2010
ANNUAL REPORT

MICHIGAN AGRICULTURAL EXPERIMENT STATION

It's official!

On Jan. 1, 2011, the Michigan Agricultural Experiment Station (MAES) became AgBioResearch.

Our new name, along with the tagline — *leading innovation in food, natural resources and energy* — better conveys the breadth and relevance of the work we do while remaining true to our land-grant mission in support of Michigan agriculture. To find out more, visit us at **agbioresearch.msu.edu.**

In the meantime, enjoy our FY 2009–2010 annual report — it's our last publication as the MAES.

Michigan State University
AgBioResearch

2010 Annual Report

MANAGING EDITOR'S NOTE: As we interviewed the scientists involved in the research projects presented in this report, they — to a person — provided us with lengthy lists of colleagues, students, organizations and funders integral to their efforts. Including all of this information would easily double the length of the report, so we opted to limit project narratives to key research elements and the importance of the work in its respective field. We do, however, want to convey the interviewees' (often repeated) acknowledgements of the individuals and organizations with which they collaborate and their gratitude for the support they receive in doing their work.

Message from the Director

Tackling climate change challenges to better weather the future

STEVEN G. PUEPPKE

As I write this, I am concluding my fifth year as the MAES director and embarking upon (this I hesitate to admit) my 36th year as a Ph.D.-toting researcher cum administrator. I used to rely on my professional elders for insights on how the world of agriculture and natural resources is changing. Now as an elder myself — well, almost an elder — I've developed some perspectives of my own.

Back in my day, the notion that climate might be changing was simply not an issue. All of us young 1970s-era plant pathologists learned that disease is the result of an interaction between pathogen, plant and the environment. "Environment" meant weather, so we studied the effects of rainy spells and those occasional hard or mild winters on disease development. We didn't think about long-term climatic trends of any sort. And we certainly couldn't imagine that scientists and policymakers would one day find themselves convulsed over the notion that human activity might be causing long-term changes in climate worldwide.

Don't expect agreement on climate change anytime soon, but do expect that the MAES will provide good, balanced information to offer options and guide the discussion. Thirty-five years ago, we wouldn't have been able to provide much help. But today, MAES scientists are working on a whole range of key climate issues. Let's highlight three of them, starting out with agricultural meteorologist and state climatologist Jeff Andresen and several of his colleagues.

Using computer modeling and 100 years of historical weather data, their research shows that Michigan, much like the rest of the world, has become wetter and warmer during recent decades. Jeff and his colleagues have concluded that more moisture and more heat in Michigan have been generally good for most agricultural crops. But we need to be cautious. Although current climate trends and research findings suggest potential increases in agricultural production, we also need to be mindful of the long-term effects on weeds, insects and plant disease. These indirect effects could turn into deal breakers or, at the very least, become very difficult to manage in a wetter, warmer future — and so we need to be prepared.

Odd as it might seem, climate change could also affect the competitiveness of Michigan products in global markets. MAES geography researcher and climatology expert Julie Winkler is leading a team of international researchers in a first-of-its-kind study to measure just such impacts. Using Michigan's important tart cherry industry as one example, the team is perfecting a system for conducting climate impact assessments for international market systems, particularly those that require long-term investments — think all those orchards near Traverse City. The research, supported by a $1.5 million grant from the National Science Foundation, will have applications not just for agriculture but for processing and even tourism. Julie and her colleagues will be providing the tart cherry industry with an impact decision guide that will help them make wise decisions about future investments.

And finally, a question: what do a village of small-acreage farmers growing jatropha trees in Thailand and carbon markets have in common — and why is it important to the MAES? Both are part of an innovative venture called Carbon2Markets led by MAES forestry researcher David Skole and his team. The program combines agroforestry — the practice of adding trees to crop and animal agriculture — with emerging carbon financial markets. The result will help farmers in 10 developing Asian and African countries boost their standards of living, while helping to slow climate change and extending MSU's global reach in agriculture and natural resources.

Here's how it works. Carbon dioxide is a greenhouse gas that traps heat in the atmosphere. Trees trap the carbon, or in the language of scientists, they sequester it. Accurate and cost-effective measurement of stored carbon

MAES Faculty Honors

The awards and recognition that MAES researchers receive each year continue to impress. Some of the highlights for fiscal year 2009-2010 are:

Rafael Auras, MAES packaging researcher, received the 2009-2010 MSU College of Agriculture and Natural Resources Excellence in Teaching: New Teacher Award.

Muraleedharan Nair, MAES horticultural scientist, received the MSU College of Agriculture and Natural Resources Alumni Association 2010 Distinguished Faculty Award. Nair, an internationally recognized pioneer in bioactive natural products chemistry, holds 49 U.S. and 30 international patents.

Phil Robertson, MSU distinguished professor, MAES crop and soil sciences researcher and chair of the Long Term Ecological Research (LTER) network executive board and science council, accepted the 2010 Distinguished Scientist Award from the American Institute of Biological Sciences on behalf of the LTER network. The network was honored for its large-scale experiments that have transformed ecological and environmental science. Robertson directs the MSU LTER site at the W.K. Kellogg Biological Station, one of 14 off-campus field research facilities in the MAES network.

Alvin Smucker, MAES crop and soil sciences researcher, was honored with his second von Humboldt Research Award by the Alexander von Humboldt Foundation in Germany. Smucker was recognized for his work on the biogeochemical mechanisms that control carbon sequestration.

James Tiedje, MSU distinguished professor and MAES crop and soil scientist, was awarded the Einstein Professorship from the Chinese Academy of Sciences (CAS). The award aims to build relationships between CAS scientists and scholars from around the world and to honor international scientists.

Edward "Ned" Walker, MAES entomology researcher, received the 2009 Founders' Memorial Award from the Entomological Society of America (ESA). The award — the ESA's most prestigious — honors scientists whose lives and careers have enhanced entomology as a profession and who have made significant contributions to the field.

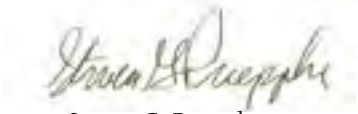
Two MAES researchers were named AAAS fellows by the American Association for the Advancement of Science. Plant molecular biologist **Robert Last** was honored for distinguished contributions to the field of plant biochemistry; water scientist **Joan Rose** was honored for distinguished contributions to the fields of quantitative microbial risk assessment and waterborne disease.

Three MAES scientists were recognized by the American Society of Plant Biologists (ASPB) for their contributions to plant biology. **John Ohlrogge**, **Robert Last** and **Michael Thomashow** received ASPB society fellowship awards for distinguished and long-term contributions to plant biology. Ohlrogge also received the Martin Gibbs Medal for advances that have served to establish new directions of investigation in the plant sciences.

Four MAES faculty members were recognized at the 2010 MSU Awards Convocation. **Gregg Howe**, biochemistry and molecular biology researcher, and **Doug Schemske**, plant biology researcher, received Distinguished Faculty Awards. **Cliff Lampe**, telecommunication, information studies and media researcher, and **Maria Lapinski**, communication researcher, received Teacher Scholar Awards.

offers farmers the potential to enhance their incomes through global carbon trading schemes. A Thai farmer with a 25-acre plot could earn up to $400 per year from the carbon market — a significant amount in a region where the average annual income is only about $1,200. The Carbon2Markets program, which was honored in 2010 for outstanding research by the Asia-Pacific Network for Global Change Research, thus helps to create a better future for everyone.

So there you have it — three MAES research groups, each tackling climate change in a different way, and all contributing to the MAES mission in a valuable way. We wouldn't have been able to conceive of it back then, but this is the reality of the MAES in the 21st century. Enjoy this year's annual report!



Steven G. Pueppke
MAES Director

food and health

Prevention, vigilance and ongoing research are key to ensuring that crops, animals and humans remain healthy and vital.

From creating visual tools that help people better understand the complexities of the food system and developing new approaches to reducing the risk of food-borne illness, to finding ways to improve disease resistance in plants, Michigan Agricultural Experiment Station (MAES) scientists are hard at work to provide Michigan growers and commodity groups with the critical information and resources they need to remain competitive in the global economy, and consumers with knowledge that helps ensure their health and well-being. The projects highlighted in this section provide a snapshot of the innovative research being done in this priority area.

[Visualizing the **Food System** for the **Health** of It]

PHOTO: VAL OSOWSKI

Eco-labels can be an effective visual tool for producers and manufacturers to use to differentiate their products in the marketplace, as well to as communicate their values and principles to consumers.

Almost everyone is familiar with the adage 'A picture is worth a thousand words.' MAES food system scientist Phil Howard is taking these words to heart by creating visual tools to help people better understand the links between food system changes and community health.

"The food system has become so complex that it's difficult even for experts to figure out what is happening," said Howard, who is also an assistant professor in the Department of Community, Agriculture, Recreation and Resource Studies (CARRS) at Michigan State University (MSU). "Visuals are effective tools because our eyes can take in far more information than our other sensory organs, allowing us to process large amounts of data more easily and quickly. Visually depicting the food system with maps, charts and diagrams is a useful way to show people the full scope of the changes occurring so that they can make informed decisions."

Over the past several years, Howard, along with MSU geographers Kirk Goldsberry and Chris Duvall (who is now with the University of New Mexico), has been laying the groundwork for identifying and visualizing the "nutritional terrain" of urban food environments in Michigan.

"The accessibility of healthy food choices varies considerably depending on an individual's geographic location," Howard said. "A number of recent studies have quantified and mapped links between demographics, food accessibility and diet."

Using U.S. Census and retail location data, Howard and his team looked at seven Michigan communities — Benton Harbor, Flint, Grand Rapids, Highland Park, Pontiac, Saginaw and Ypsilanti — to analyze community demographics and develop an atlas of nutritional accessibility for these cities, which was shared with community organizations.

"Although there were problems with the accuracy of some of the retail data, the basic information gleaned from this study will help communities identify gaps in retail access," Howard said. "These maps will prove particularly useful if they want to find a location to establish a youth farm stand or farmers' market that is mutually beneficial to vendors and community members who want fresh produce."

Eco-labels are another important visual tool that can help bring food system values and practices into focus for consumers

"Visually depicting the food system with maps, charts and diagrams is a useful way to show people the full scope of the changes occurring so that they can make informed decisions." • PHIL HOWARD

and raise awareness of farmers' options to reach market niches and potentially garner price premiums for their products, Howard said.

"Eco-labels summarize a whole suite of standards and criteria through a visually recognizable logo, allowing people to support particular standards and criteria that matter to them through their purchases," he explained. "The increasing popularity of these labels has helped to move the food system in more ecologically sustainable and socially just directions, but with so many choices, it's difficult to know which of these eco-labels have the greatest potential for success."

To help address this issue, Lia Spaniolo, a CARRS graduate student working with Howard, conducted focus groups with consumers in southern Michigan to assess their interest in and support for eco-labels. Participants were asked a series of questions, including what their general motivations were for making food purchases and how these motivations applied to a select set of emerging eco-label criteria — domestic fair trade, family-farmed, humane treatment of animals, integrated pest management, locally grown and pasture-raised.

"Findings showed that participants were willing to pay more for value, but they wanted to know much more about their food and wanted more transparency in the food system," Howard said. "Participants were also generally supportive of all the eco-label criteria presented but were most interested in the 'humane,' 'local' and 'domestic fair trade' designations."

Spaniolo also compiled a brochure, "Eco-Label Programs for Michigan Farmers," to help crop and livestock producers determine which, if any, eco-label programs would benefit them. The brochure is available online at https://www.msu.edu/~howardp/ecolabelspamphlet.pdf.

The bottom line for Howard? To make sure that communities, individual consumers and producers get the big picture.

"The whole motivation is to help people understand changes in the food system so that they can respond positively to them," Howard said. "Visualization is a very effective tool for me as a researcher, but it is even more so in communicating my work. It's a really underutilized tool; I think we can do a lot more to increase peoples' visual literacy through our outreach efforts." •

[Fighting **Big, Bad Bugs**]

Each year, about 76 million people in the United States get sick from contaminated food. According to the U.S. Food and Drug Administration's **Bad Bug Book**, more than 50 bacteria, viruses, parasites and toxins are considered food-borne pathogens.

MAES food scientist Elliot Ryser, one of the country's leading microbial food safety experts, is working to help companies control bacterial transmission of what he calls "The Big Three" in food: *Listeria monocytogenes*, *Salmonella* and *E. coli* O157:H7.

