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The Ohio State University; Ohio Agricultural Research and Development Center

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The Ohio State University; Ohio Agricultural Research and Development Center

For more information, visit our web site:
http://www.oardc.ohio-state.edu/seeds
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Current and Past Industry Partners

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6062 Holdings, LLC
AccuDX, Inc.
Ag-Spectrum
Alltech
Alpaca Jack’s Suri Farm
American Aggregates Corp.
American Coal Ashland Association
American Hosta Society
Ampac Seed Company
Anonymous
Antorchas Foundation
Archer-Daniels-Midland Company
Argus Control Systems, Ltd.
Asgrow Seed Company
Athersys, Inc.
Aviagen
BASF Plant Science GmbH Agrarzentrum Limburgerhof
Bass Endowment
Bayer Corporation
Bayer CropScience LP Environmental Sciences
Bedding Plants Foundation, Inc.
Berlin Natural Bakery
Biotechnology Research and Development Corporation
Boehringer Ingelheim-NOBBL
British Columbia Greenhouse Growers’ Association
British United Turkeys of America
California Avocado Commission
Camelid Health Foundation
Campbell R and D
Cargill Animal Nutrition Center
Cattlemen’s Carcass Data Service
Center for Asceptic Processing and Packaging Studies
Central Ohio Hosta Society
Certified Angus Beef
Ciba Crop Protection
Cinergy
City of Columbus
Cognis Deutschland GmbH and Co.
Consortium for Plant Biotechnology Research
Cooper Farms, Inc.
Cultiva
Dairy Management, Inc.
Danone
DeVenture
Donlar Corporation
Dow Agrosciences
Dynal Biotech
E.I. DuPont de Nemours and Co.
Eagle-Picher Minerals, Inc.
Earthgro
Edstrom Industries, Inc.
Elanco Animal Health
Eli Lilly and Company
Farmland Industries
First Energy
Floriculture Industry Research and Scholarship Trust
Food Science Australia
Fremont Pickle Growers Association
Fruit Growers Marketing Association
Garick
General Chemical
George F. Ackerman Company
Great Lakes Hosta Society
Gregson Technologies, Inc.
Gustafson, Inc.
Harris Moran Seed Company
Hillshire Farm and Kahn’s
Hirzel Canning Co.
Holmes Cheese Company
Holmes Cheese Table
Horticultural Research Institute
Iams Corporation
Infectech, Inc.
Ingredient Innovations International
Integrated Research Technology, LLv
J. Frank Schmidt Family Charitable Foundation
Jarrow Incorporated
Jatco, Inc.
Kamiasahi Feed Lot, Ltd.
Kanter Associates
Kohlpyr
Kraft Foods Global, Inc.
Kurtz Brothers, Inc.
Lilly Research Laboratories
CURRENT AND PAST INDUSTRY PARTNERS

Lipha Tech, Inc.
Lipton Tomato Research Center
Loveland Industries, Inc.
Magical Farms, Inc.
Maple Leaf Farms, Inc.
Martek Biosciences Corporation
Merial Limited
MicroBio Limited
Mid-America Food Processors
Middlefield Cheese
Midtech
Midwest Regional Hosta Society
Ministry of Culture, Education, and Scientific Exchanges, Spain
National Fish and Wildlife Foundation
National Sea Grant Program
National Wildlife Federation
Natural Fiber Composites Corporation
North American Strawberry Growers Research Foundation
Nourse Farms, Inc.
Novartis Crop Protection, Inc.
Nursery Growers of Lake County Ohio, Inc.
N-Viron International, Inc.
Ohio Bioprocessing Research Consortium
Ohio Corn Marketing Program
Ohio Dairy Farmers Federation
Ohio Dairy Producers
Ohio Floriculture Foundation
Ohio Fruit Growers Society
Ohio Lawn Care Association
Ohio Nursery and Landscape Association, Inc.
Ohio Pork Producers Council
Ohio Poultry Association
Ohio Seed Improvement Research
Ohio Sheep and Wool Program
Ohio Soybean Council
Ohio Space Grant Consortium
Ohio Vegetable and Small Fruit Research and Development
Ontario Greenhouse Vegetable Growers
Optimum Quality Grains, LLC
Otterbein College
Outback
Park Foundation
Pennington Seed, Inc., Oregon Division
Petroseed
Pfizer
Pharmacia, Wyeth Ayerst Research
Philip Morris, Inc., Shared Solutions in Agriculture
Phycotransgenics
PIC USA
Pig Improvement Company
Pioneer Hybrid International
Polter Berry Farm
Protein Technologies International
Purity Foods, Inc.
Quality Liquid Feeds
Rainbow Treecare Scientific Advancements
Rainforest Phytoceuticals
Raven
Rhodia, Inc.
Roche Vitamins, Inc.
Satloc
Select Sires
Seminis Vegetable Seeds, Inc.
Small Farm Institute
Syngenta
The Chef’s Garden, Inc.
The Garland Company, Inc.
The HANOR Company, Inc.
The Scotts Company and Subsidiaries
Theis Technology Inc.
Thomas Cook
Toh Products, LLC
Top Soil Precision Ag
Tree Research and Education Endowment Fund
TruGreen-Chemlawn
Turkish Republic Harran University
Valent U.S.A. Corp.
Warner Endowment Grant
West Texas A&M
Wilmington College
As new challenges present themselves in the twenty-first century, so begins an era where discoveries in bioscience provide unprecedented opportunities for economic and societal advancement. As Agbioscience continually tops the charts as Ohio’s number one industry, The Ohio Agricultural Research and Development Center (OARDC) at The Ohio State University remains on the vanguard of cutting-edge research, establishing itself amid the essential drivers of Ohio’s economy.

The economic powerhouse that is Ohio’s Agbioscience industry is unparalleled. No other economic engine comes close to making the kind of impact generated by agriculture, food, and the nursery and landscape industry. This massive industry yields more than $80 billion annually, employs one in every six Ohioans, and supports a diversified and dynamic economic sector that touches the lives of everyone in the state.

OARDC is the research and development headquarters for Agbioscience research in the state of Ohio, and it serves as the state’s signature research center for realizing progress in all significant aspects of the bio-based economy. In fiscal year 2008, OARDC generated the following in Ohio: 1,609 jobs, $156.3 million in economic output, $59.2 million in personal income for Ohio residents, and $5.5 million in state and local taxes. In a knowledge-driven economy, intellectual property is perhaps the most valuable property that can be produced.

With the changing nature of the economic and societal trends as well as the impact of globalization, agriculture, food, and the green industry also depend on innovators and researchers to generate new processes or products. Ohio’s largest industry increasingly links with other industries to take on common challenges and opportunities in key areas such as environmental restoration or the development of bio-renewable sources of energy, fuel, and industrial goods.

Addressing the differing challenges and vast opportunities of Ohio’s largest industry is the ultimate goal of SEEDS: The Research Enhancement Competitive Grants Program. SEEDS promotes excellence in The Ohio Agricultural Research and Development Center, promoting research consistent with the mission and vision of OARDC and encouraging connections across disciplines, with industry and other external partners.

Established in 1996 and supported by an appropriation from the Ohio General Assembly to OARDC, SEEDS: The Research Enhancement Competitive Grants Program is unique among US state-assisted universities. In fostering high-quality research among OARDC and College of Food, Agricultural, and Environmental Sciences-supported scientists, SEEDS enables those scientists to collect preliminary data needed to give them a competitive edge in national programs and provides them with leverage to attract industry support.

OARDC’s SEEDS program is just one of the many ways in which Ohio State University’s innovative research and development connects to industry and community on a global scale. Currently, Ohio State is ranked nineteenth among the nation’s public universities and has been among the top 25 public research universities in each U.S. News & World Report ranking. Total research expenditures at Ohio State have more than doubled over the past 10 years, climbing to $720 million in 2007. In 2008, Ohio State ranked second in industry-sponsored research, generating a statewide impact of nearly $4 billion. According to the National Science Foundation’s assessment of sponsored research expenditures, Ohio State is now among the top 10 public research universities in the country.
Objectives

SEEDS was created to encourage partnerships with industry and other stakeholders and to increase the competitiveness of OARDC/CFAES scientists in extramural grant programs. While these objectives remain the program’s cornerstone, SEEDS has grown to include a total of seven objectives:

- Increase the competitiveness of scientists in extramural grant programs.
- Encourage partnerships with industry and other stakeholders.
- Encourage the development of interdisciplinary teams.
- Encourage international collaborations.
- Support the exploration of enterprises that are potentially new to Ohio.
- Provide the opportunity to take part in the grant-writing proposal review process.
- Provide undergraduate students with research experience.

Program Achievements

SEEDS or SEEDS-funded researchers and/or graduate students have

- invested $1,931,218 in projects requiring matching funds, generating $3,735,985 in industry matches—a return of about $2 on each dollar invested.
- enabled scientists to establish collaborations with colleagues from Africa, Argentina, Australia, Belgium, Brazil, Chile, France, Ireland, Italy, Mexico, New Zealand, Norway, the Philippines, Switzerland, Taiwan, Uganda, and Zimbabwe.
- applied for nine US patents using results of initial findings. Three patent applications have been granted, and three licensing agreements have been obtained.
- published a total of 627 peer-reviewed scientific manuscripts, abstracts, popular press articles, bulletins, and/or book chapters and made more than 1,100 presentations throughout the world.
- produced 30 doctoral dissertations and 66 master's theses.
Achievements by Objectives

Objective 1—Increasing the competitiveness of scientists in extramural grant programs.

The Seed Grant Competition and the Agency External Competitions specifically address Objective 1. However, all the other competitions may result in additional funding from outside sources.

Of the 31 projects completed and reported in calendar year 2008, $1,156,828 was generated in extramural funding. Of the life of SEEDS, 280 projects have been completed and $34,464,383 has been generated extramurally.

Over the life of SEEDS, OARDC has invested $551,362 in matching funds for Agency External Grants, which generated $3,917,390 in extramural funding.

Objective 2—Encouraging partnerships with industry and other stakeholders.

The Matching and Industry Small Grant Competitions address Objective 2.

Of the nine grants requiring at least a dollar-for-dollar match and completed during calendar year 2008, OARDC provided a total of $247,950 while industry matched those dollars with $362,608.

For the life of the program, OARDC has provided $1,931,218 toward Matching and Industry Small Grants while industry matched those dollars with $3,735,985.75—a return of $1.94 on each dollar invested.

Objective 3—Encouraging the development of interdisciplinary teams.

The Interdisciplinary Team Competition specifically addresses Objective 3.

During calendar year 2008, four interdisciplinary teams completed projects. These teams reported receiving $137,700 in extramural funding.

Overall, SEEDS has supported research projects in the approximate amount of $9.6 million in all categories and has received close to $43 million in matching and extramural funding—a return of about $5 for each dollar invested.

Objective 4—Encouraging international collaborations.

All competitions may have an international collaboration component, and international relationships are encouraged. OARDC scientists have collaborated with scientists from Africa, Argentina, Australia, Belgium, Brazil, Chile, France, Ireland, Italy, Mexico, New Zealand, Norway, the Philippines, Switzerland, Taiwan, Uganda, and Zimbabwe.

Objective 5—Supporting the exploration of enterprises that are potentially new to Ohio.

New Enterprises are considered to be crops, animals, products, goods, and services that currently are not produced for biological, physical, cultural, processing, economic, or social reasons. The New Enterprise Competition is designed to explore new enterprises and to eliminate the barriers that constrain existing ones.

The New Enterprise Competition has received 25 applications; 10 have been funded.

Funded projects include:

- New Commodity Enterprises in Ohio—Evaluation and Education
- Development of New Biological Products for Slug Control
- Direct Conversion of Agricultural Wastes to Electricity Using Rumen Microbes in Microbial Fuel Cells
- Domestication and Commercialization of Paraxacum—A New Crop to Fuel Ohio’s Agricultural and Rubber Industry

Over the life of the program, six colleges and 23 departments have participated in the Interdisciplinary Team Competition, with OARDC investing $4,037,198 and teams competing successfully and reporting $8,901,015 in extramural funding—a return of $2.21 on each dollar invested.
Objective 6—Providing undergraduate students with research experience.

A total of 52 applications to the Director’s Undergraduate Research Program have been received. Thirty-three applicants have received awards.

The Director’s Undergraduate Research Program provides undergraduate students with a professional grant-writing, research and reporting experience. Projects are designed, submitted for review, and carried out with a faculty mentor. Once the project is completed, students take an independent studies class to write their research report in the form of a scientific journal article using their faculty advisor as an editor. Some of these reports have been published. In addition, many students present their research at professional meetings and at competitions such as the Denman Undergraduate Research Forum, a university-wide program presented by The Ohio State University Office of Research and the University Honors and Scholars Center.

Objective 7—Providing graduate students with the opportunity to take part in the grant-writing/review process.

