INTSORMIL

More Than 30 Years of Excellence

A deeper look into the commitment, passion and hard work INTSORMIL continually invests in reducing and preventing global hunger and poverty in developing countries.

INTSORMIL

Wishing to expand the effort to increase worldwide agricultural production, the U.S. Congress in December 1975 approved an amendment to the Foreign Assistance Act of 1961. Included in the amendment was Title XII, "Famine Prevention and Freedom from Hunger." A main objective of the new Title was to provide the means by which U.S. universities could make their expertise in science and technology more available to low-income countries, and thus help them solve food and nutrition problems. One component of the Title XII program is "support for long-term collaborative university research, in developing countries themselves, on food production, distribution, storage, marketing and consumption." Collaborative Research Support Programs (CRSPs) are one of the avenues of achieving this objective.

The Sorghum/Millet Collaborative Research Program (INTSORMIL) established in 1979 combines the resources and research talent of host-country research institutions, six U.S. land grant universities, USDA/ARS and the U.S. Agency for International Development (USAID). This 30-year

report shows that the INTSORMIL research program is one in which researchers from the U.S. and host countries can effectively collaborate.

Sorghum and millet are basic food grains for millions of people. Most of them are located in the poorer nations of the world where economic, labor, soil and water resources are limited. The research is challenging because sorghum and millet production and use in less-developed countries are impeded by problems such as heat and drought stress, insects, diseases, and storage and marketing difficulties. INTSORMIL has strived to overcome these problems through a collaborative program of research, technical assistance, training and institution building.

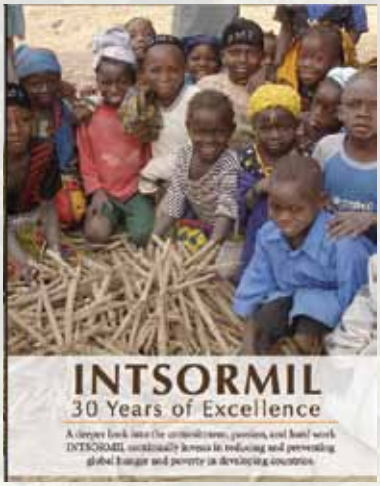
The impacts of INTSORMIL research in the host countries are multiplied through workshops, newsletters, webpage updates, information exchanges, scientist exchanges and an international exchange of sorghum and millet germplasm.

INTSORMIL's research program helps to alleviate world hunger and, thus, to realize the goals of USAID and the Board for International Food and Agricultural Development (BIFAD); INTSORMIL's research applies to all farms in the world where sorghum and millet are grown.

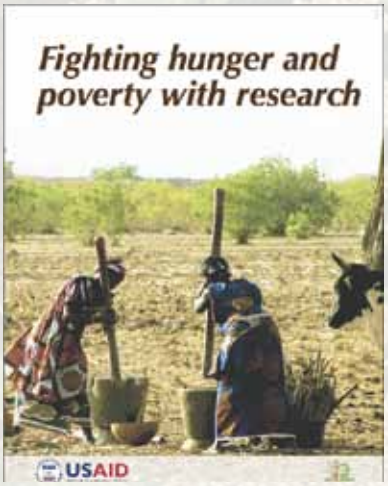
The INTSORMIL team is a large one. We appreciate the Grant and Leader with Associates Cooperative Agreement support from USAID. Also the cooperation of the International Agricultural Research Centers, particularly ICRISAT and the USAID Missions, has been vital to the success of our collaborative research.

Institutions in the host countries have been able to improve sorghum and millet varieties and production techniques, food quality, farming systems, agricultural policy, and scientist training. The results are core to INTSORMIL's effort to fight hunger with research.

– John Yohe
INTSORMIL Program Director



Happy Malian children gathered around recently harvested pearl millet heads while their mothers are threshing pearl millet nearby.
Photo courtesy of E.A. "Short" Heinrichs



Women threshing recently harvested pearl millet heads in a village in Mali, western Africa.
Photo courtesy of E.A. "Short" Heinrichs

Fighting hunger and poverty with research

In Zambia in southern Africa, a farmer can afford to build a new house for his family. In Ethiopia in the Horn of Africa, farmers are using new varieties of sorghum and millet to feed their families. In Burkina Faso in western Africa, the residents of a village give USAID and INTSORMIL the credit for providing new storage facilities for their grain crops. In El Salvador in Central America, bakers experiment with sorghum flour in making bread. At several U.S. universities, aspiring plant breeders from Central America and Africa learn the ropes from established INTSORMIL scientists.