E. coli is a natural inhabitant of the intestines of all animals, including people, where it helpfully suppresses the growth of harmful bacteria. But the O157:H7 serotype produces large amounts of potent toxins that severely damage the lining of the intestines and can cause severe cramping, fever and bloody diarrhea. Some very young children infected with O157:H7 have developed hemolytic uremic syndrome, which can lead to kidney failure. In most cases, symptoms usually clear up after about eight days and are mild in many people, so exact case numbers aren't known. Undercooked or raw hamburger has been linked to many O157:H7 outbreaks, but alfalfa sprouts, unpasteurized fruit juices, dry-cured salami, lettuce, raw milk and cheese curds also have been implicated.

PHOTO: KURT STEPNITZ

Using the only pilot plant-scale processing line for leafy greens in the country, Ryser and his team are working to provide food safety solutions for the growing and handling of leafy greens.

After an outbreak of *E. coli* O157:H7 was linked to contaminated spinach and lettuce in 2006, Ryser began a multipronged research program to give the leafy greens industry hands-on information about steps that could be taken if contamination were detected.

"The overall goal of this five-year research study is to develop strategies to enhance the safety, quality and shelf life of ready-to-eat foods, focusing on providing critical quantitative data on the transfer of *E. coli* O157:H7 during commercial-scale processing of leafy greens," he explained.

He and a team of 10 students conducted an experiment to determine how fast a lettuce processing line would become contaminated if a small amount of contaminated product happened to get into the mix, as well as how widespread the contamination would be.

Using a commercial-sized processing line in his lab in the Trout Building, the researchers contaminated 20 pounds of radicchio leaves with non-pathogenic strains of *E. coli* O157:H7 and ran it through the processing line (shredding, washing, drying) and then ran 2,000 pounds of uncontaminated iceberg lettuce through the equipment. They sorted through 40, 50-pound bags of greens and combed through all the bits left on the processing equipment to determine the final location of the contaminated radicchio. They found radicchio in every bag of processed lettuce and more than 200 small pieces on the processing line.

"We wanted to demonstrate how far the contaminated product can actually spread during processing," Ryser said. "This will give the processor a good idea of how much product is at risk if they do have a contamination event. The goal is to give the leafy green industry suggestions about improved equipment design, when they need to shut down the line and sanitize the entire processing line, and how much additional product may be at risk if *E. coli* O157:H7 is later found in a bag of salad greens.

"Having the only pilot plant-scale processing line for leafy greens in the country, my laboratory is uniquely positioned to provide answers to these and other urgent questions related to *E. coli* O157:H7 transfer and reduction during commercial shredding, step-conveying, fluming, washing and drying of leafy greens," he added. ●

"The overall goal of this five-year research study is to develop strategies to enhance the safety, quality and shelf life of ready-to-eat foods." ● ELLIOT RYSER

To see an MSU Today video story on Ryser's research to detect E. coli *in lettuce processing, visit: www.msutoday.msu.edu/shows/20/index.php?segment=3.*

[Reducing **Food Safety Risk** in **Fresh Produce**]

PHOTO: KURT STEPNITZ

As the popularity of ready-to-use foods grows, researchers are exploring ways to improve the overall quality and shelf life of fresh produce by managing sanitation and packaging.

Food safety is front page news. The names of bacteria such as *E. coli* 0157:H7 and *Salmonella* are becoming household words as product recalls are more and more a part of our daily news diet. U.S. Department of Agriculture data show that fresh produce is now the leading cause of *E. coli* O157:H7 food-borne illness outbreaks in the United States.

In an effort to improve food processing technologies, minimize the risk of food-borne illness, and enhance produce quality and shelf life, several MAES projects are underway to identify ways to make and keep our food supply safe.

One segment of the food supply that is causing significant concern is fresh and fresh-cut produce, particularly packaged leafy greens. From 1996 to 2007, leafy vegetables accounted for 34 percent of all outbreaks due to microbial contamination traced back to a specific fruit or vegetable. The sanitation process that these packaged salads currently undergo is not always sufficient to eliminate contamination.

MAES packaging researchers Maria Rubino and Rafael Auras are exploring how packaging might complement the sanitation process for fresh cuts and vegetables.

"We're looking at turning packages into small sanitation chambers to allow for a longer and more thorough exposure to the appropriate bactericide; in the case of this project, chlorine dioxide gas," Rubino said.

"We know that, for chlorine dioxide to work, it has to be in direct contact with the product," Auras said. "Bactericide gases such as chlorine dioxide are commonly applied by flashing the package head space. The gas is supposed to work its way down through the package, but it doesn't always reach all of the product surfaces."

Before they could begin their research, Rubino and Auras needed to know if exposure to chlorine dioxide damaged the package material or changed it in a way that compromised its ability to ensure product safety and adequate shelf life.

Siriyupa Netramai, a doctoral packaging student in Rubino's lab, spent a year developing and validating a method to characterize the interaction of chlorine dioxide with packaging materials.

Rubino and Auras then engaged engineering postdoctoral fellow Brajesh Tripathi to conduct computer simulations on the distribution, flow and dissipation of chlorine dioxide gas in both rigid clamshell containers and produce bags. On the basis of his findings, Tripathi designed a rigid container to test specific gas distribution, and a produce bag with perforated reservoirs for the bactericide that facilitate an even distribution of gas and contact with all fresh produce surfaces throughout the bag.

Netramai tested the new, flexible packaging design by bag-

ging shredded romaine lettuce contaminated with *E. coli* in one- and two-reservoir bags. The packages were flashed with chlorine dioxide gas at two dosage levels, stored at 4 degrees centigrade and sampled at one, four and seven days.

"We found that, with the reservoir design, the low dose of gas accomplished almost the same level of pathogen reduction as the high dose, and the lettuce quality was significantly higher," Rubino said. "The rigid container insert design works the same way as the reservoir system by channeling gas throughout the container."

"We're looking at turning packages into small sanitation chambers to allow for a longer and more thorough exposure to the appropriate bactericide." • MARIA RUBINO

The most promising container designs and treatments will be tested at the MSU Biosafety Level-2 Pilot-Scale Food Processing Facility.

Developing packaging that maintains product quality and prolongs shelf life while offering environmental benefits is another aspect of ensuring a safe, sustainable food supply.

MSU packaging researcher Eva Almenar is collaborating in an MAES-supported project to develop biodegradable packaging for whole and fresh-cut vegetables and fruits.

Almenar and members of her lab are working with a team of MSU bioengineering, food science and human nutrition, horticulture, and packaging researchers to compare the performance of corn-based, compostable containers made using polylactic acid (PLA) with several types of conventional, petroleum-based packages. The purpose of this research is to determine the effect of various types of packaging materials and technologies on the storage life of fresh produce, including shredded romaine lettuce, chopped and peeled onions, blackberries, cherries, blueberries and strawberries.

"Our research shows that, in some cases — depending on the produce and packaging design — PLA performs better than the conventional plastics tested." Almenar said. "We are now trying to determine, more specifically, what the needs are for different products so that we can improve the effectiveness of these packages.

"These findings support the possibility of new approaches for maximizing the shelf life of fresh produce," she continued. "In addition, packaging material such as PLA has the potential to be returned to the fields as fertilizers and soil conditioners, benefiting the farmer and reducing solid wastes in landfills." •

[Untangling the Web of Disease Resistance in Plants]

At the end of 2000, the entire DNA sequence of *Arabidopsis*, a relative of the mustard plant that is used as a model for much research on plants, was completed. For the first time, scientists knew the sequence of about 25,000 genes necessary for the plant to function. As a follow-up to this project, the National Science Foundation launched *Arabidopsis* 2010 with the goal of knowing the function of every gene in the plant by 2010. As the year winds down, scientists are still working toward that goal, but exciting discoveries have been made, including some by MAES plant pathologist Brad Day.

Research done in 2009 by Day and Miaoying Tian, a postdoctoral scientist in his lab, was the first to show that the actin cytoskeleton plays a role in resistance to bacterial pathogens in plants. Building on this work, Day and collaborators from Purdue and Oregon State universities are collaborating to analyze the function of all the proteins that regulate the actin cytoskeleton.

"The actin cytoskeleton is like a dense cobweb in the cell," Day explained. "It's similar to the system of railroad tracks and electric cables that run across the United States. In the cell, electrical stimuli, proteins and other cell components move

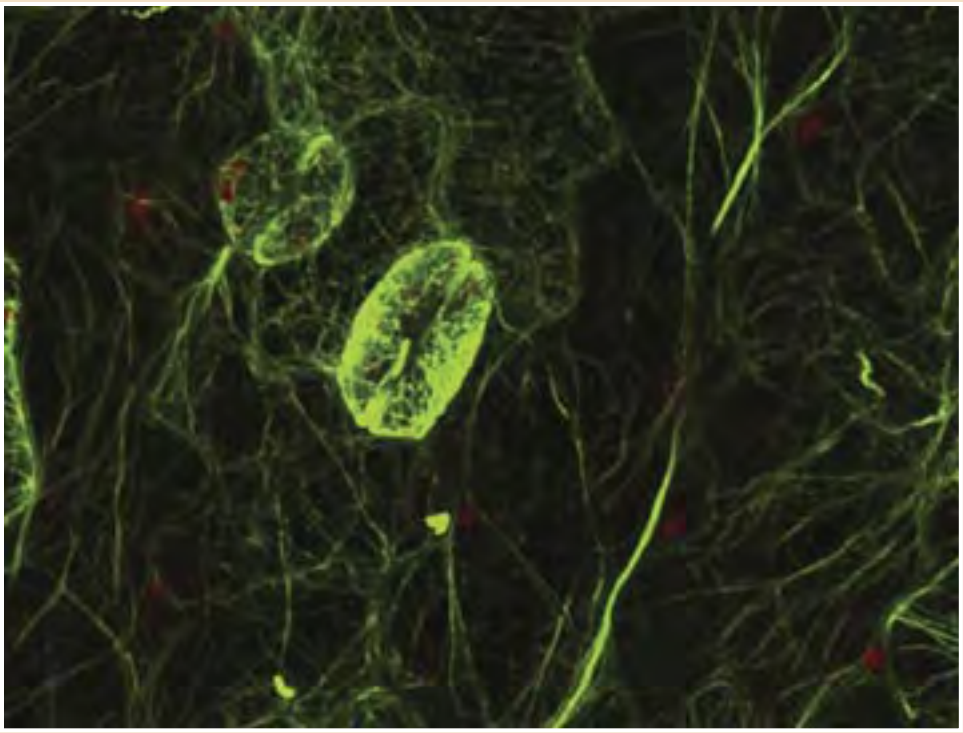


PHOTO: MASAKI SHIMONO

Fluorescent labeling allows researchers to look at live plant subcellular structures in fine detail. The above image shows the *Arabidopsis thaliana* actin cytoskeleton following infection with *Pseudomonas syringae* (note the rod-shaped bacterium positioned within the plant stomata; center).

along the 'cables' of the actin cytoskeleton. It's a way for cellular structures to communicate with one another and to transport cell components."

Scientists knew that the actin cytoskeleton played a role in disease resistance to bacterial pathogens in mammals, but this function had never been demonstrated in plants before Day and Tian showed that knocking out one of the actin-binding proteins stopped *Arabidopsis* from defending itself against *Pseudomonas syringae*, a bacterium that causes surface damage in plants at low temperatures.

"In the earlier work, we looked at a select group of binding proteins. We're now expanding that research to look at the contributions of every actin-binding protein to see how much each one affects disease resistance."

Collaborating with Chris Staiger at Purdue and Jeff Chang at Oregon State, Day is using a laser capture microdissection (LCM) instrument among other technologies to study the actin-binding proteins.

LCM is the most advanced method available to analyze single cells from plants and animals and provide a cellular "snapshot" of what happens in individual cells during processes such as metabolism or disease response. Only a handful of institutions in the country use LCM for plant biology.

"LCM is pretty incredible," Day said. "You can focus on a single molecule within a cell or select a single chromosome within that cell and sequence it. We can determine the levels of hormones and the rates of gene expression or protein content in a single cell, and we can analyze 1,000 cells a minute. This allows us to push the envelope of answering basic plant biology questions."

Day was already pushing the envelope by using variable angle epifluorescence microscopy (VAEM) to look at live plant subcellular structures in fine detail. VAEM combines the power of laser confocal microscopy with the ability to fine-tune the laser, allowing scientists to view single, fluorescently labeled macromolecules. Day was the first to use VAEM to look at disease resistance in plants.

