

AdvanCES in Research



FINDING SOLUTIONS TO THE WORLD'S MOST CRITICAL CHALLENGES



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College of Agricultural,
Consumer and
Environmental Sciences



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Before *AdvanCES in Research* was produced to share new ACES discoveries with you, patient and persistent researchers had to accomplish the following:

- Painstakingly weigh rats and measure their food intake
- Carefully catch small birds in mist nets, then take blood samples and tag each bird with a tiny radio transmitter
- Walk down endless rows of corn and soybean fields in all kinds of weather
- Travel dusty dirt roads in Brazilian heat
- Observe family mealtimes with hundreds of participants
- Tirelessly track over 200 couples' memories of their romantic relationships
- Snorkel for hours in cold, shallow water to monitor 70 largemouth bass nests
- Clock countless work hours in laboratories and greenhouses

You get the idea. And this issue represents but a small sampling of the research projects done in recent years in the College of ACES.

We hope learning more from the stories within will help you appreciate the effort—sometimes tedious and strenuous—required to achieve advances that benefit us all.



Robert J. Hauser
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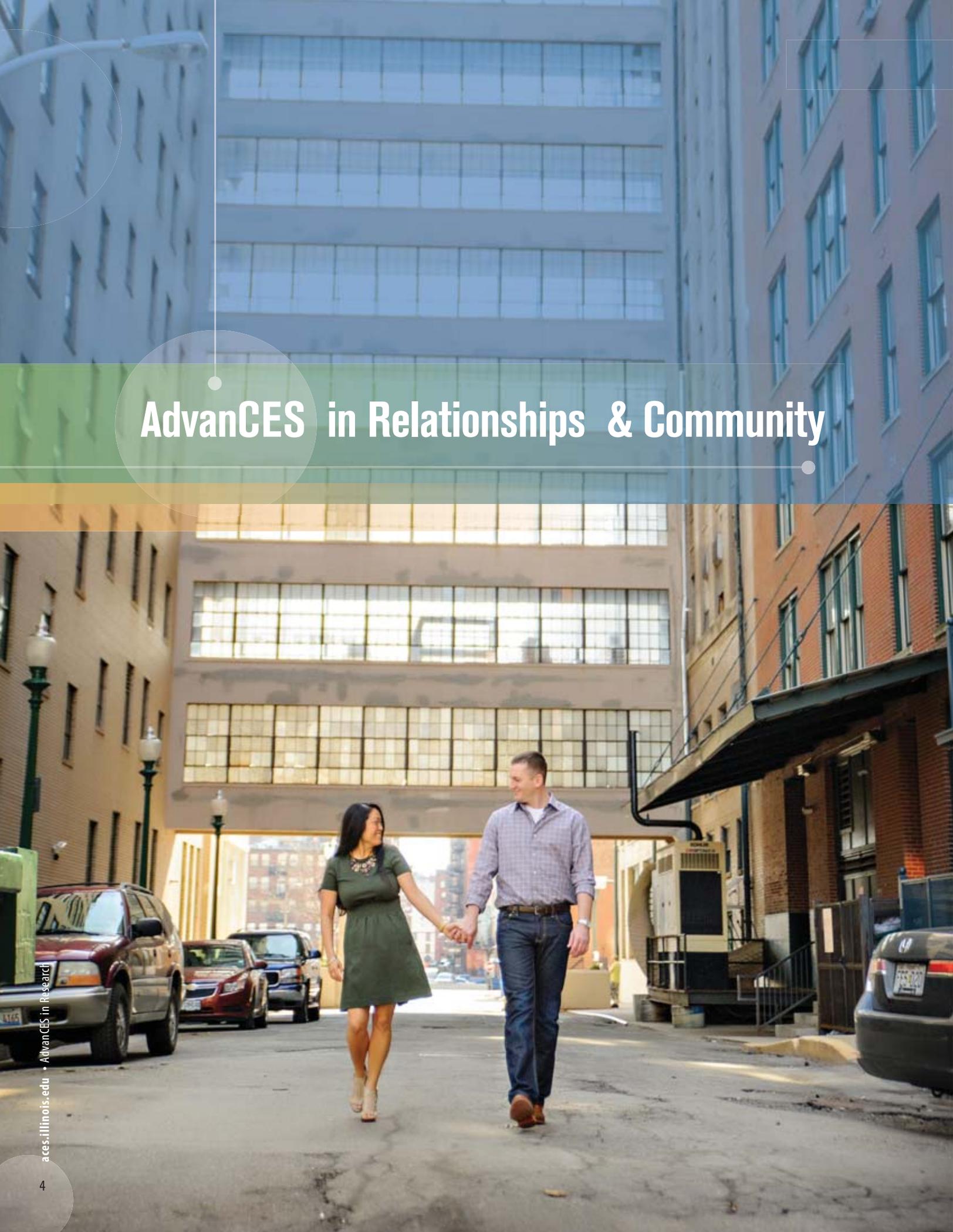
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Photo: ADM Institute staff member Grace Kenney in the Philippines for a course on postharvest loss.

A photograph of a man and a woman walking hand-in-hand down a city street. The woman is wearing a green dress and the man is wearing a blue and white checkered shirt and blue jeans. They are walking towards the camera. The street is lined with multi-story buildings. In the background, a skybridge connects two buildings, featuring large glass windows. The sky is clear and blue. The overall scene is bright and sunny.

AdvanCES in Relationships & Community

Good marriage can buffer effects of dad’s depression on young children

What effect does a father’s depression have on his young son or daughter? When fathers report a high level of emotional intimacy in their marriage, their children benefit, said a University of Illinois study.

“When a parent is interacting with their child, they need to be able to attend to the child’s emotional state, be cued in to his developmental stage and abilities, and notice whether he is getting frustrated or needs help. Depressed parents have more difficulty doing that,” said Nancy McElwain, a U of I professor of human development.

But if a depressed dad has a close relationship with a partner who listens to and supports him, the quality of father–child interaction improves, she noted.

“A supportive spouse appears to buffer the effects of the father’s depression. We can see it in children’s behavior when they’re working with their dad. The kids are more persistent and engaged,” said Jennifer Engle, the study’s lead author.

The researchers used data from a subset of 606 children and their parents who participated in the Eunice Kennedy Shriver National Institute of Child Health and Human Development (NICHD) Study of Early Child Care and Youth Development.

When their child was 4½ years old, parents ranked themselves on two scales: one that assessed depressive symptoms and another that elicited their perceptions of emotional intimacy in their marriage. Parents were also observed interacting with their child during semistructured tasks, which was repeated when children were 6½ years old.



“At this stage of a child’s development, an engaged parent is very important. The son’s or daughter’s ability to focus and persist with a task when they are frustrated is critical in making a successful transition from preschool to formal schooling,” Engle said.

Interestingly, depressed mothers didn’t get the same boost from a supportive spouse.

That may be because men and women respond to depression differently, Engle added. “Men tend to withdraw; women tend to ruminate. We think that high emotional intimacy and sharing in the marriage may encourage a woman’s tendency to ruminate about her de-

pression, disrupting her ability to be available and supportive with her children.”

Depressed men, on the other hand, are more likely to withdraw from their partners. “This makes emotional intimacy in the marriage an important protective factor for fathers,” McElwain said.

The study emphasizes the need for depressed parents to seek support—if not from their spouses, from friends, family, and medical professionals, she added.

The study was published in *Developmental Psychology*.

Could your relationship with your mother increase your child's chances of obesity?

Could the quality of your attachment to your parents affect your own child's risk for obesity? A new University of Illinois study says it could.

"If your mother regularly punished or dismissed your anger, anxiety, or sadness instead of being sensitive to your distress and giving you strategies for handling those feelings, you may be insecurely attached and parenting your children in the same way. A child who doesn't learn to regulate his emotions may in turn develop eating patterns that put him at risk for obesity," said ACES researcher Kelly Bost.

The U of I study documents the association between a parent's insecure attachment and their child's consumption of unhealthy foods, leading to weight gain, she said.

"We wanted to discover the steps that connect attachment and obesity. Scientists know that a person's attachment style is consistently related to the way he responds to negative emotions, and we thought that response might be related to three practices that we know are related to obesity: emotion-related feeding styles, including feeding to comfort or soothe; mealtime routine; and television viewing," she said.

According to Bost, children form secure attachments when their caregiver is available and responsive. That attachment gives the child a secure base to explore her environment, protection in times of distress or uncertainty, and a source of joy in everyday interactions.

When that secure base isn't there, an insecure attachment can result, and children who are insecurely attached often experience feelings of anxiety and uncertainty in close relationships. As adults, they are especially at risk for ineffective parenting with respect to some of the factors implicated in childhood obesity, she said.

In the study, 497 primary caregivers of 2½- to 3½-year-old children completed a widely used questionnaire to determine adult attachment, answering 32 questions about the nature of their close relationships. They also rated themselves on a scale that measured depression and anxiety.

Parents then responded to questions about how they handled their children's negative emotions; whether they engaged in emotion-related, pressuring feeding styles known to predict obesity; the frequency of, planning of, and communication during family mealtimes; and estimated hours of television viewing per day.

The families are part of the university's STRONG (Synergistic Theory and Research on Obesity and Nutrition Group) Kids program, a "cells-to-society" approach to the study of

childhood obesity. The children are enrolled full-time in 32 child-care centers.

"The study found that insecure parents were significantly more likely to respond to their children's distress by becoming distressed themselves or dismissing their child's emotion. For example, if a child went to a birthday party and was upset because of a friend's comment there, a dismissive parent might tell the child not to be sad, to forget about it. Or the parent might even say, Stop crying and acting like a baby, or you're never going over again," she said.

That pattern of punishing or dismissing a child's sad or angry emotions was significantly related not only to comfort feeding but also to fewer family mealtimes and more TV viewing, which led to children's unhealthy eating, including self-reported sugary drinks, fast foods, and salty snacks, Bost said.



“One explanation might be that insecure moms are more easily overwhelmed with stress, find it more difficult to organize family mealtimes, and allow their children to watch more television as a coping strategy,” she suggested.

The study’s findings provide valuable information for health professionals who are working with parents and children, she noted.

“Clinicians can help address children’s obesity by giving parents practical strategies to help kids deal with negative emotions like anger, sadness, and boredom. That means helping them describe what they’re feeling and working on problem-solving strategies with them,” she said.

Also, telling a child to “clean your plate” or “eat just three more bites and you can have dessert” sends the wrong message, she said.

“In fighting childhood obesity, one of the most important lessons we can teach children is to eat when they’re hungry and recognize when they’re full. We want to encourage children to respond to their internal cues and encourage parents not to promote eating under stress or eating to soothe.”

It’s also useful to give busy working parents practical plans for establishing a routine for mealtime planning, she said.

Co-authors are the U of I’s Angela Wiley, Barbara Fiese, Brent McBride, and the STRONG Kids team as well as Amber Hammons of Fresno State University, formerly a U of I postdoctoral researcher.

This research was funded in part by grants from the Illinois Council for Agricultural Research and the USDA National Institute of Food and Agriculture. It appeared in an issue of the *Journal of Developmental & Behavioral Pediatrics*.



Passing food family-style teaches day-care kids to respond to hunger cues



When children and child-care providers sit around a table together at mealtime, passing bowls and serving themselves, children learn to recognize when they are full better than when food is preplated for them, reports a new University of Illinois study of feeding practices of 2- to 5-year-old children in 118 child-care centers.

“Family-style meals give kids a chance to learn about things like portion size and food preferences. When foods are preplated, children never develop the ability to read their body’s hunger cues. They don’t learn to realize, ‘Okay, this is an appropriate portion size for me,’” said Brent McBride, director of the U of I Child Development Laboratory and lead author of the study.

The study found that Head Start centers were in significantly greater compliance with this and other benchmarks from the Academy of Nutrition and Dietetics than other centers surveyed, including participants in the USDA’s supplemental nutrition assistance program CACFP and non-CACFP state-licensed centers.

The academy’s benchmarks were issued in 2011 to combat the problem of child obesity. One in four preschool children is over-

weight or obese, and more than 12 million preschoolers consume up to five meals or snacks daily at the nation’s child-care centers, McBride said.

“The academy also recommends that providers eat with children so they can model healthy behaviors, which Head Start staff are required to do,” said Dipti A. Dev, a U of I graduate student in nutritional sciences.

Teachers are also asked not to pressure children to take one or two more bites or finish a serving before another food or activity is offered, she said.

The researchers said that providers need to help children recognize their feelings of hunger and fullness.

“Instead of asking, ‘Are you done?’ teachers should ask children, ‘Are you full?’ Or they should say, ‘If you’re hungry, you can have some more,’” explained Dev, who is developing information on best feeding practices to share with providers.

“Asking the right questions can help children listen to their hunger and satiety signals,” she said.

The Illinois research is the first study to evaluate whether child-care providers are adhering to the academy’s guidelines for feeding practices. Most providers did promote healthy

feeding by serving nutritious foods and not pressuring children to eat or restricting them from eating. Head Start programs stood out, though, as having the best policies and feeding practices.

In fact, Head Start teachers who use family-style meals are strong advocates for them, the researchers said.

“Teachers who don’t do family-style meals have all these reasons that they don’t: there’s too much waste, it’s messy, young kids don’t have the developmental skills—the fine motor control—to do that,” McBride said.

“But Head Start teachers were telling us ways you could help develop those fine motor skills: for instance, using scoops in the sandbox or pouring water at the water table,” he added.

“When you first do easel painting with a two-year-old, it’s really messy because they don’t have fine motor control, but you still do it even though it’s messy. The same thing is true for family-style meal service. It may be messy at first, until children develop the appropriate skills and learn to pour the right way or hold the cup as they’re pouring. It’s a developmental progression,” he said.

If children don’t want to eat, teachers shouldn’t urge them to eat anyway out of concern that the kids may get hungry before the next meal or snack is served, McBride said.

“If a child doesn’t eat at one meal, he’ll compensate for it over a 24-hour period. Making kids eat when they’re not hungry is probably the worst thing you can do. It teaches them not to pay attention to their body’s signals,” Dev said.

The research was funded by the U.S. Department of Health and Human Services and the Illinois Trans-Disciplinary Obesity Prevention Program Seed Grant Program. It was published in the *Journal of the Academy of Nutrition and Dietetics*.

Future of children in the U.S. trending #hungry

Alleviating food insecurity in the United States is one of our country's leading challenges. The magnitude is great, especially among children—nearly 16 million U.S. children, or more than one in five, live in households that are food insecure. In other words, according to the U.S. Department of Agriculture, they live in households without access to adequate food due to lack of money or other financial resources. Craig Gundersen of the University of Illinois and James Ziliak of the University of Kentucky have reviewed research on the subject and published recommendations for the next steps needed to reduce food insecurity among the country's children.

"One reason food insecurity remains high is that we don't fully understand what causes it, particularly among children," said Gundersen, Soybean Industry Endowed Professor in Agricultural Strategy. "For example, we know that greater income lowers the risk of being food insecure, but even at incomes two and three times the poverty level, there are children in food-insecure households. Clearly there are numerous other factors besides income that determine whether a household is food insecure."

Gundersen and Ziliak summarized prominent themes contributing to childhood food insecurity that they observed in research. Related factors include mental and physical health of the mother; family structure, such as if the child lives in a home with both biological parents and/or with extended-family members; child-care arrangements; and belonging to certain at-risk populations, including immigrants and children with a parent who is in prison.

The researchers' report ends with a discussion of federal assistance programs, such as the Supplemental Nutrition Assistance Program (SNAP). "A high proportion of eligible children do not receive free or reduced-price meals through the National School Lunch Program," Gundersen said. "This is often ascribed to the

stigma that some children face for receiving the meals or their dissatisfaction with the meals, which is especially true for high school children."

In addition, Gundersen noted, in many communities feeding programs for children are not available during the summer when school is not in session. This may be one reason food insecurity among children tends to spike during summer months.

"One way to increase the rate at which people apply for these federal programs is to improve access," Gundersen said. "If the office hours are only during the day, parents are forced to choose between missing work and the corresponding wages or failing to enroll in SNAP." He suggested that perhaps counties could be rewarded for increasing participation rates among eligible households.

The report also suggests that the benefit levels of SNAP be reexamined because, for example, food costs are not uniform across the country.

"We have learned a great deal from existing research, but we need to learn more about

what is causing food insecurity in the first place," Gundersen said. For instance, we know that households with at least one person with a disability are substantially more likely to be food insecure than other households, even after controlling for other factors like income, but why?"

In addition to gathering quantitative data, Gundersen said that research could benefit from more personal interviews, with a richer set of questions and multiple approaches to interpreting the responses. "A more personal approach would yield information about the coping mechanisms that families use when their food resources are exhausted, the triggers to food insecurity, the hurdles people may face when they apply for food assistance, and how disabilities make it harder to procure and prepare food." Along with such qualitative data, Gundersen recommends having longer-term longitudinal surveys that interview individuals over multiple years.