Despite these successes, INTSORMIL's work isn't complete. The challenges presented by climate change and the mandates issued by USAID's "Feed the Future" initiative and by the U.N. Millennium Development Goals make the work of INTSORMIL even more critical. With ample funding, scientists and staff members of the International Sorghum, Millet and Other Grains Collaborative Research Support Program (the SMOG CRSP, best known by its common name INTSORMIL) will continue to contribute to the world's food security. Although INTSORMIL scientists in the U.S., Africa and Central America have worked diligently for more than 30 years, they still have work to do to develop varieties of food grains that will contribute to food security among hungry people in Africa and Central America.

This report has three goals:

1. To identify INTSORMIL's accomplishments over the last 30 years,
2. To tell stories of farmers who use INTSORMIL research to improve their families' lives and of scientists who have learned how to help those farmers, and
3. To describe current efforts by INTSORMIL scientists.

In this report, you will also find short explanations of processes and concepts central to the INTSORMIL objectives, such as an explanation of the concept of food security and of the process of crop rotation.

The stories were written by six undergraduate students in the University of Nebraska-Lincoln College of Journalism and Mass Communications (CoJMC), with the collaboration of one CoJMC graduate student. All the students worked on the U.S. stories in the spring of 2010; in May 2010, three students accompanied me to Africa to see for themselves the work of INTSORMIL in Zambia, Ethiopia and Burkina Faso and to attend the West Africa regional meeting of INTSORMIL scientists. In the fall of 2010, advertising students and an advertising professor developed a plan to distribute this report and to spread the word about INTSORMIL's accomplishments over more than 30 years. In the spring and summer of 2011, a CoJMC graduate student worked along side three CoJMC faculty members in designing and laying out the report.

– Carolyn Johnsen
Managing Editor

INTSORMIL

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A brief history of INTSORMIL

Story by Jamie Klein & Carolyn Johnsen

"Who in the room has been trained through INTSORMIL?" Bruce Hamaker, Ph.D., asked, his voice amplified by microphone to fill the large conference room.

Seventeen people raised one hand; some jokingly raised two. Some of these scientists were American, and some were from Burkina Faso and other countries in western Africa. It was May 18, 2010—the first day for the INTSORMIL West Africa regional meeting at the Hotel Palm Beach in Ouagadougou, Burkina Faso, and the 17 scientists with raised hands had either received training or earned an academic degree because of INTSORMIL.

Since 1979, when INTSORMIL was established, it has helped hundreds of students and scientists earn advanced degrees and has helped farmers in western, eastern and southern Africa and in Central America to grow improved varieties of sorghum and other grains.

INTSORMIL's vision, as stated on its website, is "to improve food security, enhance farm income and improve economic activity in the major sorghum and pearl millet producing countries in Africa and Central America."

In addition, the improved varieties of grain have benefited U.S. farmers.

"The role INTSORMIL played in bringing germplasm back to the U.S. to develop greenbug-resistant hybrids resulted in higher yields and reduced pesticide costs," INTSORMIL Program Director John Yohe, Ph.D., said in 2006, when INTSORMIL received a $9 million grant from USAID to continue its work. By 2011, USAID's awards to INTSORMIL had exceeded $97 million.

In recent years, INTSORMIL scientists have expanded their food-security mission by including research in food science efforts like making bread and beer from sorghum and research designed to create new markets for farmers' grain.

On UNL's east campus, INTSORMIL offices are surrounded by agricultural science buildings. Nebraska squirrels run by the building in the summer, and white snow usually falls thickly in the winter. INTSORMIL has been at UNL since 1979, when the CRSP was established.