"The idea is that this disease resistance work in *Arabidopsis* will be a template for other plant systems," Day said. "I've already been contacted by a soybean researcher who is interested in our actin-binding protein work. If we can understand the concepts in *Arabidopsis*, we can apply them to more complex plants." ●

> **"The idea is that this disease resistance work in *Arabidopsis* will be a template for other plant systems."** ● BRAD DAY

environmental stewardship

and natural resources and policy

The need to develop economically and environmentally sound approaches to address environmental and natural resources challenges is increasingly important.

Policies, practices and science-based knowledge must constantly evolve to promote stewardship and sustainability in light of new opportunities for increased productivity, resource-saving technologies and enhanced quality of life. The projects showcased in this section reflect some of the innovative work being done by Michigan Agricultural Experiment Station (MAES) scientists in this area to help individuals, communities, natural resources managers and policy makers at all levels make informed decisions and wise choices.

[Going Green from Top to Bottom]

PHOTO: BRAD ROWE

Green roof test plots, such as those pictured here, allow researchers to analyze how various plants affect a roof's benefits, including temperature moderation, noise reduction and carbon sequestration.

Michigan State University (MSU) has always been green, but thanks to 10 years of research by MAES horticulture researcher Brad Rowe, the campus has become even greener. And he hopes to help the rest of the state green up as well.

Rowe oversees MSU green roof research on top of the Plant and Soil Sciences Building and the Communication Arts and Sciences Building, and at the Horticulture Teaching and Research Center. The program began in 2000 when MSU helped the Ford Motor Company install a 10-acre green roof on an assembly plant in Dearborn.

A green roof involves growing plants — ranging from succulents, such as sedum, to trees and shrubs — on rooftops. The depth of the soil medium influences which plants can be grown. Rowe's research has shown that, besides offering aesthetic benefits, green roofs can:

- Reduce airborne pollution, including some greenhouse gases.
- Reduce storm water runoff — a major problem in dense urban areas — by more than 60 percent.
- Moderate temperatures for both the building that sports the roof and structures around it, reducing energy consumption and the urban heat island effect.
- Reduce noise.
- Increase roof durability and longevity.
- Attract beneficial insects, such as native bees and other pollinators.

A typical green roof system is composed of 2 to 6 inches of lightweight, engineered soil that drains water, holds roots and nourishes the plants. Sedum's drought tolerance enables it to grow in shallow soils without additional irrigation — the plant can survive more than 88 days without water — and its hardiness helps it triumph over weeds.

Though green roofs aren't as popular in the United States as they are in Europe, especially Germany, Rowe said the amount of green roof space in North America has been doubling each year since his research began.

"Most of these systems are on government and commercial buildings, but it's a growing business, and there is a lot of interest."

Rowe's decade of research has helped identify particular species of plants that are best suited for green roofs. In 2010, he began studying the feasibility of growing vegetables such as tomatoes, peppers, cucumbers, basil and green beans on the green roof test plots, but because these plants are more labor-, nutrient- and water-intensive, they may negate some of the roof's benefits.

"Most of these systems are on government and commercial buildings, but it's a growing business, and there is a lot of interest." • BRAD ROWE

"It may be an issue, but we don't know," Rowe said. "That's why we're studying it. Unless you live someplace like New York City, it probably makes more sense to grow vegetables at ground level."

Rowe also has tracked and analyzed how various species of sedum affect the roof's benefits, such as carbon sequestration and temperature moderation.

"We were one of the first groups doing this kind of long-term research on green roof technology," Rowe explained. "One of our current goals is to provide the U.S. Green Building Council with our results so that installing a green roof gets more points toward Leadership in Energy and Environmental Design (LEED) certification. Right now, a green roof contributes to LEED, but we'd like it to have a bigger impact."

Toward that goal, Rowe and his colleagues installed 20 new green roof test plots on the Plant and Soil Sciences Building in 2007. In the ensuing years, they have analyzed how much carbon the roof system's plants and soil are storing.

"If all the commercial and industrial roofs in metropolitan Detroit had green roofs similar to what we used, they could sequester approximately 55,252 metric tons of carbon," Rowe explained. "That's similar to removing more than 10,000 midsized SUVs or trucks off the road for a year. Of course, the final numbers depend on climate and green roof design, but green roofs can be a significant potential strategy for sequestering carbon in urban environments." •

For much more information on Rowe's research, visit the Green Roof Research Program Web site: www.hrt.msu.edu/greenroof/.

[Converting Wastes to Resources, Naturally]

Anaerobic digestion may sound like a lofty term, but the definition is pretty down to earth. Anaerobic digestion is a natural process that breaks down complex waste materials, such as animal waste (manure) or waste produced by food processing plants, into methane gas. The beauty of using state-of-the-art digester equipment is that the formation of the fuel occurs in real time rather than geological time – in hours to days, rather than tens of thousands of years.

One "feed" for a digester is manure. Animal waste is awkward to manage in its unprocessed state because of its high water content. According to the lead researcher on anaerobic digestion at MSU, MAES biosystems and agricultural engineering researcher Steve Safferman, digestion enables the waste material to be separated efficiently into solids and water, thereby readying the components for further processing.

"Waste is a highly unstable product, and even if it's stored and properly handled in a lagoon system, there are still the issues of odor, greenhouse gas emissions, and handling and disposal to contend with," he explained. "It's not efficient or economical to move liquid manure any great distance from where it's produced. After digestion and separation takes place, you're left with virtually liquid-free phosphorus manure with the consistency of dirt that can be easily and economically transported off-site. The resulting liquid can be spread on cropland, providing it with nitrogen."

Safferman noted that, even though the effect on global warming is reduced 21-fold simply by burning off the methane that's produced naturally through the digestion process, recycling it into energy presents a value-added opportunity.

"Investing in a digester is extremely expensive, but it leads to opportunities beyond just being able to manage manure more easily and protect the environment," he said. "Methane is a valuable byproduct that can be used for energy. Excess energy can be sold for profit, and producers can earn and sell carbon credits and receive renewable energy credits."

Safferman and his colleagues are also researching how blend-

"There is great potential for digesters as part of a diversified system, but there is more work to be done." • STEVE SAFFERMAN

ing farm and food processing wastes together could ultimately lead to more economical and efficient energy production. Though digesters currently provide a ready-made system for treating pollutants that are end products from the food processing cycle, generally food processing waste contains a lot of energy with few to no nutrients, so additives are needed to complete the process. Partnering with a farm could eliminate the need to add commercial buffers and nutrients because they would be replaced by the naturally occurring nutrients present in manure.

PHOTO: STEVE SAFFERMAN

Once waste materials are "digested," samples are bottled *(above)* and examined to determine their biogas methane potential.

"There's great potential for blending wastes, for putting two wastes together to produce so much more energy than either could alone, but our biggest challenge is determining the right ratios to use," Safferman said. "This is a key piece of the puzzle and we're still a long way from being able to consistently predict the digestibility of blends without first conducting laboratory and pilot-scale studies."

Another challenge that the researchers would like to tackle is to develop a centralized digester, one that can serve multiple producers of biomass residuals, including both large and small operations.

"The digestion process doesn't rely on size," Safferman said. "The challenges are not in the process itself or the microbiology, but in the logistics and how to make it work economically. Smaller businesses are more at risk because it's harder for them to build these technologies due to the costs involved. Just imagine if a small farm was able to extend its growing season by heating its hoop-house or a small farm was able to use the energy to open a cheese factory. The question is, how can we create a new revenue stream by creating a renewable energy source?"

For the time being, reducing the cost of investing in a digester is one of the most obvious challenges facing North American innovators. In Europe, which has upwards of 8,000 digester units in operation, economic incentive programs are in place to minimize the payback period.

"There is great potential for digesters as part of a diversified system, but there is more work to be done," Safferman said. "I have no doubt that we'll come up with advancements to reduce installation and implementation costs, but how does one really put a price tag on providing for a healthier environment?" ●

PHOTO: R. HULL, GRIZZLY AIR PHOTO

Biofuel crops — including poplar, switchgrass, Miscanthus and restored prairie grass are being grown and tested by MSU LTER scientists to determine the productivity and environmental benefits of various biofuel cropping systems.

[Using **Biofuel Crops** to **Capture** Carbon]

Greenhouse gases — carbon dioxide, methane and nitrous oxide are the main ones — have been steadily increasing in the atmosphere since the Industrial Revolution. Without some greenhouse gases, the Earth would be an ice ball. But as research has shown, high concentrations of greenhouse gases can cause slow but dramatic increases in temperature, commonly called global warming.

Both carbon dioxide and methane are carbon-based. Crops and other plants use carbon dioxide from the air during photosynthesis. When leaves, stems and other plant residues fall to the ground, the carbon is either converted back to carbon dioxide by microbes during decomposition or becomes part of soil organic matter. Certain agricultural practices, such as no-till, increase the amount of carbon in the soil by slowing decomposition. This keeps carbon dioxide out of the atmosphere. Other practices can affect methane fluxes.

"Quantitative models, together with the underlying **field research,** will help us to **design biofuel cropping systems** that are both **profitable and environmentally sustainable."** • PHIL ROBERTSON

MAES crop and soil scientist Phil Robertson directs research at the Long-Term Ecological Research (LTER) site at the Kellogg Biological Station (KBS), one of 14 off-campus field research stations in the MAES network. Part of the national LTER network funded by the National Science Foundation, the MSU LTER site is the only agricultural site in the network. He also leads sustain-

ability research in the Great Lakes Bioenergy Research Center (GLBRC), a partnership between Michigan State and the University of Wisconsin-Madison funded by the U.S. Department of Energy. Scientists in the GLBRC conduct basic research to solve some of the most complex problems in converting natural materials to energy.

Robertson is internationally known for his research on how agricultural crops can reduce greenhouse gas emissions and slow climate warming. Part of his GLBRC work focuses on biofuel sustainability research, studying carbon cycling, water quality and greenhouse gas emissions associated with biofuel cropping systems, as well as developing complex modeling technology.

"Quantitative models, together with the underlying field research, will help us to design biofuel cropping systems that are both profitable and environmentally sustainable," Robertson said. "We need to ensure that the crops we'll be using for cellulosic energy can in fact contribute to climate stabilization and cleaner air and water, as well as provide biodiversity benefits such as habitat for birds and beneficial insects.

"Models based on results from experiments in the field will allow researchers and decision makers to see possible answers to 'what if' questions about various biofuel crops in various landscapes."

KBS is the principal field site for GLBRC sustainability research; scientists have established long-term biofuel cropping systems to provide detailed information on their productivity and environmental performance. MSU researchers are investigating energy yield, water use and carbon balance of crops such as switchgrass, hybrid poplars and grass mixtures, including restored prairie.

"Different crops also provide different kinds of habitats for birds and insects," Robertson said. "And this greater habitat diversity, which translates to greater bird and insect diversity, might then provide benefits such as pest control and pollination for plants and crops in other parts of the landscape.

"The general idea is to provide the knowledge needed to design future biofuel cropping systems that provide environmental benefits in addition to biofuel feedstocks." ●

[Tapping **Social Media, Web-based Tools** to Encourage **Environmental Stewardship**]

Every day, millions of Americans use social media to connect with family members, friends and colleagues on sites such as Facebook and Twitter. In addition, social media have been effective for social action, especially with corporations and political campaigns. Now MAES researchers working with nonprofit organizations hope to use the power of social media to increase environmental stewardship practices in the Great Lakes region.

Nonprofit organizations, including those involved in environmental stewardship, have not fully taken advantage of use of social media, observed MAES information and technology researcher Clifford Lampe.

"Most nonprofit organizations prefer a broadcast mode of communication on the Internet, where there is information, but no call to participate," Lampe said. "The key with social media is interaction, so the question is how nonprofits can encourage interaction."

Lampe has been involved in online communities most of his life and was one of the first to study large-scale interactions online. He used his expertise and MAES funding to develop a Web site — Great Lakes Echo — that features regional reporting on environmental news, and to collaborate with the MSU Institute of Water Research (IWR) to create an interactive Web site that maps and encourages water conservation practices.

The Great Lakes Echo (http://greatlakesecho.org) covers environmental news in the Great Lakes region. MSU students provide most of the content.