A total of 343 master’s and doctoral students have submitted proposals in this competition. One hundred forty-four projects have been awarded. The graduate competition is run exactly like a federal competition. Graduate students who received awards are asked to serve on a panel to review applications in the following year’s competition. This experience provides students with an opportunity to develop their skills in grant-writing and reviewing—skills essential to their professional careers.
Interdisciplinary Team Research Competition

The Interdisciplinary Team Research Competition, funded at a maximum $100,000, is designed to stimulate new collaborative partnerships in multiple departments and colleges or build on existing programs of excellence. Interdisciplinary research provides expertise over several disciplines, bringing a more holistic approach to research questions and problems.
Role of Conjugated Linoleic Acid in Muscle Steatosis in Insulin Resistance
Martha A. Belury, Human Nutrition
Doug Kniss, Obstetrics and Gynecology
Petra Schmalbrock, Radiology
Macdonald P. Wick, Animal Sciences

Obesity is a growing epidemic that is characterized by dysregulation of metabolism, which can lead to type 2 diabetes as well as many other costly and chronic health conditions. Obesity refers to “excessive accumulation of lipid storage in body adipose (fat) tissues as well as in non-adipose tissues such as liver and muscle.” According to the US Center for Disease Control (CDC), overweight and obesity are both labels for ranges of weight that are greater than what is generally considered healthy for a given height. The terms also identify ranges of weight that have been shown to increase the likelihood of certain diseases and other health problems. For adults, overweight and obesity ranges are determined by using weight and height to calculate a number called “body mass index” (BMI). BMI is used because, for most people, it correlates with their amount of body fat. An adult who has a BMI between 25 and 29.9 is considered overweight. An adult who has a BMI of 30 or higher is considered obese.

According to the American Diabetes Association, type 2 diabetes is the most common form of diabetes. In recent years, newly diagnosed cases of type 2 diabetes are increasing rapidly, classifying the disease as an absolute epidemic sweeping the United States. The total estimated cost of diabetes in 2007 was $174 billion, including $116 billion in excess medical expenditures and $58 billion in reduced national productivity. Medical costs attributed to diabetes include $27 billion to directly treat diabetes, $58 billion to
treat the portion of diabetes-related chronic complications that are attributed to diabetes, and $31 billion in excess general medical costs. People with diagnosed diabetes incur average expenditures of $11,744 per year, of which $6,649 is attributed to diabetes. People with diagnosed diabetes, on average, have medical expenditures that are 2.3 times higher than what expenditures would be in the absence of diabetes. Indirect costs include increased absenteeism ($2.6 billion) and reduced productivity while at work ($20 billion) for the employed population, reduced productivity for those not in the labor force ($0.8 billion), unemployment from disease-related disability ($7.9 billion), and lost productive capacity due to early mortality ($26.9 billion).

In type 2 diabetes, either the body does not produce enough insulin or the cells ignore the insulin. Insulin is necessary for the body’s use of glucose for energy. When you eat food, the body breaks down all of the sugars and starches into glucose, which is the basic fuel for cells in the body. Insulin takes the sugar from the blood into the cells. When glucose builds up in blood instead of going into cells, it can cause two problems: right away, your cells may be starved for energy, and also, over time, high blood glucose levels may hurt your eyes, kidneys, nerves, or heart. Because of these severe complications, research about insulin resistance and general weight loss is absolutely critical.

There is considerable evidence that the weight-loss supplement conjugated linoleic acid (CLA) reduces adipose mass, in part, by shuttling lipids away from adipose and into the liver and skeletal muscle. Because of the strong link of insulin resistance with steatosis, the abnormal lipid retention in a cell, researchers sought to investigate the extent that CLA-induced steatosis in muscle increased insulin resistance in mice.

This study found no evidence for the induction of insulin resistance by CLA when provided in the presence of rosiglitazone. Because rosiglitazone is an insulin sensitizer and one of the most commonly used drugs for the treatment of type 2 diabetes, researchers are currently investigating the complementary effects of CLA and rosiglitazone to lower body fat in humans while maintaining insulin sensitivity needed by those afflicted with type 2 diabetes. The future of this research could potentially lead to monumental breakthroughs in both type 2 diabetes and weight loss, two of the worst health problems plaguing the nation.
Role of Metacaspases in Petunia Petal and Leaf Senescence
Michelle L. Jones and John G. Streeter, Horticulture and Crop Science
Tea Meulia, Molecular and Cellular Imaging Center, OARDC

Senescence is the last stage of plant development leading to the death of cells, organs (leaves and flowers), and whole plants. Symptoms of senescence include leaf-yellowing, petal-fading, and flower-wilting. Ornamental plants often encounter high temperature and water stresses that accelerate senescence once they leave the greenhouse production environment (i.e., postproduction). Postproduction losses due to premature senescence during shipping and retail sale can be as high as 30%. Creating plants with delayed senescence will reduce postproduction losses and increase the profitability of floriculture producers and retailers. This research can have a significant economic impact on the state of Ohio where the wholesale value of floriculture crops is over $180 million. Increasing the postproduction quality of ornamentals also provides the consumer with a better plant that will establish more quickly and have a better display life in the home landscape.

Caspase enzymes play a central role in the death of animal cells. They are involved in the cleavage and subsequent activation of enzymes involved in the cellular degradation and nutrient remobilization pathways that result in death. A family of caspase-like proteases, called metacaspases, has been identified in plants, but their role in leaf and flower senescence is not yet known.

The goal of this research was to determine if metacaspases play a role in regulating flower senescence. Flower petals provide an excellent model system for studies of senescence because they have a finite lifespan and their death is under tight developmental control. Most of the research on plant metacaspases has been conducted in Arabidopsis, but Arabidopsis flowers shed fully turgid petals that do not undergo senescence. Petunias were selected for these experiments because they flower profusely and they have large flowers, facilitating the collection of tissues needed for the biochemical and molecular characterization of metacaspases during petal senescence.
Senescence is controlled by changes in the level of gene (transcription) and protein (translation) expression. Reverse transcription polymerase chain reaction (RT-PCR) was used to clone metacaspase genes from petunia. Antibodies were generated to the metacaspases so that protein expression patterns could be determined using western blots. The antibodies were also used to determine the subcellular location of the metacaspase proteins. The metacaspase enzyme was purified, and activity assays were performed to determine the type of protease substrates that could be cleaved by the petunia metacaspases. Lastly, functional analysis using transgenic plants and transient systems were used to downregulate and overexpress the metacaspases in petunia plants and determine the effects on flower senescence.

Two metacaspase genes were cloned from petunia petals. Metacaspase enzymes are classified as type I or type II, based on the classification of caspases in animals. Type I caspases are referred to as initiator caspases and function early in the cell death pathway by cleaving and activating the type II or executioner caspases. The executioner caspases function late in the pathway during the degradation and remobilization phase of cell death. One type I metacaspase (PhMCA1) and one type II metacaspase (PhMCA2) were cloned from petunias. Transcripts (mRNAs) from both of these metacaspases were detected in petunia petals, suggesting that both play a role in flower development and/or senescence. Type I transcripts increased in senescing petals, while type II transcripts increased early during flower development.

Western blots using antibodies raised to both metacaspases were conducted to detect protein abundance and patterns of expression during flower development and senescence. The abundance of the type I metacaspase (PhMCA1) increased during petal development while the type II metacaspase (PhMCA2) was detected at flower opening and remained constant throughout petal development. Recombinant PhMCA1 expressed and isolated from *E. coli* was processed into its subunits. The petunia MCA proteins were expressed in *E. coli* so the enzymes could be purified for activity assays.

The activity assays indicated that PhMCA1 and PhMCA2 are Arginine-specific cysteine proteases. This is similar to what has been discovered in *Arabidopsis*. This type of information will lead to the identification of the specific protein substrates that are cleaved by the metacaspases, and it will further define their role in senescence. Both PhMCA1 and PhMCA2 proteins localized to the cytosol and were most abundant in vascular tissues. These patterns suggest a role in protein degradation and the subsequent remobilization of nutrients during senescence. A pH optimum of 7 to 8 supports a cytosolic location for the enzymes.

The functional role of the metacaspases was investigated by overexpressing PhMCA1 and PhMCA2 in petunia. When expression of PhMCA2 was increased, petal longevity was decreased. In contrast, overexpression of PhMCA1 did not accelerate senescence. These studies support an important role for metacaspases in flower senescence and suggest they function in protein degradation and nutrient remobilization. PhMCA1 appears to function in the execution of petal senescence, while PhMCA2 may have a regulatory role early in the senescence program. This research also identified some key differences in the regulation of *Arabidopsis* and petunia metacaspases, which highlight the importance of investigating senescence in multiple systems.

Future experiments will focus on identifying the protein substrates of PhMCA1 and PhMCA2. Identifying the specific proteins that are cleaved by the metacaspases will provide more detailed information about senescence pathways and how to manipulate them. This information can then be used to delay postproduction senescence in ornamental crops and enhance shelf life and retail value.
Maize is the most important crop in the US and shares the lead with soybeans in Ohio. While production and value vary from year to year, a typical US maize crop is valued at approximately $35 billion, and a typical Ohio maize crop is valued at approximately $1.1 billion. In addition to production, maize processing, transport, and trade are critical sources of jobs and economic strength. Maize is a vital food source for humans and livestock, but it also provides the raw material for hundreds of value-added products ranging from sweeteners and paper finishing to fuels and pharmaceuticals. The amazing yield potential of maize is its biggest asset as a cereal crop. As the demand for using maize as the raw material in ethanol production increases, the economic value of maize in Ohio is becoming more and more important for future investment and economic gain.

Unfortunately, foliar diseases such as northern corn leaf blight (NCLB) place major limitations on stable production in Ohio and the nation. This specific disease can cause significant yield loss in many regions in Ohio in epidemic years. Developing resistant maize inbred lines to NCLB is a priority in maize breeding programs. Understanding the molecular basis of the host resistance to NCLB will spur the development of new tools for the breeder and result in improved selection of highly resistant lines. Improved field resistance will ultimately lead to a substantial cost savings for producers.

Although many molecular techniques for defense gene expression analysis are available, rapid and cost-effective methods are still lacking. Scientists aimed to develop a genomic approach to deeply analyze the expressed genes in the maize genome and identify novel genes that play important roles in defense responses to NCLB. A maize leaf RL-SAGE library and a 5-RATE library were constructed. In the RL-SAGE library, 44,428 unique transcripts were identified. In the 5-RATE library, 100,080 unique transcripts were obtained. About 15–20% of the transcripts in both libraries are considered novel genes since they are not present in the existing public databases.

To identify full transcript units, SAGE and RATE tags were aligned to maize full-length cDNA reference sequences. A total of 13,798 SAGE tags matched to 3 end of cDNAs and 28,090 RATE tags matched 4,455 unique 5 cDNA. These sequences are one of the largest sets of expression tags of maize and should be important for maize full-length cDNA and genome sequencing projects. In addition, scientists sequenced two 5-RATE libraries using RNA samples from a resistant and susceptible line after NCLB pathogen infection. Sequence analysis showed that about 20% of the transcripts were unique in the resistant library, and 25% of the common transcripts had a differential expression level. The candidate genes provide the starting materials for further expound on the defense mechanism of NCLB in maize.

Researchers continue to characterize the identified defense-related genes from the two RATE libraries. The next step will be to map them in a breeding population developed from resistant tropical maize crossed with Corn Belt maize. Genes for resistance to NCLB are segregating in the population, and the discovery of DNA markers linked to those genes will help make breeding resistant lines more efficient. The release of disease-resistant lines will result in large annual cost savings for both the consumer and the producer.
Comparative Studies of Three Related Type III Effector Proteins Essential for Virulence of Plant Pathogenic Bacteria.

Pierluigi Bonello and David L. Coplin, Plant Pathology
Jong Hyun Ham and David Mackey, Horticulture and Crop Science

*Pantoea stewartii pv.* causes Stewart’s bacterial wilt and leaf blight of sweet corn and maize, which is a serious problem in the north central and eastern United States, including Ohio. *P. stewartii* is transmitted by the corn flea beetle and it survives over winter in the beetle’s gut. Infection occurs through insect feeding wounds on the plant. Bacteria grow in the water-conducting vessels of the corn plant, causing it to wilt. Water-soaked lesions can also occur in the intercellular spaces of the leaves.

Researchers observed a *P. stewartii* protein that is critical for the bacterium’s ability to cause Stewart’s wilt. Mutant bacteria that cannot make WtsE, an effector protein, do not cause the disease. WtsE is produced in the bacteria but functions inside cells of the host plant. It is delivered by a secretion system, which is a bacterial structure that functions like a hypodermic needle to inject WtsE into plant cells.

The long-term goal of scientists is to understand what WtsE does inside the plant cell so that its activity can be blocked, enabling the resistance of corn plants to the disease. Other plant pathogenic bacteria make related proteins, which collectively are called AvrE-family proteins, so this research will be applicable to many important diseases of other crops.