Five INTSORMIL staff members provide support for scientists around the world. Currently, three of INTSORMIL's U.S. scientists work at UNL; 14 U.S. scientists work at five other land grant universities: Kansas State, Ohio State, Purdue, Texas A&M and West Texas A&M. Scientists at the U.S. Department of Agriculture and in Central America and several African countries also collaborate with INTSORMIL. All these scientists and staff members provide the "C" (Collaborative) and "R" (Research) in CRSP.

Preparing sorghum forage and placing it in an open silo in El Salvador.

Photo courtesy Rene Clara Valencia
INTSORMIL collaborating plant breeder

Dr. Larry Butler (left), former INTSORMIL biochemist, and Dr. Gebisa Ejeta with sorghum seed to be sent to East Africa for evaluation against the parasitic weed, *Striga*.
Photo courtesy of Purdue University

Yohe, who has been program director for 22 years, said INTSORMIL personnel have worked hard.

"The program is designed to cover pretty near the whole matrix of agriculture in the developing world," Yohe said.

Since the beginning of the program, INTSORMIL scientists have worked in all regions of Africa and in Central America. Until 1988, the program had activities in the Philippines and India. Through the early 1990s, research was conducted in Brazil and Columbia. INTSORMIL's work in Brazil, Columbia, India and the Philippines was ended due to budget constraints.

In 1984, Earl Leng, Ph.D., the first INTSORMIL program director, retired. Glen Vollmar, Ph.D., served as program director from 1984-1988 when he moved up to Director of International Agriculture Programs at UNL. In 1988, Yohe was named director; he had been working for USAID as a project officer.

In addition to its food-security goals, INTSORMIL develops and maintains relationships with master's and doctoral students. The program has trained 1,156 collaborating scientists, which include students from the U.S. and around the world.

"We've done a lot of unique things over the years. We've had some really outstanding science," Yohe said.

In addition to its current success in fostering deep-rooted relationships among dozens of collaborating scientists in the U.S. and in 21 countries in Africa and Central America, INTSORMIL has enabled germplasm transfers and created sorghum and millet varieties that resist weeds, insects and drought—all efforts that target the problems of food security. Six specific examples follow.

1 A sorghum variety valued for its nutritive value and drought resistance and released in El Salvador in 2004 has become popular throughout Central America both as a grain for livestock and for human food. The variety, known as "Sureño," was developed by the Texas Agricultural Experiment Station with INTSORMIL support.

2 In 2008, Salvador Zeledon, an INTSORMIL scientist in El Salvador, won first place for a paper he presented at a scientific meeting in Costa Rica. The paper described Zeledon's work to develop a sorghum hybrid that would "provide economic benefits to producers, industrialists and consumers of sorghum" in Central America.

3 About 20 years ago in Zambia, farmers told Zambia Agricultural Research Institute (ZARI) scientists (many collaborate with INTSORMIL) about their problems with pesky birds that would peck away pearl millet grain in the farmers' fields, depleting much of the yield. Farmers challenged ZARI scientists and plant breeders to help them find a way to deal with the birds. At first, plant breeders suggested that farmers in the area plant pearl millet at the same time—this way the birds would eat some grain from each field and not deplete one farmer's yield.

ZARI research, supported by INTSORMIL, led to the creation of a pearl millet that grows with bristles in the panicle (grain head). Now

INTSORMIL
Success Through The Years

Title XII mandate

"...improve the participation of the agriculturally related universities in the United States' governmental efforts internationally to increase world food production and provide support to the application of science to solving developing countries' food and nutrition problems."

1975

Congress approves the Title XII Amendment to Foreign Assistance Act to establish the Collaborative Research Support Program (CRSP)

1978

USAID releases planning grant for the establishment of the INTSORMIL CRSP

when birds try to peck out the grain, the bristles poke their eyes. The birds may try again, but will soon grow irritated and find something else to eat. The ZARI scientists met the farmers' challenge.

4 Gebisa Ejeta, Ph.D., an agronomy professor and INTSORMIL scientist at Purdue University, won the World Food Prize in 2009. Ejeta made important contributions to INTSORMIL's mission with his research on *Striga*—a major parasitic weed of sorghum and pearl millet in Africa and in other parts of the world where sorghum is grown. *Striga* infestations have largely been eliminated in the U.S., but in the late 1950s, *Striga* attacked U.S. maize (corn).