"The site is a good aggregation of regional environmental news and is one of the few Web sites with original environmental coverage," Lampe said. "It is also important to make these kinds of sites fun by creating ways for people to participate, such as having quizzes and asking for comments."

Many of the lessons learned from the Great Lakes Echo project have been applied to an initiative at the IWR called Networked Neighborhoods for Eco-Conservation (NECO).

"By having a **common mapping interface** for environmental practices **across the Great Lakes region** on the site, we were **able to fill a big gap.**" • JEREMIAH ASHER

"We are working more and more in urban areas, and there is an increasing concern about runoff and its impact on sewer system overflow," said Jon Bartholic, MAES researcher and IWR director. "We know that a lot of low-impact practices, such as rain barrels and rain gardens, are being established in urban areas. Individually, they don't have a major impact, but cumulatively, do they improve the health of the Great Lakes region?"

To help address this question, Bartholic, IWR colleagues Jeremiah Asher and Lois Wolfson, Lampe and Jeff Grabill, co-director of the Writing in Digital Environments Research Center at MSU, teamed up with nonprofit environmental groups in southeastern Michigan, Wisconsin and Ohio to develop a NECO Web site (www.networkedneighbors.org). The goal of the site is to track individual environmental practices by using mapping technology and to use social networking to encourage others to adopt these practices.

"The mapping technology is a key element of the NECO Web site," Asher said. "One environmental group had no idea what the other group was doing. By having a common mapping interface for environmental practices across the Great Lakes region on the site, we were able to fill a big gap."

Now that the tracking interface is in place, Asher and the rest of the team hope that people will adopt more practices and continue sharing information with one another on the site. They also are encouraged to share their environmental practices on social networking sites such as Facebook and Twitter. People who do not have a practice to add to the site can use forums to post questions and get answers. This is another way that the team hopes to increase interest in environmental practices.

"In addition to the environmental benefits, there are definite economic benefits to these practices," Wolfson added. "Rain barrels — which can help to manage thousands of gallons of water a year — are the most popular practice, often resulting in substantial savings on the cost of watering lawns and gardens."

PHOTO: INSTITUTE OF WATER RESEARCH

The Networked Neighborhoods for Eco-Conservation Web site provides users with the online tools they need to map and share environmental practices across the Great Lakes region.

Other urban environmental practices include rain gardens, green roofs, porous pavements, buffer strips and detention basins.

"Empowering citizens to share and use environmental practices is ultimately good for the Great Lakes, but it is also good for all the local lakes and streams in Michigan," Bartholic said. "The Web site is a valuable application of social networking and a powerful way to have people become familiar with what environmental practices their neighbors are using." ●

enhancing profitability

in agriculture and natural resources

Agriculture's essential role in growing and sustaining Michigan's economy is undeniable — production agriculture, food processing and related agribusinesses generate an estimated $71.3 billion annually and employ about 1 million Michigan residents.

Additionally, Michigan produces more than 200 commodities on a commercial basis and is second only to California in agricultural diversity. Michigan Agricultural Experiment Station (MAES) researchers from a range of disciplines are working to provide growers and commodity groups with the critical information they need to remain viable and competitive in the global economy while conserving Michigan's vast array of natural resources and reducing production-related environmental stresses.

[Putting a Premium on Information Sharing in the Global Market]

PHOTO: AKIRASTOCK VIA ISTOCKPHOTO

Specialty coffee businesses have borrowed from wine terminologies to describe the aroma, flavor, body and character of coffee from different growing conditions as a way to help differentiate and add value to their products.

Organic. Free-range/cage-free. Limited edition. Sustainably produced. These are just a few of the product attributes that are garnering consumer attention and price premiums in the specialty food market. Specialty and premium food products have been one of the fastest growing sectors of the food market. U.S. sales of organic food and beverages alone have grown from $1 billion in 1990 to $24.8 billion in 2009, according to industry data.

This burgeoning growth and the complexity of an increasingly global marketplace have created several challenges, however, including the need to maintain an adequate flow of product information across the food supply chain — especially between producers and consumers.

To address this challenge, MAES agricultural economist Dave Weatherspoon is leading a team of agricultural, food and resource economics scientists and graduate students in exploring ways to organize food supply chains that create more effective market and communication channels.

"A lack of information sharing about product attributes and consumer preferences can keep growers from receiving the price premiums they deserve for their products," Weatherspoon said.

He and his team are focusing on two product markets — fresh eggs and specialty coffee.

"Consumers are becoming more aware of the nutritional, ethical and environmental issues around food production and are increasingly interested in consuming quality products that are considered to be sustainably produced," he said. "For this reason, we decided to study the fresh egg market to determine the price premiums of certain individuals attributes — organic, welfare-managed [e.g., free range, cage free], nutritionally enhanced and vegetarian-fed. We were also interested in whether an egg received a super premium when two attributes — organic and welfare-managed — were stacked together.

The data for this study came from supermarket retailers in Baltimore, Boston, New York, Philadelphia and the Washington, D.C., area.

Findings showed that the individual attributes of organic, welfare-managed and nutritionally enhanced carried price premiums equal to 16.5 cents, 3.57 cents and 2.30 cents per egg, respectively, over a base egg price of 7 cents. The vegetarian-fed attribute had no significant effect on egg price.

Although the group had expected the price premiums identified for the individual attributes, they were surprised by the stacked attribute results.

"We expected organic and welfare-managed eggs to command a higher premium because consumers would easily associate the perceived animal health benefits and be willing to pay more for a multi-attribute product," Weatherspoon said. "What we found instead is that these eggs garnered a significantly lower premium than eggs marketed only as organic — 11.26 cents versus 16.5 cents."

Weatherspoon posited that one explanation for the discrepancy might be that consumers are uncertain about what "welfare-managed" or "sustainably produced" means — particularly when the egg is already labeled "organic" — and therefore are not willing to pay a greater premium for the additional attribute.

"There's a lack of premium because there's a lack of understanding by the consumer about what is actually being offered," he said. "Our findings clearly point to the need for improved information flow in the premium egg market."

Specialty coffee is another commodity where Weatherspoon and others believe that more effective communication channels could improve producers' and buyers' understanding of products and market opportunities.

"Coffee is usually sold in one of two ways," Weatherspoon said. "There is either a one-to-one trading contract between a producer and a seller, or it is sold in bulk at some kind of general auction. Either way, little information is shared about the product to the consumer, and the producer knows little about the consumer's preferences."

An innovative market approach uses a competition-plus-auction model. Coffees are "cupped" and rated on a 100-point scale by a national and international jury of tasters. Quality ratings and characteristics, coffee samples and production information are then shared with both growers and potential buyers. A month or so after the cupping competition, the coffee is sold through an online auction.

"When you think about how much information this approach sends up and down the supply chain, it's phenomenal," Weatherspoon said. "Now we're able to say that coffees that have these characteristics receive this kind of price premium."

Improving information flow in these niche markets is a win-win, he said.

"Producers can maximize their profit because they are in the appropriate market for their product and consumers can identify and purchase products with the qualities they desire." ●

"A lack of information sharing about product attributes and consumer preferences can keep growers from receiving the price premiums they deserve for their products." ● DAVE WEATHERSPOON

[Beating the Bugs to Michigan Tree Fruit]

Controlling pests is part of growing fruit anywhere, but it's even more important in Michigan.

"Michigan appears to be a melting pot of most of the major pests of tree fruit found in western and eastern North America," said MAES tree fruit entomologist Larry Gut. "More than 30 kinds of insects and mites may need to be controlled in Michigan orchards in any given season."

Michigan is a major fruit-producing state — more than 115,000 acres of orchard land contributes a farm-level value of $176 million annually to the state's economy (Michigan Department of Agriculture, 2007) — so finding ways to manage and control tree fruit pests economically is of vital importance to growers. Approximately 30 percent of the productions costs associated with fruit production are in pest management.

PHOTO: KURT STEPNITZ

Codling moth *(above)* is the worst apple pest in Michigan. Up to 90 percent of an apple crop can be damaged if an effective control program is not in place.

Related issues for growers are increased fuel costs, regulations governing pesticide usage, concerns about pesticide resistance and worker safety, and the public's interest in reducing pesticide use.

To address these issues, Gut is heading up a project that involves on-farm research to evaluate the effectiveness of methods to detect the pests as well as new control and management methods that can assist growers in using and applying the newer reduced-risk pesticides effectively and economically.

Research objectives include determining the efficacy of reduced-risk and organophosphate-replacement insecticides in controlling major tree fruit pests; developing and delivering effective alternatives to chlorpyriphos and endosulfan — insecticides known commercially as Lorsban and Thiodan — for control of trunk-boring pests of apple, cherry and peach; developing effective pheromone-based mating disruption technologies; and developing, delivering and optimizing economically and environmentally sustainable pest management programs.

Mating disruption of tree fruit pests is one of the more environmentally-friendly, sustainable pest control measures. It's been used by growers for more than 40 years, but work needs to be done to determine how best to utilize this control method. Gut and a group of entomologists released a research report on this subject (published in the January 2010 edition of the Proceedings of the National Academy of Sciences) that has brought a more specific direction and focus on mating disruption.

"In our mating disruption research, we've found that an 'attract and kill' tactic may be more effective than the traditional pheromone mating disruption for some tree fruit pests, which just disrupts the mating process without actually killing the tree fruit pest," Gut said. "Findings from our large-cage studies on how codling moth responds to sex pheromones have demonstrated that 'attract and kill' tactics reduce the number of visits per night to a pheromone source. This led us to develop our own disruption materials that are showing promise, for which we are working on getting patents."

Gut and his colleagues have also collaborated with a major agricultural producer of mating disruption materials to create automated dispensers so that the expensive, active ingredients in the dispensers are used judiciously. These modified dispensers have reduced costs to growers by 25 percent.

"Because of the research conducted and the information disseminated from our results, over a third of Michigan's 30,000 apple growers use pheromone mating disruption," Gut said. "This is the largest adoption of this control method by apple growers in any state except for California."

The project studies on reduced-risk and organophosphate-alternative chemicals for cherry orchards found that they worked well for pest control, but they cost 40 percent to 50 percent more than standard materials, and twice as many cherry fruit flies were captured in the reduced-risk orchard blocks.

"More than 30 kinds of insects and mites may need to be controlled in Michigan orchards in any given season." • LARRY GUT

Codling moth control programs evaluating two newly registered insecticides — rynaxypyr (reduced-risk) and flubendiamide (alternative) — found that they provided good fruit protection.

Gut added that, after reviewing what is working in the project, he and a large group of fellow entomologists are thinking about what they'd like to see happen with future fruit tree pest control.

"Our pie-in-the-sky research would be on efficient, solid-set canopy pesticide delivery systems," he said. "There would be built-in sets of nozzles in the trees, which could deliver smaller amounts of pesticide right to the tree, with no use of tractors. Good timing of pesticide delivery would help with the judicious use of these expensive chemicals. That's what we are seeing in our crystal ball." •

[Producing **Healthier Oil, Greener Fuel**]

As gas prices continue to fluctuate and more countries consider limiting their carbon emissions, discussion is increasing about ways to provide fuels that are not made from petroleum. University distinguished professor and MAES plant biologist John Ohlrogge has spent a good part of his career studying oilseed crops with a goal to eventually create products for the chemical industry, including plastics, polymers and oils.

"If we can create plants that produce more oil or oil with special properties, it gives everyone more options," he said. "Farmers can grow higher value crops, and manufacturers will have alternatives to crude oil."

For the past several years, MSU plant biology research associate Timothy Durrett and visiting plant biology professor Michael Pollard have been working with Ohlrogge to isolate a useful gene from the seeds of *Euonymus alatus* (commonly known as burning bush because it turns brilliant red in the fall).

