism. Also, because photosynthesis is responding to physiology, it can provide a useful monitor of the performance or health of the plant. It's almost like taking your temperature to see if you are sick."



*"To supply food and fuel for the next century there is a need to increase the efficiency with which photosynthesis captures solar energy. It is also important to deal with the impact of climate change because photosynthesis is particularly sensitive to fluctuations in environmental conditions."*

— David Kramer

## Lab plants differ from those in the field

Plants in the field have to deal with rapid and unpredictable changes in the environment. Light, temperature, humidity, water and pollutants can all change dramatically over short periods. But much of the scientific knowledge of plants comes from studies completed under artificially well-controlled laboratory conditions.

It turns out that plants need lots of mechanisms to deal with environmental fluctuations, and these are not necessary in the laboratory. Simply put, Kramer said, many factors have been missed — including identifying the genes required for efficient photosynthesis.

To uncover these genes and their functions, Kramer and his colleagues have

developed machines and techniques to probe photosynthesis under conditions found in nature.

"Photosynthesis is less efficient than it theoretically could be, but plants don't care," he said. "That's because they didn't evolve to make us biofuels — they evolved to survive."

## Making the move to MSU

Kramer came to MSU two and a half years ago after spending 15 years of his career at Washington State University (WSU). Michael Thomashow, director of the MSU Plant Research Laboratory, is impressed by the achievements of Kramer and his lab, the Center for Advanced Algal Plant Phenotyping (CAAPP).

"People could do some of the things [Kramer] has done on individual plants — you harvest the plant, take it and study it under this various instrumentation — but you've taken the plant out of its environment," Thomashow said. "But the CAAPP systems are transformative because they allow you to observe the plants as they're growing — you can change the environment to more closely mimic the environmental fluctuations found in nature."

Postdoctoral fellow Jeffrey Cruz has been working with Kramer for 15 years. Together, they have created hundreds of instruments, many from scratch; some of the prototypes repurposed parts from old instruments. With a Ph.D. in biochemistry, Cruz has had to also become knowledgeable in areas such as electronics, computer programming and computer-aided design, and mechanical engineering.

"We've ended up with a bunch of things that look like they're out of Frankenstein's lab," Cruz said. "The reason is that they don't have commercial instruments for the measurements we love to take, so we've made our own."

The first CAAPP invention to be commercially produced is called the Environmental Photo Bioreactor (EPBR). It sells for \$10,000 apiece. The machine simulates conditions of a production pond to study more than a dozen strains of algae

(for use as biofuel) at once.

“With the help of MSU, we started a company [Phenometrics] to do just that,” he said. “Now it’s commercialized and being used in more than 20 labs throughout the world, including Japan, Greece and Australia.”

Postdoctoral biochemistry student Ben Lucker, who has extensive experience with algae, began working with Kramer while they were both in Washington. Like Cruz and 10 others, he opted to follow Kramer to MSU. Together they’ve developed numerous EPBR prototypes.

“Through it all, one goal has held steady — to create tools to propel this research to the next level and change the playing field,” Lucker said. “I believe that it’s working.”

## It’s crunch time

When light shines on a plant, the organism not only absorbs the light through its chlorophyll but emits light energy in response. Scientists can measure the radiated energy and then calculate how much energy the plant is storing. CAAPP advancements are allowing researchers to measure thousands of plants at once and even capture the changes in rapid-fire digital images and video.

Long gone are the days of looking at two plants on a bench top, Kramer observed.

“We’re running out of time,” he said. “It’s what we call the hyperdimensional problem because you cannot solve today’s problems with a single instrument. You have to look at many plants under many different conditions, and measure many different things. With old equipment, the job would be endless. Every parameter you put in doubles the number of things you have to measure. The new approach allows us to do this, to measure photosynthesis in detail in high throughput.”

One of the most critical clues to unlocking photosynthetic efficiency lies within the plant cells. Researchers are trying to determine how specific genes control the plant functions, their behaviors or phenotypes. Currently, CAAPP has 18 multidisciplinary projects in the works, and

all of these are examining plant phenotypes in new ways.