5 Lloyd Rooney, Ph.D., at Texas A&M University and Bruce Hamaker, Ph.D., at Purdue University are working with national programs in western Africa on processing and marketing of sorghum food products. Sorghum and pearl millet, traditional African crops, both have their origins in Africa.

6 USAID funds INTSORMIL in five-year increments. The current five-year grant of $12.9 million supports INTSORMIL's work through Sept. 30, 2011.

From 2006 to 2009, INTSORMIL experienced a 33 percent reduction in its budget. But beginning in September 30 of 2009, USAID gave INSTORMIL a budget increase, which has allowed more research in western Africa. But with inflation, the program hasn't been able to restore all its previous research endeavors.

An economic study done by the Batelle Memorial Institute—an Ohio-based charitable trust—analyzed INTSORMIL's impact and concluded, in 2006: "INTSORMIL is presently having a significant impact through projects at the pilot or individual village level—the next step must be to roll these impacts out to regional and national scales."

Accordingly, despite funding limitations, INTSORMIL scientists and staff have expanded their work into marketing and technology transfer, adding that effort to research in plant breeding, plant pathology, entomology and food science.

Increasing INTSORMIL's visibility is part of this new effort. Hamaker, one of two INTSORMIL coordinators for western Africa, said one of the first steps toward a more recognizable program is to give INTSORMIL's logo more prominence on INTSORMIL products—like bags of grain or vehicles purchased by INTSORMIL. In 2006, INTSORMIL officially became the "Sorghum, Millet and Other Grains Collaborative Research Support Program," with the acronym of "SMOG CRSP." But the long-standing program will continue to be called "INTSORMIL," because that name has international recognition.

Dr. Bourema Dembele (left), Deputy Director General of Mali's Institut d'Economie Rurale, and Dr. Lloyd Rooney of Texas A & M University are long-time INTSORMIL collaborators.

Photo by E.A. "Short" Heinrichs

At the 2010 West Africa regional conference, Hamaker recalled INTSORMIL projects that started in the western African countries of Niger and Mali in the early 1980s, with training as the main goal. Hamaker expressed some awe at the 30-year history of the program: "That's very unusual for a development project to last that long."

1979 USAID awards 1st grant to the University of Nebraska-Lincoln (UNL) to establish the INTSORMIL Management Entity (ME)

1984 USAID awards 2nd grant to UNL for ME

1991 USAID awards 3rd grant to UNL for ME

Food security defined

Story by Caroline Brauer

Imagine a healthy child who skips through a grocery store adding food to a shopping cart. Now imagine a starving child who sits quietly while her stomach bulges from poor nutrition, and every bone in her body is visible. These are some differences between people with food security and people without.

Statistics released at the 2009 World Summit on Food Security said more than one billion people in the world experience chronic hunger. That would be like everyone in the United States, Canada, Mexico, Japan, Germany, Spain, France, Russia and the United Kingdom suffering from chronic hunger. These hungry people need more than food; they need food security.

Food is a tangible item people can see, smell, touch and eat. But food is only a part of food security. Food security, according to the 1996 World Food Summit, is the ability of all people to "at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life." The World Health Organization says food security has three parts: food availability, food access and food use.

Food availability means the proper quantity of food is obtainable on a consistent basis. But food availability relies on food access.

People with access to food have the resources to acquire nutritious foods. You could give people a lifetime supply of doughnuts, but that wouldn't give them food security. They'd still lack proper nutrition.

Food use is the most important part of food security. People know how to use food when they can meet their nutritional needs cleanly and safely. Laying an entire uncooked meal in front of people experiencing chronic hunger won't help them unless they know how to properly prepare the food.

Different people and organizations disagree on what drives food security. Some corporations, like Monsanto, say their technological advances in agriculture will increase food security. But Josh Viertel, president of Slow Food USA, says high-tech agriculture is causing food insecurity. Oxfam International says global climate change is reducing agricultural production and, thus, reducing food security. The World Health Organization lists rising energy prices and subsidized production of bio-fuels as factors causing global hunger because the agricultural production for bio-fuels is replacing food production.