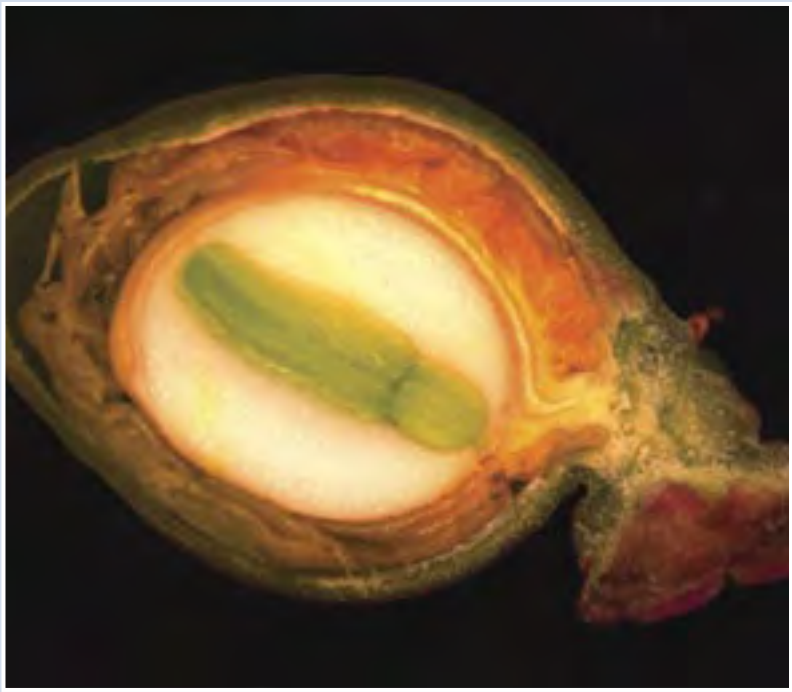


PHOTO: TIM DURRETT

In the developing fruit of a burning bush seed *(seed cutaway above)*, the white seed endosperm produces novel acetyl triacylglycerols or acTAGs, and the orange aril tissue around the seed produces normal vegetable oil.

"Dr. Pollard realized that the burning bush seeds produce an unusual oil that might have a number of valuable uses," Ohlrogge said. "The special component of these oils is a group of compounds called acetyl glycerides, or acTAGs. Though acTAGS are related to vegetable oils that are the basis of the world's oilseed industry, they have different characteristics — including lower viscosity (i.e., a thinner oil)."

Despite this special oil production, burning bush isn't a suitable oil crop, so the scientists set out to isolate a gene from burning bush that is responsible for the production of acTAGs.

Burning bush isn't a rare plant, so collecting the necessary samples was relatively easy — the researchers gathered their samples from plants on the MSU campus. Pollard first studied the biochemistry of the seeds to understand what type of enzyme was involved in this biosynthesis. With this information, Durrett used new DNA sequencing technology to identify the gene responsible for the plant's production of the novel, high-quality oil.

From the DNA information, Durrett was able to identify the correct gene. To prove that the gene could be used in other plants, he inserted the burning bush gene into *Arabidopsis* — common mustard weed and a cousin of canola – and succeeded in producing acTAGs in the seeds of the transgenic plants.

"The high viscosity of most plant oils prevents their direct use in diesel engines, so the oil must be chemically converted to biodiesel," Durrett said. "The lower viscosity acTAGs could possibly be used as a direct-use biofuel for some diesel engines. The acTAGs also are expected to perform better at low temperatures than regular vegetable oils, and that may also make them suitable for conversion into diesel fuel."

In addition to possible use as fuel, the acTAGs have potential in the food industry. Because acTAGs contain fewer calories than other vegetable oils, they may be able to be used as a reduced-calorie food oil.

Yet another potential use is in the production of polymers for the chemical industry. Soybean oil and other plant oils are increasingly used to produce plastics such as polyurethane. The acTAG structure can be used to influence the type of polymerization that occurs with plant oils and therefore expand the range of products available to the chemical industry.

Durrett is now working to boost the amount of acTAGs produced by the modified *Arabidopsis*. Purity levels have been as high as 70 percent. Additionally, the gene has been introduced into other oil-producing crops.

"If we can create plants that produce more oil or oil with special properties, it gives everyone more options." • JOHN OHLROGGE

"It should now be possible to produce acTAGs in transgenic oilseed crops or single-cell production systems such as algae, which are the focus of much current effort in biofuels research," said Pollard, who is keen to explore the technology's commercial potential. "With the basic genetics defined and thus one major technical risk greatly reduced, the way is open to produce and assess this novel oil in food and nonfood applications." ●

[Harvesting Fuel at the Smallest Scale]

MAES chemical engineer Mark Worden studies some of the smallest organisms, working to refine them to help produce high-value bioproducts.

Researchers at the Massachusetts Institute of Technology (MIT) tapped Worden's bioreactor expertise and asked him to be part of a team working to exploit a bacterium's potential to produce a type of butanol that can be used as an automobile fuel. The group is working to build a reactor system for *Ralstonia eutropha*, a common soil bacterium that the scientists aim to engineer to metabolize hydrogen and carbon dioxide to produce isobutanol, a fuel that can be used as a replacement for gasoline.

This endeavor constitutes the first research aimed at redirecting the bacterium's metabolism to convert this "green" gas mixture into the automotive fuel isobutanol.

"*Ralstonia eutropha* has been used industrially to produce biodegradable plastics from sugars," Worden said. "However, because sugars can also be used for food, scientists are taking advantage of this microbe's ability to grow on other, non-food, renewable feedstocks — thus negating the food versus fuel debate. For example, *Ralstonia* can produce products from a gas mixture containing carbon dioxide — a waste greenhouse gas — and hydrogen and oxygen, which can be produced by splitting water."

Anthony Sinskey, MIT professor of biology, leads the genetic engineering team.

"The ultimate goal of this project is to accelerate innovation in clean energy technologies, increasing America's competitiveness and creating jobs." • MARK WORDEN

"The MIT group is focused on the biology of the bacterium and engineering it to produce isobutanol," Worden explained. "Early this spring, the group members realized they needed a bioreactor expert, and I was asked to be a collaborator. My role is to build a reactor system at Michigan State University for this unique fermentation system."

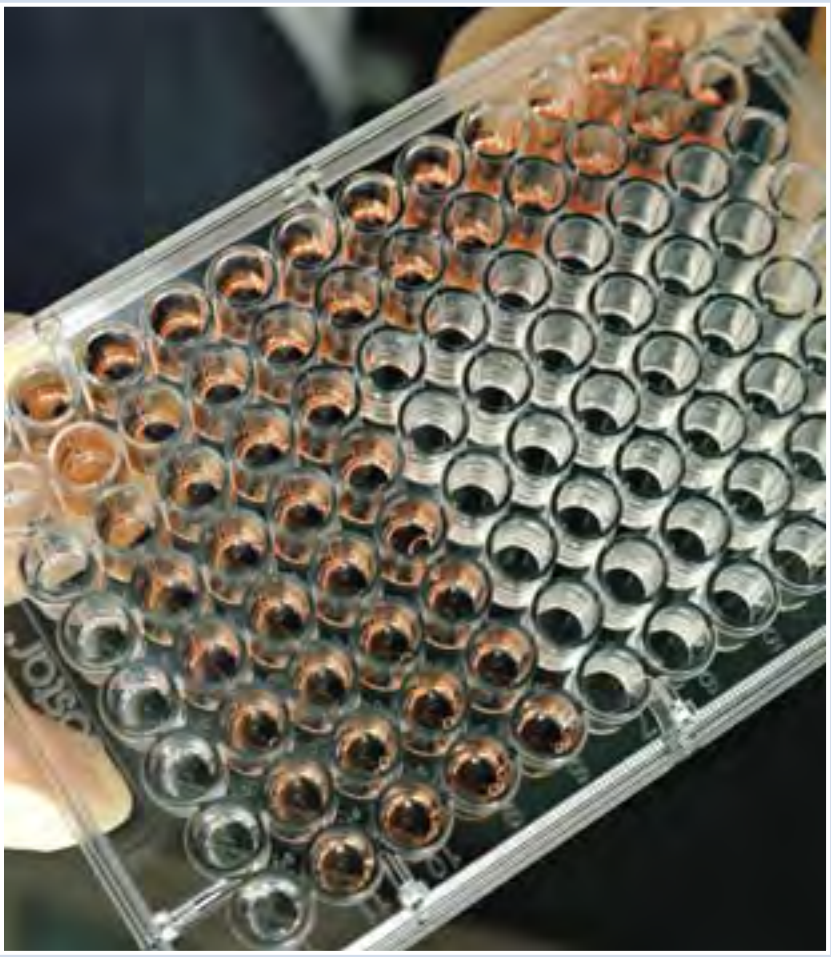


PHOTO: HARLEY SEELEY

As isobutanol is created, it can be lethal to the bacterium producing it. Microwell plates *(above)* are used to periodically collect samples that are then run through a "reader" to see how the bacterium is faring.

Innovative bioreactor designs are being explored to simultaneously increase efficiency and safety.

Worden has to overcome two major challenges in developing the bioreactor system. Once *Ralstonia eutropha* is engineered to produce isobutanol, the isobutanol eventually will build up to a toxic level and kill the bacterium. So he must create a way to "harvest" the isobutanol without interrupting the fermentation process. Secondly, because the bacterium's energy source — hydrogen gas — is not very water-soluble, Worden must figure out how to feed it to the bacterium in a water-based system.

"We also have to make sure the bioreactor system is safe," Worden said. "The *Ralstonia* cells need a little bit of oxygen to grow, but hydrogen and oxygen together are flammable, so you have to be careful that you don't end up with the wrong hydrogen-oxygen ratio. We don't want a mini-Hindenberg incident, so we need to figure out how the two gases can co-exist in the system and minimize any risk of explosion."

Worden is developing plans to build the bioreactor and is watching as his collaborators work to engineer the bacterium.

"Carbon dioxide is a greenhouse gas produced by combustion of fossil fuels and even some fermentations that make biobased products," Worden said. "The proposed process offers the simultaneous benefits of consuming carbon dioxide and producing a liquid fuel that could be directly substituted for gasoline."

Isobutanol offers distinct advantages over ethanol as an automotive fuel because it can be used as a direct substitute for gasoline in today's automotive engines; ethanol is typically mixed into gasoline in small proportions.

"Isobutanol has a high energy content — about 85 percent that of gasoline — is an oxygenate to help reduce emissions, has a relatively low volatility to reduce evaporative losses, and has a low tendency to retain water so it can be easily transported and stored," Worden said.

"The ultimate goal of this project is to accelerate innovation in clean energy technologies, increasing America's competitiveness and creating jobs." •

secure food and fiber systems

Sustaining a safe, secure food and fiber system and keeping people and animals healthy make up a large and important part of the Michigan Agricultural Experiment Station (MAES) mission.

In research initiatives ranging from effectively managing forest and Great Lakes fisheries resources to improving the health and well-being of swine, cattle and poultry, MAES researchers continually discover new and better ways to help protect and enhance our food and fiber supply and improve human and animal welfare. This section features some of the significant research being done in this area.

[Managing **Sustainable Forests** in **Michigan**]

PHOTO: SUSAN SPAULDING

The jack pine ecosystem is characterized by dense stands of relatively young trees interspersed with small grasses and shrubs. All the vegetation is generally dry and sparse, making it susceptible to fire.

When a forest fire swept through Michigan's Crawford County near Grayling in May 2010, MAES forestry researcher David Rothstein could not believe the unforeseen opportunity it provided. Rothstein studies the effects of fire on carbon cycling in forests, particularly jack pine forests in northern Lower Michigan. His work is contributing to knowledge about the effects of fire on ecosystem carbon balance, as well as providing tools to agencies for the sustainable management of forests in Michigan.

"The fire made a direct hit on a previous study site where we had done all kinds of measurements on carbon and nutrient cycling, so in the summer we went back to resample," Rothstein said. "We hope to get a much better idea of how much carbon is lost to the atmosphere because of fire, as well as a better understanding of short-term fluxes following fire. Ideally, it will follow the predictions of our original research. This is a great opportunity to test our knowledge about how carbon changes with time."

In 2002, using space-for-time substitutions, Rothstein predicted that jack pine ecosystems are a source of carbon to the atmosphere for seven to 10 years following a stand-replacing wildfire. As the forest grows, it transitions to a strong carbon sink or storage reservoir and absorbs carbon for the next 20 to 30 years. After this, the forest maintains a rough equilibrium with carbon in the atmosphere. All of this is important because carbon dioxide is a greenhouse gas that, through its concentration in the atmosphere, helps regulate the temperature of the planet.

Rothstein considers the jack pine forests of northern Lower Michigan to be a great natural laboratory for studying the dynamics of carbon and nutrient cycling following major disturbance.

"I have never encountered a place like this," Rothstein said. "The soils are quite uniform because of the glacial history; jack pines are all that grows here, and there are lots of fires, all the time. The result is about as close to a controlled experiment as you can get in fire ecology research."