Funding for this work was provided by the U.S. Department of Agriculture Food and Nutrition Service. The research was published in *The Future of Children*.

Craig Gundersen



Are leaders born or made? New study shows how leadership develops



Hardly a day passes without pundits crying for leadership among public figures, whether they are the NFL commissioner and team owners or high-ranking government officials. If University of Illinois experts didn't have evidence that this valuable trait can be taught, they might join the collective clamor that's engulfing much of the country.

But a new U of I study supports the idea that leaders are made, not born, and that leadership development follows a specific progression.

Past research suggests that leadership is 30 percent genetic and 70 percent a result of lessons learned through life experiences. Given these percentages, U of I professors Kari Keating, David Rosch, and Lisa Burgoon sug-

gest an effective pathway to leadership development.

"In only 15 weeks in our introductory class, students reported significant gains in three important components of leadership: self-efficacy, or confidence in their ability to lead; skills; and motivation to lead," said Keating, who teaches leadership courses in the College of ACES agricultural leadership education major.

Rosch, an assistant professor of agricultural education, said the new study shows that science is involved in teaching leadership development.

"It's a three-legged stool: we call it being ready, willing, and able. Students first become ready to learn about being a leader; then they become willing to learn the skills necessary to

practice leadership; and finally they're able to lead because they have the skills and the motivation to do it. You can't really move on to the other legs of the stool until you've achieved a certain amount of this readiness," he explained.

If students enter the course with low levels of self-efficacy—saying 'I don't really think of myself as a leader' or 'I'm not confident in my abilities'—they don't increase in being willing and able in 15 weeks, but they make big increases in readiness, he added.

"It's like a math class. You're not ready to do calculus if you don't know the basics of algebra," he noted. "This shows us we need to work on readiness so students can make the most of advanced leadership courses."

Students who come into the introductory class with leadership readiness, saying, "I've got this, I'm a leader," have a different learning experience. They become willing to lead people even when it's not a big resume builder, Keating said.

So what is leadership? Burgoon, director of the minor in leadership studies, said that "historically, leaders have been viewed as being male and power oriented. It used to be if you were tall, articulate, and well-schooled, you were a leader in other people's minds."

And students often take a positional view of leadership. "But," Rosch said, "just as a year in a cave doesn't make you a geologist, being senior class president doesn't make you a leader."

Leadership is more than that, he said. "The

definition we use in the course is that leadership is an individual influencing a group of people toward a common goal. So how do you influence people? You can lead through your interactions, your relationships, your communication, the way you express thanks, your ethics," he said.

"Leadership isn't done in a vacuum. It's done with others," Keating added.

Students in the class complete 10 to 12 self-assessments to learn where their own strengths and weaknesses as a leader lie. Keating said that by the end of the semester, a student may say, "I don't do any of this relationship stuff. I'm mainly authoritative in the way I lead. Maybe I need to alter what I'm doing so our team can get better results."

Rosch said every semester a dozen students come to him after job interviews reporting that they advanced because they were able to demonstrate and talk about leadership. He added that academic advisers are beginning to recommend leadership courses to students who aren't in the leadership major or minor.

"If we could pretest students for leadership proficiency in much the same way we test for chemistry placement, we'd be able to make our resources more efficient and maximize the learning potential in our program," he noted.

Keating, Rosch, and Burgoon co-authored the study. The research, which was published in the *Journal of Leadership Education*, was partially funded by a grant from the U of I Provost's Office.

Peer pressure can influence food choices at restaurants



Brenna Ellison

If you want to eat healthier when dining out, research recommends surrounding yourself with friends who make healthy food choices. A University of Illinois study showed that when people eat in groups at a restaurant at which they must state their food choices aloud, they tend to select items from the same menu categories.

“My conclusion from the research is that people want to be different, but not that different,” said food economist Brenna Ellison. “We want to fit in with the people we’re dining with. It goes against the expectation that people will exhibit variety-seeking behavior; we don’t want to be that different from others.”

Ellison analyzed the lunch receipts from a full-service restaurant for three months. One section of the restaurant was the control group, with guests receiving menus with the item and price only. Another section received menus with calorie counts for each entrée. And a third section had both the calorie count and a traffic light symbol that indicated caloric ranges: green traffic light items contained 400 calories or less, yellow light items had between 401 and 800 calories, and red light items contained more than 800 calories.

Although the research data was drawn from the paper receipts—because the study hinged on all three menu versions being used

at specific tables—Ellison also went undercover at the restaurant to observe.

“I would help bus tables sometimes so that I could watch and make sure that the tables were getting the right menus,” Ellison said. “Or I would send people in as ‘secret eaters.’ They could order whatever they wanted; I just wanted to make sure that they got the right menu for that section.”

Because she stopped by the restaurant every day to pick up receipts, Ellison was able to get additional information directly from the servers. “They said that people talked about the traffic lights a lot. And we did find that larger tables, which received the traffic light menus, ordered fewer calories on average, which suggests there was some peer pressure to order lower-calorie items,” she said.

Receipt data was analyzed using a “random utility framework,” where the utility, or happiness, each individual receives from his or

her food choice depends not only on the characteristics of that choice (item price, calories, etc.), but also on the characteristics of peers’ choices.

“The big takeaway from this research is that people were happier if they made choices similar to those sitting around them,” Ellison said. “If my peers are ordering higher-calorie items or spending more money, then I am also happier, or at least less unhappy, if I order higher-calorie foods and spend more money.

“The most interesting thing we found was that no matter how someone felt about their order category originally—even if it was initially a source of unhappiness, such as items in the salad category—this unhappiness was offset when others had ordered within the same category,” Ellison said. “Given this finding, we thought it would almost be better to nudge people toward healthier friends than healthier foods.”

One detail not included in the data is who ordered first at each table. Ellison said she wants to get this information the next time she runs a similar experiment. “Previous studies have shown that if you don’t have to order audibly, everyone just gets what they want, without any peer pressure involved,” she said. “Research suggests that you should always order first because the first person is the only one who truly gets what they want.”

This study was published in *Food Quality and Preference*.





If your relationship isn't moving toward marriage, you probably can't admit it

Dating couples who have moved toward marriage over the course of their relationship remember accurately what was going on at each stage of their deepening commitment. But couples whose commitment to each other has stagnated or regressed are far less accurate in their relationship memories, says a new University of Illinois study.

"People like to feel that they're making progress as a couple. If they're not—if, in fact, the relationship is in trouble—they may have distorted recollections that help them feel like they're moving forward because they need a psychological justification to stay in the relationship," said ACES researcher Brian G. Ogolsky.

The researchers expected to find some distortion in romantic partners' memories. "One theory was that recollections might be higher across the board because people like to remember the best possible course of their relationships. But as we looked at couples' actual experiences and compared relationships that were developing in a positive direction with those that were not, we saw that the accuracy of their memories diverged rather sharply. It's fascinating how memory works in couples," he noted.

Ogolsky said that both findings—that highly committed people remember their relationship history accurately and that couples in trouble don't—are important.

"When a couple is considering making a lifelong commitment, they have a lot at stake. It's important that they have accurate recollections of how their relationship evolved," Ogolsky said.

But if a couple's relationship is undergoing a slow and painful death, it no longer serves their purpose to remember the course of the romance accurately. To avoid constant

disappointment, the two misremember how things are going, he noted.

The nine-month study followed 232 never-married heterosexual couples who had dated on average for just over two years. Each member of the couple reported on their chances of marrying, being careful to take their partner's views into consideration.

Each month, participants rated their chances of marriage from 0 to 100 percent, and researchers plotted a graph from the results. At the end of the study, participants reflected on their entire relationship to see how their recollections matched up with reality.

The researchers looked at the actual and remembered trajectories of three groups: advancers, who had gone on to a deeper state of involvement; maintainers, who may have been casually dating at both the beginning and the end of the study; and regressers, who had reverted from serious to casual dating or had broken up and gotten back together again.

"Couples who had deepened their commitment remembered their relationship history almost perfectly. The graphs for this group were really interesting because the plot of the end-of-study recollection could be placed right

on top of the one we had graphed from the monthly check-ins," Ogolsky said.

Maintainers recalled their relationship as being lower at the beginning than they had reported, yet higher at the end. "They had given themselves some room to grow and remembered the recent past as better than they had reported it being. If they saw maintenance as stagnation, that's a way of addressing that cognitive gap. It helps them feel that their relationship is developing in some way—that they're making progress," he noted.

The most interesting group was the regressers, Ogolsky said. "If we looked at their history as they reported it to us over the nine-month period, we could see that their chances of marriage were plummeting. Yet their recollection was that things had been going okay. Of course, they hadn't seen the graph so they didn't know their trajectory looked this dire, but it's fair to say they were in denial about the state of their relationship."

Catherine A. Surra of Pennsylvania State University Harrisburg was a co-author of the study. Funding was provided by the National Institute of Mental Health. It was published in *Personal Relationships*.



A close-up photograph of a woven basket filled with fresh vegetables. The basket is filled with asparagus spears, several artichokes, and pieces of broccoli. The lighting is warm and natural, highlighting the textures of the vegetables. A semi-transparent green banner is overlaid across the middle of the image, containing the title text. A thin white vertical line runs down the left side of the page, ending in a small white circle that points to the banner.

AdvanCES in Diet, Health, & Nutrition

Celery, artichokes contain flavonoids that kill human pancreatic cancer cells



Professor Elvira de Mejia (left) and doctoral student Luis Mojica extract flavonoids from foods and herbs in her U of I laboratory.

Celery, artichokes, and herbs, especially Mexican oregano, all contain apigenin and luteolin, flavonoids that kill human pancreatic cancer cells in the lab by inhibiting an important enzyme, according to two University of Illinois studies.

“Apigenin alone induced cell death in two aggressive human pancreatic cancer cell lines. But we received the best results when we pretreated cancer cells with apigenin for 24 hours, then applied the chemotherapeutic drug gemcitabine for 36 hours,” said Elvira de Mejia, an ACES researcher in food chemistry and food toxicology.

The trick seemed to be using the flavonoids as a pretreatment instead of applying them and the chemotherapeutic drug simultaneously, said Jodee Johnson, a doctoral student in de Mejia’s lab and co-author.

“Even though the topic is still controversial, our study indicated that taking antioxidant supplements on the same day as chemotherapeutic drugs may negate the effect of those drugs,” she said.

“That happens because flavonoids can act as antioxidants. One of the ways that chemotherapeutic drugs kill cells is based on

their prooxidant activity, meaning that flavonoids and chemotherapeutic drugs may compete with each other when they’re introduced at the same time,” she explained.

Pancreatic cancer is very aggressive, and there are few early symptoms, meaning that the disease is often not found until it has spread beyond the pancreas. Ultimately the goal is to develop a cure, Johnson said, but prolonging the lives of patients would be a significant development.

Cancer of the pancreas is the fourth leading cause of cancer-related deaths, with a five-year survival rate of only 6 percent, she said.

The scientists found that apigenin inhibited an enzyme called glycogen synthase kinase-3β (GSK-3β), which led to a decrease in the production of anti-apoptotic genes in the pancreatic cancer cells. Apoptosis means that the cancer cell self-destructs because its DNA has been damaged.

In one of the cancer cell lines, the proportion of cells undergoing apoptosis went from 8.4 percent in cells that had not been treated with the flavonoid to 43.8 percent in cells that had been treated with a 50-micromolar dose. In this case, no chemotherapy drug had been added.

Treatment with the flavonoid also modified gene expression. “Certain genes associated with proinflammatory cytokines were highly upregulated,” de Mejia said, “and these upregulations may have facilitated cancer cell growth inhibition.”

According to Johnson, the scientists’ in vitro study, published in *Molecular Nutrition and Food Research*, is the first to show that apigenin treatment can lead to an increase in interleukin 17s in pancreatic cells, indicating its potential relevance in anti-pancreatic cancer activity.

People with pancreatic cancer would probably not be able to eat enough flavonoid-rich foods to raise blood plasma levels of the flavonoid to an effective level. But scientists could design drugs that would achieve those concentrations, de Mejia said.

And preventing this frightening disease is another consideration. “If you eat a lot of fruits and vegetables throughout your life, you’ll have chronic exposure to these bioactive flavonoids, which would certainly help to reduce the risk of cancer,” she noted.

The studies were funded by USDA. The second study was published in *Food and Chemical Toxicology*.

Eight grains for a healthy, sustainable diet



The digestibility of nutrients is an important aspect of nutrition, but it can be hard to measure in humans. Researchers at the University of Illinois are studying digestibility in pigs in hopes of improving human nutrition by determining the quality of protein in cereal grains.

In 2013, the UN Food and Agriculture Organization (FAO) recommended using a new measurement called the digestible indispensable amino acid score (DIAAS) to describe the protein content of foods. The DIAAS takes into account the concentration and ileal digestibility (in the distal part of the small intestine) of each indispensable amino acid in the protein. Because ileal digestibility studies are impractical to conduct in human subjects, animal models are often used to determine amino acid digestibility. The growing pig is the animal model recommended by FAO.

A team led by Hans H. Stein, professor of animal science, recently published DIAAS values for eight cereal grains that may be used in

human nutrition: yellow dent corn, Nutridense corn, dehulled barley, dehulled oats, polished white rice, rye, sorghum, and wheat.

"In developing countries, cereal grains may be a major source of dietary protein, especially for children," said Stein. "Determination of protein quality in cereal grains provides important information on how these products contribute to a sustainable diet."

Stein's team determined the standardized ileal digestibility of amino acids for the eight cereal grains when fed to growing pigs. Next they converted those values to DIAAS using a formula that compares the digestible amount of a given indispensable amino acid in one gram of the dietary protein to that in one gram of the reference protein, where the reference is the "ideal" protein in terms of amino acid composition. The DIAAS value of the reference protein is 100.

The DIAAS values for the eight cereal grains evaluated by Stein's team were 77 for dehulled oats, 64 for polished rice, 54 for

Nutridense corn, 51 for dehulled barley, 48 for yellow dent corn, 47 for rye, 43 for wheat, and 29 for sorghum.

"In most cases, the concentrations of digestible amino acids in cereal grains are not sufficient to fulfill requirements for proper growth and development," said Stein. "What we observed is that diets based on yellow dent corn, rye, and sorghum require more amino acid supplementation than diets based on rice, dehulled oats, dehulled barley, Nutridense corn, or wheat."

He added that cereal grains and grain co-products for human consumption are usually cooked or processed before being consumed and that further work is needed to estimate the effects of food preparation and processing on protein quality.

Co-authors of the paper are Sarah K. Cervantes-Pahm and Yanhong Liu. The research was published in the *British Journal of Nutrition*.

Genetic risk for obesity found in many Mexican young adults

As many as one in three Mexican young adults may have a genetic predisposition for obesity, said a University of Illinois scientist who conducted a study at the Universidad Autónoma de San Luis Potosi.

“The participants who inherited genetic risk factors from both parents were already 15½ pounds heavier and 2 inches bigger around the waist than those who hadn’t. They also had slightly higher fasting glucose levels,” said Margarita Teran-Garcia, a professor of food science and human nutrition.

The study tested 251 18- to 25-year-olds for risk alleles on the FTO gene as part of the Up Amigos project, a collaboration of scientists at the U of I and the Mexican university. The researchers are following the 10,000 yearly applicants to the Universidad Autónoma de San Luis Potosi to learn how changes in students’ weight, body mass index (BMI), and eating and exercise habits affect their health over time.

According to Teran-Garcia, the FTO gene is associated with a predisposition to obesity,

increased BMI, and increased waist circumference. These traits can in turn contribute to many health-related problems, including cardiovascular disease and diabetes.

Of the young adults tested, 15 percent had inherited the genetic risk from both parents—in other words, they carried two copies of the risk allele. Another 20 percent had inherited risk from one parent, meaning they had one copy of the risk allele. Sixty-five percent of the students in the study did not carry the risk allele.

“If young people realize early that they have this predisposition, they can fight against it. If they are at risk for obesity, eating a healthy diet and getting regular exercise are even more important for them,” Teran-Garcia said.

She noted that 65 percent of Hispanics in the United States are of Mexican origin, according to a Pew Hispanic Center survey.