Whatever the theoretical arguments, two things remain factually clear. One: Organizations like USAID, the World Health Organization and the Food and Agriculture Organization of the U.N. acknowledge hunger exists and are working to eliminate it. Two: About one billion people didn't eat yesterday, haven't eaten today and won't eat tomorrow.

USAID awards 4th grant to UNL for ME

1997

USAID awards 5th grant to UNL for ME

2002

These Ethiopian children have benefited from INTSORMIL's mission of delivering food to African and Central American nations.
Photo by John Yohe

INTSORMIL CRSP OBJECTIVES

1. Facilitate growth of rapidly expanding markets for sorghum and pearl millet.
2. Improve the food and nutritional quality of sorghum and pearl millet to enhance marketability and consumer health.
3. Increase the stability and yield of sorghum and pearl millet through crop, soil and water management while maintaining or improving the natural resources of soil and water.
4. Develop and disseminate information on the management of biotic stresses in an integrated system to increase grain yield and quality in the field and in storage.
5. Enhance the stability and yield of sorghum and pearl millet through the use of genetic technologies.
6. Enhance global sorghum and pearl millet genetic resources and the conservation of biodiversity.
7. Develop effective partnerships with national and international agencies engaged in the improvement of sorghum and pearl millet production and the betterment of people dependent on these crops for their livelihood.
8. Provide graduate-degree education, short-term training and distance education that link researchers, policy makers and development practitioners.

2007 USAID awards 6th grant to UNL for ME. Official name changed to "Sorghum, Millet and Other Grains CRSP."

2009 INTSORMIL scientist Gebisa Ejeta wins World Food Prize

2010 USAID awards 7th grant to UNL for ME

INTSORMIL makes personal impacts

Story by Jamie Klein

To get to Makwenda, a village in Zambia, you have to brave some rough roads. It's a bumpy ride. The village is in Lusitu, which is part of the Siavonga District in Zambia where you can see the physical impacts of INTSORMIL—and not just in the fields. Here, some farmers have used profits from the yields of seeds developed by INTSORMIL to build grocery shops or small houses.

One farmer who has profited with INTSORMIL's help is Masten Muchindu. One day in May 2010, Muchindu, wearing a blue Hawaiian shirt and blue open-toed sandals, talked with visiting INTSORMIL scientists about his method of storing grain. His children and several other kids watched while chewing on sugarcane in the shade of a hut.

Muchindu, 43, is married with five children. The entire family helps manage the farm, but Muchindu also hires others to work for him. He pays them in cash, although some would rather have food prepared for them instead, he said through a translator.

Muchindu started farming with INTSORMIL seeds in 1993 or 1994. He said he wants to continue his work because he has seen the benefits of INTSORMIL in his own profits.

"He's not the only one benefiting from the crop. Even the neighbors benefit," said F. P. Muuka, who translated for Muchindu. Muuka is a plant breeder with the Zambia Agricultural Research Institute.

Muuka said Muchindu sometimes gives seeds to farmers who can't afford to buy them. Top priorities, however, are feeding his family, then the neighbors and then selling grain on the market.

His wife, Betty, demonstrated an old method of grinding grain. In the shade of a large tree, she knelt and bent forward, gripping a large rectangular rock and smashing the sorghum grain between it and another large stone that lay on the ground before her.

She made small grunts as she lifted the heavy rock and dropped it again and again on the grain. Betty Muchindu's efforts are just one example of the physical labor that INTSORMIL scientists are working to make easier—especially for women.

To Dr. Senayit Yetneberk, a food scientist at the Melkassa Research Center in Ethiopia, INTSORMIL means extra funds for her project concerning female empowerment. Half the funds come from INTSORMIL; the Ethiopian government provides the other half. The money has bought three major pieces of equipment: a computer, a texture analyzer and a tangential abrasive-dehulling device. The equipment helps Yetneberk learn more about the qualities of the grains she studies: sorghum, pearl millet and teff.

The funds also help Yetneberk bring 50 women to Melkassa for training. The center—which is south of Ethiopia's capitol, Addis Ababa—is part of the Ethiopian Institute of Agricultural Research (EIAR, a government agency) and is partially supported by INTSORMIL.