In analyzing the amino acid sequences of AvrE-family proteins, it was found that they all contained one or two copies of a five amino acid pattern. This pattern has recently been reported as critical for the activity of a number of effector proteins from animal pathogens, including *E. coli*, *Salmonella*, and *Shigella*. This amino acid pattern containing animal effectors was shown to mimic the function of an important class of signaling proteins called “small G-proteins.” This mimicry affects the shape and membrane functions of host cells in a way that is disadvantageous to bacterial infection.

Findings that WtsE and other AvrE-family effector proteins contain the amino acid pattern indicated that these effectors from plant pathogenic bacteria might also mimic small G-proteins that are found in plant cells. Scientists tested the hypothesis that these special patterns are important for the function of WtsE in promoting the ability of *P. stewartii* to cause Stewart’s wilt.

The study used a molecular genetics approach to test the importance of the amino acid pattern and determine if WtsE functions like a plant G-protein. Researchers constructed mutations that specifically disrupted the amino acid pattern WtsE. The nature of these mutations was the same as those that had been shown to disrupt the function of animal effectors containing the amino acid pattern. Scientists first demonstrated that the mutation of both amino acid patterns severely compromised the ability of *P. stewartii* to cause disease in corn. Then a variety of delivery systems was developed to introduce just the WtsE protein into cells of both corn and the well-characterized model system plants.

Scientists also developed a number of assays to demonstrate and quantify the ability of this protein to cause cell death, suppress host defense responses, and promote bacterial growth. Loss of the amino acid pattern knocked out the ability of WtsE to cause cell death and suppress defenses, but the protein still had the ability to promote growth of the pathogen in plants. Therefore, it is evident that WtsE is likely to mimic G-proteins and do other things to help *P. stewartii* grow in its host and cause disease.

This research has opened new avenues to a deeper understanding of WtsE function, the nature of Stewart’s wilt, and bacterial pathogenesis in general. Building on the preliminary results and assay systems developed during this project, researchers have formulated a number of questions and hypotheses that will be addressed in the coming years. How does WtsE damage host cells? How does it suppress host defenses? How does it use G-protein mimicry to produce these effects? What other function of WtsE promotes bacterial growth in the plant? The answers to these questions will ultimately provide strategies for the prevention or control of Stewart’s wilt of corn and other bacterial diseases of plants.
Industry Small and Matching Grant Competitions

The Industry Small and Matching Grant Competitions are designed to develop partnerships with private industry and nonprofit foundations. Industry Small Grants provide up to $6,000 from the SEEDS program, while Matching Grants provide up to $50,000. Investigators are required to obtain at least a dollar-for-dollar match from industry for both of these competitions.
Strawberry Cultivar Tolerance of New Weed Control Practices
Douglas Doohan, Horticulture and Crop Science

Strawberry tolerance to most registered herbicides is incomplete. Some of the older strawberry varieties such as Kent and Honeoye were considered to be sensitive to Sinbar—commonly used to control weeds in strawberry crops—while varieties such as Veestar are considered relatively tolerant to Sinbar. Because Sinbar is the principal herbicide used to combat weeds in strawberry crops, every new strawberry variety’s tolerance to this herbicide is of great interest to producers.

Research was conducted to characterize the response of strawberry cultivars to the herbicide Sinbar and also to the recently registered herbicide Spartan. Four field studies were established: three trials at OARDC and the fourth at Polter Berry Farms in Fremont, Ohio. A fifth site was later established at the Fremont OARDC Research Station. Multiple sites were required for the Sinbar trials because of a suspected interaction with soil particle size and organic matter (OM). Strawberry tolerance to Spartan herbicide is known to decrease when soil pH is greater than 6.5; therefore, a Spartan trial was established on a site where soil pH had been elevated to pH 7. Dormant strawberry plants were transplanted at each site during the spring season. Weeds were controlled by cultivation and hand-weeding to control those that tolerated the test herbicide applications. Each herbicide treatment was replicated 4 times, and a plot was a single row of strawberry.

Sinbar was applied immediately after planting; Spartan, however, was applied to the designated plots in late fall, after onset of crop dormancy. Sinbar treatments were evaluated visually for crop injury at one, three, and six weeks after treatment. Spartan treatments were evaluated, and fruit yield from all Wooster plots was recorded in June.

Strawberry cultivars varied in response to both the Sinbar rate and timing of applications. The incidence of chlorosis, the yellowing or whitening of a plant’s leaves caused by lack of chlorophyll, was used to measure strawberry cultivar sensitivity. Cultivar sensitivity was the greatest in Honeoye strawberry variety and the least sensitive in Darselect. Chlorosis increased with increasing rates of Sinbar and was maximum with the 6 oz/A (2X) rate applied to Honeoye the same day as transplanting. Injury was more severe when strawberry was treated at planting in comparison to treatments applied four weeks after planting (WAP). Regardless of initial injury, chlorosis of all varieties declined rapidly as new leaves developed. Chlorosis caused by Sinbar could not be detected in any Wooster trial.

Significantly lower yield was detected in Honeoye and Evangeline when Sinbar was applied at planting, corresponding with the observed ranking of cultivar sensitivity the previous spring. Yield reductions were only noted at the highest rates of application. However, no effect on yield was noted when Sinbar application was delayed until four WAP.

Strawberry cultivars responded much differently when treated with Spartan. Cabot, Evangeline, and Jewel were the most sensitive varieties. Brunswick and Honeoye were not affected by the herbicide application, even at the highest rate. Fruit yield was not affected by Spartan rate in any variety.

Scientists concluded that Sinbar should not be applied until strawberry plants are well established. Evangeline and Honeoye yield were affected by 3 and 6 oz/A applied at the time of planting, even though visual effects on the crop were not apparent at harvest time. Producers should delay Sinbar application until four weeks after planting to completely eliminate a possibly negative effect of lessened fruit yield. Research on strawberry cultivars continues to be essential for producers around the globe. As more strawberry varieties are developed, sensitivity testing to herbicides—especially Sinbar and Spartan—will continue to be a high priority for the industry.
Each year, approximately 75 million acres of soybeans are planted in the United States; Ohio ranks sixth in soybean production, having planted 4.6 million acres of soybeans in 2007. Until recently, most soybeans were planted using row-crop planters with individual planter units that were filled by hand, one bag of seed at a time. Today, most soybeans are planted with grain drills and seeders that are filled mechanically, using an auger or conveyor belt to lift the seed from ground level to the top of the hopper. Rapid refilling improves productivity by reducing down time, and it can increase crop yield through timelier planting.

Augers and conveyors are more likely to damage the seed compared to loading by hand. Damaged seeds often do not germinate and grow. This results in farmers buying more seed to compensate for the loss. If for example, the germination rate were reduced by 5% as a result of damage by the loading augers, farmers would need to buy 5% more seed, which would cost Ohio farmers millions of dollars. By better understanding the impacts of seed damage during auger transport, Ohio farmers can eliminate wasted seed and potentially lower input costs during a time when costs continue to rise.

This research was conducted to determine if the soybean germination rate was affected by the use of four different bulk handling systems compared to soybeans that were not handled. If the bulk handling systems are found to significantly damage the soybean seeds, adaptations to the bulk handling systems can be made to lessen this impact.

The primary objective of this study was to determine which of the four types of bulk handling systems provided the least amount of damage to the seed. The following systems were tested: a steel auger with standard steel flighting, a plastic-cupped auger that places a distinct cup at the tip of the flighting, a traditional auger with synthetic brush bristles located in the outer inch of steel, and a conveyor belt method of bulk transport.

Data was collected from the four different types of handling systems at three different speeds. All collection methods were constant, and the seed was collected from the outlet of the transport system. Four samples were collected from each handling system and then germinated using a warm germination testing method for seven days.

General recommendations for farmers using bulk handling systems were determined from the results. Ohio farmers should operate augers at low speeds and keep the auger well supplied with grain. The use of soft padding at the nose of the auger reduced the chance of damage. The replacement of old augers along with keeping the tubes and bearings in good shape to prevent vibrations decreased the chance for damage. These results have been shared with manufacturers, and the results will soon be provided to farmers.
Field Evaluation of Microdochium-Resistant Pumpkins, Year 2
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Microdochium blight (also known as Plectosporium blight or white speck) is a destructive foliar disease in pumpkin crops throughout Ohio. The disease is caused by a fungus that overwinters in crop debris and then produces spores, which are spread by water splash to healthy foliage during early- to mid-summer. The fungus initially causes superficial lesions on leaf veins, and then quickly spreads to leaf blades, petioles, stems, and developing fruit.

Heavy foliar infection results in defoliation, very often accompanied by cracking and death of infected stems. As the disease progresses, spores are splashed onto the fruit, causing the characteristic white speck symptom. Even a low incidence of the disease can have substantial economic impact because fruit are scarred and unmarketable.

Recommendations for controlling this disease include both long rotations between pumpkin crops and application of protectant fungicides beginning in early summer. Both of these practices increase production costs for Ohio growers. The best control for this disease would be the use of pumpkin varieties with high levels of resistance to the disease. Currently, no such commercial pumpkin varieties exist.

Previous efforts have been made to identify and field-test sources of resistance to this disease. In 2005, it was determined in greenhouse tests that resistance to Microdochium blight could be found in Cucurbita moschata, a species closely related to Cucurbita pepo, the species most commonly used in the breeding of jack-o’-lantern-type pumpkins. In 2006, the resistance in Microdochium blight was indeed confirmed in a field trial.

In 2007, several lines of C. pepo, C. moschata, and two interspecific hybrids were tested in a field trial to determine their reaction to Microdochium blight, with particular attention to the disease resistance characteristics of the interspecific hybrids. Additionally, information was obtained on the horticultural characteristics of these varieties to determine their suitability for commercialization as jack-o’-lantern-type pumpkins.
The field trial was established at the Western Agricultural Research Station, located in South Charleston, Ohio. Entries chosen included eight *C. pepo* varieties, seven *C. moschata* varieties, and two varieties of *C. argyrosperma*. Several of the entries chosen were provided by the National Plant Germplasm System. Two interspecific hybrids (*C. pepo* x and *C. moschata*) were included to test the idea that resistance to Microdochium blight from *C. moschata* would be expressed in the hybrid. The pumpkin cultivar Pro Gold 510, which is susceptible to the disease, was used as a standard commercial check. Individual plots consisted of single, 30-foot rows of each variety. Each variety was replicated four times in a completely randomized design.

Foliar disease severity was assessed twice during August by estimating the percent of petiole, or leaf area, covered with lesions in a 5-foot diameter circle in each plot. Final foliar blight ratings (1–5 scale) and fruit lesion severity ratings (1–5 scale) were made on all foliage and fruit in each plot during mid-October. All plots were trickle-irrigated to maintain one inch of water per week.

Symptoms of white speck were obvious by late July. By August, 57–71% of petiole surfaces and 50–57% of leaf blade surfaces were covered with white speck lesions in the susceptible *C. pepo* varieties: Stocna, Yellow Oval, and the commercial check cultivar Pro Gold 510. In all *C. moschata* entries and the interspecific hybrids, foliar disease (petiole and leaf blade) was below 13%. White speck severity was intermediate for two entries of *C. argyrosperma* and for one variety of *C. pepo* (Little Gem).

Results of a second disease severity assessment, conducted during late August, were comparable to those seen earlier in the season, with Yellow Oval disease severity over 73% for both petioles and leaf blades, while *C. moschata* entries were below 8%. Both interspecific hybrids had relatively low disease severity ratings, although Hybrid 2 had approximately 17% petiole and leaf area covered by lesions. By October, foliage in susceptible varieties was almost totally destroyed by Microdochium blight. Fruit scarring by Microdochium lesions was most obvious on Stocna, although other susceptible entries were also severely affected as well.

Resistant varieties and hybrids generally had healthy foliage and virtually no fruit scarring. Findings of this study indicate that resistance to white speck exists in the genus *Cucurbita*, and *Cucurbita moschata* appears to be a useful source of resistance to Microdochium blight. Also, interspecific hybridization is a promising means for incorporating Microdochium blight resistance into commercial pumpkin varieties. The use of hybridization in pumpkins to ward off Microdochium blight could mean potentially significant cost savings for producers.
Cucumber beetles are the key insect pest of cucumber, pumpkin, and squash crops due to their direct feeding damage plus their vectoring of bacterial wilt disease. Many growers use soil-applied systemic insecticides such as Admire or Furadan for preventive control of beetles. For growers who do not use soil insecticides because of environmental concerns or high cost, a possible alternative is a trap-out strategy. The goal of a trap-out strategy is to attract pests into traps where they are killed before they have a chance to feed on the crop. A kairomone trap, which is used in the trap-out strategy, uses a lure that mimics cucurbit flowers in order to attract the beetles. The trap also uses poison bait made of cucurbitacin, which is a feeding stimulant, plus a low dose of carbaryl insecticide. The trap attracts the striped cucumber beetle and the spotted cucumber beetle as well as the western corn rootworm beetle.