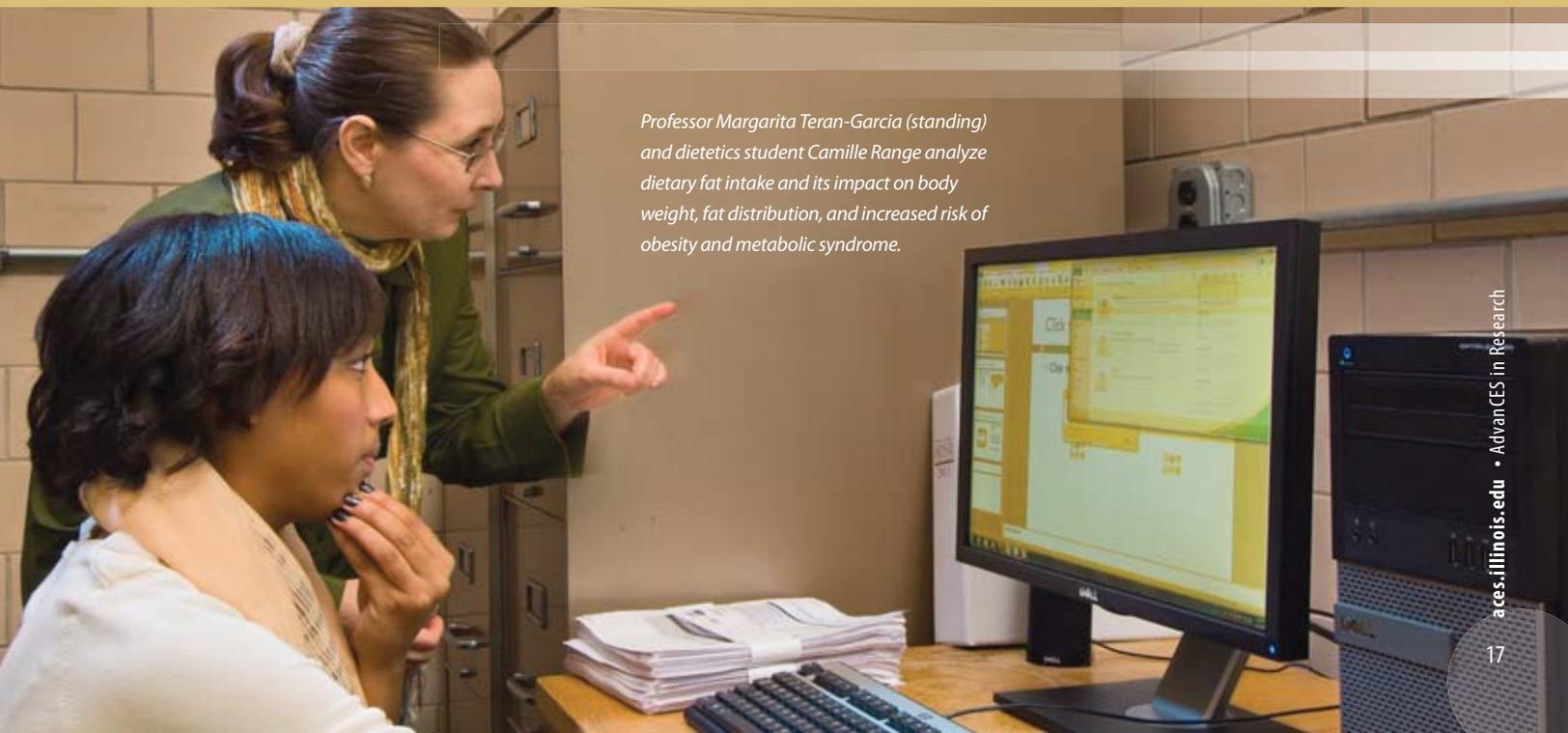
Although FTO markers and analysis are available for large groups of Caucasians, Asians, and African-Americans, few studies have exam-

ined the effects of this gene in Mexican and Mexican-American populations.

“This is the first study to target young adults in Mexico, although one other study has followed older Mexican adults who had already been diagnosed with diabetes, obesity, and obesity-related diseases,” she said.

Scientists hypothesize that “fat” genes may be influenced by epigenetic modifications, she said. “So even if you have this predisposition, you may be able to change the way those genes behave by eating a balanced diet and getting more exercise. These good habits are especially important for young people who have a genetic risk for obesity.”

Co-authors are Michelle Mosley of the U of I Department of Food Science and Human Nutrition, Flavia C.D. Andrade of the U of I Department of Kinesiology and Community Health, and Eduardo Medina-Cerda and Celia Aradillas-Garcia of the Universidad Autónoma de San Luis Potosi in Mexico. It was published online in the *Open Journal of Genetics*.



Professor Margarita Teran-Garcia (standing) and dietetics student Camille Range analyze dietary fat intake and its impact on body weight, fat distribution, and increased risk of obesity and metabolic syndrome.

Shift in gut bacteria may offer good news for weight loss



Kelly Swanson

Most Americans don't get the recommended amount of fiber in their daily diet, though research has shown that dietary fiber can cause a shift in the gut toward beneficial bacteria, reducing the risk of colon cancer, type 2 diabetes, and other diseases. A new study from the University of Illinois shows that two specific functional fibers may also have the potential to assist in weight loss when made part of a long-term daily diet.

Kelly Swanson, a U of I animal scientist, and his team had previously looked at a snapshot of what bacteria were present in the gut after a person's diet was supplemented with polydextrose and soluble corn fiber. Using the samples from the same trial, Swanson used whole-genome sequencing to explore the full range of bacterial genomic information in the gut after fiber supplementation.

The new information is helping reveal more about the functional capabilities of the bacteria in the gut when these fibers are consumed as part of a regular diet.

"In the gut, bacteria have the capacity to do a lot of different things, such as fermenting proteins, carbohydrates, or other substrates," Swanson said. "We have already been able to identify what bacteria are there and the changes that occur with diet, and now we are asking if we can change the machinery or the capacity of what functions the bacteria have. Knowing what bacteria are there may matter, but it may not matter as much as identifying their function."

Hannah Holscher, a postdoctoral researcher and registered dietitian in animal sciences, said what was most surprising and novel in the recent study was a shift in the Bacteroidetes:Firmicutes ratio toward more Bacteroidetes, something the researchers had not seen previously.

"This was of particular interest to us because other research has shown that having more Bacteroidetes may be beneficial; with a higher proportion, the individual tends to be leaner. With higher Firmicutes, the individual tends to be more obese," Holscher said. "We don't know if there is any causality for weight loss, but studies have shown that having a diet higher in fiber is protective against obesity. It's an exciting shift and helps to drive researchers to study these fibers as part of a weight loss diet."

Holscher added that the whole-genome sequencing data also revealed shifts in the functional capacity of the microbiome, including modifications in nutrient metabolism. "We saw a decrease in genes associated with protein metabolism, which correlated with the reduced protein fermentation that occurred in the study participants' guts when they consumed the fibers," she said. "The information from this study, in combination with the results from the previous study, has allowed us to put

together a more complete picture of what the bacteria in our gut are doing."

The samples sequenced for bacteria genomic information were part of a study Swanson and his lab conducted in 2012. Twenty healthy men with an average fiber intake of 14 grams a day were given snack bars to supplement their diet. The control group received bars that contained no fiber; a second group ate bars with 21 grams of polydextrose, which is a common fiber food additive; a third group received bars with 21 grams of soluble corn fiber.

Fecal samples were collected from the participants, and DNA was then subjected to 454 pyrosequencing, which provided a snapshot of all the bacterial types present. The previous study examined only one gene used for identification purposes, while the current study used whole-genome shotgun 454 pyrosequencing to examine the full range of bacterial genetic information in the fecal microbiome.

Holscher stressed that though there were significant shifts in the gut bacterial populations with fiber supplementation, when the supplements were stopped populations seemed to revert to where they were before. "The take-home is if people want to make changes to the diet and have a healthier gut, they need to be everyday changes.

"We need more fiber in our diets from lots of different sources," Holscher said. "These two fibers look like they could be beneficial when included in a balanced diet along with whole



grains, fruits, vegetables, and legumes.”

Holscher added that only 10 percent of Americans meet their daily fiber needs of 25 to 38 grams—most eat only 12 to 14 grams a day.

Polydextrose and soluble corn fiber are ingredients often used in foods such as cereals, cereal bars, baking mixes, and drinks. Holscher said they appeal to food companies as product ingredients because they are lower in calories and do not negatively affect taste or texture.

“These fibers also tend to be better tolerated, causing less gas, bloating, and discomfort. They can be provided at higher levels than other types of fiber, such as inulin,” she added.

The researchers hope to continue studying polydextrose and soluble corn fiber for their potential in aiding disease prevention and weight loss.

“We’re hoping this study helps people realize that diet—what you eat every day—does affect the bacteria in your gut. We saw these dramatic shifts in bacterial populations with fiber supplementation, but then those shifts went away when people stopped using the supplements,” Holscher said.

“It’s an important concept because we are not at the point of giving someone a single pill to change the microbiome; it’s not like using an antibiotic to treat an infection. We want to make sure that diet stays in the conversation because it has a significant impact,” she added.

Co-authors of this study are Swanson, Holscher, J. Gregory Caporaso, Seema Hooda, Jennifer M. Brulc, and George C. Fahey, Jr.

Partial funding was provided by General Mills. The research was published in the *American Journal of Clinical Nutrition*.

Scientists learn how soy foods protect against colon cancer



Professor Hong Chen (left) and Ph.D. student Dan Zhou analyze changes in gene expression caused by bioactive components of soy.

University of Illinois scientists have evidence that lifelong exposure to genistein, a bioactive component in soy foods, protects against colon cancer by repressing a signal that leads to accelerated growth of cells, polyps, and eventually malignant tumors.

"In our study, we report a change in the expression of three genes that control an important signaling pathway," said Hong Chen, a professor of food science and human nutrition.

The cells in the lining of the human gut turn over and are completely replaced weekly, she noted. "However, in 90 percent of colon cancer patients, an important growth-promoting signal is always on, leading to uncontrolled growth and malignancies. Our study suggests that aberrant Wnt signaling during the development of colon cancer can be regulated by soy-rich diets."

"The good news," said Yukun Zhang, a doctoral student in Chen's laboratory, "is that a diet rich in soy genistein represses those signals through epigenetic modifications at the regulatory regions of those genes."

Chronic exposure to genistein, a soy flavone, reduced by 40 percent the number of precancerous lesions in the colons of laboratory rats exposed to a carcinogen and also reduced Wnt signaling to normal levels, she said.

The scientists modeled lifetime exposure to soy by feeding one group of pregnant rats and their offspring a diet containing soy protein isolate and another group a diet that contained genistein compound. At seven weeks of age, offspring rats were exposed to a carcinogen, and they continued eating either the soy protein or the genistein diet until they were 13 weeks old.

At that time, the researchers inspected the colons of rats in both soy groups and compared them to rats in a control group, noting the number and severity of tiny abnormal growths in each. They also compared Wnt signaling before and after the carcinogen exposure to see whether either diet had any effect on its upregulation.

In the genistein-fed animals, signaling levels were similar to those in rats that had not received the carcinogen.

"Genistein decreased the expression of three genes and repressed this signaling process that is associated with abnormal cell growth and cancer development," Chen said.

She said this finding shows that colon cancer is an epigenetic disease, meaning that dietary and environmental factors can influence genes to be switched on or off so you have a different pattern of gene expression, leading to a change in disease susceptibility.

It has long been known that immigrants to Western countries from Asia—where soy is a traditional food staple—experience rising levels of colon cancer as they adopt the eating habits of the nations they now call home, she said.

"The genetic information you inherit from your parents is not the whole story. Our dietary choices, our exposure to environmental toxins, even our stress levels, affect the expression of those genes," she said.

Yukun Zhang and Qian Li co-authored the study, which was funded by the National Institutes of Health, the U of I Research Board, and the Illinois Soybean Association. It was published in *Carcinogenesis*.

Illinois scientists put cancer-fighting power back into frozen broccoli

Broccoli researchers at the University of Illinois had bad news, then good news to report. In their first study, published in the *Journal of Functional Foods*, they learned that frozen broccoli lacks the ability to form sulforaphane, the cancer-fighting phytochemical in fresh broccoli. But a second study demonstrated how the food industry can restore the frozen vegetable's health benefits.

"We discovered a technique that companies can use to make frozen broccoli as nutritious as fresh. That matters because many people choose frozen veggies because they're more convenient and less expensive," said Elizabeth Jeffery, an ACES food scientist.

"Whenever I've told people that frozen broccoli may not be as nutritious as fresh, they look so downcast," she added.

As little as three to five servings of broccoli a week provides a cancer-protective benefit, but that isn't true for bags of broccoli that you pluck out of your grocery's freezer, she noted.

The problem begins when soon-to-be-frozen broccoli is blanched, or heated to high temperatures, to inactivate enzymes that can cause off-colors, tastes, and aromas during the product's 18-month shelf life, she explained.

The extreme heat destroys the enzyme myrosinase, which is necessary to form sulforaphane, the powerful cancer-preventive compound in broccoli, she said.

"We know this important enzyme is gone because in our first study we tested three commercially frozen broccoli samples before and after cooking. There was very little potential to form sulforaphane before the frozen broccoli was cooked and essentially none after it was cooked as recommended," said Edward B. Dosz, a graduate student in Jeffery's laboratory.

Professor Elizabeth Jeffery and Ph.D. student Ed Dosz solubilize and analyze different plant products for bioactive components.

In the second study, which appeared in the *Journal of Food Science*, the researchers experimented with blanching broccoli at slightly lower temperatures instead of at 86°C, the current industry standard. When they used a temperature of 76°C, 82 percent of the enzyme myrosinase was preserved without compromising food safety or quality.

Sulforaphane is formed when fresh broccoli is chopped or chewed, bringing its precursor glucoraphanin and the enzyme myrosinase into contact with each other. The researchers first thought that thawing frozen broccoli in the refrigerator might rupture the plant's cells and kick-start the enzyme-substrate interaction. It didn't work, Dosz said.

But they had previously had success using other food sources of myrosinase to boost broccoli's health benefits. So the researchers decided to expose frozen broccoli to myrosinase from a related vegetable.

When they sprinkled daikon radish—in an amount that's invisible to the eye and undetectable to human taste buds—on the frozen broccoli, it worked with the myrosinase to form sulforaphane, Dosz said.

"That means that companies can blanch and freeze broccoli, sprinkle it with a minute

amount of radish, and sell a product that has the cancer-fighting component that it lacked before," he said.

One question remained: Would sulforaphane survive the heat of microwave cooking? "We were delighted to find that the radish enzyme was heat-stable enough to preserve broccoli's health benefits even when it was cooked for 10 minutes at 120°F. So you can cook frozen broccoli in the microwave and it will retain its cancer-fighting capabilities," Dosz said.

Jeffery hopes that food processors will be eager to adopt this process so they can market frozen broccoli that has all of its original nutritional punch.

Until they do, she said, consumers can spice up their frozen broccoli after cooking with another food that contains myrosinase to bring the cancer-fighting superfood up to nutritional speed.

"Try teaming frozen broccoli with raw radishes, cabbage, arugula, watercress, horseradish, spicy mustard, or wasabi to give those bioactive compounds a boost," Jeffery advised.

USDA and the National Institute of Food and Agriculture (NIFA) and Sakata Vegetables Europe funded this research.



Color from corn

Consumers care about the foods they eat and serve to their families. They want improved nutrition and ingredients that are nutritious, simple, and natural, including the colors used in foods. Through a collaboration with and funding from Kraft Foods, a multidisciplinary group of researchers in the College of ACES has been charged with the task of studying the technical and economic feasibility of extracting food colors from one of the most plentiful resources found in the Midwest—corn.

One aspect of the study is to determine what processing techniques will be most effective at recovering color from a variety of corn hybrids. Vijay Singh, of the Department of Agricultural and Biological Engineering (ABE), is an international leader in developing new technologies in corn processing.

“In the U.S., we process close to 6.3 billion bushels of corn each year, out of 14 billion that are produced,” said Singh. “Three major commercial techniques are used to process corn into food, fuel, and industrial products: the first is wet milling, the second is a dry grind ethanol process, and the third is dry milling. My work is to look at these three techniques and see if we can tap into them to extract color pigments from one of the co-products that they’re already producing.

“We need to determine what will happen to each process if we change to a colored corn instead of using the traditional yellow dent corn,” Singh continued. “Does it change the process? Where does the color go? Will we still get clear white starch, like we do with yellow dent corn?”

ABE graduate students Pavel Somavat and Zhaoqin Wang began the study using the dry grind ethanol process, where the raw corn is finely milled and cooked. The starch is fermented and converted into ethanol, and the three nonfermentable fractions—germ, fiber, and protein—are carried through the process and recovered at the back end as distillers dried grain with solubles, or DDGS, a co-product fed to ruminant animals.

“We ran close to 20 very different colored cultivars through the dry grind ethanol process, and we found two things,” said Singh. “First, we got fairly good ethanol yields from these corn types; second, we found that most of the pigments go in the DDGS.”

Elvira de Meija, a professor of food science and human nutrition, extracts the pigments from the DDGS (and other co-products) to determine the functionality and stability of the color. Singh’s study has a second component. “We are running one type of purple corn through all three corn processes. In the Department of ABE, we have lab techniques that can simulate the three traditional processes very closely. We can process anywhere from 100 grams of corn to a kilogram to 25 kilograms. We are generating co-products from each process, and we will work with Dr. de Meija to do a complete mass balance to study where these color pigments are going in the different co-products.”