One project is an extension of an earlier effort, the Chloroplast 2010 project, started by professor of biochemistry and molecular biology Robert Last. The study looked at mutant chloroplasts and their response to photosynthesis. The study found that only 2 percent of the genes had a reproducible phenotype; the rest had genes of unknown function (GoUFs).

“Our question was ‘Why don’t they have a function?’ Our idea is that these genes do have functions, but not under lab conditions — under real-life conditions. They are thus likely to be important for productivity and robustness of photosynthesis in the field, in the environment they have to cope with,” Kramer said.

So far, they have tested light variations that mimic field conditions and can now find 10 times more effects than typically seen under laboratory conditions.

“That means we’re on the right track,” he said. “These are not genes of no function, they’re genes of emerging function, and we are getting to know how they work.”

Another project involves professor of plant biology and MSU AgBioResearch scientist **Katherine Osteryoung**, who’s looking at mutant plant cells with odd-shaped chloroplasts that don’t divide properly. This project is using a Kramer device to take pictures and videos of the chloroplasts in an effort to discover gene function.

Kramer is also collaborating with professor of biochemistry and molecular biology Gregg Howe, university distinguished professor of plant biology Sheng Yang He and postdoctoral fellow Elham Attaran. They are examining how photosynthesis is influenced by insect attacks. These plants go into “defense mode” and divert energy from growth into defense by, among other things, making chemicals that deter pests from feeding. Plant defense takes away energy from growth and productivity. It also seems to affect photosynthesis; exactly how is the subject of the study. The group started out using conventional instrumentation, but moving the plants individually to the instrument took so much time that they missed important effects and,

even worse, stressed the plants and masked the effects they wanted to study.

“Now we build a system that measures all the plants all the time without stress, and we see all the effects,” Kramer said. “Using this instrument, the team has found new response effects of defense on photosynthesis. One of the responses has to do with how the plant controls the small pores on the leaves called stomata.”

Kramer is working with MSU molecular biologist Brad Day on a similar defense response project involving stomata regulation. Stomata must open to let in CO<sub>2</sub>, a vital part of photosynthesis. In response, the plant releases water, making it more susceptible to invasion from bacteria, viruses, fungi and even insects.

Crop plants are only about 1 percent efficient in photosynthesis so many researchers are focused on determining where all the energy is going. Kramer is exploring this concept with MSU Department of Biochemistry and Molecular Biology chairperson Tom Sharkey.

“Plants deliberately dissipate this energy because it’s toxic,” he said. “We’re asking, ‘Are there other steps downstream from the initial reactions of photosynthesis where the energy is lost?’ This technology lets us assess that by measuring photosynthesis continuously and adding it all up, integrating it and comparing it to growth.”

Multidisciplinary collaborations are a driving force of the CAAPP mission. As more and more researchers are looking at improving energy efficiency in plants, Kramer said a big push will be in practical application.

“There are lots of efforts now to improve plants and algae, particularly in yield,” he said. “Scientists are working feverishly. Basically, they’ll make variants using traditional breeding or genetic engineering or mutagenesis, and then they go to their greenhouse or growth cabinets and grow them. They’ll look for their performance.

“The problem is that if they’re not looking under the right conditions, they could be selecting for exactly the wrong things. This is very clear because the big companies do this. They see a variety that does great in the

greenhouse under controlled conditions, and when they put it in the field, it performs poorly. The question is — why does it perform poorly and how can we improve it.”

## Looking down the road

Because of the multidisciplinary possibilities at MSU, Kramer believes the university is primed to become an international destination for next-generation phenotype research. One obstacle, he says, could be insufficient data storage capacity.

“CAAPP is going to produce over 200 terabytes [one terabyte is equal to 1012 bytes] of data a year, maybe a lot more,” he said. “The estimate keeps increasing. We have to analyze all of that and make connections back to the genes, etc. This is the way it has to work, and we need to be there.