Preliminary tests in Ohio found that the number of beetles caught in the traps was much higher if a squash plant was placed next to traps than if traps were used alone. This study was conducted to evaluate whether crop damage could be prevented or significantly reduced by early-season trapping so that growers could benefit from an alternative control strategy. This research is of particular interest to growers who prefer to minimize the use of insecticides and capitalize on the use of other alternatives.

Research was conducted in one large cucumber field and two small pumpkin fields. Each field had plots with beetle trapping stations spaced every 20 feet along one edge of the plot, as well as plots without beetle trapping stations for comparison. A trapping station consisted of one kairomone trap next to one plastic box containing three potted squash seedlings that were treated with a soil drench of Admire insecticide. Beetle damage to crop plants adjacent to trapping stations was compared weekly with crop damage in plots adjacent to no trapping stations. Dead beetles caught in kairomone traps and at the base of potted, treated seedlings were counted by species twice per week for two months.

At the cucumber field, 15,099 beetles were removed by the 20 trapping stations over the two-month period, for an average of 755 beetles per station. The number of beetles removed was low for the first two weeks but surged greatly in late May when removal averaged 46 beetles per trapping station per day. At the pumpkin fields, the number of beetles removed was lower, but trends were similar to those in cucumbers.

At all sites, the number of striped cucumber beetles was usually higher on the plant component of the trapping stations than in the kairomone trap component. However, the trend in spotted cucumber beetles was the opposite, with higher numbers caught in the traps than in the potted, treated plants. Western corn rootworm beetles were also caught in larger numbers in traps than on potted, treated plants.

Despite the large number of beetles removed by trapping stations, no consistent beneficial effect of reduced damage to the crop was found. In only one of six weeks in which damage was evaluated in cucumbers, beetle damage to the cucumber seedlings in plots with trapping stations was significantly less than in plots without trapping stations, and beetle damage was never significantly less in pumpkins. Most beetles were trapped after the crop emerged rather than before emergence, which was not as expected. A follow-up study is needed to evaluate whether damage could be lessened if traps are placed around all sides of a field rather than along just one edge. Once the optimum trap placement strategy is uncovered, growers could potentially utilize the information to reduce the use of pesticides from their regimen.
A low reproductive rate is one of the primary limiting factors in beef production efficiency. The length of pregnancy in cattle dictates that cows give birth only once each year. Maintenance costs for the breeding herd represent a major portion of beef production costs. It has been demonstrated that costs per unit of output are reduced by at least 24% when beef cows give birth to twins. This concept is only applicable to beef cattle; twin births have the opposite effect on efficiency of production in dairy cattle. As a result of complications associated with twin births—decreased milk production and prolonged rebreeding interval—it has been estimated that each occurrence of a twin birth costs the dairy industry between $100 and $250.

Through a particular study not designed to increase ovulation rate, scientists discovered that if aspects of ovarian function were coordinated in a certain sequence, approximately 50% of cows have spontaneous double ovulation. Four experiments were then performed to understand why this sequence led to double ovulation, and to develop a technology to induce twin pregnancies in beef cattle. Scientists aimed to increase production efficiency in beef cattle through increasing production of twins. On the opposite end of the spectrum, the same information gained through research could potentially prevent twin pregnancies in dairy production.

The initial phases of the study determined the manner in which reproductive hormones responded to the ovarian cycles, which resulted in double ovulation during preliminary research. These conditions were replicated, and the cows were treated in a manner that would result in double ovulation. During this phase, four reproductive hormones—estradiol, progesterone, luteinizing hormone (LH), and follicle-stimulating hormone (FSH)—were measured. These reproductive hormones are vital to various ovarian functions, as they indicate and can also cause double ovulation. Throughout the rest of the study, cows were treated with various hormonal regimes in an attempt to develop a producer-friendly technology that would consistently induce double ovulation in cattle.

For the first experiment, in animals treated to cause spontaneous double ovulation, scientists expected to find an increase in FSH compared to the cows expected to have single ovulation. While 42% of cows in that treatment had double ovulation, researchers did not detect differences in FSH as compared to cows expected to have single ovulation. LH also did not differ between treatments. Differences in progesterone and estradiol were as expected and did not provide any guidance as to the mechanisms that lead to double ovulation. Three subsequent experiments were conducted to determine the efficacy of using a pharmacological treatment to coordinate ovarian development along with FSH as a system to induce double ovulation. Ovarian events were coordinated using an approach that could easily be applied by producers, and FSH was given in an attempt to increase double ovulation.

Researchers found that when a cow’s ovarian events are coordinated in a manner to cause double ovulation, concentrations of FSH might not be the determining factor in the occurrence of double ovulation. Furthermore, administration of FSH in the technology researchers developed for producer use did not consistently cause double ovulation; rather, it was associated with wide variation in ovulation rate.

In order for scientists to perfect a technology that increases twin births in beef cattle while decreasing them in dairy cattle, future researchers need to continue to investigate other hormonal factors that might lead to double-ovulation technology. The creation of this technology would increase efficiency in some beef production systems, and the knowledge gained should ultimately aid in the prevention of twin births in dairy cattle.
Trees are often more stressed in urban environments than in natural forests; stress is thought to promote pest problems in trees because it weakens the trees’ natural defenses. Historically, tree management recommendations have emphasized certain practices, such as fertilization, that increase tree growth. However, fertilization may generally decrease pest resistance and stress tolerance by decreasing concentrations of defensive metabolites and suppressing root growth due to the trees’ high carbon demands for vegetative growth. The tree growth regulator paclobutrazol was thought to have the opposite effect. In theory, paclobutrazol should slow vegetative growth while increasing production of fine roots and defensive compounds.

Researchers sought to investigate the effects of paclobutrazol on the physiology and pest (insect and disease) resistance of paper birch and Austrian pine. It was predicted that the regulator would enhance pest resistance and stress tolerance.

Through the course of the study, scientists found that paclobutrazol decreased the height and radial growth of paper birch and Austrian pine, with no effect on photosynthesis. Plant allocation theory predicts that when growth is decreased with no accompanying effect on photosynthesis, then the availability of carbon to support other processes—such as the production of secondary metabolites and root growth—should increase, thereby increasing insect resistance. Paclobutrazol did increase foliar concentrations of condensed tannins in paper birch, and it enhanced birch resistance to infamous tree pests such as the gypsy moth and the whitemarked tussock moth. Also, paclobutrazol doubled the density of fine roots in Austrian pine, which would be expected to enhance drought stress tolerance. Paclobutrazol had no effect on root density of paper birch.

Paclobutrazol essentially decreased the growth of both paper birch and Austrian pine, as scientists initially predicted. However, effects on pest resistance and root growth were species-specific; paclobutrazol enhanced pest resistance of paper birch but had no effect on Austrian pine. Conversely, paclobutrazol enhanced root growth (and presumably drought stress tolerance) of Austrian pine but had no effect on root growth of paper birch.

This research confirmed the potential of paclobutrazol as a useful tool for the tree care industry. Through its versatile abilities, paclobutrazol can bolster the natural defense and stress resistance of trees in urban environments. Cultural practices that enhance resistance to pests and stress will provide the foundation for holistic plant health care programs for urban forests, ornamental landscapes, and nurseries while decreasing pesticide use in urban environments; this research brought the industry one step closer to doing just that!
Water is becoming one of the world’s most precious resources. Legislation requiring nurseries to protect and preserve clean water has been enacted in several southern and western states. In Florida, legal restrictions in 2004 limited nursery irrigation amounts by 40% compared to 1992 levels, and tighter restrictions are likely due to the Clean Water Act; thus, nursery producers must develop production methods that use less water without sacrificing plant growth and quality. Increasing the efficiency of irrigation delivery is one method of increasing water-application efficiency. Water-application efficiency has been defined as the amount of water stored in the root zone compared to the total amount of water applied. In container production, 100% water-application efficiency equates to zero leachate or leakage.

A major increase in water-application efficiency occurred when growers shifted from overhead irrigation to micro-irrigation. For example, overhead irrigation application efficiencies ranged from 12–50% while micro-irrigation application efficiencies ranged from 44–72%.

Cyclical or pulse irrigation—irrigating containers with lower volume for several short periods—compared to one or two irrigation events per day increased both water-application efficiency and plant quality. Increased water-application efficiency was attributed to increased lateral water movement (or alternatively, decreased channeling) in substrate. An alternative approach is the multi-pot box system, which increases irrigation water use efficiency by capturing rainfall and excess irrigation in reservoirs with later delivery to the crop via sub-irrigation.

Water-application efficiency could be further increased if an efficient irrigation delivery system is coupled with a plant-integrated monitoring system. One monitoring approach uses relative ET-modeling and crop coefficients to estimate crop water needs. Because crop water coefficients are specific to each crop, production location, and period of the growing season, the ET-modeling approach has not been widely adopted. Modeling container crop water use has been demonstrated, but its practical application requires equipment and technical expertise not found in most nurseries. Others have used plant water stress to control irrigation events; however, significant lag times between stress onset and plant response have limited commercial adoption.

Another approach monitors substrate moisture content. Various instruments are available to monitor soil moisture, but none have been widely adopted for nursery distribution within a container; thus, the appropriate location and orientation of substrate moisture sensor probes has not been determined.

For container-grown plants, the combination of container geometry and substrate physical properties dictates the maximum volume of plant-available water. The amount of water held by a substrate following saturation and gravitational water loss is termed container capacity. Container capacity can be determined gravimetrically in real-time. Then, irrigation can be applied to plants within a narrow range of substrate moisture contents, resulting in 100% water efficiency. Maintaining substrate moisture content at or near 100% container capacity will also increase plant growth.

The objective of this study was twofold: 1) to determine if gravimetric monitoring of a plant-substrate-container unit could be used to manage irrigation volume on a real-time basis, and 2) to study the effect of reduced irrigation volume on baldcypress (*Taxodium distichum*) growth, water use, and nutrient uptake. The research findings showed that substrate moisture content can be monitored gravimetrically to significantly reduce leaching and irrigation volume without compromising plant quality when baldcypress is irrigated at 100% ECC. Future research is needed to investigate the effects of reduced leaching fraction on plant growth in other production systems.

In a recently completed study, Jon Sammons, a graduate student, demonstrated that similar-sized baldcypress plants could be grown with his “near-zero irrigation monitoring system” with one-half of the fertilizer and water of plants under standard irrigation and fertilizer application practices.
Functional Cloning of Avirulence Genes from *Phytophthora infestans*
Sophien Kamoun, Plant Pathology

Plant pathogenic oomycetes, nutrient-absorbing parasitic organisms, cause devastating diseases on numerous crops and ornamental and native plants. The most infamous oomycete pathogens are known as *Phytophthora*. Diseases caused by *Phytophthora* result in estimated yearly losses of more than $10 billion worldwide. These pathogens affect plants as diverse as potato, soybean, cocoa, and strawberries. *Phytophthora infestans*, the cause of the Irish potato famine, remains a destructive pathogen resulting in multibillion-dollar losses in potato and tomato production. Recently, the use of broad-spectrum disease resistance genes (*R*) has emerged as a potentially viable strategy to manage the late-blight disease. However, a better understanding of the mode of action of these *R* genes is essential to evaluate their potential efficacy. The objective of this research was use a functional genomics approach to identify avirulence genes, which negatively impact the ability of a pathogen to infect its host plant. Many avirulence genes are now known to represent a subset of toxic factors involved in the mediation of the host-pathogen interaction. Scientists focused specifically on *Phytophthora infestans* that are recognized by specific *R* genes.

In collaboration with BASF Plant Science, scientists used a functional genomics approach to identify the specific avirulence genes, AvrBlb1 and AvrBlb2 of *Phytophthora infestans*. Both avirulence genes are members of a family of proteins that are known to be located inside plant cells. AvrBlb1 appeared to be a well-known *Phytophthora infestans* gene that is upregulated during host infection. AvrBlb2 is a novel gene that encodes small amino acids protein. Both genes are members of gene families in *Phytophthora infestans*, with variable levels of complexity. Both also have several closely related duplicated copies that were found during the study.