Singh said they hope to show that the different corn varieties can be plugged into one of the traditional commercial processes without any negative effects. “What if an ethanol plant can use these colored corns, rather than



number 2 yellow dent corn, and still get good ethanol yields? But now they're also pulling high-value color pigments from the DDGS. That would significantly increase the value of that co-product. After they extract the color, they can put whatever residue is left back in the traditional market where DDGS are sold."

Singh said after evaluating the traditional commercial processes, the next step will be to determine if there is "a better way."

"For instance, could we design a new system that would efficiently recover the color pigment at the front end of the process and still use the remaining material in one of the existing commercial processes? Our goal," he concluded, "is to develop the most effective and efficient bioprocess possible."

Vermont P. Dia, Megan West, and Leslie West also contributed to the research, which was published in the *Journal of Agricultural and Food Chemistry*.

Other key faculty involved in the project include Jack Juvik, a crop sciences professor of plant breeding and genetics, and Gary Schnitkey, a professor of agricultural economics. Juvik will study the different corn hybrids to determine whether the yield of a hybrid is comparable to yellow dent corn, and which are the traditional breeding techniques that can be pursued with genetics to improve the yield. Schnitkey will do an economic evaluation of the project to determine the cost of producing and processing the corn, and ultimately, the value of the dye that is produced.

Zhaoqin Wang, graduate student in bioprocessing, and Vijay Singh discuss the dry grind process used to recover color from corn.



Understanding of infant brain development aided by piglet brain atlas



Magnetic resonance imaging (MRI) operator Nancy Dodge takes a brain scan of a piglet in the Beckman Institute.

A new online tool developed by researchers at the University of Illinois will aid studies into postnatal brain growth in human infants based on the similarities seen in the development of the piglet brain, said Rod Johnson, professor of animal sciences.

Through a collaboration among researchers in animal sciences, bioengineering, and U of I's Beckman Institute, Johnson and colleagues Ryan Dilger and Brad Sutton have developed a magnetic resonance imaging (MRI)-based brain atlas for the four-week-old piglet that offers a three-dimensional averaged brain and anatomical regions of interest.

This brain atlas, created from images from multiple piglets, will serve as a template for future studies using advanced MRI techniques that can provide important information on brain macro- and microstructure during this critical period of development. The template, as well as tissue probability maps that were also created, is being freely distributed.

"The piglet brain is similar to the human brain in that it is gyrencephalic [the cerebral cortex has convolutions rather than being smooth] and experiences massive growth and development in the late prenatal and early postnatal periods. We are concerned that environmental insults such as infection or poor nutrition during these early periods may alter the trajectory of brain development," Johnson said.

"Pigs provide an excellent translational model for biomedical research," he added. "This

is a new tool that may be useful to others in the biomedical community."

While an atlas did already exist for the adult pig, it was created from a single adult animal, said Matthew Conrad, a doctoral student in Johnson's lab. "The benefit to using an averaged brain is that it will produce a template that is a better representation of the population. The more animals included, the better," he said.

The atlas was created by first taking MRI images of the brains of 15 four-week-old piglets, nine females and six males. The images were then reconstructed into 3D volumes for each pig. Through a series of deformations and averaging of the data sets, the images were eventually aligned to create the final averaged brain.

Conrad explained that having an averaged brain template available will allow better use of the software needed for more advanced techniques in studying the volume of brain regions.

An example of these techniques includes voxel-based morphometry (VBM), which can be used to detect volume difference in the brain. Also being conducted are diffusion tensor imaging (DTI), which looks at white-matter track development and connectivity in brain regions, and magnetic resonance spectroscopy (MRS), which looks at white matter and neurochemical changes in the brain.

"The atlas will be used as the population average. When new data sets are brought in,

you first line up the new brain images to this template," Conrad said.

Previous research using MRI imaging of piglets has studied the effects of iron deficiency on brain development. "For that we did MRI imaging and manual segmentation. With manual segmentation you are looking at volume changes within very large areas of the brain, but with VBM we can pinpoint smaller changes within discrete brain areas," Conrad said. "We are now reanalyzing data from those piglets and replicating this study with new protocols, which will allow us to see changes that we didn't see before."

Another study is looking at the effects of postnatal infections, such as pneumonia, on brain development. "These types of infections are common in infants, and again it's a period of time when the brain is undergoing rapid development," Johnson said.

The brain atlas project and related studies are funded by a grant from the National Institutes of Health. The atlas and other resources created during this project are available online at pigmri.illinois.edu.

Matthew S. Conrad, Bradley P. Sutton, Ryan N. Dilger, and Rodney W. Johnson were co-authors of the study. The research was published in *PLOS ONE*.

Smaller meals fed more often may curb obesity in cats



Feline obesity is most often linked to excessive food intake or insufficient physical activity. But in both people and their pets, cutting back on calories alone often results in failed weight loss or weight regain.

So how do you encourage your cat to get more exercise?

Researchers from the University of Illinois interested in finding a method to maintain healthy body weight in cats looked at an earlier suggestion that increasing meal frequency could help increase overall physical activity.

The idea is to feed cats the appropriate amount of food needed to maintain a healthy body weight, but to offer it in more frequent, smaller meals throughout the day.

Animal sciences researcher Kelly Swanson and his lab determined that both increasing the frequency of meals and offering meals with added dietary water does promote more physical activity in cats. Neither change involves decreasing overall daily food intake.

"It all comes down to energy in and energy out. It's simple on paper, but it's not that easy in real life, especially in a household with more than one pet. But I think these two strategies are very practical ideas that people can use," Swanson said.

During the study, the researchers used collar monitors to evaluate cats' activity between meals. In the first experiment, the cats were divided among four rooms and fed dry kibble. One group was fed a random number of meals daily; the other groups were fed four times a day, two times a day, or once a day. All cats received the same overall amount of food; only the feeding frequency varied.

In the second experiment, the cats were divided between two rooms and fed twice a

day with a 70 percent hydrated diet, using similar amounts of dry kibble as in the first experiment to maintain body weight. Water was added to the kibble an hour before each meal-time.

The researchers evaluated each cat's "food anticipatory activity," meaning activity two hours before meals were given. During the dry kibble experiment, they noticed that the cats were much more active during those times, especially those fed four meals a day and those fed at random times.

"If they know they are going to get fed, that's when they are really active," Swanson said.

The cats showed an even greater spike in activity in the second experiment, when they were fed meals with added water. However, Swanson said, the biggest difference in peak activity times occurred in the periods after the cats had eaten. Factors such as increased use of the litter box, for example, could have come into play.

"Veterinarians will be interested in this because it gives them evidence to recommend something to pet owners that could help with

feline obesity and diabetes," Swanson said. "When cats are allowed to feed ad libitum, it's difficult to prevent obesity. It is important to identify the right diet. Many owners with multiple cats are accustomed to dumping a pile of food out for all of them, just once per day.

"The owner does have an active role in helping with weight management," he added. Owners often overfeed their cats, assuming that the small amount of food needed isn't going to satiate their pet. "Because most pet foods are so digestible and nutrient dense, owners see that small bowl of food and think, there's no way they can survive on that—but they can," Swanson said.

Adding water to dry food, or using wet canned food, may provide cats a greater gut fill. Swanson also said once the dry kibble absorbs the water, it does look like "more" to the owner, perhaps alleviating the fear that the pet is not being fed enough.

Co-authors of the study were P. Deng, E. Iwazaki, S.A. Suchy, and M.R. Pallotto. The research was published in the *Journal of Animal Science*.



Enhancing broccoli for anticancer benefits also lengthens shelf life



While looking for methods to increase the already well-recognized anticancer properties of broccoli, researchers at the University of Illinois also found a way to prolong the vegetable's shelf life.

And, according to the recently published study, the method is a natural and inexpensive way to produce broccoli that has even more health benefits and won't spoil so quickly on your refrigerator shelf.

Jack Juvik, a crop sciences researcher, explained that the combined application of two compounds, both natural products extracted from plants, increased the presence of cancer-fighting agents in broccoli while prolonging the storage period after harvest.

"We had figured out a way to increase the anticancer activity in broccoli, but the way we figured it out created a situation that would cause the product to deteriorate more rapidly after application," Juvik said. "For fresh-market broccoli that you harvest for immediate sale, it's not too big a deal, but many of these products have to be shipped, frozen, cut up, and put into other products. Usually the idea is to get it from the farm to at least the distributor [grocery store] within two to three days.

"If we could figure out a way to prolong broccoli's appearance, taste, and flavor long after harvest and maintain the improved health-promoting properties, then that would be of great interest to growers," he added.

The researchers first used methyl jasmonate (MeJA), a nontoxic plant-signal compound (produced naturally in plants) to increase the broccoli's anticancer potential. They sprayed it on the broccoli about four days before harvest. When applied, MeJA initiates a



process of gene activity affiliated with the biosynthesis of glucosinolates (GS), which are compounds found in the tissue of broccoli and other brassica vegetables (such as cauliflower, cabbage, and kale).

Glucosinolates have been identified as potent cancer-preventative agents because of their ability to induce detoxification enzymes, such as quinone reductase (QR), that detoxify and eliminate carcinogens from the human body.

However, during this process, MeJA also signals a network of genes that lead to plant decay by inducing the release of ethylene, Juvik explained. "While we can use MeJA to turn on phytochemicals like the glucosinolates and dramatically increase the abundance of those helpful anticancer compounds, MeJA also reduces the shelf life after harvest," he said.

So the researchers tried using the recently developed compound 1-methylcyclopropene (1-MCP), which has been shown to interfere with receptor proteins in the plant that are receptor-sensitive to ethylene. They applied the compound after harvesting the same broccoli that had been treated with MeJA before harvest.

"Ethylene will move and bind to ethylene receptors, and that binding process initiates decay. What this compound does is more competitively land on the protein and bind to or push out ethylene," Juvik explained. "It basically stops or dramatically slows down the decay associated with ethylene.

"The combination is good," he said.

Like MeJA, 1-MCP is also a nontoxic compound naturally produced in plants, although Juvik said synthetic forms can be produced. He stressed that both the MeJA and 1-MCP treatments require very small amounts of the compounds.

"The compound is very cheap, and it's about as toxic as salt. It takes very little to elevate all the desirable aspects. It's volatile and disappears from the product after about 4 hours," he said.

The use of these treatments could make a great impact on important global dilemmas such as food security issues and health care costs, Juvik said.

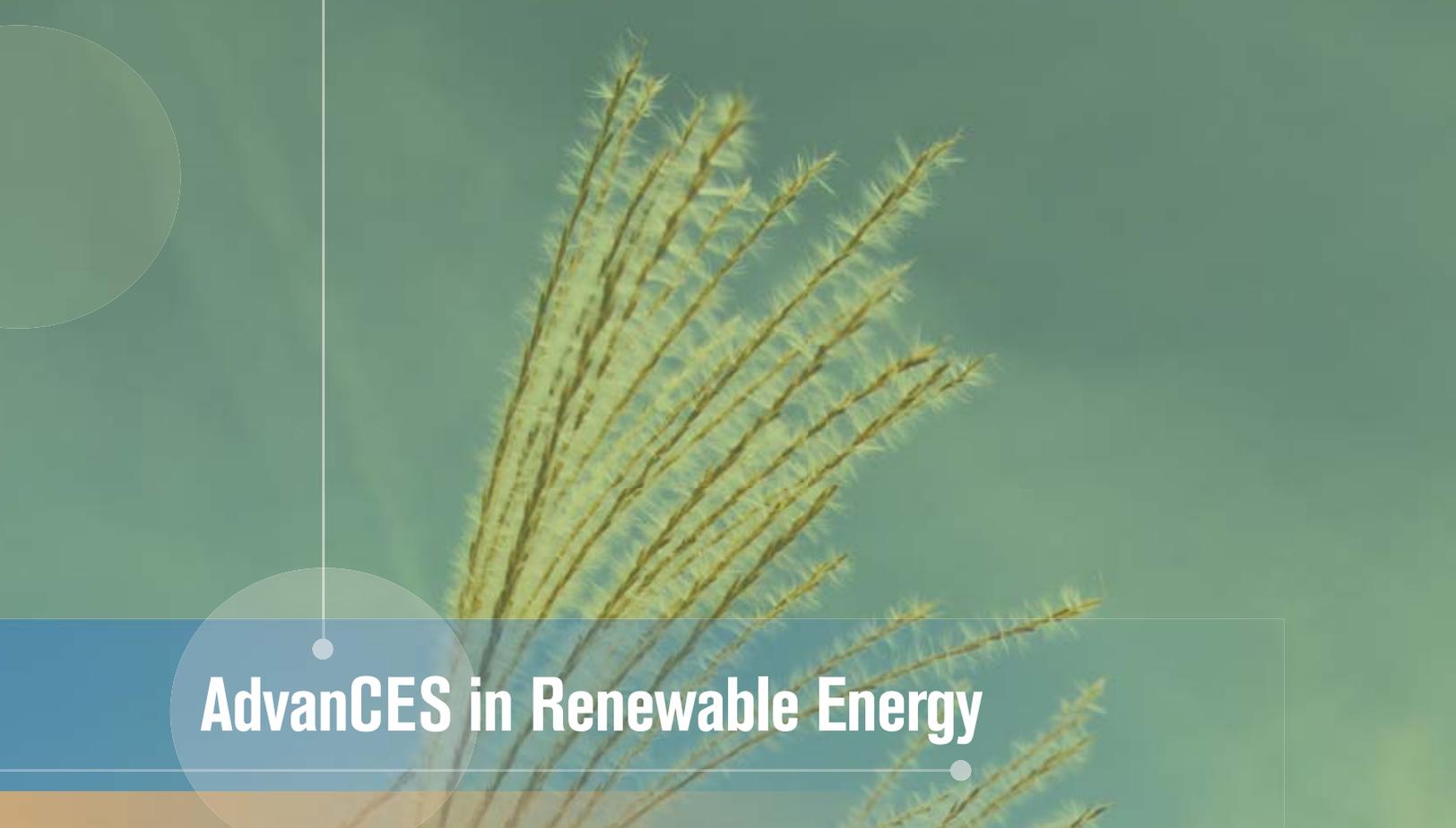
"It's a fairly cheap way to maintain quality, but it provides a preventative approach to all the medical costs associated with degenerative diseases. These are not pills that go in and take

away or change damaged tissues, but it's a way to protect people by reducing the risk they currently have to different diseases. This treatment won't take all the risk away, but it could prevent further damage," he said.

As for its impact on impending global food security concerns, Juvik said any mechanisms that will improve people's health, especially later in life, will benefit food security.

"We need to look at what mechanisms we can use to improve not only food security but the functioning of people later in their life spans. When you look at how much the United States spends on medical costs associated with diseases, you see it's a huge burden on the economy, which is the same in all countries. It basically utilizes resources that could be used to improve food security," Juvik said. "Also, promoting and prolonging food stability with quality after harvest means less waste, which is a big issue in terms of food security."

Co-authors of the study were Juvik, Kang Mo Ku, Jeong Hee Choi, Hyoung Seok Kim, Mosbah M. Kushad, and Elizabeth H. Jeffery. AgroFresh, a division of Rohm & Hass, provided 1-MCP and equipment for the research. This research was published in *PLOS ONE*.



AdvanCES in Renewable Energy

“Look-ahead” sensor helps predict yield in bioenergy crops

A “look-ahead” sensor that converts the bending load of napiergrass to a measure of yield was one of four yield-sensing approaches developed by University of Illinois researchers in a study conducted in Florida, Florida.

Napiergrass, also known as elephant grass, resembles sugarcane in stature and methods of propagation. The grass is emerging as a candidate bioenergy crop, but limited studies are available for napiergrass yield sensing, a technology that could play an important role in implementing precision agriculture and reducing harvesting cost. Alan Hansen, a professor in Agricultural and Biological Engineering (ABE), and Sunil Mathanker, an ABE postdoctoral researcher, worked with colleagues from John Deere and BP Biofuels to field-test the four yield-sensing approaches and document their correlation to napiergrass yield.

A stem-bending yield sensor was developed to fit a John Deere 3522 sugarcane billet harvester. Four load cells were fitted between two parallel pipes to form a push bar, which was installed between the crop dividers about 1.2 meters above the ground and 1.5 meters ahead of the basecutter. The study also investigated the hydraulic pressures of basecutter, chopper, and elevator drives as indicators of yield. Three pressure sensors were fitted to the inlets of the hydraulic motors operating the basecutter, chopper, and elevator on the John Deere harvester.

The sensor that measured stem-bending force was the most accurate among the four methods tested. “What’s particularly good

about this sensor,” said Hansen, “is that you’re able to measure yield at the point of entry. This is somewhat unique. In combine harvesters, for instance, you’re monitoring a yield sensor at a point much further along in the flow of material, where the grain is about to enter the tank at the top of the combine. The delay between when the grain comes in and when it reaches the point of measurement creates a potential for error, and we have to come up with an estimate in relation to the time lag. So having this look-ahead sensor right up front is of significant value.”