“That is why we have close collaborations with bioinformatics experts such as Jin Chen, assistant professor in the MSU-DOE Plant Research Laboratory, for a reliable data storage and management plan, and more importantly, for an efficient way to discover interesting patterns out of the big mass of data.”

Kramer has developed a new instrument that will make data collection in the field easier and more cost-effective, but it brings with it the added potential to compound the data storage problem.

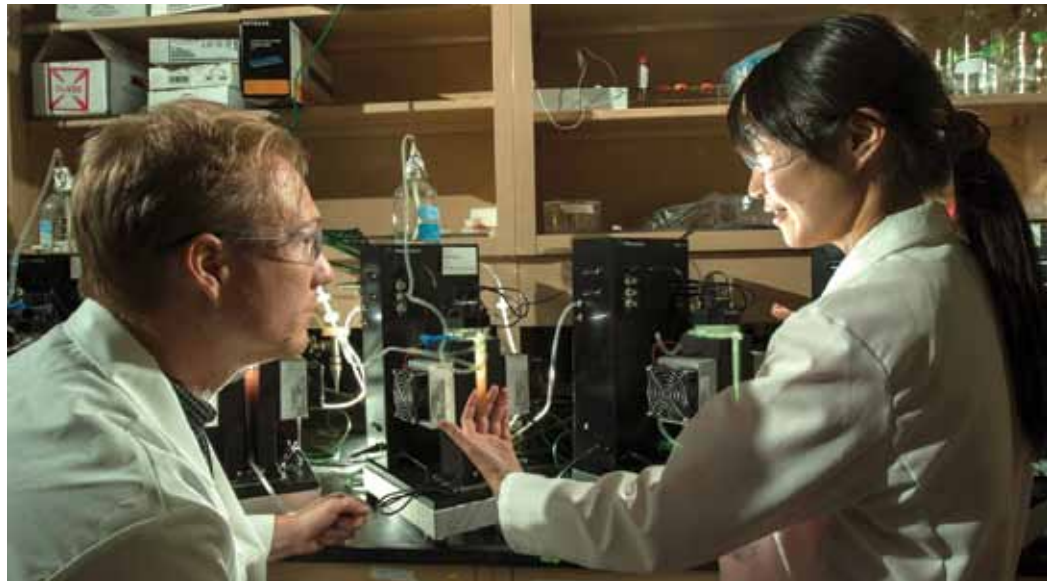
“Humans are very good at capturing data and applying new selection pressures — saying to the plant, ‘I will let you live because I’m going to kill everything else if you make lots of corn for me.’ We can manipulate these things and we have been for the past millennia.

“We’ve been engineering through breeding many, many crops. We haven’t specifically bred for the kinds of productivity we need for biofuels or that we need for the next stage in terms of yield. That’s the challenge of the next decades.” 🌱

RIGHT: MSU Hannah distinguished professor of biochemistry and molecular biology David Kramer oversees the Center for Advanced Algal Plant Phenotyping (CAAPP). Kramer began studying photosynthesis 20 years ago. He soon realized the equipment he needed wasn’t available so he began building it himself.

CENTER: Postdoctoral biochemistry student Ben Luckner and Kaori Kohzuma, a postdoc student previously with the Kramer lab, discuss an experiment using the first CAAPP invention commercially produced called the Environmental Photo Bioreactor (EPBR). The machine simulates conditions of a production pond to study more than a dozen strains of algae (for use as biofuel) at once.

BOTTOM: Some CAAPP instrumentation like this white light fluorescence imager prototype allows researchers to capture photosynthetic changes in plants through rapid-fire digital images and video.



**(Modern Day Milestones — continued from page 9.)**

“What attracted me to MSU was the opportunity to work both in the field and in the lab on a problem. MSU plant research has always been part Extension, part laboratory research, so we’re always thinking in terms of how we are going to solve disease problems,” Sundin explained. “We want the growers to be able to implement the best, safest, most practical and most economical solutions to those disease problems.”