The identification of AvrBlb1 and AvrBlb2 will provide a greater understanding about the diversity of these genes in *Phytophthora infestans* populations for future research. This will enable scientists to evaluate the extent to which the genes have wide-spectrum activity against *Phytophthora infestans*; it will also help scientists monitor the potential occurrence or emergence of these pathogens. The ultimate elimination of these pathogens could mean salvaging many crops as well as a potential annual savings of nearly $10 billion.
Because food safety is constantly on the mind of today’s consumers, scientists aim to increase the effectiveness of preservation methods against harmful bacteria that make their way into the food supply. One of the most harmful bacteria is *Escherichia coli* O157:H7, which causes food-transmitted diseases with symptoms ranging from bloody diarrhea to kidney failure. Yousef’s team previously found that combinations of ultra-high pressure processing (UHP) and the additive tert-butylhydroquinone (TBHQ) were exceptionally effective against pathogenic *E. coli*. However, before adaptation of the new findings by food processors, scientists should reveal the mechanism of lethality of the UHP-TBHQ combination. UHP is a promising emerging technology for preserving food, and TBHQ is an antioxidant food additive that has been used in many foods without detrimental effect on product quality.

Understanding the response of pathogenic *E. coli* to preservation methods is crucial for developing effective protective strategies for safer food. Therefore, combinations of UHP and TBHQ were tested against pathogenic and non-pathogenic *E. coli* as well as other strains with various mutations in selected genes. Treatment with UHP at 400 MPa for five minutes decreased *E. coli* viable populations by 2.4–3.7 orders of magnitude (i.e., 2.4–3.7 log CFU/ml); however, presence of TBHQ increased UHP lethality by 1.1–6.2 log CFU/ml, depending on the strain tested. The rest of *E. coli* strains responded to TBHQ, UHP, and their combination in a manner that depended on the type of mutated gene. This response revealed that certain proteins that contain iron-sulfur cluster are critical to the synergy between TBHQ and UHP against *E. coli*. These proteins are involved in significant bacterial cell functions such as sulfur mobilization, nitrate metabolism, and maintenance of intracellular oxidation-reduction (redox) potential. Mutations in genes maintaining cell redox potential and anaerobic metabolism were associated with *E. coli* resistance to UHP-TBHQ combination.

In conclusion, a mechanism has been proposed for the enhanced lethality of ultra-high pressure treatment by TBHQ against *E. coli* O157:H7. The mechanism revealed in this research may benefit food processors using UHP-based preservation as well as biologists interested in studying pressure-tolerant marine organisms. Consumers will also greatly benefit from this research because the pathogen studied is responsible for over 70,000 illnesses annually in the United States.
Seed Grant Competition

The Seed Grant Competition is designed to encourage new and innovative research and generate the preliminary data needed for successful application to competitive extramural funding sources. Seed Grants are supported at a maximum level of $50,000.
The implementation of the National Organic Program (NOP) in October 2002 impacted all interested agents in the organic food market from farmers to consumers; yet, the nature of the impact remains uncertain. On the consumer side, organic buyers have a range of motivations and information about the organic industry and are often vocal in their demand for quality. However, those same consumers are constrained by a high degree of imperfect product substitution, low absolute total volume of aggregate demand for organic product relative to non-organic/conventional products, and the tendency to be less sensitive to price differentials.

Marketers may be beginning to realize that some organic buyers associate organic content with localness. It remains uncertain whether the value of the organic identity of a product becomes enhanced when used in conjunction with another quality claim such as a location-association claim. Scientists conducted a series of investigations that attempt to determine the factors that influence the adoption of and the qualification for organic producers and food processors considering organic marketing strategies. This research considers the diffusion/adoption process, consumers’ valuation of organic foods, and the firm’s choice of organic content and location-association messages.

Like any other market, the current structure of the organic food industry is influenced by the degree of competitive rivalry within the industry. In response, agribusinesses are making choices that will impact their long-run sustainable competitive advantage, including the decision to adopt NOP practices. Government-endorsed, quasi-voluntary, quality-standardization programs such as NOP can have a wide range of impacts. Customer demands to substantiate the organic identity of the firm’s product can be met. Market structure can also be reinforced through the development of entrance barriers to nonconforming potential organic producers. Such a strategy may also be associated with the relative weakness of domestic primary producers, which is forcing certain domestic organic manufacturers to outsource ingredients.

Researchers considered the role of third-party certifiers within the organic food market. This study gained new insights into the operational level of global organic food supply chains as well as the nature of the market for certification and the nature of the relationship between adopters of a production certification scheme and the suppliers of certification. In addition, this investigation questions the informational, distributional, and environmental constraints that influence a potential adopter’s decision to adopt and qualify for certified organic production practices, the degree of alignment of service offerings across certification firms, and the regulatory rapprochement of national/international organic certification schemes across international regions.

The actions of innovation suppliers and their impact on the ultimate magnitude of organic production adoption rates can be easily observed by noting the current trends within the organic market. Economic agents (including primary producers, processors, third-party certifiers, and consumers)
are relatively dispersed geographically across the United States due to the tendency of organic marketers to target local-minded consumers; however, there is evidence that economic regional clustering of the organic food industry is an indication of asymmetric distribution of market access opportunities to potential adopters provided by the innovations diffusion agent or supplier. Evidence of vertical supply-chain regional agglomeration is prevalent in statistical correlations between the number of certified producers per state, the number of new product introductions per state, total organic sales per state, and the number of third-party certifiers per state. These strong positive correlations support the theory that local monopsony power of NOP-certification held by third-party certifiers exists in some economic regions; this may be acting as an adoption constraint in the supply-chain flow of information and organic market access opportunities. These research findings imply that the forces of economic agglomeration are impacting the temporal and spatial development and structure of the organic food market within the United States.

A hedonic pricing model was utilized in order to determine the aggregate implicit value of an organic claim. Scientists used data from all new US food products released into the market since 2000. This investigation also tested the hypothesis that the implicit value of the organic quality claim increased following the inception of the NOP. Further, researchers explored whether the implicit value of the organic quality claim is higher in the presence of the USDA organic seal. In particular scientists were interested in exploring the difference between 100% organic and 95% organic messages. Previous consumer research suggests no statistically significant difference in willingness to pay for such product categories; however, consumers might easily misjudge the content of organic foods due to the fact that label messages vary slightly.

The cost of sourcing 100% organic ingredients may be significantly higher than that for 95%, making firm profit margins more attractive. Interactive effects of using multiple claims might also impact the use of a particular claim, such as “organic.” As the number of product claims used by a firm to differentiate their product increases, the marginal change in the premium charged for each product/quality characteristic is unlikely to be zero. Specifically, the premium for a particular nutritional quality characteristic should be positive when it is used in conjunction with an organic claim because it is believed that producers recognize that organic food consumers perceive organic products to be healthier than conventional counterparts. However, bounded rationality (information overload due to crowded product labels and busy shoppers) will likely confound a simple linear relationship.

It is assumed that processors who market their product as organic will strive to qualify its organic content level for use of the NOP seal on the product label at the lowest cost. This assumption holds so long as it is believed by the organic food market that the seal effectively substantiates the organic claim. Likewise, organic consumers see little difference between the two top levels of NOP certification because both can carry the quality seal. This study found that there is evidence that processors perceived the difference between the 100% and 95% organic certification to be minor. Thus, firms are choosing to produce their product at the second level, where manufacturing and certification costs are lower compared to that at the 100% level. Furthermore, at the 95% level, firms are eligible to use the NOP seal without incurring the additional costs of high value organic ingredients needed for the production of their new product.

The USDA National Research Initiative is funding further organic marketing research. The market for organic foods appears to have been facilitated by the introduction of the NOP. Opportunities to deliver value-added, segregated crops abound. Food processors are responding to demand for multi-ingredient foods with organic content, yet the adoption of certified organic practices remains low in many regions and crop/livestock systems. Given concerns about consistent supplies, food processors, and food service operations, retailers seem willing to import ingredients and food products, thus leading to a ten-fold international trade deficit for organic products.

Future research will evaluate the evolving market for organic foods, considering aspects of consumer demand, market intelligence, marketing strategies, and international trade. Scientists seek to further facilitate organic markets by better understanding the relevant market and trade dimensions. Two rounds of consumer experiments/surveys will explore factors such as the synergy/confounding effects of organic and other quality claims (e.g., health, local, scale of farm/firm). Emerging trends in food-label messages (such as joint marketing of organic and nutritionally enhanced/functional attributes, product reformulation efforts in response to changes to the National List, and firm brand/product strategies) will be explored using two proprietary food-label databases. Surveys of organic certification agents, food processors, food service operations, and retailers will evaluate the market orientation of organic supply chains, paying particular attention to trends shaping the flow of certified organic ingredients and foods. The role of codes developed by independent organizations such as the Codex Alimentarius Commission and the International Federation of Organic Agriculture Movements will be evaluated to determine whether regulatory differences between various organic standards have been reduced by NOP.
Effects of Androgens on Estrogen Receptor Turnover
Horacio Cardenas-Seijas and William F. Pope, Animal Sciences

Fertility problems affect the reproductive efficiency of livestock and are frequently related to embryonic and fetal losses. The uterus plays critical roles in embryonic and fetal development; as such, adequacy of its functions is required for successful reproduction. Estrogens are hormones secreted by the ovaries and are major regulators of uterine functions. Estrogens influence the uterus by binding and activating cellular proteins called estrogen receptors. Estrogen receptors can be activated by numerous estrogenic compounds present in the environment. Excessive estrogen stimulation has been related to abnormal uterine functions and cancer. Identification of factors that control the amounts of estrogen receptor are important for understanding uterine functions, helping to find ways to improve animal fertility, and decreasing the incidence of uterine diseases.

Androgens such as testosterone are secreted by the ovaries. In experiments using pigs, scientists have observed that androgens decreased amounts of the estrogen receptor and, simultaneously, inhibited estrogenic actions in the uterus. It appears that androgens can work as natural protectors of the uterus against excessive estrogenic stimulation. The objective of the research was to determine if androgens affected the estrogen receptor by increasing its degradation.

Cells from the pig uterus were isolated, cultured, and treated with estrogen, androgen, and an inhibitor of an important system of protein degradation, the proteasome. The proteasome is a cluster of proteins found in the cytoplasm of living cells; it degrades damaged proteins. Androgens decreased amounts of the estrogen receptor, supporting the concept that androgens might function as regulators of estrogen actions. Inhibition of the proteasome system completely blocked the effect of androgen on the estrogen receptor, suggesting that androgens might enhance proteasomal degradation of this receptor.

Research will continue to confirm and expand these findings and observations. It is of interest to determine whether enhancement of proteasomal degradation of the estrogen receptor induced by androgen is specific, and, if so, to identify the mechanism of specificity. Development of methods to regulate estrogen effects has been of great interest in biology and biomedicine.
Reduction of Tetracycline Resistance Present in Food-Animal Manures by Composting and Anaerobic Digestion
Frederick C. Michel, Food, Agricultural, and Biological Engineering
Zhongtang Yu, Animal Sciences

Antimicrobial drugs are arguably the most important drugs developed in human history because they have saved lives and cured infections (of both humans and animals) in a magnitude not matched by any other type of drugs. Resistance to antimicrobial drugs has developed against all antimicrobial drugs in almost all types of bacteria (both pathogenic bacteria that cause diseases and non-pathogenic bacteria) and is becoming more and more widespread. The widespread occurrence of antimicrobial resistance not only poses a severe risk to the health and well-being of both humans and animals but also leads to considerable economic losses. The Institute of Medicine estimates the annual cost of infections caused by antibiotic-resistant bacteria to be $4 to $5 billion US dollars. Thus, antimicrobial resistance has become a great concern not only in the US but also other countries around the globe.

Because a large quantity of antimicrobial drugs (up to 50% of the antimicrobial drugs produced in the US) is used in farm animal production to promote growth performance, much of the concern over antimicrobial resistance is directed at the use of antimicrobial drugs in farm animals. Animal manure is the largest antimicrobial resistance reservoir because most of the antimicrobial resistance arising from farm animals winds up in animal manure; thus, animal manure treatment offers a critical control point to contain and/or destroy antimicrobial resistance.

Scientists investigated the reduction of antimicrobial resistance to tetracycline and macrolide-lincosamide-streptogramin B (a superfamily of related antimicrobial drugs) in manure treatment systems employed by animal farms. The research objective was to identify effective manure treatment systems so that they can be used to reduce the antimicrobial resistance arising from animal farms. Investigators studied both full-scale, on-farm animal manure treatment systems and lab-scale manure treatment systems. Using antimicrobial resistance to tetracyclines and macrolide-lincosamide-streptogramin B as models, it was found that storage of animal manure and wastes in conventional, on-farm lagoons does not result in any significant reduction of antimicrobial resistance. Treatment of animal manure and wastes by biofilters (biological treatment reactors consisting of bacteria, which is attached and packed into solid medium for the purpose of pollutant removal) did not appreciably reduce antimicrobial resistance either. Anaerobic digestion and composting at mesophilic temperature (no higher than 37°C) significantly reduce the antimicrobial resistance in animal manure. The most effective treatment was composting at thermophilic temperature (55°C), which resulted in five to seven orders of magnitude (99.999% to 99.99999%) reduction in antimicrobial resistance.