While the look-ahead sensor showed the best correlation with yield, Mathanker said, issues including crop lodging, harvester speed, and the ability of critical components to respond to sudden changes in ground speed pose a challenge for this sensing approach. Varietal characteristics, harvest time, moisture content of the stems, soil conditions, sensor height, and physical properties of the stems could also influence the bending force experienced on a push bar.

Among the three hydraulic pressure-sensing approaches, the chopper pressure showed the highest correlation with yield. A reasonable correlation was found between the basecutter pressure and yield, although in addition to yield, it was expected that the basecutter pressure would depend on cutting height. Chopper and elevator pressures were less affected by factors other than yield compared to basecutter pressure.

“Based on the results of this study,” Mathanker said, “the stem-bending yield sensor showed potential for real-time napiergrass yield prediction. It can also be used to control operating parameters of the harvester, such as travel speed, and to generate yield maps for precision agriculture. We believe this stem-bending, force-sensing approach can be extended to other thick-stemmed crops.”

In addition to Hansen and Mathanker, co-authors were H. Gan of the University of Illinois, J.C. Buss of John Deere, and J.F. Larsen of BP Biofuels. The research was published in *Computers and Electronics in Agriculture*.

Jason Buss (left) and Hao Gan assemble the stem-bending biomass yield sensor.



Complete sorghum genome may usher in new uses for food and fuel

Although sorghum lines underwent adaptation decades ago to be grown in temperate climates, a University of Illinois researcher said he and his team have completed the first comprehensive genomic analysis of the molecular changes behind that adaptation.

Patrick Brown, ACES plant breeder and geneticist, said having a complete characterization of the locations (loci) affecting specific traits will speed up the adaptation of sorghum and related grasses to new production systems for both food and fuel.

Brown is working on the project through the Energy Biosciences Institute at the U of I, hoping to use the sorghum findings as a launching pad for working with complex genomes of other feedstocks. EBI provided the startup funding for the study.

To adapt the drought-resistant, tropical sorghum to temperate climates, Brown explained, sorghum lines were converted over the years by breeders' selecting and crossing exotic lines with temperate-adapted lines to create lines that were photoperiod-insensitive for early maturity, as well as shorter plants that could be machine-harvested.

"Surprisingly, no one had ever really genotyped these lines to figure out what had happened when they were adapted," Brown said. "Now that genotyping is cheap, you can get a lot of data for a modest investment."

Previous studies had looked at a specific genomic region or a smaller subset of these lines. "This is the first study to look at all of them. A previous paper had come out looking at a specific region of chromosome 6. What we did was not much more expensive, and we got a bigger picture completely technology enabled," he said.

The researchers used a new technique called genotyping-by-sequencing (GBS) to map genetic differences in 1,160 sorghum lines. Brown said GBS is a technology developed in the last two years. He and his team, along with other researchers, have made re-

finements to the GBS process. "We're now able to cover the whole genome, with some gaps in individual lines," he said.

While much improvement has been made for grain sorghum, Brown said, little has been made for sweet or bioenergy types.

"Up to this point sorghum has been grown mostly for grain. It's pretty short stuff, doesn't blow over on the windy high plains, and is really hardy. But now there is a lot of interest in other uses for sorghum, such as growing sweet sorghum in areas where they grow sugarcane, and growing biomass sorghum for bioenergy through combustion or cellulosic technology."

Getting a complete map of the traits researchers are most interested in—plant height and maturity—will help unlock the diversity in the exotic lines and bring it into grain sorghum, Brown said.

"We'll be able to start moving forward. We'll basically be able to breed all these

sorghum types more easily and use the genes that we have bred for in grain sorghum over the last hundred years and move them into sweet sorghum and biomass sorghum. We think that finding those genes is going to be critical," he said.

Even with this complete genetic map, Brown said, the research is still not at the end point.

"The case I always make is that over here we have grain sorghum, where we've done almost all the plant breeding, and where we've stacked the good genes. Over there we've got exotic sorghum, which hasn't been improved at all, yet it's where most of the genetic diversity is. For that genetic diversity to be useful to grain sorghum, we need to know where the genes are for height and maturity so we can bring in good diversity while keeping grain sorghum short and early like producers need it," he said.



On the other hand, Brown added, if improvements are to be made for sweet, forage, or biomass sorghum, researchers will need to bring in some of the genes from grain sorghum for traits like seed quality and early-season vigor.

"This is the general agronomic stuff we've been breeding for, not the genes for dwarfing and earliness. Most of this sorghum now goes to chicken feed or ethanol in the United States."

"We do have a collaboration with Markus Pauly, an EBI researcher based at the University of California, Berkeley, who is looking at the composition of sorghum. But the bigger problem with biomass sorghum right now is the moisture content of the biomass. With miscanthus or switchgrass, you can go in and harvest in February when it's pretty much bone dry and all the nitrogen has already been moved back down underground; sorghum doesn't work that way," Brown said.

Because biomass sorghum is grown annually, growing until frost comes, it has a high moisture content when it is harvested. "When we cut it down, there's tons of biomass. I don't know that there's anything else that can match it in the area, but the biomass is really high in moisture. For the existing cellulosic idea [of producing fuel from biomass] as it stands now, that is not very useful," he said.

"That's one of the roadblocks to biomass sorghum right now," Brown said. "Sweet sorghum, where you would squeeze the sugary juice out like with sugarcane, may be closer on the horizon. There is an ethanol plant starting up in southern Illinois that plans to use 25 percent sweet sorghum.



Graduate student Payne Burks uses a small sugarcane press to juice a stalk of sweet sorghum.

"Right now, we're using sorghum as a model—maybe we can find sorghum genes that we can also tinker with in Miscanthus or sugarcane."

Brown added that genetic studies and improvements could bring other value-added opportunities for sorghum grain. "It's not quite as nutritious as corn, but researchers are investigating it as a way to combat obesity. They are looking at compounds that would prevent you from absorbing all the nutrition from your food in the small intestine," he said.

Another gene found has shown that sorghum produces a huge amount of antioxidant in the grain's outer layer. "It produces 10 times more antioxidant than blueberries, which are high in antioxidant. The yield of sorghum hybrids with those traits isn't quite what it needs to be yet. There is stuff to work out with all of this," he said.

Co-authors of the study were Brown, Carrie S. Thurber, Justin M. Ma, and Race H. Higgins. The study was published in *Genome Biology*.

Pat Brown (left) with former students Elizabeth Hawkins and Ben Bergeson evaluate sweet sorghum lines for Brix and juice yield.



“Green” pretreatment of miscanthus for biofuels

Two University of Illinois scientists have developed an environmentally friendly and more economical way of pretreating miscanthus in the biofuel production process.

“We pretreat the biomass with switchable butadiene sulfone in the presence of water to break down the plant cell wall, which consists of cellulose, hemicellulose, and lignin, the source of biofuels and value-added products,” said Hao Feng, a U of I professor of food science and human nutrition who also has extensive research experience with biofuels.

Compared with current industry practices, the new technique is a green alternative; butadiene sulfone can be recovered at potentially high yields because the solvent’s decomposition gases are also the raw materials for its production. This means that butadiene sulfone can be reused after pretreatment, Feng said.

The commercial availability for both production and recovery of this chemical should allow for a transfer of these operations into a biorefinery, Feng said. “It’s a big advantage in terms of both economy and environmental impact.”

The current chemical pretreatment process uses relatively harsh conditions to break down the tough structure of grass and other biomass. Enzymes are then used to release the sugars that are converted to fuels through a fermentation process, Feng explained.

“These chemicals not only produce compounds that are toxic to fermenting microorganisms, they often result in by-products that have negative environmental impact,” he said.

Why is this new solvent so important? “Pretreatment is the most expensive step in the production of biofuels and chemicals from lignocellulosic biomass,” said J. Attilio de Frias,

co-author of the study and a former doctoral student in the Feng laboratory.

According to de Frias, butadiene sulfone has the unique ability to “switch” in equilibrium to 1,3-butadiene and sulfur dioxide at relatively low temperatures, forming sulfurous acid in the presence of water.

Using this relatively inexpensive and recoverable chemical to pretreat biomass in one step under mild conditions is definitely a step in the right direction, he said.

“At temperatures ranging from 90 to 110°C, the sulfurous acid hydrolyzes hemicellulose. Then butadiene sulfone helps to solubilize lignin, with most of the cellulose preserved for downstream enzymatic hydrolysis,” de Frias explained.

The scientists said their data shows promise for the separation of hemicellulose and lignin and the preservation of cellulose. They were able to remove up to 58 percent of lignin and 91 percent of hemicellulose and preserved 90 to 99 percent of cellulose with the new process.

Feng said that this is the first time that this solvent has been successfully used as a pretreatment in biofuel production.

“We look forward to its testing and adoption by biofuel manufacturers that are working with Miscanthus and other biomass crops,” he said.

This research was published in *Green Chemistry*.



Professor Hao Feng (right) and doctoral student Xiaojuan Wang feed biomass into a tubular reactor before pretreatment.

Search for better biofuel microbes leads to the human gut

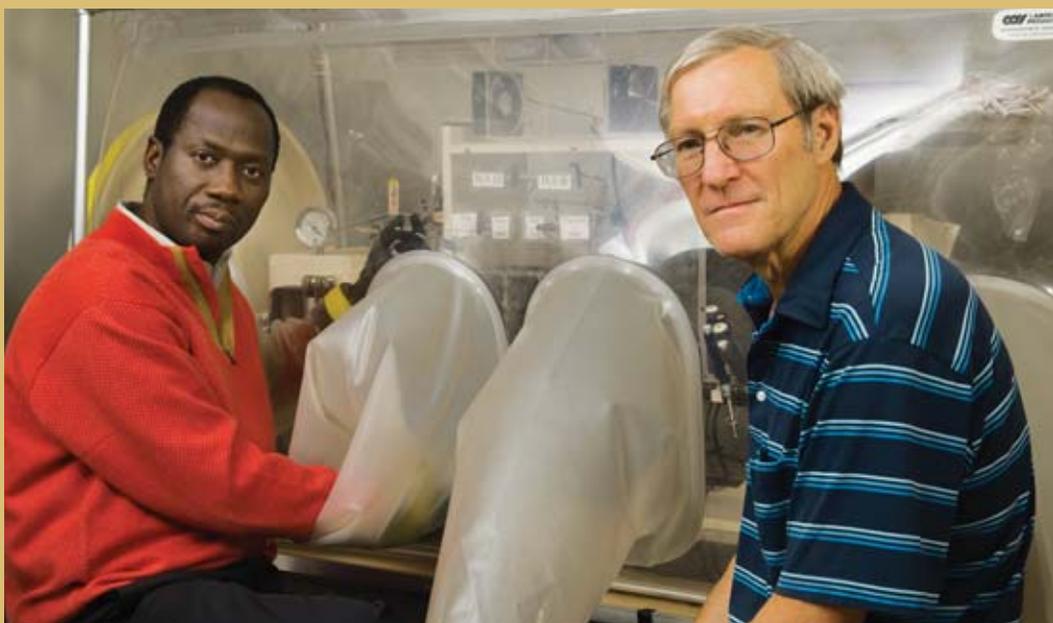
Scientists have scoured cow rumens and termite guts for microbes that can efficiently break down plant cell walls for the production of next-generation biofuels, but some of the best microbial candidates may reside in the human lower intestine, researchers report.

Their study, reported in the *Proceedings of the National Academy of Sciences*, is the first to use biochemical approaches to confirm the hypothesis that microbes in the human gut can digest fiber, breaking it down into simple sugars to ferment them into nutrients that nourish human cells. These findings have significance for human health but also for biofuel production, since the same sugars can be fed to yeast to generate ethanol and other liquid fuels. The human microbes appear to be endowed with enzymes that break down a complex plant fiber component more efficiently than the most efficient microbes found in the cow rumen, the researchers report.

Their work in cows led the researchers to the human microbes, said University of Illinois animal sciences and Institute for Genomic Biology professor Isaac Cann, who led the new analysis with his colleagues, animal sciences professor Roderick Mackie and M.D./Ph.D. student Dylan Dodd. Cann also is a microbiology professor and a principal investigator at the Energy Biosciences Institute. Dodd is now at Stanford University.

"In looking for biofuel microbes in the cow rumen, we found that *Prevotella bryantii*, a bacterium that is known to efficiently break down [the plant] fiber hemicellulose, gears up production of one gene more than others when it is digesting plant matter," Cann said.

When searching a database for similar genes in other organisms, the researchers found them in microbes from the human gut. The team focused on two of these human microbes, *Bacteroides intestinalis* and *Bacteroides*



Isaac Cann (left) and Roderick Mackie

ovatus, which belong to the same bacterial phylum as *Prevotella* from the cow.

"We expressed the human gut bacterial enzymes and found that for some related enzymes, the human ones actually were more active [in breaking down hemicellulose] than the enzymes from the cow," Cann said.

When the researchers looked more closely at the structure of the human enzymes, they saw something unusual: many single polypeptide (protein) chains actually contained two enzymes, one of which was embedded in the other. Further analysis of the most important protein revealed that the embedded component was a carbohydrate-binding module, which, as its name implies, latches onto carbohydrates, such as hemicellulose. This enzyme shreds the plant fiber hemicellulose so that other enzymes can work on it to break it down into its unit sugars.

Working with U of I biochemistry professor Satish Nair, the researchers also noticed that the carbohydrate-binding module "put a kink" in the fiber when it bound to it. This bending action may bring the fiber close to the other enzyme in the protein so it can get to work breaking the bonds between the sugars. Further research is needed to confirm this hypothesis, Cann said.

The study points to human microbes as a potentially potent source of those that can aid in biofuel production, Cann said.

"In addition to finding microbes in the cow rumen and termite gut, it looks like we can actually make some contributions ourselves," he said. "And our bugs seem to have some enzymes that are even better than those in the cow rumen."

The Energy Biosciences Institute and the U.S. Department of Agriculture funded this research.

Improving breeding efficiency, survival rate of bioenergy crop

Miscanthus has become an important feedstock crop in the emerging bioenergy industry because it is high yielding, needs few inputs, and adapts well to temperate climates. But with limited diversity in the crop, researchers know the survival of miscanthus over time is at risk.

Recent work led by Erik Sacks, assistant professor of plant breeding and genetics in the College of ACES, and his team, including professor of plant biology and crop sciences Steve Long, is providing new information on the evolution and genetic makeup of the perennial grass crop *Miscanthus x giganteus* (Mxg) that could lead to improved breeding and greater security of the crop.

The work is funded by the U.S. Department of Agriculture and the U.S. Department of Energy as part of a larger Obama administration effort to diversify the nation's energy portfolio and accelerate development of new clean energy.

"There are a lot of named cultivars or varieties of miscanthus, but when we looked at their molecular markers, we saw that essentially they're all the same," Sacks said. "This isn't a good situation for establishing any new crop, really—to have that little genetic diversity—because if you start planting a monoculture of one clone over a wide area, eventually a pest could take everything down all at once. We learned this lesson in the past with reduced genetic diversity in the maize crop. We don't want to repeat that mistake with miscanthus."

The researchers are now looking at hundreds of populations of one parental species of the Mxg crop, *M. sacchariflorus* (Msa), from its natural range in China, Japan, Korea, and Russia. Through DNA sequencing, they will obtain thousands of genetic markers to determine population structure, then will use field trials at multiple locations to evaluate yield potential and adaptation.

By combining the DNA sequencing information and field data they will be able to associate traits of interest with molecular markers, which can be used to improve breeding efficiency and allow plant breeders to quickly develop improved biomass cultivars of Mxg. A previous study conducted by Sacks has helped to trace the genetic diversity and population structure of the other parental species of the



Miscanthus x giganteus (Mxg)

hybrid Mxg, *M. sinensis* (Msi), providing new information for breeding and improvement of Mxg as a bioenergy crop.

“This study is the next logical step because the miscanthus species used for bioenergy—*M. x giganteus*—primarily is a cross between *M. sacchariflorus* and *M. sinensis*,” Sacks explained. “We need to understand something about both species in terms of genetic diversity and population structure and have access to germ-plasm to understand the traits and molecular markers to improve breeding efficiency. We know about the structure of *M. sinensis*, but *M. sacchariflorus* is a black box to us. We only know a little about it, and it may be more complicated than *M. sinensis*.”

Because miscanthus can be crossed with sugarcane, this project will also provide materials and data that could help in the development of more cold-hardy sugarcanes and “energy canes.” The research was published in the *Annals of Botany*.

Siyao “Clare” Liu (left) and Erik Sacks examine some miscanthus crosses isolated from other miscanthus plants as part of their bioenergy research in the Plant Sciences Greenhouses.



Sharing the risks and costs of biomass crops



Farmers who grow corn and soybeans can take advantage of government price supports and crop insurance, but similar programs are not available for growers of biomass crops such as miscanthus. A University of Illinois study recommends a framework for contracts between growers and biorefineries to help spell out expectations for sustainability practices and to designate who will assume the risks and costs associated with these new perennial energy crops.