The facilities and collaborations available at MSU have enabled this significant work to take shape and become something incredibly valuable to the apple industry.

“The facilities and my colleagues are world-class — that makes our work progress much faster, and it broadens the scope enormously,” said Sundin, who has collaborated with researchers in Spain and Germany on fire blight. “The quality of research we can do is better because we have access to these other tools and experts. Because we are MSU, we attract a lot of academic professionals that might not go somewhere else. That’s critical.”

Biofuels is another area of MSU plant research that exemplifies the university’s leadership. **Bruce Dale**, an MSU AgBioResearch scientist and university distinguished professor of chemical engineering and materials science, has developed a method to convert cellulosic biomass (plant material from non-food crops such as crop residues and grasses) into enhanced animal feed and sustainable biofuels. The patented process, known as AFEX™ (ammonia fiber expansion), which

involves subjecting the biomass to high temperatures and concentrated ammonia, opens up the plant cell walls to more easily release their sugars. The ammonia is recovered, and the complex plant structure is now much more easily used to produce biofuels and ruminant animal feeds. Dale is working closely with a Michigan-based “de-risking” company, MBI International, on the project.

“By taking the research and finding a way to make it commercial, we’re taking what has been done on a smaller laboratory scale and trying to make it useful on a much larger scale,” he said. “We are very fortunate to have MBI International as our partner in this effort. MBI has the necessary intellectual and physical resources to de-risk and commercialize laboratory processes such as AFEX and they have helped MSU enormously toward this goal.”

The Great Lakes Bioenergy Research Center (GLBRC) has also aided in this innovative project, allowing Dale and other MSU researchers to collaborate with faculty members at other institutions, such as the University of Wisconsin, to develop a better understanding of the physical-chemical effects of AFEX and how pretreated cell walls interact with enzymes and microbes to produce fuels. In the GLBRC effort, Dale notes that he has been fortunate to work with a number of talented graduate students and researchers from different backgrounds. In particular, professor Venkatesh Balan, a biochemist, has been at the forefront of the Dale lab’s efforts to understand the AFEX process while professor Seungdo Kim has

applied his expertise in life cycle assessment to understand how to design sustainable biofuel systems.

In examining how and where to plant these non-food crops, Dale consulted with MSU AgBioResearch scientist and MSU professor of entomology **Doug Landis**, as well as with other faculty. By intelligently placing the grasses and other types of crops in the landscape, Landis and Dale hope to enhance local biodiversity and other environmental services.

“We can get a more biodiverse landscape by planting more perennial grasses, and doing so would also improve water quality and sequester carbon,” he said. “The idea is to contribute to the sustainable design of biofuel systems.”

Dale said that working with faculty and staff at MSU has been a huge contributing factor to the success of his research.

“I’m always a bit overawed by the possibilities,” he said. “It’s the opportunity to work with no institutional barriers with people from all areas of expertise in widely different fields. It’s just a different way of thinking about and approaching complex problems.” 🌱

LOWER LEFT: Short course students gather in the greenhouse to learn about gardening in 1928. *Photo courtesy of Michigan State University Archives and Historical Collections.*

BELOW: MSU horticulture professor Amy Iezzoni’s research on cherry breeding has yielded a variety that is resistant to cherry leaf spot.





# MSU AgBioResearch Scientists FEATURED IN 2013 PRESIDENT'S REPORT

## SOWING A MORE SUSTAINABLE FUTURE

James 'Jim' Kelly  
Kigali, Rwanda



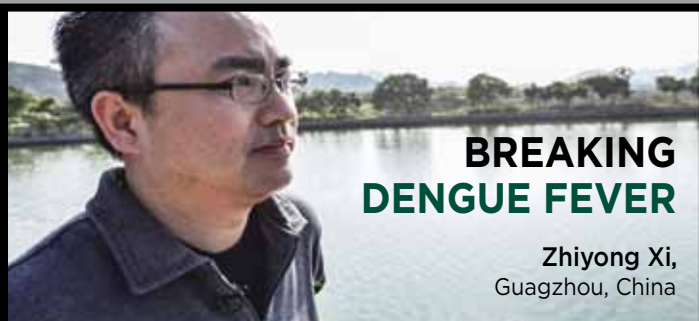
## PUTTING HARMFUL WASTE TO HEALTHY USE

Steve Safferman  
Dimondale, Mich.