The dynamics of these particular forests are also important because they are the primary nesting habitat for the federally endangered Kirtland's warbler. The bird likes to nest in the mixed vegetation of grasses and shrubs below the living branches of jack pines. Until recently, the Kirtland's warbler nested only in the jack pine forests of northern Lower Michigan, but conservation efforts have helped to increase the bird's nesting in jack pine forests in the Upper Peninsula and in parts of Wisconsin.

Historically, fire was the most important disturbance agent for regenerating jack pines. Jack pines do not grow in the shade, and without a major disturbance to create sunlit areas for young

"We hope to get a much better idea of how much carbon is lost to the atmosphere because of fire, as well as a better understanding of short-term fluxes following fire." • DAVID ROTHSTEIN

jack pines to regenerate, more shade-tolerant species soon dominate the forests. Today, large portions of Michigan's jack pine forests are managed as plantations. The trees are harvested and used for pulp and paper, and then the clear-cut area is replanted with jack pines. The Michigan Department of Natural Resources and Environment (DNRE) is involved in the management of the plantations, and Rothstein communicates with DNRE staff members about areas where current management does or does not mimic the natural dynamics.

"We are doing a lot of comparative studies that show the natural dynamics of the systems and how they compare to the plantations," Rothstein said. "Clear-cutting is the best available tool for managing jack pines in the absence of fire, but traditional harvest practices fail to mimic many important structural features associated with forests regenerated by wildfire."

In the future, Rothstein hopes to study the potential effects of climate change on jack pine ecosystems.

"Now that we have a good understanding of the dynamics of this system, we want to investigate whether we can use what we know to predict what will happen to the growth and regeneration of jack pine forests under future climate scenarios," Rothstein said. "Jack pine forests in northern Lower Michigan are at the southern limit of the species' range, so we would expect some shift northward if the overall climate is warming. The question is whether other species, such as oaks, will come to dominate areas currently occupied by jack pines." ●

[Angling for **Optimum Fish Populations**]

The Great Lakes are one of the most productive fisheries in the United States, providing commercial fishers and recreational anglers with livelihoods and leisure time pleasure. According to Michigan Department of Natural Resources and Environment (DNRE) data, an estimated 1.2 million licensed anglers fished 6.9 million days on the Great Lakes in 2009. The economic impact of recreational fishing in Michigan is well over $1 billion annually.

The success of these fisheries is driven, in large part, by an effective fish stocking program. Every year, about 12 million salmon and trout are released into Lake Michigan waters alone.

To help determine how best to manage fish populations in the Great Lakes, MAES fisheries and wildlife scientists Mike Jones and Jim Bence are leading an initiative to provide guidance on the methods for assessing and managing the largest recreational and commercial fisheries in the Great Lakes — salmon, lake trout, lake whitefish, perch and walleye — and to manage a key pest species, the sea lamprey.

"Keeping the fisheries in these waters adequately stocked is tricky business," said Jones, who is also co-director (along with Bence) of the Quantitative Fisheries Center (QFC) at MSU. "Great Lakes fishery management agencies are often faced with making tough decisions about how many fish to stock. If too many are planted, the fish run out of food and survival rates plummet. If too few fish are stocked, opportunities for anglers are decreased."

The overarching goal of this project is to assist such fishery management agencies as the Michigan DNRE, the Great Lakes Fishery Commission and the Chippewa-Ottawa Resource Authority in finding better ways to assess fish stocks and make more informed management decisions.

"We're faced with all sorts of questions — 'how many fish to harvest,' 'how many hatchery fish to plant and where,' 'how many offspring will be produced,' and 'will climate affect them'," said Jones. "It's really hard to count fish."

To answer these questions, Jones and about 20 other MSU students and faculty members must first analyze multiple sets of

PHOTO: DAVE KENYON

Improved population assessment models will help fishery management agencies keep the Great Lakes fisheries adequately stocked.

data to determine survival rates, feeding patterns and reproduction rates. These data are then used to build computer models for each species' populations. "What if" questions are then fed into the models, which, in turn, predict what will happen on the basis of the questions asked.

"For example," Jones explained, "for yellow perch in Lake Michigan, our decision model simulation results essentially suggest that the current approach [in which constant fishing regulations lead to a constant low proportion of the stock being harvested] provides reasonable benefits given the difficulties of implementing a more complex management approach. On the other hand, our model simulation results for lake whitefish and trout in 1836 treaty waters showed that changes to stock assessment models and the handling of input data would improve population assessment models for these fisheries."

"It's an ongoing partnership," Bence added. "They monitor the stocks, we build and apply the models, and they use the results to make better decisions."

"It's an ongoing partnership. They monitor the stocks, we build and apply the models, and they use the results to make better decisions." • JIM BENCE

Simulation modeling is also being applied to compare options in another important fisheries management area — sea lamprey control.

"Cost-effective suppression of this potentially devastating pest species is a cornerstone of Great Lakes fishery management," Jones said. "Without sea lamprey control, there would be no salmon fishery in Lake Michigan. Our models help the Great Lakes Fishery Commission decide how best to allocate scarce resources to control this destructive invasive species."

"The results of these simulation models are used to advise decision makers in the fishery management community about the risks associated with their decisions," Bence said. "Then they decide how much risk they are willing to take."

Although improved fishery management approaches and properly managed risk will benefit the Great Lakes fisheries, Jones is mindful that Mother Nature still has the upper hand.

"One lesson I've learned in doing this work is that nature has a lot more influence in what happens to fish populations than humans do," he said. "There's a tendency in my field to look at how things have gone wrong and blame it on decision makers. The truth of the matter is that, when we start to look carefully, many of the most important factors are ones over which we have little control." ●

PHOTO: ALDA PIRES

Enteric diseases are among the most economically significant diseases affecting swine and other food-producing animals.

[Tackling **Disease** from the **Inside Out**]

Diarrhea. Almost everyone gets it at some time, and almost no one wants to talk about it.

It may not make for polite conversation, but diarrheal illness is a serious health problem in the United States and the world. "Bad" food is often the culprit. Each year, food-borne pathogens cause an estimated 76 million illnesses, 325,000 hospitalizations and 5,000 deaths in the United States alone, according to U.S. Department of Agriculture Economics Research Service data.

This data also shows that five food-borne pathogens — *Campylobacter* (all serotypes), *Salmonella* (nontyphoidal), *E. coli* O157, *E. coli* non-O157 STEC and *Listeria monocytogenes* — account for about $6.9 billion per year in medical costs, productivity losses and costs of premature deaths in the United States, not to mention the staggering costs — both economic and reputational — to food producers.

To address this serious problem, MAES large animal clinical sciences researcher Linda Mansfield is part of a multi-institutional effort involving more than 30 scientists in experiment stations at nine universities. They're working to improve food safety by preventing and controlling enteric (intestinal) diseases in swine and cattle.

"You can improve food safety by intervening at several critical points," Mansfield said. "There's been a lot of emphasis on postharvest food safety, but eliminating or reducing the pathogen threat before products leave the farm improves safety even further. To do that, you need to know your enemy."

Campylobacter jejuni, one of the most prevalent bacteria that cause gastrointestinal disease in the United States, is one of several pathogens that Mansfield and her collaborators are investigating. It is carried by poultry, cattle and swine, and it can be transmitted to people through meat and milk. The illness it produces is distinctly unpleasant — vomiting and diarrhea that

can progress to bloody diarrhea that lasts for seven to 10 days. Infection with *Campylobacter jejuni* has also been linked to cancer of the digestive tract and to development of autoimmune diseases such as Guillain-Barré syndrome, Miller Fisher syndrome and reactive arthritis. People can die from these autoimmune diseases or be left with lameness or paralysis.

"Right now, little is known about how *Campylobacter* causes disease in humans and animals, and there are few genetic tools for these studies," Mansfield said. "Thus, it has been difficult to develop vaccines for people or animals. And it's tricky. For example, if you don't know how *Campylobacter* causes autoimmune disease, a vaccine may actually induce it."

Mansfield's Comparative Enteric Diseases Laboratory at Michigan State University has developed a mouse model that is being used to study the genetics of *C. jejuni*.

"These mice act as surrogate human patients to help us understand how this bacterium causes disease," she explained. "We're also using them to test treatments and vaccines to prevent *Campylobacter* infections. Screening a large panel of *C. jejuni* strains in these mice has allowed us to recognize that the genetic makeup of the bacterium — and of the human or animal — determines whether the outcome is mild or severe diarrheal disease. We have also used these mice to show that particular strains of *C. jejuni* cause autoimmune disease and others do not. Collectively, this research will allow us to decide which strains are important to control."

Mansfield and her fellow researchers classified the strains into categories, called pathotypes, on the basis of the disease they cause. Working with Michael Konkel at Washington State University and Gireesh Rajashekara at Ohio State University, she is identifying the *C. jejuni* virulence factors that are most important in producing severe diseases in humans.

"There's been a lot of emphasis on postharvest food safety, but eliminating or reducing the pathogen threat before products leave the farm improves safety even further. To do that, you need to know your enemy." • LINDA MANSFIELD

"The ultimate goal is to rid food animals of this bacterium to prevent further transfer to people," she said.

C. jejuni is just one of the pathogens being investigated by the research group. Together, the researchers aim to significantly improve the detection of novel or emerging causes of enteric diseases; develop interventions and preventive measures that reduce the incidence of enteric infections of cattle and swine; and provide training and dissemination of information to students, producers, veterinarians and diagnostic laboratories.

"We are among the few people who actually like talking about diarrhea," Mansfield said. "And it's important that we don't talk just to ourselves. The more we know about these pathogens — especially the ones that are the real menace — the more misery we can help prevent." ●

[Finding the **Answers** to **Tough Animal Welfare Questions**]

As voters across the country contemplate ballot initiatives calling for changes in livestock housing practices to allow animals to more easily express natural behaviors, MAES animal scientists and engineers are spearheading projects that will collect data that constituents can consider before casting their votes. Results derived from this research will be precedent-founding — for the first time, decisions can be made on the basis of facts instead of theory or emotion.

"For us to be able to design non-cage systems that really benefit or improve life for these birds, we must first understand how these housing systems affect their behavior and health on an individual basis." • JANICE SIEGFORD

MAES animal scientist Janice Siegford is the lead investigator of a research team that's using wireless sensors to monitor the health and well-being of egg-laying chickens in non-cage environments. Studies are centered on how chickens use space and resources such as nesting boxes and perches when their movement is not restricted by cages.

Siegford explains that the sensors will allow researchers to track individual birds and determine what behaviors they are expressing so that they won't be basing all decisions on the activities of the group.

"How can I follow one bird visually if she is housed in a flock with hundreds or thousands of other birds?" she said. "I really can't do it. If we really want to know what's going on for birds and guarantee that what we're doing is in the bird's best interest, we have to know at the level of the bird, not just the level of the group.

"If we're pushing to change housing systems for hens to enriched cages or open aviaries for reasons of animal welfare but we can't monitor birds at the individual level," she continued, "we're making decisions before we know how the individual birds are affected. Our decisions may have negative consequences."

The sensor, which weighs less than 1 ounce, is mounted on the chicken's back. It tracks the hen's activity, from her movement with respect to other hens to roosting to eating or drinking to laying an egg or using a nesting box. The data will serve as a scientific basis for determining the resources and space allocations that chickens need and can be used to design non-cage systems for laying hens that provide the best possible animal welfare for the animals.

"Having hens live in a non-cage environment may seem to be the perfectly natural setting, but if a non-cage system is poorly designed, it can lead to health problems, feather pecking and cannibalism — all natural behaviors in hens," Siegford said. "For us to be able to design non-cage systems that really benefit or improve life for these birds, we must first understand how these housing systems affect their behavior and health on an individual basis."

Although researchers are still perfecting sensor programming and adapting the technology for use in commercial settings, the long-term goal of this research is to improve the design of non-cage housing systems. Siegford said the bottom line is conducting the animal welfare research.

PHOTO: KRISTA BEEKER

A new wireless, wearable sensor *(above)* is being tested by researchers to determine its effectiveness in monitoring the welfare of egg-laying chickens in non-cage environments.

"Our assessments are not production- or economic-driven but bird-driven," she said. "It's great if consumers and producers can use the information we develop, but our real hope is that the birds can benefit because we've acquired a true understanding of hen behavior and where problems exist, and how they can be corrected." ●

families and community vitality

Healthy, vital communities with an active citizenry are well-equipped to address the challenges facing many of today's families.