“The current biomass market operates more along the lines of a take-it-or-leave-it contract. But to encourage enhanced participation and promote a more sustainable, stable biomass supply, a new kind of contract needs to be created,” said Jody Endres, a U of I professor of energy, agricultural, and environmental law.

A good contract gives everyone more certainty, Endres said.

“Incomplete contracts are the hazard. We need to develop contracts that nail down all of the details and are transparent about who is taking on the risk and who is paying for it. If we get these considerations into the contracts, those who finance this new biomass crop industry will have more certainty to invest.”

The study identifies considerations that should be included in the framework for a biomass contract, including a control for moral hazard, a risk incentive tradeoff, existing agricultural practices, and risk and management tools. All these specifications will help make the industry more sustainable, financially and environmentally.

Endres said that if biorefineries receive money in the form of carbon credits for reduc-

ing pollution, contracts should include financial incentives for farmers because they bear the risks associated with sustainability practices.

“Suppose a sustainability contract lists the default as integrated pest management rather than application of traditional pesticides,” Endres said. “The farmer takes on some risk to provide a sustainable product, but the biorefinery gets carbon credit for those sustainable practices. This reality should be worked into the contract—if the farmer assumes the risk of IPM, some sort of up-front payment or incentive should account for this risk. Due to the power relationships in this industry, the onus is on the biorefinery to be the leader in developing contracts in this new landscape.”

The perennial nature of biomass crops also makes developing contracts challenging.

“We’re in a unique and complicated environment, and traditional agricultural contracting structures just don’t apply,” Endres said. “Crop insurance is not currently available for farmers who grow biomass crops, so they take on additional risk. And landowners see high prices for traditional commodity crops and do not want to be locked into a multiyear contract with a lessee to grow a perennial biomass crop,” she said.

Although sustainability requirements are important, Endres said, having an adequate supply of biomass is important as well. “We’re trying to envision a future in which we have a lot of biomass, and one way to secure that is to recognize all of the risks and costs, especially when it comes to sustainability practices. The situation is unique, and we do not yet have contracts for this aspect of the industry,” she said.

Biomass standards groups, in which Endres participates, are considering too how the value of sustainability practices can be measured at the watershed, “eco-shed,” or airshed level rather than on the scale of individual farms. Endres said that this is another way to ensure that balance is achieved between producers and consumers of biomass, including through contracts.

“I’m optimistic that it can be done,” she said. “Growers and refiners right now are concerned with the industry being financially sound. But, they are also being asked by sectors that may use biofuels to incorporate sustainability verification, which requires significant intellectual and monetary investment.

“There is a real need for education in both developed and underdeveloped countries about biomass contracting,” Endres said. “We’re trying to shift the paradigm from traditional agriculture to something that’s more sustainable—and that takes knowledge. If we don’t have that knowledge here in the United States and we’re trying to draft contracts in our very developed system, how is this going to be

rolled out in say, Africa, or other areas where the use of production contracts is much more rare, especially in the small-farm context?”

The research, supported by funding from the Energy Biosciences Institute and USDA National Institute of Food and Agriculture, was published in the *UCLA Journal of Environmental Law and Policy*. A. Bryan Endres and Jeremy J. Stoller were co-authors.



Jody Endres

AdvanCES in Environmental Protection



Soil microbes shift as shrubs invade remnant hill prairies

Perched high on the bluffs of the Midwest's big river valleys are some of the last remnants of never-farmed prairie grasslands. These patches, edged by forest, are slowly being taken over by shrubs. A University of Illinois study examined the soil microbes on nine patches, also called "balds," that had varying degrees of shrub invasion and found an interesting shift in the composition of the microbial community.

"When we looked at the soil samples from a lightly encroached hill prairie remnant, it was very clear that there was a set of fungi that look like grassland fungi, a set of fungi that look like tree fungi, and a set with the features of both at the shrubs between the grassland and the trees," said ACES microbial ecologist Tony Yannarell. "As the degree of shrub encroachment increased, so did the amount of change in the fungal communities, and those shrub fungi joined the forest group to become one big woody community."

Yannarell said that on the balds that were completely encroached, the soil samples across the entire remnant were the same. "You get this shift toward woody fungal communities that mirror how much shrub density you have in the hill prairie," he said.

Yannarell said that forest and prairie microbial communities are always very different from each other, even in this case, where they are only a couple of

meters apart. And because of the close proximity, with the same overall climate conditions and soil origin, the researchers could rule out a lot of factors that would normally affect a change in microbial community structure.

Soil microbes underneath the shrubs tend to resemble either the prairie microbes or the forest microbes, but shrub soil bacteria show a different pattern of resemblance than shrub soil fungi. The shrub bacteria are more like what researchers found in open prairie than what they found in the forest. But the shrub fungi looked a lot more like the forest fungi.

"We think what we found is the signature of these early changes, these early shifts of microbial communities toward a woody fungal community," Yannarell said. "This first study reveals only one side of the change. We think we can firmly conclude that there are some woody, plant-like fungi. But we don't know if they are enhancing the invasion. They could be holding it back if there are shrub diseases.

"We're also interested in knowing if the shrubs have changed these microbes, because that could have an effect on a landowner's ability to restore a heavily encroached hill prairie," Yannarell said. "If you cut down all of the shrubs, you haven't changed the microbial communities that live in the soil that the shrubs created. We want to know if those shrubby communities can be invaded by grasses or whether they have changed something fundamentally so that it will be harder to restore the prairie."

Yannarell explained that the remnant hill prairies are on portions of the bluffs where the soil is erodible, and because the bluff is facing the sun for more of the year, it's slightly warmer and slightly drier. More frequent fires would tip the scale toward grassland, but fires have been suppressed for many decades in the area because people live and farm nearby. The hill prairies are shrinking as the forest, and now native shrubs, such as dogwood, sumac, shrubby black locust, and eventually red cedar, move in.

"We don't know yet what kind of long-term impact this could have on the environment," Yannarell said. "As the environment becomes unfavorable for certain microbes, those microbes will die off," he said. "The shrubs could be driving out grass-loving fungi in favor of shrub-loving fungi. It's yet another example of a monoculture taking over."

Yannarell said that this research will be the foundation for a lot of future work for his group. Contributing authors were Sarah E. Menning and Alyssa M. Beck. Funding was provided by the National Great Rivers Research and Educational Center. The study was published in *Microbial Ecology*.



Left: Looking north from the bluff in Fults Hill Prairie Nature Preserve in Monroe County, Illinois

Right: Tony Yannarell sampling root nodules and rhizosphere soil from a bushclover plant

Birds roosting in large groups less likely to contract West Nile virus

Although it would seem logical that large numbers of roosting birds would attract more mosquitoes that carry West Nile virus and would contract the disease when bitten, recent research at the University of Illinois found the opposite to be true. That is, when large groups of birds roost together, the chance that an individual bird will get bitten by a mosquito carrying West Nile virus and subsequently contract the disease actually goes down.

“Our study is the first field-based evidence to support with an experiment what’s called the ‘encounter-dilution effect’ acting in a vector-borne disease system,” said ACES researcher Bethany Krebs. “There have been other laboratory and modeling studies that suggest that mosquitoes feed less per individual in a group than they do on a solitary bird, but it’s hard to get the information in natural settings.”

The experiment was conducted over three years. “We trapped mosquitoes inside and outside of roosts from 2010 to 2012 to determine whether roosts attracted more mosquitoes than nonroost sites,” Krebs said. “Then we sent the mosquitoes to a lab in Texas that ran analyses to determine if they carried the West Nile virus. Uninfected house sparrows were used as sentinel birds to assess host risk of West Nile exposure in 2012—the timing coincided with the historical period of peak West Nile virus transmission in the Chicago study areas known to be ‘hot spots’ for the disease.”

The house sparrows were placed in flight cages—23 birds in cages near communal roosts and 25 in nonroost cages. Krebs explained that sentinel birds are used by public health departments as sort of a “canary in the

coal mine” early warning system to detect the presence of a vector-borne disease.

“Only three sparrows near roosts contracted West Nile virus, whereas 11 birds in nonroost cages were infected,” Krebs said. “So the risk of West Nile virus exposure for those



House sparrow

sentinel birds caged within roosts was significantly lower than for birds caged in nonroost locations.”

Jeff Brawn, ecologist and head of the ACES Department of Natural Resources and Environmental Sciences, described how this study sheds light on the spread of vector-borne diseases, such as West Nile virus, compared to those transmitted via direct contact. “If you’re in a group, the probability of infection goes way up with direct contact diseases, such as

colds and flu,” Brawn explained. “This study confirmed that the risk is spread out among the individuals in the herd; in the case of West Nile virus, which is a vector-borne disease, individual risk is minimized.”

Brawn said that it is not understood why some birds roost and others of the same species do not. But this study shows that those who do roost together benefit from a lower risk of exposure to West Nile virus infection.

The maintenance and transmission of West Nile virus goes something like this: The common mosquito *Culex pipiens* is the carrier (vector) of the disease. The mosquitoes bite birds, usually at night while they are roosting, and infect them with the virus. Crows and jays typically die after they contract West Nile virus, but robins are called “superamplifiers” of the disease: they are able to serve as hosts for the virus. When other mosquitoes bite the infected birds, the insects get the virus and transmit it through biting another host—which could be a human.

This study brings to a close almost 10 years of research on West Nile virus in the Chicago area supported by funding from the National Science Foundation. “This was the last year that we were planning to do significant field work in that area of Chicago,” Krebs said.

Brawn noted that a study like this, with many components, requires experts from many disciplines. “The study can only happen when you have field biologists, mosquito specialists, disease experts, epidemiologists—the team of researchers that worked on this project is multifaceted. That’s what it takes to do this kind of work. We collected blood samples from the birds and sent those to be analyzed.



We sent the mosquitoes to someone else who knew how to do all of the genetic analysis. It's a team working together."

Brawn added that, although the project studied birds, it could provide an implication with respect to human behavior and health risk. "If you are in the woods alone, you may have a greater probability of getting bitten than if you are in a large group of people," he said.

The study was co-authored by Marilyn O. Ruiz and Jeffrey D. Brawn from U of I; Tavis K. Anderson from Georgia Southern University; Tony L. Goldberg and Christina M. Newman from the University of Wisconsin; Gabriel L. Hamer from Texas A&M; Uriel D. Kitron from Emory University; and Edward D. Walker from Michigan State University. The research was supported by the National Science Foundation Ecology of Infectious Disease program. The research was published in the *Proceedings of the Royal Society B: Biological Sciences*.

Researcher Bethany Krebs (on ladder) assembling one of the flight cages used to house a sentinel sparrow for research on the relationship between roosting and West Nile virus transmission

Common mosquito, Culex pipiens



Longer catch-and-release time leaves nests more vulnerable

During spawning season, the largemouth bass male attentively guards its nest. Recent ACES research found that catch-and-release angling could give predators the perfect opportunity to consume the bass young. In fact, time spent away from the nest during a catch-and-release event and the exhaustion the event creates for the bass male are critical to the survival of the embryos, particularly in lakes with high densities of brood predators.

“One of our main conclusions was that in a lake where there are very few brood predators, when you angle a male away from his nest and then immediately release him, the chance of a negative impact is less, but if the nest is located in a part of a lake where there is a high density of brood predators, once the male is removed, predators get into the nest very quickly,” said ACES fisheries research scientist Jeff Stein. “On average, the time it took brood predators to begin eating bass young was less than five minutes in cases where the nest was located near schools of brood predators.”

Stein said that the message to anglers is that if they are catch-and-release angling for nesting bass early in the year, it’s best to get the fish back into the water as soon as possible, especially if the lake is known to have a high density of largemouth bass predators, such as bluegill, pumpkinseed, and rock bass.

In the study, 70 largemouth bass nests were located in nine lakes in southeastern Ontario and southwestern Quebec; the lakes were closed to public angling during the data collection period. All of the lakes contained natural largemouth bass populations, with varying numbers of known brood predators. Stein snorkeled in shallow water wearing a neoprene wetsuit that provided him buoyancy



for hours at a time. He observed the nests and assigned scores representing the number of brood predators and the quality of parental care demonstrated by the largemouth bass dads. (The females leave immediately after laying the eggs and have no part in parental care for the nests. The males defend the nests from predators.)

Nesting males were captured and held in a live well for 15 minutes, then released—but they took another 30 minutes on average to return to their nests. Stein put that return time into perspective by comparing catch-and-release practices for both professional and amateur anglers.

“A pro who isn’t interested in anything about the fish other than having caught it will rip that fish over in about 15 seconds into the boat and spend only about another minute or two with the fish before releasing it back into the water,” Stein said. “Casual recreational anglers may be afraid they’re going to lose the catch and so may play it a little more, which exhausts the fish more. After the fish is caught, it might accidentally flop around on the floor of the boat for a while. Anglers may put it in a live

well if they’re thinking of keeping it or until they get the camera out. Five minutes or more elapse.”

Stein said that by the time the fish is finally released back into the water, it is tired and stressed. He compared the fishes’ extreme level of exhaustion to asking a marathon runner to hold their breath at the finish line.

When “dads” are released back into the water, they don’t head right back to the nest. “They’re disoriented, so they go to the bottom to sit and recover for a while and get their heart rate back to stasis,” Stein said. “The fish is saying, ‘Okay, I lived through whatever that was. Now where is my nest?’ By the time it actually gets back to the nest, it has been gone from it 30 minutes.”

Because bass typically spawn only one time per year, when the water temperature reaches a critical threshold, it’s doubtful that a male that loses its eggs to a predator will spawn a second time. This means that, in places with a high density of brood predators, catch-and-release, particularly during spawning season, could reduce the bass population.

The bass population may also be affected by how many males are captured each year. “In a lake with 100 bass nests but very little angling pressure and not many predators, one, two, or three nests where the male gets captured and the nest is raided won’t make a big difference in the overall population, because most of the first-year young are going to survive,” Stein said. “But in a smaller lake with lots of bluegill and lots of anglers throughout the spawning season—that scenario could affect the next generation of bass.”

Fishing spawning beds for bass is a known strategy among knowledgeable anglers, Stein said. “During spawning season, the males are



Jeff Stein prepares to snorkel in a lake in Canada to observe largemouth bass nests.

highly aggressive and the females are big because they're full of eggs ready to spawn. Some jurisdictions, some provinces, and some states in North America disallow any fishing for bass or require catch-and-release angling during the spawning season," he said. "Illinois has a regulation for streams that prohibits harvesting smallmouth bass from April 1 to June 15 to encourage a successful spawn.

"I could envision a future where regionally or in specific lakes in which we know some bass populations may be at risk because of the presence of large numbers of brood predators and because angling pressure is really high, management would track these ingredients that can have a high negative impact on the bass population," Stein said. He added that in some areas of Ontario, for example, bass fishing doesn't open until the fourth weekend in June.

"We definitely know that the success rate of largemouth bass nests is lower when parental care is interrupted," Stein said. "During catch-and-release angling, the male may become so physically taxed that it doesn't continue parental care. The big question we're still looking at is how the interruption of care affects the whole population."

Stein is a senior research scientist with the Illinois State Natural History Survey, part of the Prairie Research Institute at the University of Illinois, and an adjunct professor in the ACES Department of Natural Resources and Environmental Sciences.

The study was co-authored by David Philipp and was published in *Environmental Biology of Fishes*. Partial funding was provided by the Federal Aid in Sport Fish Restoration Project F-69-R and by the Ron Ward Scholarship from the Champaign-Urbana Bass Club.

Desire to reproduce drives active nightlife of birds

For a nonnocturnal bird, the yellow-breasted chat spends a significant amount of time visiting other birds' territories during the night. A University of Illinois researcher who was studying birds' movement during the day noticed that males were active almost every night, while the females were also active at night, but particularly during the window of time when they were fertile.

"We were studying the chat's movement during the day, but we gathered data on the birds 24/7 and started seeing all of this nocturnal movement and wondered what they were doing," said ACES ornithologist Michael Ward.

"I was using data from the night readings at first to calibrate the system," Ward said. He explained that females get up at night to roll their eggs so the membrane inside won't stick to the shell. That little bit of night movement was a way to test the triangulation software because the researchers know the locations of all nests, thereby providing a baseline for com-

parison. "I started plotting it out and thought, This can't be right. This bird is on the nest for an hour or two and then it's all over the place. It can't be that these signals are bouncing around that much. It has to be that the birds are actually moving off the nest."

Ward said that the chats' night vision isn't any better than ours, so they probably weren't out foraging for insects to eat. There was no obvious reason for these birds' nightly escapades. Then he noticed that females were only moving during their fertile period.

"These movements are much more common than you would expect," Ward said. "You might expect some females to get up randomly during the night, but the pattern of these nocturnal forays suggests that they may be trying to increase their reproductive success by searching out partners other than their own social mate."