"Women are resourceful," Yetneberk said. "This (project) will empower them."

Yetneberk's project will teach Ethiopian women to bake and sell food items made from sorghum, maize (corn) or teff so they can work toward becoming economically independent.

Betty Muchindu demonstrates how she grinds sorghum grain.

Photo by Kate Veik

Dr. Senayit Yetneberk has used INTSORMIL funding to buy equipment for her food science lab in Ethiopia.

Photo by Kate Veik

Farmers in eastern Ethiopia gather to tell visitors what INTSORMIL means to them.
Photo by Kate Veik

Yetneberk will work with five groups, each with ten female farmers, to teach them how to make snacks or other baked goods and how to sell them.

The funding for her research is not Yetneberk's first experience with INTSORMIL. She completed six weeks of training at both Purdue University and Texas A&M University in 1994 on a partial sponsorship by INTSORMIL.

Yetneberk said the scientists she met in the U.S. were "wonderful people," and she was able to make many personal and professional contacts.

"My professional perspective has widened, which is profitable to me. I'm confident in myself in my profession," Yetneberk said.

Another Ethiopian scientist, Taye Tadesse (also with EIAR) described the effect of INTSORMIL on Ethiopian scientists and research.

"There is an impact on the implementation of the research," Tadesse said.

Tadesse said Ethiopian scientists often don't have the resources to get their research out to farmers, but INTSORMIL provides the links to help farmers use new grain varieties and methods and technologies recommended by the scientists.

Near the east end of the Rift Valley in Ethiopia is Miesso—another town where INTSORMIL science helps local farmers.

On a cloudy day in May 2010, 15 farmers gathered to talk about their lives and farming. They sat on the porch of a community building and under a nearby acacia tree.

The farmers said they recognized the technology (such as seeds and advice) that INTSORMIL and Ethiopian government agencies provide. The farmers also said the recommendations from agriculture programs around Ethiopia, including INTSORMIL, help them make the most of their workdays.

Stalk borers, which can stunt sorghum growth and reduce grain production, are major pests for the farmers, but scientists with INTSORMIL and other programs have advised the farmers on how to deal with stalk borers. For example, crop rotation can reduce the numbers of stalk borers in the soil. By growing sorghum one year, then pearl millet the next year farmers can control a stalk-borer infestation. In another method, farmers can plant elephant grass first, and stalk borer will use it as a host. Then farmers remove the elephant grass and grow sorghum, thus reducing the crop's chances of stalk-borer infestation.

Through a translator the farmers said without this kind of advice they would not have the chance "to change our lives."

Mamed Yesuf, a 50-year-old farmer, said if he works hard he can change his life. He also said he happily accepts professional recommendations because although he has some knowledge of indigenous farming, professional advice can help him tackle farming challenges.

"We need recommendations to learn," he said through a translator.

Whether by providing sophisticated equipment to a scientist or by showing a farmer how to fight off crop pests, INTSORMIL has spent more than 30 years trying to help improve the world's food security and making a difference in the lives of Africans, Central Americans and North Americans.

INTSORMIL by the numbers

3-4
Years needed to create a sorghum hybrid

10
Collaborative Research Support Programs (CRSPs) sponsored by USAID

Dozens
New sorghum lines introduced

About 1,200
Graduate students trained by INTSORMIL scientists

Thousands
Farmers using INTSORMIL-developed practices and technology

8
INTSORMIL objectives

21
Collaborating countries in Africa and Central America

4,000+
Participants in INTSORMIL-sponsored conferences and workshops since 2001

32
Years that INTSORMIL has existed

6
U.S. Land-Grant Universities that are currently INTSORMIL partners

18
U.S. Principal Investigators (PIs)

Hundreds
Scientific papers published

11
U.S. Universities partnering with INTSORMIL over the years

$97,503,102
Total funding from USAID since 1979

Variety Development and Research

FACT...

*More than one billion people - one sixth of the world's population - suffer from chronic hunger.

*Each year, more than 3.5 million children die from undernutrition.

*Hunger robs the poor of a healthy and productive life and stunts the mental and physical development of the next generation.