## BREAKING DENGUE FEVER

Zhiyong Xi,  
Guangzhou, China



## PROTECTING PANDAS — AND THE PLANET

Jianguo "Jack" Liu  
Wolong, China



## NOURISHING PEOPLE AND THE ECONOMY

P.S. MohanKumar  
Lilongwe, Malawi



## CULTIVATING AN INDUSTRY— FROM VINE TO WINE

Paolo Sabbatini  
Traverse City, Mich.



**Lucky for us, Michigan is home to an unprecedented selection of agricultural goodness (2nd only to California). Be sure to support locally grown.**

- ▶ With more than 17,000 acres, Michigan leads the nation in high bush production
- ▶ Grown, harvested and processed by 600 family farms in the state
- ▶ Annually contribute more than \$118.5 million to Michigan's economy
- ▶ Allegan, Berrien, Muskegon, Ottawa and Van Buren counties are primary growing regions
- ▶ MSU AgBioResearch's Jim Hancock developed four blueberry varieties – Draper, Liberty, Aurora and Huron; Draper and Liberty are the most widely planted Northern highbush blueberry varieties in the world
- ▶ One of the only fruits native to North America but found on almost every continent
- ▶ One of the only naturally blue foods, although they don't start out that way: they first appear white, turn red and finally blue, making them the "all-American" berry
- ▶ The annual North American harvest, spread in a single layer, could cover a four-lane highway from Chicago to New York
- ▶ Approximately 30 species
- ▶ July is National Blueberry Month