In the field portion of the study, 32 birds were captured in mist nets; their age and sex were logged, then they were fitted with light-

weight backpack radio transmitters emitting a signal that was picked up by four towers, each with six antennas. The signal strength provided directionality and allowed the researchers to compute the bird's location using a simple triangulation. The bird's location was recorded every three minutes, which yielded approximately 12,000 points per bird. The birds' nests were located and checked every two to three days until eggs hatched or the nest was eaten by a predator. Chats typically have one brood of four eggs each year and lay one egg a day beginning about three to five days after they become fertile. It's not a broad fertility window.

Ward said there is not a lot of research into this kind of bird behavior; in fact, this is one of the first studies suggesting that diurnal birds move around at night for reproduction.

"We know that females generally sleep on or near the nest but that males usually have two or three sites in the area that they go to every night, usually pretty far away from the nest," Ward said. "Females nest in dense shrubbery, so it would be difficult at night for the male to see the female leaving the nest."

Ward said it's a lot like "a soap opera." Other studies have shown that male birds will harass the female or choose not to help her feed the young if they suspect infidelity. "Males are active at night and looking to copulate, but when their female is fertile, they don't leave their territory. They try to either keep her around—which doesn't seem to be working very

Michael Ward





Female yellow-breasted chat

well—or keep other males from coming in. It goes both ways. Females sneak around to other territories, and so do males.”

How does the female on a nightly rendezvous know that the male she is visiting is actually awake and receptive? Ward said that in the case of yellow-breasted chats, a type of warbler, the male sings a sort of low song so the female can find him and hook up.

Ward also described in the study what he calls “nightclubs.” He found forest areas on the edge of the habitat that were not appropriate for nesting but were frequented in the middle

of the night by both males and females. “If males and females are interested in copulating, and there is a known location, it would make sense to go there,” he said.

With foraging for food and building nests by day and cruising around all night, when do these birds actually sleep? Ward said that the researchers noticed that, much like a human after a late night party, the day after the bird had a pretty active night, it wasn’t as active the next day.

Ward said that this behavior may explain why the chat and other species that are gener-

ally territorial prefer to nest near others of the same species.

“Given their movements into others’ territories, efforts should be made to conserve large chunks of habitat that can accommodate many territories,” Ward said.

Mark Alessi, Thomas Benson, and Scott Chiavacci contributed to this article. The research received funding from the Illinois Department of Natural Resources. It was published in an issue of *Animal Behaviour*.

Wetlands more cost effective in nutrient removal

According to a U of I study, removing nitrogen from the environment “the natural way” by creating a wetland is a long-term solution, and one more cost effective than upgrading a wastewater treatment plant. But it isn’t necessarily socially beneficial to offer landowners multiple payments for the environmental services that flow from such created wetlands.

“In the areas we studied in Bureau County with small wastewater treatment plants, it was much cheaper to do pollution control by installing just a few wetlands than it was to have the plants do the upgrades that would be necessary to achieve the same result,” said U of I environmental economist Amy Ando.

Bureau County was selected for the simulation because it is a rural area with waterways with heavy nitrogen and phosphorus pollution, some population density, and a couple of treatment plants. “In some ways, it’s a poster child for an environment where a program like this could work,” Ando said. “There is enough farmland to put in some wetlands, but there are also enough people contributing to the treatment plants who are generating nutrients—so there are parties on both sides that could trade with each other.”



Amy Ando and Nicholas Brozović scouting wetlands in Illinois

The study analyzed the amount of land needed to reduce nitrogen pollution, the costs of actual wetland restorations, and factors such as the opportunity costs to the landowner from no longer farming the new wetland area.

“Wastewater treatment plants can already remove nitrogen, but their current technology is capable of removing it only up to a point,” Ando said. “To remove more nitrogen, they would have to make upgrades. The cost of phosphorus removal isn’t high, but for nitrogen, the upgrades are pretty expensive.”

Ando also explained that, depending on how environmental permit markets are set up,

if an area is set aside as a wetland, the landowner could qualify for several incentive programs through pollution trading markets, even if the original purpose of the wetland conversion was only to reduce nitrogen.

“This is a big issue in the design of markets for ecosystem services,” Ando said. “A wetland does a lot of things. It will filter out nutrients, but it also creates habitat for waterfowl, and it might sequester carbon. The cost of installing a wetland is large enough that in some cases no single payment might be enough to convince farmers to do it, but if they get paid for the full value to society of all three benefits, then they might be willing.”

“There’s a heated debate among scholars and environmental groups and people who are trying to get these markets into place about whether farmers should be able to ‘stack’ payments. With our study we were trying to be agnostic and just ask, What effects would stacking have on market outcomes?” she said.

Under some circumstances, Ando said, not allowing multiple payments for the same action can result in inefficiently low levels of conservation activity on parcels of land that generate nutrient removal and other benefits such as wildlife habitat. However, some farmers



may be willing to convert farmland to wetland on the strength of just one payment.

“Ideally we want to pay farmers to create a wetland that they would not have done without the payment,” Ando said. “Some farmers might not need an extra incentive and would have been happy to do the wetland for the nitrogen payment alone. In our study area, we found that allowing multiple payments may or may not make society as a whole better off, depending on the details of the policy situation.”

When questioned about the fairness of stacking credits, Ando said, “Fairness is a different question from efficiency and from cost effectiveness overall. If multiple payments for a single wetland don’t increase the provision of ecosystem services relative to single payments, then they are not cost effective. Some of that money could be used to pay a different landowner and get more services overall. So there might be a trade-off between what seems fair and just and what yields the greatest environmental benefit to society for a fixed amount of money available for payments,” she said.

The research was funded in part by the U.S. Environmental Protection Agency and the U.S. Department of Agriculture’s National Institute of Food and Agriculture. Additional authors are Adam H. Lentz and Nicholas Brozović. The research was published in the *Journal of the American Water Resources Association*.



AdvanCES in Agricultural Economics & Production

Grain market mystery solved

Something extraordinary happened in the futures market for grain beginning in 2005. The cash price and the futures price, which normally converge by the time a grain contract matures, weren't coming together. Instead, they were moving farther apart—and not by just a little. By September 2008, the wheat futures price was an unprecedented \$2 higher per bushel than the spot price in Toledo, Ohio, at delivery. The cause of this unusual nonconvergence was a simple difference in the storage rate, but discovering that took several researchers almost three years of hard work and quite a bit of anxiety.

"Agriculture and producer groups went ballistic," agricultural economist Scott Irwin said about the incident. "It looked like someone was really getting taken advantage of. There were hearings. There was an official Senate investigation. The phone calls and emails I received were representative of the firestorm about this issue."

Irwin said that because the phenomenon happened at exactly the same time that grain prices were spiking, people began to blame futures speculators.

"The argument was that index funds and speculators were pushing up futures, causing a

bubble, and that one piece of evidence for the bubble was the fact that cash and futures didn't converge," Irwin said. "The belief was that the cash market was reflecting the right fundamentals and the futures were badly overvalued by the bubble."

After Irwin and his colleagues first noticed the price discrepancy, they were approached by the Chicago Mercantile Exchange and began working to solve the mystery.

"We had already been studying the spike in grain prices and whether this could be considered a bubble," Irwin said. "But when the futures market is two dollars above the cash market, your intuition is that the market is just broken. That was what almost everyone in the world argued: the market was broken."

Irwin referred to the "Masters Hypothesis," a view popular at the time named for testimony by hedge fund manager Michael Masters that commodity index investments were to blame for the nonconvergence. Irwin and his colleagues refuted the claim, saying that the size and length of time involved in this episode of nonconvergence were different from similar price bubbles caused by market manipulation.

So if not an actual market bubble, then what was it?

"We got connected with a colleague at the University of California, Davis, and together built a theoretical model to try to figure out how these pieces, these arcane specifications in a contract, really fit together and how one affected the other," Irwin said. "It turned out that it was a storage rate that was built into the contract, and the rate had been set too low. It was a eureka moment. The Chicago Board of Trade futures market took our recommendation, and it fixed the problem."

Irwin explained that for almost 30 years the Chicago Board of Trade had set the contract storage rates at 5 cents per month per bushel. "Everyone knew that the rate could be adjusted and might need to be adjusted as market conditions changed. The smart traders bid the storage rate into the price.

"Our model conclusively shows how the rate-per-month difference properly explained that two-dollar gap," Irwin said. "The model finally made sense of it all."

This research was published in the *American Journal of Agricultural Economics*. Additional authors are Philip Garcia and Aaron Smith.



The profound properties of maize

We live in a world that will need to feed more than 9 billion people by the year 2050. Research to increase food production is being conducted around the globe, and two scientists in the College of ACES are looking at the root of the matter—literally.

Tony Grift, associate professor in agricultural and biological engineering, and Martin Bohn, associate professor in crop sciences, have collaborated to develop high-throughput measurement techniques to acquire phenotypical data describing corn roots. Research in the last decade has indicated that in regard to corn production, the plant's root structure might have a more profound impact on yield than the part of the plant above ground. The per-plant yield has remained the same since the 1940s, but the root angle of the plant then was much wider compared to today's narrower root angle, which allows seeds to be spaced much closer together.

While observing crop characteristics or traits, called phenotyping, of aboveground plants is often difficult and tedious, phenotyping root systems is even more problematic. There are no instruments that can study root systems in place in a nondestructive manner.

So Grift and Bohn developed the CRIB—corn root imaging box—an instrument that can photograph up to 600 maize roots per day. This rate is very important, since a typical maize experiment can involve thousands of plants. The CRIB's highly diffuse illumination prevents shadows from obscuring fine root structures. The digital cameras and the system that rotates the roots to acquire lateral images are all computer controlled.

Once the images were acquired, analysis software was used to measure two of the traits considered most important when analyzing corn yield: root complexity and the root top angle.

"The problem with measuring the complexity of a root system is that there is no real



Roots of corn on the U of I South Farms and a corn root image with computer-generated root angle and stalk diameter

definition for root complexity and no standardized way to measure it," said Grift. "So we used fractal dimension as a proxy for root complexity. Fractals are complex structures. They're objects that are irregular, but self-similar at various scales, like snowflakes [meaning the whole has the same shape as one or more of its parts]. So we went on the assumption that corn roots are complex objects that can be regarded as fractals, because self-similarity is present in these roots as well."

Root top angle is the second trait that was measured. Although human discrepancies in observation make defining a "correct" root top angle elusive, a method was specified that performed consistently for "well-behaved roots," meaning they have a stalk that can be distinguished and that the transition point from stalk to root mass is identifiable. After reading a 2009 paper by Graeme Hammer (published in *Crop Science*), Grift and Bohn wrote a new machine vision algorithm to measure root angle and applied it to more than 10,000 roots, virtually overnight.

Using the data collected for both traits, Bohn and his students in crop sciences were

able to produce maps that highlight areas in the corn genome responsible for the phenotypic expression of the traits.

"We want to take these data and correlate them with genetic information," said Bohn. "We want to find the genes that are involved in root structure development. What root systems are more drought tolerant or more efficient in absorbing nutrients? The final goal is to understand and improve the agronomic performance of plants. We want to understand what a root system looks like that enables the plant to produce as much yield as possible under potentially adverse conditions or stresses."

Grift concluded, "We won't be able to feed 9 billion people by simply using more fertilizer or irrigation or agricultural land. We have to accelerate crop yields. Crop breeders need to accelerate the development of cultivars that feature high yields and engineers need to be flexible enough to understand the way crop scientists work. Synergistic collaboration between departments is imperative."

The research was published in *ScienceDirect, Biosystems Engineering*.

Climate change provides good conditions for fungus in soybeans

With over 100 diseases that can attack soybean crops, why should charcoal rot suddenly rise to the top of the most-destructive list? University of Illinois scientists cite the Earth's changing climate as one reason that more research is needed on the fungus that causes charcoal rot.

Fungi may often be associated with cool, damp growing conditions, but *Macrophomina phaseolina*, the fungus that causes charcoal rot, prefers hot and dry drought conditions.

"As the climate continues to change and we see more extremes in the weather, including hotter, drier summers, this fungus will have more favorable conditions to gain a foothold in soybean and other crops," said Osman Radwan, an ACES molecular biologist. "If we look at diseases of soybean, we find that soybean cyst nematode is at the top, but in the past decade or so, charcoal rot has become one of the top 10 diseases that affect soybean yield."

In examining previous studies on charcoal rot, Radwan and his team noticed that worsening weather conditions associated with climate change, such as higher heat and drought, brought an increase in the incidence of charcoal rot in soybean. He suggests that a research strategy be created to develop a high-yielding soybean that is both resistant to charcoal rot and drought tolerant.

"Right now we are screening lines of soybean to charcoal rot and drought stress, in collaboration with Glen Hartman, a USDA Agricultural Research Service and U of I plant pathologist," Radwan said. "His team is screening for charcoal rot resistance, and I am screening for drought tolerance. Our ultimate goal is to identify the line that shows resistance to both charcoal rot and drought stress and in this way improve soybean tolerance to both the pathogen and the extreme weather conditions."

Radwan's review of the research will provide the necessary background to help develop a strategy for the next step.

Radwan emphasized that it's not just soybean crops that are at risk from charcoal rot. The fungus causes the disease in about 500 other host plants, including corn, sorghum, sunflower, and other important crops. The fungus also grows in high concentrations of salt; this isn't much of a problem for growers in the United States, but it is in developing countries, where salinity is an issue. Consequently, plants must be able to tolerate drought, tolerate salt, and resist this fungus, all at the same time.

One intriguing direction is possible interactions between *M. phaseolina* and other soil pathogens, such as soybean cyst nematode (SCN) and sudden death syndrome (SDS).

"We have some assumptions about whether SCN can increase or decrease the incidence of charcoal rot, as resistance to both pathogens might be controlled by two different pathways," Radwan said. He explained that biotrophic pathogens, such as SCN, need plant tissue to survive, but the fungus that causes charcoal rot is necrotrophic, meaning that it kills the plant tissue, then lives on the dead plant cells.

"We need to understand at the molecular level how these two pathogens interact when they are present in soybean fields. Understanding the mechanisms of molecular interactions between SCN and *M. phaseolina* will help molecular biologists and breeders design an effective method to control both diseases and to breed soybean for resistance to both pathogens," he said.

Although no plants have complete resistance to the fungus, some soybean lines have been shown to have partial resistance.

In controlled greenhouse conditions, Radwan grows a variety of soybean cultivars in sandy soil and then stops watering the plants



Osman Radwan in greenhouse

to simulate drought. The susceptible ones wilt and, even after adding water, don't recover. Those that are tolerant to drought survive.

"If we screen for drought stress, we hope to find some cultivars that are charcoal rot resistant and others that are drought tolerant so that we can cross them," Radwan said. "Of course, they also must have good agronomic traits, such as having a high yield potential, in order to be acceptable to farmers."

Laura V. Rouhana, Glen L. Hartman, and Schuyler S. Korban contributed to the research, which appeared in *Plant Molecular Biology Reporter*.

Waterhemp uses unique mechanism to thwart herbicides

Responding to the first known report of waterhemp population showing resistance to HPPD (4-hydroxyphenylpyruvate dioxygenase)-inhibiting herbicides such as Callisto, Impact, and Laudis, weed scientists at the University of Illinois have identified two unique mechanisms in the weed that have allowed it to “get around” these herbicides.

Dean Riechers, an ACES weed physiologist, worked with other U of I researchers to describe two distinct metabolic detoxification mechanisms that conferred resistance to mesotrione (Callisto) and atrazine (Aatrex) in an Illinois waterhemp population.

“Waterhemp is very diverse, which you can see in the crop field. There are red plants, green plants, tall, short, bushy—basically a germplasm pool. If you keep spraying the same herbicide over and over, eventually you’re going to find the rare plant that can resist it,” said Riechers.

Of great concern in the identified waterhemp population was the way in which the plants resisted the activity of the herbicide—in much the same way that corn naturally resists HPPD-inhibiting herbicides.

“In the pharmaceutical industry, doctors know that you can’t keep recommending the same ampicillin prescription. You might have a limited time you can use that, and then you have to use something different,” Riechers said. The analogy applies to waterhemp as well. “It mimics corn, but it also mimics the ‘superbacteria’ that are resistant to all the antibiotics out there. Weeds are kind of like bacteria in that respect—at least this population is. Whatever active herbicide we apply, with the exception of glyphosate, it doesn’t work anymore,” he said.

The study was prompted in 2009, when a seed corn grower from central Illinois realized he had a problem. The HPPD-inhibiting herbicides



he was using were no longer killing waterhemp plants, which by then had grown into a literal mat of weeds across the field, said Riechers.

“It became obvious to the grower that something was wrong, but it had probably started years before,” Riechers said, adding that the grower had been planting seed corn continuously every year (rather than rotating with another crop), using HPPD-inhibiting herbicides for at least eight years in a row.

“Mesotrione and atrazine are normally two very good herbicides that are safe on corn but still kill waterhemp,” Riechers said.

Working with Syngenta Crop Protection, the maker of the HPPD-inhibiting herbicide Callisto, the researchers looked first at herbicide target genes in the waterhemp plants, expecting to find signs of a mutation in the plant’s HPPD gene sequence or expression or in reduced herbicide absorption. They were able to establish that none of these measures was behind the resistance.