Researchers concluded that both anaerobic digestion and composting—especially at elevated temperatures—are effective and practical to reduce antimicrobial resistance arising from animal production. Some antimicrobial-resistant bacteria may survive the animal manure treatment systems; these resistant bacteria will be disseminated into the environment when the treated manure is applied to land, posing potential risk to humans and animals. These persistent bacteria and their potential risk will be the subject of future planned studies.
Understanding the Function of a Target Gene in Fat Cell Development
Kichoon Lee and Steven C. Loerch, Animal Sciences

The increased prevalence of obesity over the last few decades has raised concerns about health risks associated with this problem. Economically, the US spends an estimated $117 billion annually in extra health costs related to obesity. Ohio spent 6.1% ($3.3 million) of its total medical expenditures in 2003 for obesity treatment. In the livestock industry, reduction of subcutaneous fat and enhanced intramuscular fat in animal carcasses will be beneficial to livestock producers and the consumer. Therefore, the discovery and understanding of the interactions between nutrients, metabolites, new and old genes, and biological pathways is necessary if researchers are to be successful at manipulating the development, localization, and quantity of fat tissue in humans and livestock.

Recently, microarray technologies have been successfully used to compare the expression profiles of several thousand genes simultaneously in different biological conditions. A novel gene that is highly expressed in fat tissue was identified by our microarray studies. The similarities to other known genes indicate that the novel gene might be involved in retinoic acid and fatty acid metabolism. An increasing number of researchers also report that retinoic acid regulates adipocyte—a cell that synthesizes and stores fat—development in vitro and fat accretion in vivo.

The objectives of this study were to characterize protein function and to identify the role of a target gene in adipose tissue development. This was done by using in vitro and in vivo systems in a transgenic mouse model. Researchers proposed that the gene product might be involved in vitamin A and lipid metabolism in fat cells, and also that the genetic modification of the target gene could affect adipocyte development and vitamin A metabolism.

Scientists investigated the regulation of the gene expression during the process of fat cell development in vitro and in vivo. The gene was found to increase dramatically during differentiation in vitro and in vivo. Researchers developed genetic systems to deliver the target gene in a preadipocyte cell line for the large production of the target protein. In addition, several founder lines of transgenic mice overexpressing the target gene were successfully generated to study the role of the target gene in adipocyte development in vivo.

For the second half of the proposal, investigators focused on the function of the target gene in adipocyte development using genetically modified fat cell lines and transgenic mice. Overproduction of the target gene in the fat cell did not show the significant differences in fat accretion in the cell line and transgenic mice. Because vitamin A is stored in various forms, measuring the different forms of vitamin A in the tissues and blood will be critical to understand the role of the target gene in the future studies. In addition, dietary challenges with different amounts of vitamin A will be necessary to exaggerate the effect of the modification of the target gene on fat accretion and vitamin A metabolism in the transgenic mice.

This research was the first to show that the target gene can now serve as a new adipocyte differentiation marker and is possibly involved in vitamin A metabolism. The preliminary data and resources obtained from the SEED Grant are now being used to prepare a National Institute of Health. The research will focus on more in-depth details in vitamin A metabolism and fat accretion.
Strawberries as a Functional Food: Chemoprevention of Bladder Cancer
Mark L. Failla and Russ Klein, Human Nutrition

In the United States, bladder cancer is the fourth most common malignancy in men, and the ninth most common type of cancer in women. Effective strategies are needed to reduce the development and progression of this fast-spreading disease. Epidemiologic and laboratory data suggest that diets rich in fruits and vegetables are associated with a reduced risk of bladder cancer. It has also been suggested that these diets are associated with the abundance of a family of compounds referred to as anthocyanins in berries. Anthocyanins are water soluble pigments responsible for the blue, purple, and red color in many plant tissues. Strawberries and black raspberries contain high levels of anthocyanins and are well-liked by consumers, making them an ideal focus for chemoprevention studies.

Scientists have examined the chemical stability of black raspberry anthocyanins, the ability of the bladder cancer cells to accumulate these anthocyanins, the effect of anthocyanin-rich extract on the replication of bladder cancer cells, and also the digestion and absorption of these compounds in the laboratory rat.

Initial studies using an extract from strawberries did not show inhibition of bladder cancer cell growth and replication. Researchers then compared a similar extract from black raspberries and observed inhibition of the replication of these cells. Subsequent studies with these cells characterized this inhibitory activity and examined possible mechanisms responsible for the observed change. In order for these compounds to have the inhibitory activity in humans, the anthocyanins must be absorbed and delivered to bladder tissue.

Armed with this knowledge, scientists administered extract in a single dose to laboratory rats. The stability of the anthocyanins in the gut as well as their presence and abundance in urine were then examined. The results of this study revealed that some anthocyanins from the extract were absorbed and present in urine in the bladder. Thus, the compounds of interest are present in the fluid in contact with bladder cells lining the exterior of the organ.

The research findings support the need for chronic feeding studies using animal models to more critically assess the absorption, tissue distribution, and metabolism of ingested anthocyanins from berries. Also, the effect of berries and their extract on the development and treatment of bladder cancer needs to be further investigated. Finally, investigation of anthocyanin absorption and excretion in urine is merited to develop the experimental protocol needed to directly determine the efficacy of berry fruit and extracts for prevention and treatment of bladder cancer.
Marketing and production contracts are becoming increasingly important to the economic viability of farmers and agro-food enterprises. The movement toward contracts is not surprising as scientific discovery transforms a handful of traditional commodities into a multitude of differentiated products. Firms with particular needs for specialized products can design contracts to provide customized incentives to achieve congruency across employees, suppliers, and business partners. However, poorly designed contracts can reduce a firm's competitiveness. Contracts also serve as conduits for inducing changes in production efficiency via technology transfer, and for shifting liability and responsibility for environmental quality compliance.

While business-oriented social scientists are recognizing the importance of “getting the incentives right,” contract theory is an evolving field with many unresolved questions. The objective of this study was to sharpen investigators’ understanding of contract and incentive theory by using experimental economics to investigate major hypotheses put forth by contract theorists.

The rationale of this research is that the effective design of incentive systems is a critical factor to the success and commercial viability of Ohio food companies, farmers, and agbioscience enterprises operating in competitive markets. Because a typical firm’s overall objectives in an increasingly complex economic environment may not always align with the goals of employees, suppliers, partners, and venture capitalists, firms face the fundamental problem of designing optimal contracts that contain the correct incentives to align disparate goals and eliminate coordination inefficiencies and waste. Economists define optimal contracts as those contracts that allow firms to minimize the incentive and organizational costs of achieving a given objective. Agro-food firms that are able to minimize both production and organizational costs enhance their chances of surviving and being innovative in a globally competitive environment.

An additional purpose for this research is that it can provide insights that can lead to more effective design of public policy and legal rules. Social policy is intimately linked to economics because policy affects the incentives facing individuals and firms. The key to effective policy design is to identify the social objectives (e.g., environmental compliance and food safety) that policy makers want to achieve and then structure the law so that it provides the correct incentives to firms and individuals in society. However, in order to avoid unintended consequences, policy makers should understand the tradeoffs between formal and informal incentives, and the way that explicit legal rules interact with social norms and implicit trading rules across heterogeneous industries.
One problem with today’s existing studies is that they rely on observational data. Moreover, it is extremely difficult to collect observational data on tacit expectations, implicit norms, and informal cultural norms that influence behavior. It is also difficult to determine how incentive systems might respond to exogenous changes in the economic environment. To overcome these issues, this study relied on controlled experiments that eliminated many of the confounding factors that might bias results derived from observational data. Human subjects were placed in artificial economic environments, and important factors were varied to assess how people might design incentives to facilitate trade.

In one set of experiments, it was found that if a third-party (e.g., government) perfectly enforces contracts, social efficiency (value creation) is enhanced. Scientists also found that when third-party enforcement is imperfect, social efficiency will not necessarily decrease, because trading partners find ways to self-enforce contracts by relying on reputation and trust. However, opportunistic behavior by some traders leaves some sellers (analogous to growers) with profits below what they could have earned had they not signed a contract. Finally, partial or one-sided third-party enforcement causes significant efficiency losses by constraining subjects’ ability to use informal incentives.

A second phase of the study investigated a standard theory predicting that tightly specified contracts (complete contracts) covering all possible contingencies are more efficient than discretionary contracts (incomplete contracts) providing traders with discretion. Researchers found that this prediction only holds when contracts can be perfectly enforced by a third-party. With barriers to third-party enforcement (e.g., poor performance measurement technologies), increasing the degree of contractual incompleteness can potentially improve efficiency because it allows traders more latitude to use discretionary bonuses and deducts. The subjects were aware of this as they chose excessively incomplete contracts to execute trades even though more complete contracts were available. At the same time, greater incompleteness potentially increases the risk of extortion, which weakened pre-contractual incentives for parties to contract in the first place. The results suggest that real-world trading contracts should try to balance informal (discretionary) incentives against the risk of distortion.

The results from this research can be used to refine existing theory and yield publications in highly regarded social science journals. Findings can also lead to decision aides and educational materials that potentially help Ohio farmers and agribusinesses implement contracts that reduce organizational costs and increase marketplace competitiveness.
Glycitein: A Soy Isoflavone with Potential Anticancer Activity
Joshua A. Bomser, Human Nutrition

According to the Centers for Disease Control and Prevention, prostate cancer is the most common form of cancer (other than some forms of skin cancer) and the second leading cause of cancer deaths among men in the United States, after lung cancer. About 62% of all clinically diagnosed prostate cancers occur in men over the age of 65. Increased consumption of isoflavones, organic compounds found primarily in soy, may be associated with a reduced risk for prostate cancer. However, the mechanism by which soy isoflavones reduce cancer risk are not well-characterized. Understanding these anticancer mechanisms is an important step in the development of dietary recommendations to reduce cancer risk and may also lead to the development of new food products with increased health benefits.

The overall goal of this study was to examine the ability of glycitein, an isoflavone found in soy, to modulate cellular and molecular processes associated with prostate cancer development. Two primary objectives were proposed, to characterize the involvement of the vascular endothelial growth factor (VEGF) receptor in mediating the effects of glycitein on signaling pathways associated with the growth of prostate epithelial cells. The second research objective was to examine the influence of glycitein on the proliferation and differentiation of prostate epithelial cells.

To date, scientists have made progress in further elucidating the role of the VEGF receptor in mediating glycitein’s effect on cellular signaling in the prostate. This work has identified a novel mechanism by which soy isoflavones exert their anticancer activity in the prostate. These findings were recently published in the Journal of Nutritional Biochemistry (2007, 18(8), 525–532).

In addition, researchers have preliminary data suggesting that glycitein can influence prostate cell differentiation. Scientists believe that the ability of glycitein to influence cellular differentiation in the prostate may reduce loss of critical cells in this tissue during the cancer process. A manuscript detailing these findings has recently been accepted for publication in Nutrition and Cancer: An International Journal.
Characterization of Two Avian Cell Lines (DF-1 and QT-6) for Use in Studies of Avian Influenza Virus
Chang-Won Lee, Food Animal Health Research Program

According to the USDA, Avian influenza (AI)—the bird flu—is caused by type A influenza virus, which infects wild birds (such as ducks, gulls, and shorebirds) and domestic poultry (such as chickens, turkeys, ducks, and geese). There is a certain flu virus for birds just as there is for humans. As with people, some forms of the flu are worse than others. Avian influenza is primarily spread by direct contact between healthy and infected birds and through indirect contact with contaminated equipment and materials. The virus is excreted through the feces of infected birds and through secretions from the nose and mouth.

Isolation of bird flu viruses in specific pathogen-free embryonating chicken eggs or cell culture is critical for epidemiologic investigation of outbreaks and for several other purposes including vaccine production. Although embryonating eggs can support the growth of a broad range of influenza viruses, many field viruses do not readily grow in eggs, and obtaining a sufficient number of reliable, high-quality eggs is a considerable limitation in their use. Furthermore, evidence shows that the growth of influenza viruses in eggs can lead to the selection of variants containing antigenic and structural changes in the hemagglutinin molecule. For this reason, many attempts have been made to find suitable alternatives to the use of eggs for virus isolation and research purposes.

However, previously studied cell lines are mammalian in origin and limitations arise—including restricted host specificity of the cell and a possible change in receptor specificity—when using a mammalian cell line for avian influenza virus study. Therefore, it would be ideal to use a well-established, avian-origin cell line for avian influenza virus study.

This study was conducted primarily to evaluate the characteristics of two avian cell lines (DF-1 and QT-6) and their ability to support the growth of avian influenza viruses (AIVs) from different species in order to identify a cell substrate with a broad viral susceptibility range for use as an alternative to the embryonating eggs.