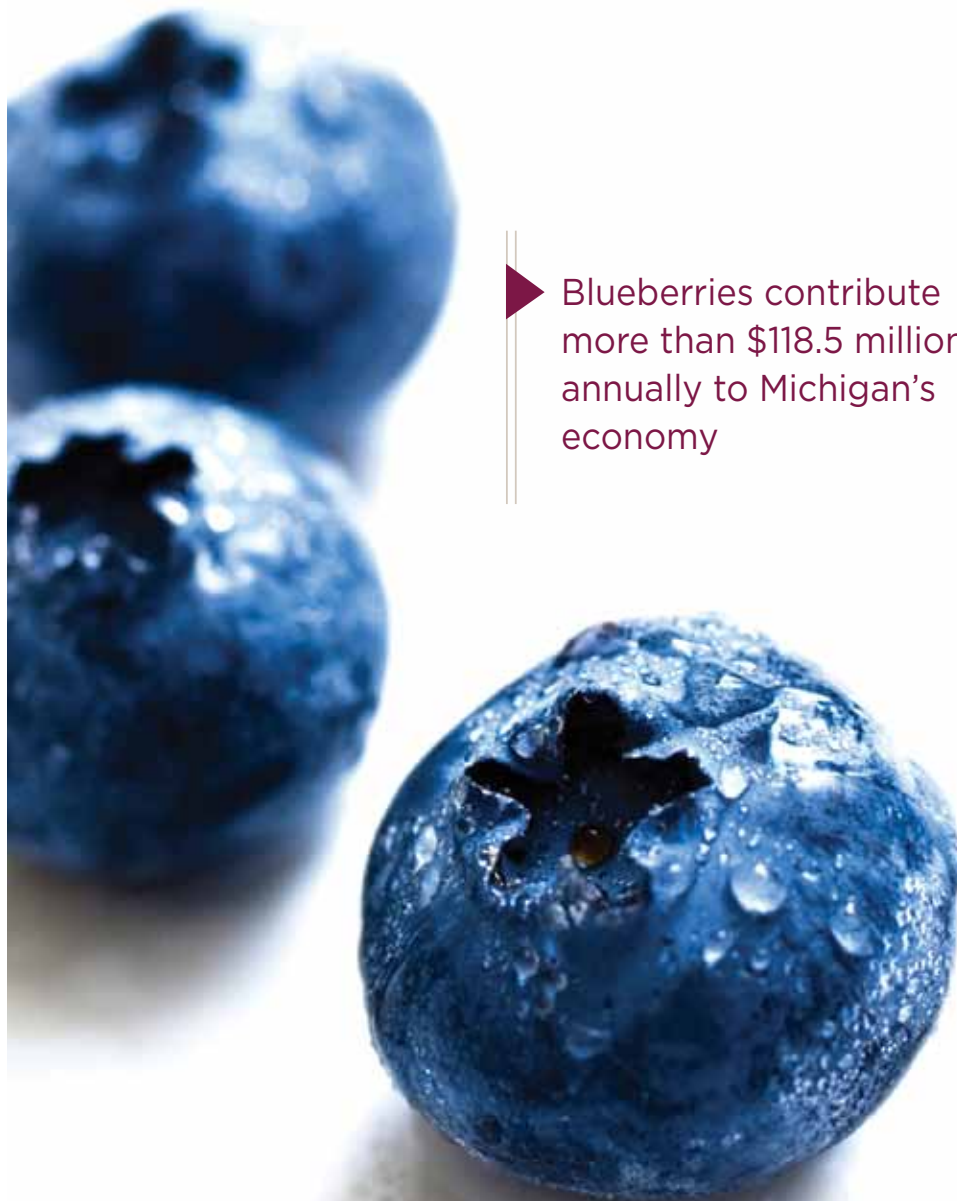
### HEALTH

- ▶ High in fiber and low in calories; a 1-cup serving contains 70 calories and 7 grams of dietary fiber
- ▶ Recognized as the fruit with the highest antioxidant activity

### PICKING AND PRESERVING

- ▶ Bluecrop, Bluejay and Jersey varieties are optimal for freezing and canning
- ▶ Do not wash before freezing when using dry or unsweetened types of packing
- ▶ Choose plump fruit that are dent-free and uniform in color
- ▶ Reddish berries are not quite ripe; they do not continue to ripen after harvesting
- ▶ Unwashed fruit should last in the refrigerator for five to seven days 🍷

# Blueberries



▶ Blueberries contribute more than \$118.5 million annually to Michigan's economy



## Old-fashioned Blueberry Pie



MSU professor of horticulture Jim Hancock

Jim Hancock, an MSU professor of horticulture, specializes in breeding blueberries and strawberries. He has developed four blueberry varieties, two of which are the most widely planted Northern highbush blueberry varieties in the world. His favorite blueberry treat is an old-fashioned blueberry pie. Although he doesn't do much cooking, Hancock has been known to make this recipe, which came from the North American Blueberry Council.



- 4 cups of fresh blueberries
- $\frac{3}{4}$  cup granulated sugar
- 3 tablespoons cornstarch
- 1 tablespoon lemon juice
- Pastry for 9-inch double-crust pie
- 1 tablespoon butter
- Half-and-half for top of pie, if desired

Rinse and drain blueberries; put in a large bowl. Combine sugar and cornstarch in a small bowl. Add sugar mixture and lemon juice to blueberries; toss gently to mix. Line 9-inch pie pan with pastry. Pour blueberry mixture into the pastry shell. Dot with butter. Cover blueberries with a pricked top crust or lattice top. Flute edges. Brush top lightly with half-and-half, if desired. Bake in a preheated 400-degree oven for 10 minutes; reduce heat to 350 degrees and continue baking 35 to 40 minutes or until filling bubbles and crust is golden brown. Yield: 8 servings.