From research that addresses the challenges of domestic violence, childhood obesity, adolescent smoking and family dynamics to the more global issues of protecting populations from diseases such as cancer, asthma and insect-borne diseases such sleeping sickness, MAES scientists are helping people cope, learn and make healthy choices. The projects highlighted in this section are just a sample of the work being done in this priority area that benefits both Michigan residents and people worldwide.

[Strengthening 24/7 **Tobacco-free Schools Policy**]

PHOTO: STACEY_NEWMAN VIA ISTOCKPHOTO

Although Michigan has had a 24/7 tobacco-free school policy for five years, many Michigan public schools either have not adopted or do not enforce the policy.

Each day about 1,000 people younger than 18 years of age begin smoking on a daily basis. That's a statistic from the Centers for Disease Control (CDC) that Hye-Jin Paek would like to change.

Paek is an MAES researcher who specializes in mass communication with a focus on health. She has researched the role that the media plays in an individual's health and has traced tobacco marketing targeting youth and the effectiveness of anti-smoking campaigns on adolescent smoking.

As a part of her five-year project on the impact of tobacco-free school policy on adolescent smoking, Paek has worked on a pilot program to establish and sustain a state team to address school-based youth tobacco prevention programs and increase the adoption and enforcement of 24/7 tobacco-free school policies in Michigan's public schools. The state team is made up of representatives from the Michigan Department of Community Health, the Michigan Association of School Administrators, the Michigan Association of School Boards, the Michigan Public Health Institute and the Michigan Department of Education.

Adopted by the Michigan Board of Education in 2005, the 24/7 Tobacco-free School Policy recommends that schools institute policies that prohibit all tobacco use in all school-related situations 24 hours per day, seven days per week.

"It involves everyone — students, teachers, parents and staff members — and it's on- and off-campus, and not just during the school day but for all the events," Paek said.

As a first step in the project — with technical assistance from the CDC and the National School Board Association — Paek and the state team conducted a survey among Michigan public schools. Of the 144 schools responding, 20.8 percent indicated that they had a comprehensive 24/7 tobacco-free policy. However, the vast majority — 66 percent — have a tobacco-free policy only for the school property.

"It was also clear that many schools do not understand the 24/7 policy," Paek said. "The whole point of the policy is to provide more extensive tobacco-free environments that will help with prevention, smoking cessation and second-hand smoke."

Paek's media-related research is helping the team understand all the environments affecting student smoking.

"Advertising is another environment," she said. "It's different from home, school or friends, but together, all four are major socialization environments. They help youth form attitudes, beliefs and even behaviors."

One of Paek's recently published research studies involves a content analysis of images of smoking and sex, also referred to as smoking fetishes, on YouTube.

"Despite the continued criticism of and regulatory efforts against smoking, pro-smoking messages are prevalent on the Internet," Paek said. "There is concern about the potential

"The whole point of the policy is to provide more extensive tobacco-free environments that will help with prevention, smoking cessation and second-hand smoke." • HYE-JIN PAEK

impact because adolescents make up the largest portion of Internet users. More research and monitoring efforts are needed to further assess smoking-related content online."

Some changes related to smoking-related environments were unforeseen. For one, problems of new tobacco products emerged, such as e-cigarettes. E-cigarettes, or electronic cigarettes, are battery-powered devices that provide inhaled doses of nicotine, but no smoke or combustion is involved in their operation.

"There is no evidence about how harmful or less harmful they are," Paek said. "I, along with the state team, will address these emerging products in the project."

In the spring of 2010, Michigan banned smoking in public places, including restaurants. Paek sees this as a positive change that could have an impact on the 24/7 tobacco-free school policies.

The next step in the project is to use smoking data at school and individual levels — available through the CDC and the Michigan Department of Community Health — to test how school-level tobacco policy affects individuals' smoking behavior.

Paek is also preparing a grant proposal with the Michigan team to do a school intervention project that will allow her to determine what kinds of policies are most effective and what types of smoking issues need to be addressed.

"We want to be able to provide schools with the information they need to create more effective tobacco-free environments and to understand why it's important," she said. •

[**Mapping** the Cause of **Tropical Disease** Improves **Lives**]

MAES geographer Joseph Messina calls it a eureka project — a wow!

Messina, who specializes in disease ecology, land use modeling and spatial sciences, and an interdisciplinary team of MSU researchers developed ecological modeling and control strategies for African trypanosomiasis in Kenya.

"We came up with results that can make a difference in people's lives," he said. "This is something that we could immediately expand over all of East Africa and eventually into southern and West Africa. The science behind it is much more cost effective than any other protocol that people have come up with."

African trypanosomiasis, or sleeping sickness, is spread by tsetse flies and occurs in both humans and livestock.

"It is a neglected tropical disease and is lethal if left untreated," Messina said. "Even the treatments are risky."

In regions where the disease is present, livestock productivity decreases substantially, costing livestock producers and consumers in sub-Saharan Africa an estimated $4.5 billion annually, according to the Food and Agriculture Organization of the United Nations. Efforts to control the disease have been hampered by a lack of information about where the flies are and the high costs associated with controlling infested areas.

A workshop that discussed various diseases in Africa that needed solutions inspired Messina.

"It dawned on me at this workshop that the sleeping sickness disease system needs to be viewed from a geographic perspective because the flies move around," he said. "The flies don't stay in one spot; the livestock don't stay in one spot. Everything is dynamic. Geography brings a new set of tools to bear on those kinds of problems."

Although sleeping sickness is a problem in most of Africa, Messina chose to work first in Kenya because the country is relatively developed and has a history of research and established partners who could collaborate on the project. In addition, tsetse flies are estimated to inhabit more than a third of Kenya, and climate change and human activities have

PHOTO: JOSEPH MESSINA

The tsetse fly is a large biting fly found only in Africa. It transmits sleeping sickness to humans and nagana (sleeping disease occurring in animals) to livestock through its saliva.

modified the environment for tsetse flies in ways that current ecological models fail to capture.

Messina and the other researchers constructed the tsetse ecological distribution model using many new technologies, such as satellite-based imagery, remote sensing and spatial models. These data were combined in a dynamic simulation model that predicts fly movement in space and time.

"We did not have the technology or the data to do this 10 years ago," Messina said. "The old maps predicted where the tsetse flies might be. We are able to predict where they are every 16 days over the whole country."

Messina hopes to effectively marry climate projections with the spatial simulation modules, and then predict where the tsetse flies will be before they ever get there.

"We can put the traps in place before the first fly ever shows up and kill off an epidemic before it happens," he said.

Part of the success of the project is four weather stations located in strategic locations in the Great Rift Valley of southern Kenya. The stations give information on the moisture content of the soil as well as minimum and maximum temperatures. This helps to localize the information and provides more specifics about where the tsetse flies may be.

"The weather stations are making a difference in the project," Messina said.

The reason that Messina is so interested in expanding the project to other countries is that the 37 sub-Saharan African countries infested with tsetse flies are home to about 70 million people with exposure risk.

Though all of this is happening in a faraway place, Messina believes the project has value for Americans, especially from a national security standpoint.

"Unrest in many locations is often the product of food or economic instabilities." He said. "If we can reduce one source of the instabilities by wiping out or reducing sleeping sickness, the people are going to do better. They can sell that cow and have better lives, instead of losing the animal or their own lives to the disease. If we are successful, we are going to see a meaningful, measurable improvement in the lives of the poorest people of Africa, and it also will bring improvements in economic stability to these countries." ●

"We can put the traps in place before the first fly ever shows up and kill off an epidemic before it happens." ● JOSEPH MESSINA

PHOTO: ALCHEMIST-HP VIA WIKIMEDIA COMMONS

Elemental cobalt *(above)* is a hard, silvery-gray metal that is used in the production of steel and alloys, especially "superalloys" used in jet engines, and in magnetic materials used for various electronic applications.

Beautiful vistas aren't the only thing that can take your breath away. Air pollution is a critical factor in the development and exacerbation of lung-related diseases, including asthma and chronic obstructive pulmonary disease. In addition to the usual culprits —ozone, automobile exhaust and cigarette smoke — metallic dust is among the potentially harmful pollution components that are linked to lung disease progression.

One metal that is of concern is cobalt, which is primarily used in the production of high-strength alloys and batteries. Workers in these industries are prone to inflammatory lung diseases as a result of inhaling cobalt dust. Cobalt is also released into the environment in the form of fine particulates as a byproduct of coal-burning power plants.

Cobalt exerts numerous biological effects, including mimicking hypoxia. Hypoxia is a condition in which the amount of oxygen reaching the organs and tissues of the body is deficient. Like hypoxia, cobalt exposure results in the activation of a family of proteins — hypoxia-inducible factors (HIFs) — that regulate our bodies' ability to adapt to low oxygen states that occur during natural and disease processes.

Although evidence is growing that hypoxia is an important modulator of the inflammatory process, the role that HIFs play in natural immunity and infection responses remains unclear.

MAES biochemistry and molecular biology scientist John LaPres is conducting research to piece together how environmental metals, such as cobalt, affect biological systems by altering HIF activity.

"Approximately 34 million Americans have been diagnosed with asthma alone, and expenditures for healthcare and lost productivity due to the disease are estimated at $20 billion

annually," LaPres said. "Understanding the causes and progression of air allergy-based disease is, therefore, important to our national health."

Using a mouse model, LaPres' laboratory conducted experiments to test the hypothesis that HIF protects the lungs from cobalt-induced toxicity.

"Very surprisingly, HIF didn't protect at all," LaPres said. "What actually happened is that mice with a compromised or decreased HIF signaling cascade actually switched from what we consider a classic response to metal-induced injury to one that was asthma-like. What these findings suggest is that your genetic makeup — for example, how much or what type of HIF you have, or whether your HIF was stimulated as a child — can alter your adult response to allergens, such as metals."

The idea about developmental exposure to allergens has been around for quite some time, LaPres noted. Dubbed the hygiene hypothesis, it posits that the increase in the prevalence of asthma and other allergy-based diseases over the past several decades is associated, to a significant extent, with how sterile our living environments have become, especially in the United States. According to the Centers for Disease Control, the prevalence of asthma alone increased 75 percent from 1980 to 1994, and asthma rates in children under the age of five increased more than 160 percent for the same period.

"People live in clean, airtight houses for energy efficiency; they don't have pollen or other air allergens blowing through their houses, so kids aren't being exposed to them," he said. "Their immune system doesn't get challenged early, so it doesn't develop an adequate immune response to these constituents."

LaPres added that asthma and other allergy-based diseases are costly, not just from an economic standpoint but physically and psychologically as well — especially for youth.

"Understanding the causes and progression of air allergy-based disease is . . . important to our national health." • JOHN LAPRES

"My daughter, who plays soccer and runs cross country, has asthma," he said. "She used to get really scared on the field and at meets before we figured out what was wrong with her breathing," he said. "It's not just a physical thing for kids, it's a mental thing. If we can get the information to parents or to the children themselves so that they understand what's going on, we can help them better prepare for these allergy-based diseases if they get them."

Although LaPres concedes that treatment and interventions are a little down the road, he believes that this work could ultimately provide a test to understand who is going to be susceptible to asthma and other allergy-based lung diseases.

"In the meantime," he said, "every researcher's goal at MSU and in our department is to contribute to the greater good. In the short term, I'm in it for the puzzle — that's what keeps me up nights." •

[Building a Better Mousetrap for Cancer Prevention]

When "smoke" gets in your eyes — or your lungs — it's not always the result of a lit cigarette. Another type of air pollution, known as particulate matter, not only contributes to smog-filled skies but, at elevated levels, is associated with increased risk of lung cancer.

Particulate matter is a complex mixture of elements that consist primarily of combustion products derived from automobiles; the burning of coal, fuel, oil and wood; and metal refineries. Many adverse health effects have been attributed to this group of air pollutants because of its ability to travel deep into the lungs.

Although an epidemiological association between particulate air pollution and lung cancer has been made, the specific components contributing to increased risk for the disease by particulate matter remain unclear.

To better illuminate this murky area, MAES pathobiology and diagnostic investigation scientist Alison Bauer and Elizabeth Rondini, a post-doctoral fellow in Bauer's lab, studied the influence of genetics on susceptibility to particulate matter-induced inflammation and the possibility that certain components of particulate matter function as tumor promoters in cancer development.