Scientists evaluated the characteristics of two avian fibroblast cell lines, one of chicken origin (DF-1) and one of quail origin (QT-6), and their ability to support the growth of AIVs obtained from a variety of avian species. The replication efficiency of the AIVs in chicken and quail was comparable to those in primary chicken embryo fibroblast (CEF) and MDCK cells. Receptor distribution analysis demonstrated a high prevalence of sialic acid a2,3-galactose-linked receptors in quail and chicken cells, which support a high growth of AIVs in these cell lines. Furthermore, the quail and the chicken cells supported high plaque-forming ability of representative highly pathogenic Eurasian H5N1 and H7N1 subtype AIVs. These two avian cell lines, especially quail cells, also showed high transfection efficiency and could be useful for reverse genetics-based rescue of AIVs. The study indicates that the chicken and the quail cell lines may be useful for avian influenza virus research in the areas of in vitro host range, molecular pathobiology, and molecular genetics.

In the future, researchers wish to expand the research scope to further validate the usefulness of these cell lines by testing large numbers of samples from different sources. In addition, these avian cell lines will be used to create the influenza virus by reverse genetics. Furthermore, selected influenza isolates will be studied both in these cells and animals to validate whether the cells can be used instead of using animals. Data from this study will be used to build and strengthen future research and proposals for competitive and external grants.
As of right now, little is known about disease resistance mechanisms in coniferous trees. Scientists are determined to gain a better understanding of the biochemical, molecular, and anatomical basis of disease resistance in pine trees. Furthering current knowledge about disease resistance in pine trees will ultimately aid in devising novel, more efficacious, and environmentally friendly disease control strategies in any setting, from the landscape to the plantation.

This issue is particularly relevant to Ohio, as Austrian pine (the species used in this study) is a widely used tree species in the landscape as an ornamental but also as a component of green barriers along highways. However, it is highly susceptible to Diplodia shoot blight and canker—a disfiguring and often lethal disease that causes extensive damage to Austrian pine and other conifers, particularly in the Midwest region of the United States.

The central objective for this study was to advance researchers’ understanding of the molecular basis of systemic induced resistance (SIR) in pine trees. SIR is a phenomenon in which resistance to further attacks by pathogens and insects is induced, naturally and plant-wide, when a plant is attacked a first time by either a pathogen or an insect. In its outcome, SIR is therefore very similar to the phenomenon of immunization/vaccination in animals. Unlike the mechanisms of vaccination in animals, however, very little is known about the mechanisms of SIR in woody plants like conifer trees.

To identify some of the SIR mechanisms, sets of potted Austrian pines were inoculated with Diplodia pinea (the causal agent of Diplodia tip blight and canker). After a certain number of days, samples were taken from the tissues underlying the outer bark of the stem, 30 centimeters away from the inoculations. These are the tissues that normally become vaccinated by these inoculations. Proteins and gene transcripts were then extracted from these tissues. The proteins were analyzed to identify those that were induced in vaccinated trees.

Scientists found several proteins that are induced in vaccinated trees. Research is currently under way in an effort to understand the proteins’ functions and to find out whether this knowledge can be utilized to screen trees for resistance before pathogen attack. Scientists are also analyzing the gene transcripts to determine if there is correspondence with the protein profile or if there are other mechanisms of resistance at the gene level that are not evident at the protein level.

To date, scientists have found that approximately 30 unknown proteins accumulate more in vaccinated than in control trees; scientists are in the process of deciphering the proteins’ potential function. These proteins, therefore, are candidates for resistance markers. Collaborations have recently begun with researchers from Miami University to catalog and annotate the proteins.

OARDC scientists also teamed up with a conifer molecular biologist at the Norwegian Forest and Landscape Institute in Norway to test some probes for known conifer defense genes on Austrian pine. Preliminary readings of the tests show that key defense genes like phenylalanine ammonia-lyase and antimicrobial protein are systemically induced in Austrian pine.
pine infected with *D. pinea* but not in wounded controls. If confirmed, these results would further support the notion that pines possess a systemic signaling system that can induce gene transcription remotely from an inducing site.

Once the potential function of the unknown genes is defined, or at least circumscribed, scientists will be able to use the genes as markers for resistance. In the course of this work, protocols for protein and RNA extraction from stem and branch phloem were optimized. These tissues are notoriously difficult to extract, especially from conifer trees.

This particular study is just a small piece that will be used to solve a much larger puzzle. The next steps will require further funding to more clearly define the host responses to the pathogen. A clearer image of the defense processes characterizing resistant plants will enable scientists to test resistance-associated genes in screening of existing Austrian pine germplasm. Scientists are hopeful that such screening will reveal plants that are naturally more resistant and will thus require less pesticide applications to control common diseases like Diplodia tip blight and canker.

Achieving the goal of creating environmentally friendly disease control strategies is a long-term endeavor that provides small incremental gains over time. Reduction in the use of pesticides to control common problems of landscape trees will bring about real economic, environmental, and health benefits, both to the pesticide applicators and to the communities affected by the application. Lastly, this cutting-edge research will contribute to a richer understanding of other conifer systems as well as a wide range of woody plants.
Developing Functional Genomics Tools for the Planthopper

Peregrinus maidis

Daniel A. Herms and Saskia Hogenhout, Entomology
Dr. Anna Whitfield, Department of Plant Pathology, Kansas State University

Peregrinus maidis, commonly known as the corn planthopper, is a major pest of corn and sorghum and transmits two devastating corn viruses: maize mosaic rhabdovirus (MMV) and maize stripe tenuivirus (MStV). To determine how the planthopper responds to virus infection, scientists dissected the guts from planthoppers reared on healthy and virus-infected corn plants. The isolated RNA from these guts was used for construction of two normalized cDNA libraries.

The cDNA libraries were constructed by Evrogen, located in Moscow, Russia, and each gut library contained approximately $5 \times 10^5$ independent clones. For sequence assembly and analysis, researchers combined the two libraries, resulting in a total of 21,888 sequence reads from individual clones. ESTs were assembled using the EST analysis computational pipeline, ArthropodEST, developed by Kansas State University Bioinformatics Center. The sequences assembled into 1860 contigs and 14,025 singletons. Based on the annotation by Blast2GO, functional roles were assigned to 60.8% of the contigs and 34.7% of the singletons. The remaining sequences comprised conserved hypothetical sequences and those with unknown functions.

The P. maidis EST collection is currently being annotated and will be deposited into GenBank. It will be one of the first planthopper sequences that is publicly available. This is important because there are relatively few sequence information resources available for hemipteran insects, which include aphids, whiteflies, leafhoppers, planthoppers, and psyllids. All these insects are important plant pests, as they are vectors of more than half of all described plant viruses and many bacterial plant pathogens. So far, only the genome of the pea aphid (Acyrthosiphon pisum) is being sequenced. However, planthoppers belong to a different suborder from aphids within the hemipterans. Comparative genome analyses of the pea aphid and P. maidis sequences may reveal candidate genes unique to hemipterans.

Current discussions are taking place with an industry partner to design a P. maidis-specific oligonucleotide microarray. When the annotation of the 15,885 ESTs is complete, investigators will finalize the microarray design and conduct microarray analyses to identify P. maidis genes that are differentially regulated upon MMV infection. Researchers envision that this may lead to the identification of candidate gut receptors and planthopper defense responses that play a role in MMV acquisition. Scientists will determine whether similar genes are also differentially regulated during MStV infection of the planthoppers.

The project results are expected to increase scientists’ understanding of virus-vector interactions. Knowledge of the role of planthopper gut receptors and insect defense response genes that play a role in virus acquisition will aid further investigations focused on targeting specific gut receptors or defense molecules for control of the insect pest.
Antibiotic Resistance Gene Transfer in Dairy Fermentation
Hua Wang, Food Science and Technology

The rapid emergence of antibiotic resistant (ART) pathogens is becoming a major public health threat, leading to significantly increased health care costs. Other problems associated with these pathogens are increased mortality rates, with the risk of running out of therapeutic options for infectious diseases. For a long time it was believed that the uncontrolled usage of antibiotics in clinics and hospitals facilitated the dissemination of antibiotic resistance (AR) in pathogens. Thus, limiting the prescription of antibiotics is by far the primary strategy to combat the AR challenge. However, the current control strategy is not sufficient to stop AR. Previous studies found ART pathogens in retail poultry and meat products, suggesting humans can obtain AR through consuming foods. But the numbers of pathogens are very small, so they do not serve as a significant avenue to transfer AR to humans.

Scientists recently discovered that many retail foods—including ready-to-consume items—contain a significant amount of ART bacteria, most of which are commensals (non-pathogenic) and some of which are even beneficial bacteria. These ART bacteria exist in large quantities in foods, and they can potentially colonize the gut and become part of its microflora after food intake. Secondly, they have the ability to transfer resistance genes to pathogens in foods and the human gut. The data indicate that the food chain may have played an important role in the spread of AR to the general public, independent from the clinical route. Revealing the significance of this pathway allows us to develop better-targeted strategies to interrupt AR transmission to humans. Because cheese products containing ART bacteria were found, researchers therefore decided to investigate whether the commercial starters were actively involved in AR gene transmission during dairy fermentation in this project.

Investigators found that while some of the ART bacteria from cheese samples were identified to be *Streptococcus thermophilus* and *Lactococcus lactis*, the commercial starter cultures containing *S. thermophilus* and *L. lactis* did not carry AR genes. Further, additional AR genes could not be delivered to and stably maintained in *S. thermophilus* isolates from cheese samples in the laboratory environment; this suggests that contamination of ART bacteria, as opposed to gene transfer events during dairy fermentation, is likely the main cause for the observed ART bacteria in these products.

This research resulted in a major collaboration with the US dairy industry. Funding in the amount of $177,682 was received from Dairy Management, Inc., to continue the study and also to create practical strategies to aid the industry. OARDC provided another industrial matching grant for the study. Successful delivery of the study also led to two funded USDA grants in total of approximately $150,000 and an international conference to reevaluate the impact of the food chain on AR transmission to humans (to be held in April 2009 in Washington, DC).

Scientists will work diligently and continue to lead this important food safety and public health research initiative in the US. Investigators plan to further expand research coverage to include other food commodities and to work with researchers from other countries to ensure global food safety.
Development of a Quantitative Bimolecular Luciferase-based Complementation System for Protein-protein Interaction Assay in Plants
Guo-Liang Wang, Plant Pathology

The function of many proteins is known to be mediated through the formation of protein associations or interactions. Traditionally, the yeast two-hybrid is the general choice for detecting protein-protein interactions. However, this popular method has limitations such as the high rate of false positive clones and the lack of plant-specific, post-translational protein modifications. Recently, several methods for in vivo protein-protein interaction detecting have been developed based on fragment complementation. Scientists developed bimolecular fluorescence complementation, which has been used in several studies for detection of protein-protein interaction in plant cells, including a rice protoplast system. Luciferase complementation assay is another system that has been proposed to detect in vivo protein-protein interaction.

Alternatively, an Arabidopsis protoplast two-hybrid (P2H) system based on certain DNA-binding and activation domains was developed recently. Both the luciferase complementation assay and P2H can be used for quantitative detection of protein-protein interaction. However, their use for large-scale interaction assay is limited, especially in monocot crops. On the other hand, making plasmid constructs for luciferase complementation assay or P2H remains is laborious and time-consuming because the cloning requires two steps for making final destination vectors.

Researchers developed a luciferase complementation assay system for protein interaction in rice cells. The systems worked very well for one-to-one protein interaction assays. However, investigators found that the system is not very sensitive. Scientists then optimized the P2H system for large-scale protein interaction assays in rice. Moreover, a novel Zero Background TA cloning technique was utilized in the two systems, allowing high-throughput making constructs by single step TA cloning for large-scale protein-protein interaction assay, which was originally a laborious process.

Two known interacting proteins were used to test the protein-protein interaction in rice cells. Interaction between the two test proteins was successfully detected within those cells. It was found that both methods can quantitatively detect protein-protein interaction in rice protoplasts. While the luciferase complementation assay is more sensitive, the P2H is more stable and suitable for large-scale detection. These two methods can also complement each other. Finally, the constructed vector system enables high-throughput cloning for large-scale testing. These systems provide a very valuable approach for large-scale gene/protein functional analysis in rice through protein-protein interaction assay.

Scientists will apply new funding from federal funding agencies to extend the systems to other cereal crops such as wheat and maize, which are important for Ohio’s agricultural industry because they are major crops grown within the state.
New Enterprise Competition

The New Enterprise Competition is designed to support the exploration of new enterprises and the elimination of barriers that constrain existing ones. New enterprises are considered to be crops, animals, products, goods, and services that currently are not produced for biological, physical, cultural, processing, economic, or social reasons. New Enterprise projects are funded for up to $50,000.
New Enterprise Competition

Development of a New Biological Product for Slug Control
Parwinder S. Grewal, Entomology

Slugs are serious pests in nurseries, home gardens, landscapes, greenhouses, and field crops in the United States, Canada, and Europe. Young seedlings are entirely consumed and mature plant foliage is damaged heavily, leaving unsightly looking plants. The only chemical control, the molluscicide bait containing metaldehyde, is often ineffective, especially under damp conditions. The active ingredients are also toxic to non-target vertebrates and invertebrates. Out of desperation, some commercial growers will formulate their own baits from carbamate insecticides that are registered for other uses. Mechanical control methods such as barriers or beer baits may help. However, these methods are often laborious and generally not satisfactory. The development of an effective biological product for the control of mollusc pests will have tremendous benefits to the nursery and landscape industry and to strawberry and lettuce producers.