Instead the researchers found that resistance was due to increased metabolism of mesotrione and atrazine—via P450 enzymes for mesotrione and GST enzymes for atrazine. The faster metabolism of the HPPD-inhibiting herbicides in waterhemp resembles the natural mechanism in corn plants, where the P450 enzymes confer tolerance to Callisto.

Riechers said there are many P450 and GST genes in plants, possibly hundreds, and they have not yet precisely narrowed down which ones are involved in waterhemp resistance. “But we know they are in the family of those metabolism genes,” he said. However, recent research in his laboratory has identified some promising leads for follow-up molecular-genetic research.

The HPPD enzyme helps protect the plant’s chlorophyll by producing protective compounds such as vitamins A and E. Rong Ma, former doctoral student in weed physiology and current postdoctoral scientist with Riechers and one of the study’s main researchers, explained that when HPPD is inhibited, chlorophyll is degraded and new leaves show bleaching. As systemic herbicides, HPPD inhibitors move toward new tissue in the plant, eventually killing it.

Older waterhemp growth in the study initially showed bleaching from Callisto, but new emerging leaves recovered and turned green due to the increased metabolism of the herbicide, Ma explained. She added that the corn in the central Illinois field study was also very short because the waterhemp deprived it of needed water and nutrients.

Although the 2009 report was the first to document this type of resistance, Riechers said, four or five other locations in the Midwest have since reported similar occurrences.

“It doesn’t appear to be isolated because it looks like there are other resistant *Amaranthus* populations coming up, including Palmer amaranth,” Riechers said. “The concerning thing is that some of these fields actually did have corn and soybean rotations. They weren’t just growing corn; they were rotating—which is what you’re supposed to do. But the waterhemp still became HPPD resistant, and we’re not sure how that happened.”



Rong Ma, a post-doctoral researcher, and Dean Riechers, a U of I crop scientist, examine waterhemp plants and select shoots for creating waterhemp clones. These vegetative clones reflect identical DNA information for use in further herbicide-resistance studies.

What are the implications for growers now that this resistance has emerged?

Ma said one of the first practices to be considered is not using the same herbicide mode of action repeatedly.

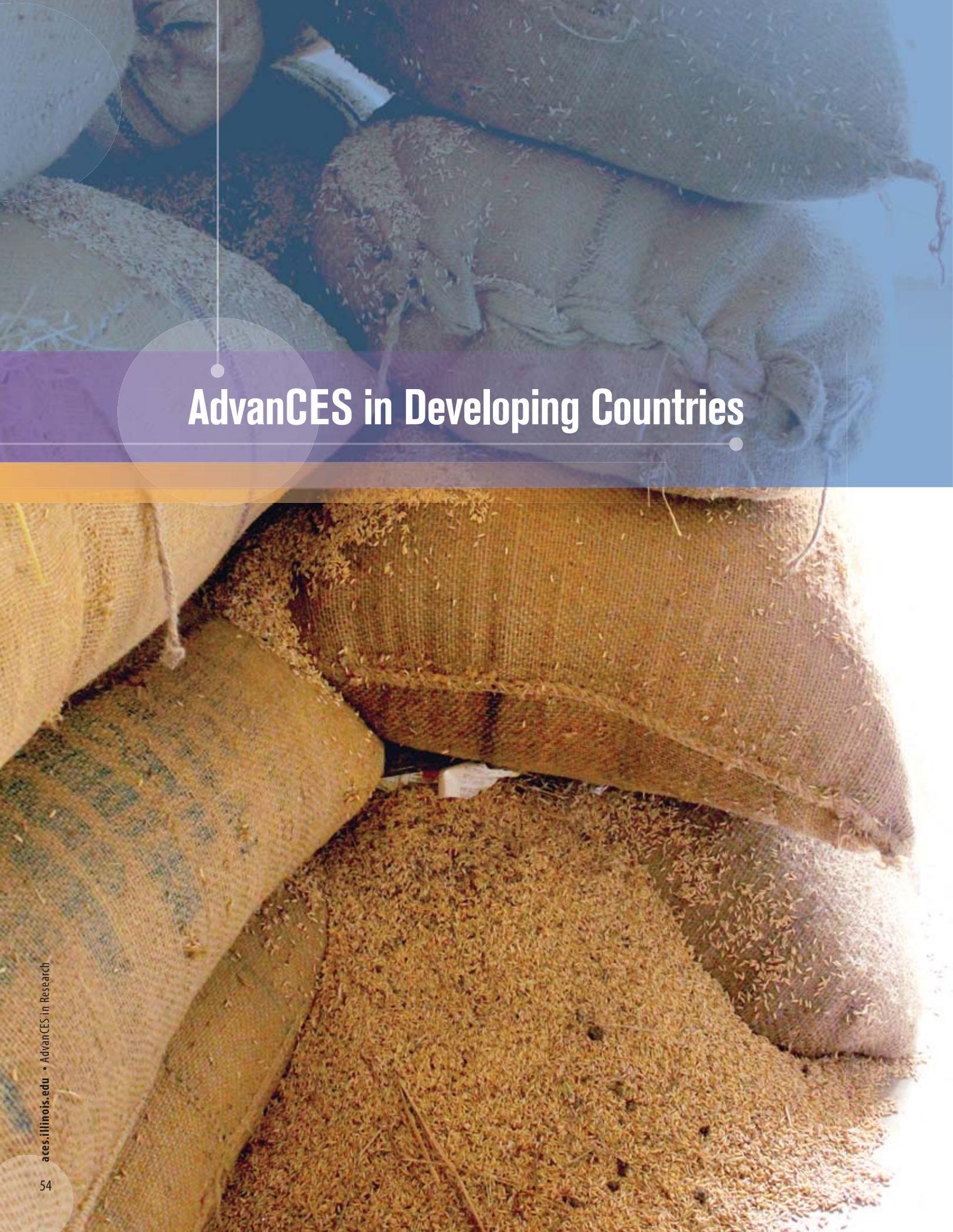
“That advice is just from the chemical standpoint, but growers could also use tillage, because there’s no resistance to tillage,” Riechers said. “Farmers use no-till systems and often plant in narrow rows, and for the most part they have gotten away from tillage for weed management. In a way we have aided waterhemp in becoming a problem by not using tillage, using the same chemical over and over, and not rotating crops.”

The researchers are now looking at new ways to overcome the resistance mechanism by blocking P450 enzymes in the weed while it is still small by using a different chemical inhibitor.

“We found that waterhemp resistance to mesotrione is due to P450s, so now we are trying to use P450 inhibitors combined with mesotrione to see if the two will work together to inhibit waterhemp resistance. But we don’t want to see any injury to corn,” Ma said.

Riechers added that if they can find inhibitors of these herbicide metabolism pathways in waterhemp and Palmer amaranth, this would be a possible way to get around resistance and still have it be safe for corn.

Syngenta Crop Protection funded this study. Co-authors of the paper were Ma, Riechers, Shiv Kaundun, Patrick Tranel, Chance Riggins, Daniel McGinness, Aaron Hager, Tim Hawkes, and Eddie McIndoe. This research was published in *Plant Physiology*.



AdvanCES in Developing Countries

When aid brings conflict, not relief

Although you might expect that development assistance could only bring relief to an impoverished village, a University of Illinois study found that villages in the Philippines that qualified for some forms of aid actually saw an increase in violent conflict.

“Interestingly, those municipalities that were eligible to receive aid but didn’t accept it saw the largest increase in violence,” said U of I economist Ben Crost. “During what’s called the social preparation phase, it would become known that a village was eligible for aid. During the period of study in the Philippines, insurgent forces from the communist New People’s Army or a Muslim separatist group attacked, and then the village dropped out of the program because they were intimidated. That’s how it is that the places that didn’t participate saw the most violence.”

Between 2003 and 2008, more than 4,000 Philippine villages received aid through a community-driven development program. The program used an arbitrary threshold of 25 percent as the poverty level at which communities qualified to receive aid.

“Of the poorest municipalities, only those below the 25 percent level qualified to receive aid,” Crost explained. “Those above the threshold were barely too ‘rich’ to get it, and the others were just poor enough to get it. That means that these places should be comparable in all respects with the one exception that these slightly poorer places were much more likely to receive aid than the slightly richer places. So the villages were almost the same in poverty levels and in background levels of violence.” The same until they became eligible for aid, that is.

Ben Crost

“The way the aid was targeted, with this arbitrary 25 percent cutoff, allowed us to compare places just below the cutoff to places just above it,” Crost said.

The study analyzed aid data from the World Bank along with data on conflict in the Philippines provided by Crost’s co-author from Stanford University, Joe Felter.

Ironically, projects anticipated to be most appreciated by their recipients may have created a higher risk of attack. “We think that one mechanism that explains our findings is that the insurgents actually tried to derail the project,” Crost said. “They didn’t want it to succeed. The insurgents had an incentive to strike and try to sabotage the program before it ever took off because its success would weaken their support among the population. We know that some municipalities actually dropped out of

the program for this reason—they were worried about insurgent attacks.”

Crost’s recent research is looking for ways to provide aid without making the recipients visible targets.

“The aid in this case was given for improvements in infrastructure,” Crost said. “One solution could be to find a more hidden way to give aid. One program we’re looking at now is conditional cash transfers, in which poor families get money if they do things like send their kids to school or have them vaccinated. These programs are popular in many developing countries. We have found some suggestive evidence that this kind of aid led to a decrease in violence.”

This study was published in *American Economic Review*. Joseph Felter and Patrick Johnston contributed to the research.



Using technology to decrease the knowledge gap in Uganda

If an extension specialist isn't available to provide training in person, is a video presentation or a video of a new agricultural practice a good substitute? The answer, according to a University of Illinois study with farmers in rural Uganda, isn't simple, particularly when gender is factored into the equation.

"The literature in the field says communication materials like videos work best to support face-to-face interaction," said ACES agricultural communications professor Lulu Rodriguez, not to replace it. "But if you don't have an extension specialist available in a certain locale, a video is the next best thing. The two modes of presenting information work well, particularly for African women learners. They follow the African penchant for having a live presenter, someone to talk to, and their affinity for visuals. Those are important components of how they learn. If situations get dire, a video is a viable option, particularly if there is a live facilitator."

This study explored the effectiveness of three training methods: traditional lecture plus field demonstration; lecture and field demonstration plus video; and video only. A video about row bean planting was shown to groups of farmers in Kamuli District, Uganda. Because the study was trying to uncover gender knowledge gaps, the groups that viewed the videos were all mixed, men and women together. The study found that the combination of lecture and field demonstration with video was significantly more effective in narrowing the gender knowledge gap. Watching video alone improved women's knowledge scores, but it did not close the gap between them and their male counterparts.



Lulu Rodriguez

"We noticed that whenever we put men and women together in a training session, the women are less likely to speak up. Men often co-opt the discussions," Rodriguez said. "The women will sit back and listen and absorb what they can. This suggests that if a video could be shown to women in a setting that doesn't require interaction with men, they would likely benefit more."

Despite the dominance of men in the training situations, in terms of actual farming, Rodriguez said, women more often have the extra cash needed to implement a new innovation, and they make the decisions about what percentage of household income will be applied to it. "Unfortunately, women's contributions are not very well acknowledged," she said.

Rodriguez explained that in Uganda, 70 to 80 percent of the agricultural labor force is women, but they don't typically have the same access as men to resources and training opportunities.

"If you want people to be aware of something, research says to use the mass media," Rodriguez said. "But if you really want people to move toward adopting an innovation, such as row planting, it's the interpersonal communi-

cation that will make a difference. The personal touch pushed them toward adopting the practice."

Rodriguez said their study selected the video on how to plant beans in rows because that practice is needed to boost the protein content of the Ugandan diet. And because the videos on row planting were already produced, the training provided another opportunity to use them, even in more remote locations.

"There is a dearth of extension educators all over the world, so if we can get these videos distributed to villages and associations, such as farming cooperatives and informal gathering places, viewers can learn a lot by themselves," Rodriguez said. The videos used in the study featured actual Ugandan farmers who demonstrated the row method of planting beans. "People loved seeing themselves and their neighbors being interviewed and demonstrating a new farming practice."

Rodriguez would like to do more in this area—testing the use of communication technologies that might make training easier, such as animated videos. She'd like to test how the African audience responds to animations as opposed to human presenters on videos.

"African society is very personal, with a strong oral tradition, so a real person telling a story is a style that resonates with them," Rodriguez said. "A cartoon is more impersonal but may be novel enough to get considerable attention."

The study was co-authored by Tian Cai, Michigan State University, and Eric Abbott, Iowa State University, and appeared in an issue of the *Journal of International Agricultural and Extension Education*.



Rural farmers and their families from the Kamuli District in Uganda

Farm managers play leading role in postharvest loss

With all the effort it takes to grow a food crop from seed to sale, it may be surprising that some farms in Brazil lose 10 to 12 percent of their yield at various points along the postharvest route. According to a University of Illinois agricultural economist, when it comes to meeting the needs of the world's growing population, that's a lot of food falling through the cracks. Farm managers who are aware of the factors that contribute to postharvest grain loss actually lose less grain. This was one of the findings in a study that examined how managers of large farms in the Brazilian state of Mato Grosso may be negatively affecting the efficiency of their own operations.

"Clearly there are things that you can do to reduce loss—you can put bed liners in trucks, you can adjust your combine, you can harvest more slowly—but for the farmers in Mato Grosso, it's not a high priority," said Peter Goldsmith. "It doesn't seem rational. If you see soybeans bouncing off your windshield from the truck ahead of you, why wouldn't you try to prevent it? It appears that farm managers in Brazil actually allow loss to happen because the cost of reducing loss is greater than the benefits."

Goldsmith said that one of the basic research questions of the ADM Institute for the Prevention of Postharvest Loss, which funded

his study, is why loss occurs. He said that although there are hundreds of articles about postharvest loss, no one is working with the farm managers to find out, from a managerial and organizational perspective, what drives the loss. There is a discrepancy between the reality of the postharvest loss and what the managers believe to be acceptable.

Goldsmith explained that in tropical regions, where the farming season lasts much longer than in the United States, the more intensive production results in two crops a year being grown on the same plot of ground—soybeans followed by corn in Brazil's tropical regions.



“Because they are in such a hurry to get the soybean crop harvested so they can get the maize crop planted before the rainy season, they may harvest too fast, desiccate green soybean to advance harvest, or expose soybean to the weather during transport, all of which results in a 10 percent loss,” Goldsmith said. “The loss isn’t intentional but rather a level that the farm manager is willing to live with in order to get that second crop of corn.”

A lack of understanding and awareness is also part of the problem. “When farmers don’t think that harvest speed is important, they have more loss. Likewise, if they don’t think that combine adjustments are important, they’ll have more loss. Those who realize that maintaining equipment is important have less loss. Consequently, technical training in the field with the equipment could be beneficial. But the cost of reducing loss further, using current technology, may exceed the benefits. Farmers may be unwilling to pay or invest in loss reduction.”

In addition to harvest speed, the study identified several other factors contributing to grain loss: irregular truck maintenance; lack of adjustment to the combine at the loading dock platform; bad weather; bad road conditions; and a lack of employee training.

Left: Samples of grain being taken from trucks in Campo Verde, Mato Grosso, Brazil

Above: Grain being stored at a large-scale facility in Mato Grosso



“What’s interesting is that the results from the survey were so mixed,” Goldsmith said. “Why wouldn’t farmers have agreed 100 percent that harvest speed contributes to loss? Insects and rodents seemed to be thought unimportant. Truck conditions and bad weather were the top factors to blame for loss, but truck conditions were mentioned by only 62 percent. These causes should be common knowledge, so I don’t know why 100 percent of the respondents didn’t agree that, for example, poor road and truck conditions contribute to loss.”

The lack of definitiveness may indicate that loss is not a “front-of-mind” issue for managers, which in turn has significant implications for policy makers seeking to reduce postharvest loss. Goldsmith believes that these tropical farmers have a variety of issues at hand that trump loss.

“We may think of Brazil as sunshine and beautiful all the time, but farming is really tough in the tropics. There are pest pressures 24/7, soils are poor, there’s an extreme rainy season, distance to markets is great, and road conditions are very rough. All sorts of factors make farming tough, but this area of the world has the greatest potential to materially augment global grain supplies.”

For the study, an initial focus group was conducted among seven farm managers to help frame the questions for an online survey. The survey respondents represent managers of some of the largest farms, not just in Mato Grosso, but in the world.

“This dominant class of operators of medium and large farm acreage in the tropics, who are producing most of the new grains, is filling the gap between where we are now and where we need to be in 2050 to feed the world,” Goldsmith said. “Sure, we can expand our crop among the developed countries of the world, but we’re only helping at the margin. The potential for new grain producers on new land is coming from farmers in the tropics.”

The study was co-authored by Anamaria Gaudencia Martins and Altair Moura and was published in *Food Security*.