"Lung cancer is the leading cause of cancer mortality in the United States and worldwide," Bauer said. "Almost 163,000 people in the United States and 1.3 million people worldwide die of lung cancer each year. Although cigarette smoke is the main risk factor for lung cancer development, approximately 10 to 15 percent of cases occur in never-smokers, implicating other important environmental, occupational and/or genetic factors."

One compound that is of concern is vanadium pentoxide, a metal oxide used primarily as an alloy additive to iron and steel. Vanadium pentoxide is released into the environment in the form of fine particulates as a byproduct of the petrochemical, mining and steel industries. Adverse respiratory effects have been reported in humans, primates and rodents exposed acutely to vanadium pentoxide.

In a National Toxicology Program study in the early 2000s, continuous inhalation of vanadium pentoxide over 24 months resulted in a significant increase in the incidence of lung tumors in mice.

"Although the study demonstrated the cancer-causing potential of vanadium pentoxide, long-term continuous exposure was required before tumors developed, and no dose response was observed," Bauer said. "Additionally, only one mouse strain was used. We wanted to look more at the genetics of different

PHOTO: LAGEREEK VIA ISTOCKPHOTO

Elevated levels of air pollution are associated with increased risk of lung cancer.

"Understanding how to intervene in or control carcinogenesis and other disease processes is very important." • ALISON BAUER

strains to see if there were varied responses to vanadium pentoxide exposure because what we know from short-term experiments is that strains matter enormously."

Bauer's laboratory looked at three strains of mice, each with different levels of susceptibility — sensitive, intermediate and resistant — and did a comparison of early events (e.g., inflammation) and tumor events later on to see if there was a correlation.

"Did we prove conclusively that particles could induce enough inflammation to elicit promotion? No," Bauer said. "But our results demonstrate that the sensitive strain had highly significant amounts of inflammation and other early signaling events in response to vanadium pentoxide, and that appeared to correlate to higher numbers of tumors in our counts."

Bauer noted that, although many people consider lung cancer a lifestyle choice-related disease, up to 24,000 non-smokers in the United States and 195,000 non-smokers worldwide die from it each year.

"These numbers alone are astounding," she said. "My guess is that people aren't aware of these kinds of numbers."

Bauer added that environmental toxicants such as vanadium pentoxide could potentially increase cancer risk for smokers as well. However, it is unlikely that only one kind of particle or pollutant is contributing to this effect.

"I don't think it can be said that, if a person is smoking and living in a polluted area, the pollution couldn't contribute to cancer development," she said. "Certainly, smoking is likely why the person gets cancer, but my argument would be that perhaps the particles are helping to promote and advance the disease even further. We just don't know. That's the kind of question that we would eventually like to address in our research."

Because tumor promotion involves changes in gene expression and is the only reversible stage of cancer development, Bauer contends that studying promoters such as vanadium pentoxide and other particulate matter constituents may identify additional pathways to target for preventive strategies against human lung cancer.

"Understanding how to intervene in or control carcinogenesis and other disease processes is very important," she said. "Investing more research dollars to find the answers to some of these critical questions will ultimately help us all breathe easier." •

[Michigan Agricultural Experiment Station]

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9302 Portland Road
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Phone: 616-693-2193
Farm Manager: Jerry Skeltis

2. DUNBAR FOREST EXPERIMENT STATION

12839 S. Scenic Drive
Rt. 1, Box 179
Sault Ste. Marie, MI 49783
Phone: 906-632-3932
Non-resident Forester: Ray Miller

3. W. K. KELLOGG BIOLOGICAL STATION

3700 E. Gull Lake Drive
Hickory Corners, MI 49060
Phone: 269-671-5117
Assistant Director for Facilities and Operations: Phil Barry

4. W. K. KELLOGG EXPERIMENTAL FOREST

7060 N. 42nd Street
Augusta, MI 49012
Phone: 269-731-4597
Resident Forester: Greg Kowalewski

5. LAKE CITY EXPERIMENT STATION

5401 W. Jennings Road
Lake City, MI 49651
Phone: 231-839-4608
Farm Manager: Doug Carmichael

6. MONTCALM RESEARCH FARM

4747 McBride Road
Lakeview, MI 48850
Phone: 989-365-3473
Farm Manager: Bruce Sackett

7. MUCK SOILS RESEARCH FARM

9422 Herbison Road
Laingsburg, MI 48848
Phone: 517-641-4062
Farm Manager: Mitch Fabus

8. NORTHWEST MICHIGAN HORTICULTURAL RESEARCH STATION

6686 S. Center Highway
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Phone: 231-946-1510
Farm Manager: Bill Klein

9. FRED RUSS FOREST EXPERIMENT STATION

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Decatur, MI 49045
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10. SAGINAW VALLEY RESEARCH AND EXTENSION CENTER

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Farm Manager: Paul Horny

11. SOUTHWEST MICHIGAN RESEARCH AND EXTENSION CENTER

1791 Hillandale Road
Benton Harbor, MI 49022
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Farm Manager: Dave Francis

12. TREVOR NICHOLS RESEARCH COMPLEX

6237 124th Avenue
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Farm Manager: Matt Daly

13. UPPER PENINSULA EXPERIMENT STATION

P.O. Box 168
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Chatham, MI 49816
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Farm Manager: Paul Naasz

14. MSU FOREST BIOMASS INNOVATION CENTER

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Director: Charles J. Reid

[Publications and Resources]

MAES encompasses the work of nearly 400 scientists in six colleges at MSU: Agriculture and Natural Resources, Communication Arts and Sciences, Engineering, Natural Science, Social Science and Veterinary Medicine.

A general **MAES brochure** which outlines the mission of the MAES is available upon request by sending an **e-mail to: maesdir@msu.edu.**

The MAES field station brochure highlights each of the 15 field stations and their specific research. No matter their official names — experiment stations, research farms, complexes or experimental forests — all are part of a statewide network of campus laboratories and off-campus field station facilities that make up the MAES. In addition to agricultural production research, MAES scientists are investigating topics that range from alternative energy and biofuels production to childhood obesity, community development, environmental stewardship, food safety and the quality of life of Michigan youth and families.

This brochure is available upon request by sending an **e-mail to: maesdir@msu.edu.**

The 2010 MAES Annual Report provides brief narratives of some of this year's important, innovative research. The accomplishments and discoveries highlighted in this report demonstrate why the MAES continues to be one of the most successful agricultural experiment stations in the country.

Futures, published two times a year by the MAES, is available as a free subscription in the United States. *Futures* is written in non-scientific terms for the general public. Each issue profiles the work of several MAES scientists organized around a specific topic. Recent issues have focused on new research frontiers, economic development and food safety.

Research to Energize Michigan's Economic Development

Winter/Spring 2010

The MAES is a research engine that helps to power and energize the state's food, agricultural and natural resources industries. As they address issues facing these industries, MAES scientists are also creating new technologies and devices that can be licensed and brought to the marketplace by Michigan entrepreneurs. At the same time, MAES researchers are creating other tools specifically aimed at encouraging, teaching and supporting businesses as they start or expand. In this issue of *Futures*, you can read how the work of MAES researchers is aiding the state and its businesses as everyone works together to turn the economic tide.

Keeping Food Safe from Farm to Fork

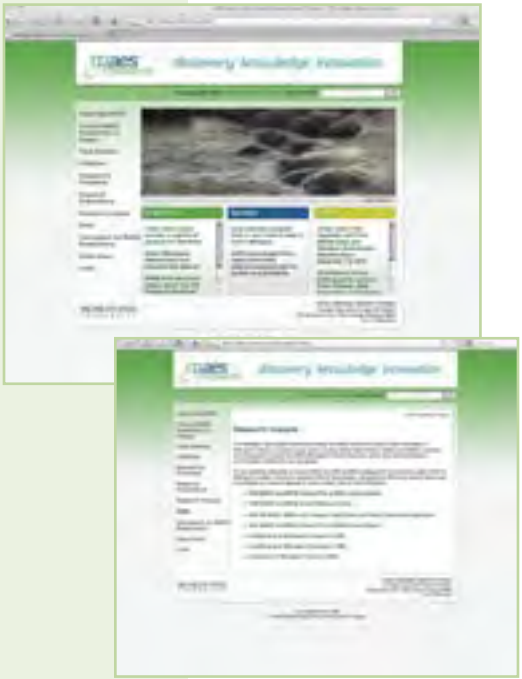
Summer/Fall 2010

Food safety is front page news. According to food safety experts, contaminated food outbreaks in the United States have more than tripled since the early 1990s, from 100 per year to more than 350 annually, and an estimated one in four Americans suffers from food-borne illness each year. Globalization of the food supply chain, new disease agents, outdated laws, changes in the U.S. population and new dietary patterns present significant challenges to our food safety system. In this issue of *Futures*, you can read about innovative research being done by MAES scientists — some of the country's leading food safety experts — and one-of-a-kind facilities and lab equipment available on campus that are helping to keep your food safe as it travels from farm fields to your table.

[Publications and Resources CONTINUED]

The monthly **MAES eNewsletter** is an electronic newsletter that highlights all of the latest accomplishments and discoveries by MAES scientists. If you would like to receive the MAES eNewsletter, please send an **e-mail to: maesdir@msu.edu.**

Ever wonder what MAES is doing in your area? Sign on to **www.maes.msu.edu** and click on **video news** to learn about tart cherry research, beet and bean research, planting and harvesting techniques and biofuels. Each field station video clip provides an in-depth look at the research being done at that location.



WWW.MAES.MSU.EDU

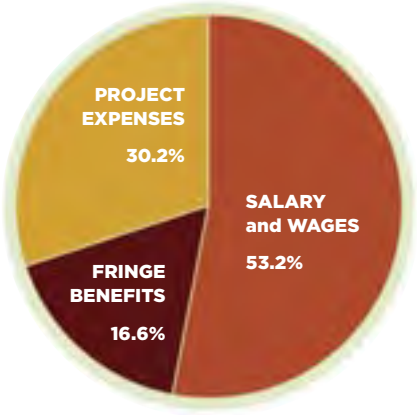
Features on the site include:

- An MAES overview
- A searchable database of MAES researchers and projects
- Field station information
- Research publications
- Research impacts
- Resource links to MSU, government, commodity groups, Michigan agriculture and natural resources organizations and experiment station directors associations
- Upcoming agriculture-related events
- Video news

[Financial Report]

July 1, 2009 to June 30, 2010

DISTRIBUTION OF APPROPRIATED FUNDS



INCOME:

Federal Appropriation		
Hatch	$	4,660,452
McIntire-Stennis	$	66,280
Hatch RRF	$	1,129,244
Hatch Animal and Disease, Section 1433	$	61,321
Total Federal Appropriations	$	5,917,297
State Appropriations	$	34,198,900
Total Appropriations	$	40,116,197
Grant — Federal, State and Private*	$	83,247,274
TOTAL INCOME	**$**	**123,363,471**

EXPENSES:

Salaries	$	21,330,916
Fringe Benefits	$	6,664,045
Project Expenses	$	12,121,236
Grants — Federal, State and Private*	$	83,247,274
TOTAL EXPENSES	**$**	**123,363,471**

PERSONNEL:

(Full-time Equivalents Funded From Appropriated Funds)

Research Staff	
Professors	52.91
Associate Professors	27.49
Assistant Professors	20.00
Research Associates and Specialists	7.78
TOTAL RESEARCH STAFF**	**108.18**
Support Staff	
Administrative Professionals	64.87
Supervisors	24.81
Clerical	18.38
Technicians	3.31
TOTAL SUPPORT STAFF	**111.37**

** *Grants are reported using most recent three-year average*

** *Does not include department chairpersons and unit administrators*

[Production Credits]

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MISSION STATEMENT

The mission of the MAES is to engage in innovative, leading-edge research that ensures the wise use of agricultural, natural and community resources and enhances the quality of life in Michigan, the nation and the world.

The mission, supported by nearly 400 scientists working in agriculture, natural resources, engineering, social and natural sciences, human ecology and veterinary medicine, has enabled the MAES to be one of the most successful experiment stations in the country. This success is due to the efforts of outstanding researchers; close partnerships and collaborations with Michigan State University Extension, federal and state agencies, commodity groups and other key stakeholders; and exceptional legislative support.

STEVEN G. PUEPPKE, DIRECTOR
MAES
MICHIGAN STATE UNIVERSITY
EAST LANSING, MICHIGAN 48824-1039

SR-130/JANUARY 2011