A molluscicidal nematode—a microscopic worm with an unsegmented body—possesses exceptional potential for the biological control of pest slugs. Recently, a commercial product called NemaSlug™ has been developed in the UK. It contains the molluscicidal nematodes Phasmarhabditis hermaphrodita. These nematodes are easily mass-produced using conventional fermentation technology, and they have produced good results in the field. Unfortunately, the nematode species commercialized in Europe has not been found to naturally occur in North America and its importation to the US is therefore prohibited. Scientists found a different species of slug parasitic nematode parasitizing snails in a nursery in Lake County, Ohio. Researchers proposed to determine the potential of this native nematode species for slug control here in the United States.

Unfortunately, this nematode species proved to be difficult to work with and produced very inconsistent results against the most common slug, Deroceras reticulatum. After three years of trying both in the laboratory and greenhouses, researchers had to suspend this project. Currently, investigators are still seeking a reliable indigenous nematode strain to control slugs in the US. If such a nematode strain is located, it would prove to be very beneficial and cost effective to the nursery and landscape industry.
Direct Conversion of Agricultural Wastes to Electricity Using Rumen Microbes in Microbial Fuel Cells

Ann D. Christy, Food, Agricultural, and Biological Engineering
Burk A. Dehority, Animal Sciences
Olli H. Tuovinen, Microbiology

Globally and locally, society is demanding clean, safe, sustainable, and ever-increasing supplies of energy. Concerns over pollution, resource depletion, and climate change implications of continual fossil fuel usage have prompted a growing interest in renewable energy sources.

One technology that could potentially help meet these demands is the fuel cell, in which fuels are directly converted to electrical energy by undergoing chemical oxidation-reduction (redox) reactions at an anode and a cathode. The simplest and most developed version currently is the hydrogen fuel cell. Despite the efficiency of hydrogen fuel cells and the fact that they do not result in environmental pollution, their advantages are partially offset by the high cost of required catalysts, the corrosive nature of their electrolytes, and the high temperatures required for operation.

The discovery of microorganisms capable of catalyzing the direct conversion of agricultural wastes into electricity when added to the high-efficiency design of fuel cells has resulted in the development of a new type of fuel cell known as the microbial fuel cell (MFC). In MFCs, bacteria generate electricity by mediating the oxidation of organic compounds and transferring the resulting electrons to an anode electrode.

This MFC research has resulted in several new discoveries. The microorganisms living in the rumen (first stomach) of a cow were found to be able to produce sustainable electrical power in MFCs when fed a regular “diet” of cellulose. Cellulosic biomass, including solid waste products of agricultural and industrial activities, is one of the most abundant renewable sources of energy on earth. However, these compounds are highly recalcitrant and hard to break down. Cows and other ruminants such as sheep, goats, camels, and llamas are uniquely adapted to utilize cellulosic materials (such as grass, hay, silage) as food due to the synergistic relationship between the animal host and its rumen microorganisms.

The electrical power output in these MFCs was sustained for over two months, with periodic cellulose addition. The results demonstrated that electricity can be generated from cellulose by using rumen microorganisms as biocatalysts. It was found that the microbial communities differed when different substrates were used in the MFCs; likewise, the anode-attached and the free-floating microbes were shown to be different within the same MFC. This study also showed that the external electrical circuit resistance significantly affects the bacterial diversity and power output of MFCs. Higher power output and greater efficiencies were achieved in MFCs with lower external resistance. The microbial populations themselves also varied at the various external resistances.

Furthermore, this study showed that methane formation competes with electricity generation at the early stages of MFC operation, but operating conditions suppress methanogenic activity over time. Future research is planned to enhance the understanding of microbial communities, interspecies interactions, and the processes involved in electricity generation that are essential to more effectively design and control cellulose-fed MFCs for enhanced performance. In addition, technical and biological optimization is needed to maximize power output in cellulose-based MFCs.
Domestication and Commercialization of *Taraxacum kok-saghyz*: A New Crop to Fuel Ohio’s Agricultural and Rubber Industry
Matthew D. Kleinhenz, Ray Miller, and John G. Streeter, Horticulture and Crop Science
Frederick C. Michel, Food, Agricultural, and Biological Engineering

Natural rubber (NR) is a unique, strategic resource with an unstable supply. The properties of NR are not duplicated in synthetic, man-made rubber and are irreplaceable in national defense, medical, transportation, distribution, construction, and other applications. Nevertheless, the rise in demand for NR continues to exceed its supply.

Currently, NR production begins with the collection of sap from *Hevea brasiliensis* trees grown primarily in Southeast Asia. Land that has been long-used to grow *Hevea* is being converted to other uses while worldwide demand for NR rises sharply. Little new land is set aside for *Hevea* planting, and NR production is not under end-user control. Therefore, other sources of NR must be identified.

Many plants produce latex, but very few produce the quantity and quality of NR needed in commercial practice. Fewer still appear to be as prepared for growth throughout Ohio and the US as *Taraxacum kok-saghyz* (TKS, Russian dandelion), a relative of common dandelion native to Uzbekistan.

Crop domestication-improvement is a continuum of activities and stages. Common food, fiber, and industrial crops began as wild plants, but their contributions to human welfare are now difficult to understate. TKS might achieve similar status but only after TKS plants can be influenced to perform reliably and the process for extracting NR from TKS roots can be streamlined. In fact, those familiar with the potential value of TKS as an industrial crop assert that TKS supply (i.e., production and processing) factors dictate the emergence of TKS-based business. In response, the TKS domestication-commercialization team has set out to: 1) enhance TKS genetic stock, 2) optimize the process for extracting rubber from TKS roots, 3) further validate the suitability of TKS-derived rubber for multiple applications, and 4) refine the methods for growing and harvesting TKS crops.

Measurable progress has been achieved in each of the four tracks. For example, the average rubber level of OARDC-grown TKS roots has increased nearly ninefold to above the commercialization threshold, and seed stocks of known pedigree have increased nearly fifteenfold. Rubber extracted from Ohio-grown TKS roots using a commercial-like process is known to possess properties similar to that of *Hevea*-based NR, the current industry standard. And, information gained from TKS field production suggests that it will require limited fertilizer, water, or crop protection inputs. The Ohio State University and its partners have also established a Program of Excellence in Natural Rubber Alternatives (PENRA). PENRA will bring attention to the program’s partners through its ability to advance TKS-related science and industry.

Procedural challenges associated with the domestication and commercialization of TKS are large but minor in comparison to the opportunities represented to Ohio and the US. A reliable, domestic supply of NR would stabilize the supply of this key resource, diversify and strengthen incomes, and enhance ties between two signature Ohio industries: agriculture and rubber.
Developing a Novel Commercial Delivery System for Entomopathogenic Nematodes
Parwinder S. Grewal, Entomology

Entomopathogenic nematodes (EPNs) are lethal insect parasites that are currently used worldwide to combat a wide variety of insect pests. The infective juveniles (IJs), the only non-feeding stage, persist in the soil and search for suitable insect hosts. The IJs penetrate into the insect hemocoel through natural openings, and they then release symbiotic bacteria. Toxins produced by the nematodes and bacteria kill the host within 24 to 48 hours. The nematodes then feed on the multiplying bacteria and decaying host tissues and complete one to three generations in the host cadaver. Upon depletion of the food resource, next generation IJs form and then exit the cadaver in search of new hosts.

EPNs are effective against soil-dwelling insects, have no reported non-target effects, and are not harmful to mammals. Improvements have been made in the large-scale production of EPNs, and several species and strains have been identified for use against specific target pests. The developments of superior formulations like wettable, dispersible granules and wettable powders have improved storage stability of EPNs, but short shelf life still remains a major obstacle in the widespread commercial use of EPNs.

EPN products are normally mixed in water and applied as a spray to the target substrate or area. Nematode fitness and survival may be reduced by environmental factors such as high temperature and desiccation as well as factors associated with spray equipment. Therefore, scientists proposed to develop a novel method of delivering the nematodes through commercial potting medium used in greenhouses and interiorscapes. In the initial trials, investigators found that the infective juvenile nematodes mixed in the potting medium survived only for a few weeks.

Researchers then decided to explore the potential of using nematode-infected insect cadavers as a means to enhance survival of nematodes in the commercial potting medium. Cadavers of two different insect species were tested. It was found that the nematode *Steinernema carpocapsae* survived better in the cadavers of the wax worm *Galleria mellonella* than in the mealworm *Tenebrio molitor*. It was also found that the nematodes can survive in the potting medium up to six months when delivered through the infected insect-cadavers; when delivered as aqueous suspension, the nematodes survived for only one month.

This research shows the potential delivery of nematodes in the form of infected insect cadavers through commercial potting medium. Using nematodes in this fashion cuts costs associated with separate storage, transport, and application of EPNs. Further nematode research is needed to improve storage stability of nematodes in the potting medium. Once nematodes can be used and stored in the potting medium, the nursery and landscape industry can utilize this technology as a potential alternative to certain chemical pest control.
Publications, Presentations, and Graduate Students

Sharing knowledge through publications and professional meetings is an important part of research, as is training graduate students for careers in research. Using data from SEEDS projects, OARDC scientists have reported publication of 578 peer-reviewed articles, bulletins, abstracts, and popular press articles. More than 1,000 presentations have been made in locations throughout the world. Eighty-five graduate students have been supported on SEEDS projects, providing them with the skills needed to move forward with scientific research in the future.
Presentations and Posters


Chen, Jing, Yu, Zhongtang, Michel, Frederick C., Fluhraty, Francis L., Wittum, Thomas, & Morrison, Mark. Development and application of real-time PCR assays for quantification of erm genes conferring resistance to macrolide-lincosamide-streptogramin B.


Deol, Y. S., & Grewal, P. S. Development of a novel delivery system for entomopathogenic nematodes. OARDC Annual Conference. Columbus, OH. 4/21/05.

He, J., Keatley, K., Failla, Giusti, M. Anthocyanins with specific structures are stable in the digestive tract—A kinetic study of black raspberry anthocyanins in rat stomach and intestine. 2008 Institute of Food Technology Annual Meeting and Food Exposition. 7/15/08.


Keatley, K., He, J., Klein, R., Kresty, L., Giusti, M., & Failla, M. Anthocyanins from black raspberry inhibit proliferation and cell signaling pathways of human bladder epithelial cancer cells. 2007 Institute of Food Technology Annual Meeting.


Keatley, K., He, J., Klein, R., Kresty, L., Giusti, M., & Failla, M. Anthocyanin-rich extracts from black raspberries inhibit growth promoting and anti-apoptotic signaling pathways in human bladder carcinoma cell lines. OARDC.

Lee, Chang-Won, Hong, Keumsuk, & Strother, Megan. Replication of influenza viruses in chicken-orig (DF-1) and quail-orig (QT-6) cell lines. American Veterinary Medical Association. Washington, DC. 7/14/07.

Mackey, David. Bacterial type III effectors inhibit plant defenses by perturbing vesicle traffic. Ohio State Plant Molecular Biology/Biotechnology (PMBB) annual symposium. Columbus, OH. 4/07.


Michel, F. C., Chen, J., Sreevatsan, S., Morrison, M., & Yu, Zhongtang. Application of real-time PCR assays for the quantification of genes encoding resistance to antibiotics in composted, liquid stored and anaerobically digested manure.


Moon, Youyoun, Chapin, Laura, J., & Jones, Michelle L. Cloning and functional analysis of type I and type II metacaspases during flower senescence in *Petunia x hybrida* cv. Mitchell Diploid. OARDC Annual Conference. The Ohio State University.


Shanahan, Christopher J., Atalay, Tekle, & Hooker, Neal H. Exploring location-association quality claims on food labels. ACCI Annual Conference. St. Louis, MO. 4/21/07.


Shanahan, Christopher J., Sporleder, Thomas, & Hooker, Neal H. Adoption of product innovations by food processors: Inimitable first mover marketing strategies. IAMA Annual Meeting. Parma, Italy. 5/26/07.


Welty, Celeste. Cucumber beetle management by a trap-out strategy. Ohio Fruit and Vegetable Growers Congress. Sandusky, OH. 1/15/08.

Wu, Steven, & Roe, Brian. Discretionary latitude and the nature of relational contracting. Allied Social Science Associations Annual Meetings. Chicago, IL. 01/06.

Publications