### (Plant Sciences timeline continued from page 9.)

#### 1938:

Plant scientist E.E. Down releases the Michelite bean, dramatically increasing U.S. farm income

#### 1940:

Horticulturist Stanley Johnston (class of 1920) develops Redhaven peach, still one of the world's most widely grown varieties



#### 1942:

Plant pathologist Donald Cation first demonstrates virus transmission through soil while conducting fruit tree disease control research

#### 1947:

Horticulturist Roy E. Marshall develops apple juice clarifications that revolutionize the industry

#### 1958:

Forest geneticist Jonathan Wright develops a provenance testing system used worldwide in tree improvement and breeding

#### 1958:

Horticulturists Shigemi Honma and O. Heeckt hybridize snap and lima beans, transferring the early germination and early maturity from the snap bean to the lima bean

#### 1967:

Horticulturist Stanley Johnston created hybrids of the highbush blueberry and the lowbush blueberry to create the Northland and Bluehaven varieties



#### 1972:

Horticulturist Shigema Honma releases Snowball self-blanching cauliflower, eliminating the need to tie leaves over the developing head to prevent greening

#### 1974:

Bean breeder Wayne Adams and USDA-ARS plant pathologist Fred Saettler release Montcalm, the first halo blight-resistant kidney bean, credited with revitalizing the industry

#### 1976:

Silviculturist James Hanover releases the red, white and blue tri-hybrid spruce tree for America's bicentennial



#### 1979:

MSU wheat researchers increase wheat yields by 50 percent with the introduction of two white winter wheat varieties — Frankenmuth and Augusta

#### 1984:

Biochemist Jack Preiss and his colleagues discover that bacterial genes can increase plant starch production

#### 1985:

Food toxicologist Jim Pestka develops a process to screen for aflatoxin B-1, a poison produced by fungi that can contaminate spices, corn, small grains, cottonseed, peanuts and dairy



#### 1990:

Microbiologist and molecular geneticist Mike Thomashow discovers the CBF cold-response pathway that controls both freezing and drought tolerance in plants

#### 1992:

Plant scientist Chris Somerville helps discover how to produce plastics from plants

#### 1994:

Alumnus Philip Rowe unveils the Goldfinger banana variety, resistant to the wilt diseases that devastated the industry in the 1980s and 1990s



#### 2002:

Plant biologist Katherine Osteryoung uncovers new components of chloroplast division machinery and how they function in plant cells

#### 2010:

Crop and soil scientist Dechun Wang develops aphid-resistant soybean germplasm called Sparta — the Soybean Aphid Shield

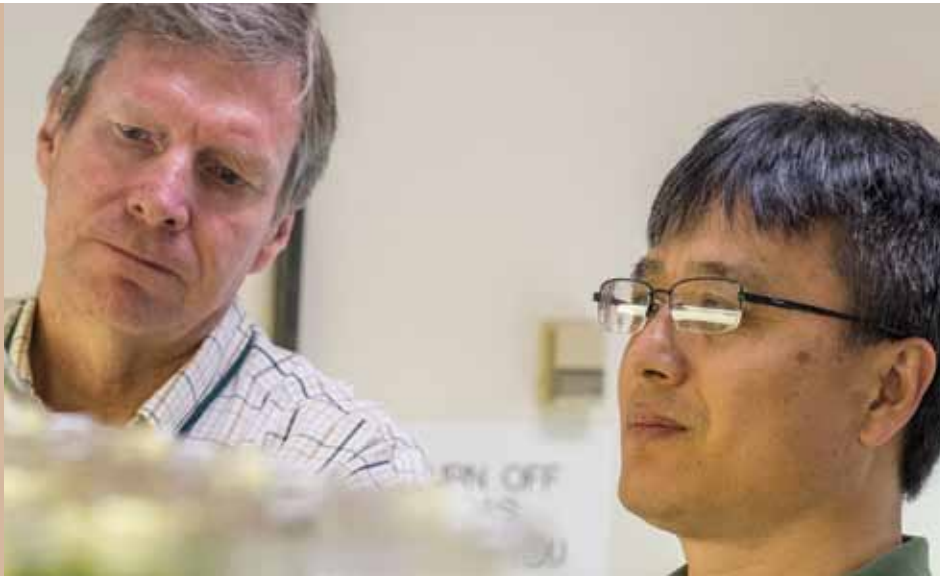
#### 2010:

Plant biologist John Ohlrogge and colleagues identify a gene from seeds of burning bush that shows benefit for biofuel production



#### 2013:

Biochemist and molecular biologist Christoph Benning leads efforts to discover a process to boost oil production in plants to benefit use in biofuels



LEFT: (From left) Vance Baird, professor and chair of the Department of Horticulture and director of the MSU Plant Biotechnology Resource and Outreach Center (PBROC), and Guo-Qing Song, PBROC associate director and an assistant professor in the Department of Horticulture, discuss producing progeny plants for commercial markets.

“You can test the expression of transgenes or native genes in single cells or tissue explants, but that is just showing that they function in isolation. Growers and consumers need a whole plant with the new trait(s),” Baird said.

The PBROC collaborates with MSU researchers as well as with commercial organizations outside of the university to do this kind of work. Baird, an MSU AgBioResearch scientist, credits Guo-Qing Song, PBROC associate director and an assistant professor in the Department of Horticulture, with having the expertise to develop systems to effectively transform, regenerate and rapidly propagate a variety of plants, from blueberries to rhubarb.

“From propagating traditional varieties to endangered plant species to creating new varieties of plants through genetic engineering, the PBROC is a centralized source for those technologies,” he said. “We want the center to become more of a resource for more of MSU’s plant scientists.”

### MSU helps international scientists

Reaching out to help others around the world is an MSU trademark. Grumet and Hancock are part of an MSU research team headed by Karim Maredia, MSU professor of entomology, that is using a \$10.4 million grant from the Bill and Melinda Gates Foundation to connect African biosafety regulators with advances in technology.

“There are critical problems in Africa that can be solved with plant biotechnology improvements, especially hunger and nutrition,” Hancock said.

In May, the MSU team worked with a group of African university professors who came to campus to learn more about biotechnology and biosafety and to develop a short course that will be delivered to regulators in Africa.

Other short courses have attracted scientists and policymakers from all over the world. Others have come to study at MSU and work with researchers to add to their

technological knowledge. The PBROC also helps with this outreach effort — in particular, providing hands-on workshops.

“Some countries are more open to biotechnology than others,” Grumet explained. “What we try to focus on is the science. The ultimate decision about whether biotechnology is used in their countries depends on many things, but we hope to provide the scientific background needed to make the assessments, interpret the data and make decisions that best fit their needs.”

*In May, the MSU team worked with a group of African university professors who came to campus to learn more about biotechnology and biosafety and to develop a short course that will be delivered to regulators in Africa.*

## Southwest Michigan Research and Extension Center

The Southwest Michigan Research and Extension Center is located in a very diverse agricultural region of the state. Fruit and vegetable breeding and variety evaluations are just part of the work at the 350-acre site. Other projects include cherry rootstock testing, peach production and establishment and production practices for table and wine grapes (Michigan is the No. 4 producer of grapes in the country, most of them juice grapes). The center hosts several educational meetings each year, including demonstrations on proper pesticide storage and use.



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*Projects include cherry rootstock testing, peach production and establishment and production practices for table and wine grapes*

MSU AgBioResearch supports a network of campus laboratories and 13 off-campus research centers that provide more than 300 scientists the opportunity to focus their research and outreach activities on the agricultural and natural resource needs of particular regions of the state. The off-campus centers range in location from Chatham in the Upper Peninsula to Benton Harbor in southwestern Michigan. Each is dedicated to high-quality science and innovation that benefit the state and its citizens.

# MICHIGAN STATE UNIVERSITY

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## AgBioResearch

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AT LEFT: A young girl sits on a lily pad in a small pond in the Beal Botanical Gardens. She holds a pennant for Michigan State College (MSC), the name MSU held from 1925-1955. *Photo courtesy of Michigan State University Archives and Historical Collections.*