*Reducing chronic hunger is essential to build a foundation for investments in health, education and economic growth. It is critical to the sustainable development of individuals, communities and nations.

– from USAID's "Feed the Future" statement of opportunity

In USAID's quest to improve food security, the agency has enabled INTSORMIL scientists to create varieties of grain crops that increase small farmers' harvests of these grains and, thus, improve farm families' nutrition and increase the possibility of farmers making a profit on their crops. The five stories in this section describe both that research and its results.

The stories include a description of germplasm as "agriculture's insurance policy," a profile of INTSORMIL sorghum breeder Gary Peterson of Texas A&M University and a short comparison of two common plant-breeding methods—one used by INTSORMIL scientists. INTSORMIL's science must benefit U.S. farmers as well as farmers in Africa and Central America; accordingly, the fourth story in this section illustrates how seed companies take INTSORMIL science from Texas A&M University test plots to farmers around the world—including in the U.S. The fifth story describes a new sorghum variety developed by INTSORMIL scientists that has great potential for increasing the incomes of small farmers in a water-short area of Nicaragua.

Among other things, the U.N. Millennium Development Goals aim to halve, between 1990 and 2015, the proportion of people who suffer from hunger. This first goal contains this language:

*Despite some progress, one in four children in the developing world are still underweight.

*Children in rural areas are nearly twice as likely to be underweight as those in urban areas.

*In some regions, the prevalence of underweight children is dramatically higher among the poor.

This information only increases the urgency of continuing to work to achieve food security. To that end, the stories in this section demonstrate the efforts of INTSORMIL scientists and staff to continue that work by developing varieties of grain suited to small farms in Africa and Central America.

– By Carolyn Johnsen

High-tannin sorghum cultivar in a breeding plot at Texas A&M University.
Photo by E.A. "Short" Heinrichs

Texas A&M plant-breeding program supports INTSORMIL

Story and photos by Alia Conley

To an untrained eye, the 3,000 rows of sorghum plants look identical.

But Gary Peterson, Ph.D., can look at a sorghum plant and name the seed and plant color, know what diseases it has and if there is insect damage. He can describe the characteristics of the two parent plants, too.

"You just learn," Peterson said. "You learn what things look like. You learn if you make crosses, what type of material is going to come out of that." Peterson is an INTSORMIL scientist and professor of grain-sorghum breeding at Texas A&M University (TAMU).

For two weeks every July, Peterson walks row-by-row outside in 90-degree, humid weather in Corpus Christi, Texas, and makes notes with his electronic pad. He's looking for sorghum with a full head of white seed, and for plants about five feet tall for varieties suitable for Africa and three to three and a half feet tall for U.S. crops. He duplicates this process in Puerto Rico and in Lubbock, Texas.

In fact, Peterson spends most of his time in Lubbock, as a sorghum breeder at the Texas A&M AgriLife Research and Extension Center. He has no laboratory. Sorghum fields are his workplace.

Sorghum breeding is the only job Peterson has had; 2010 was his 28th year in the fields and as a part of INTSORMIL. So Peterson has been with the INTSORMIL program for nearly as long as it has existed.

"It's really enjoyable because there's a tremendous amount of diversity," Peterson said. "You get to be out in the field and identify those things that look good."

Corpus Christi is one of the best areas to grow sorghum because of the climate. Any sorghum variety that performs well here can also perform well across the United States and in southern Africa.

All of Peterson's work in the fields examining 16-foot-long rows of sorghum culminates in one objective—to create a sorghum plant that can resist biotic stress like disease and insects and abiotic stress like drought. When Peterson scans the fields, he's looking for sorghum varieties that will thrive despite these stresses and produce a high yield of high-quality grain.

From planting to maturity, sorghum has a life cycle of about four months. In the first 30 to 40 days, the seed germinates and the plant grows roots and all of its leaves. The sorghum panicle (which will eventually produce the plant's grain) forms about this time and, in the next 30-35 days, will emerge from the plant. Flowering occurs for about seven days. After flowering, the grain takes 30 to 40 days to mature and dry and is then ready for harvest.

Peterson has three research locations – one each in Puerto Rico, Corpus Christi and Lubbock. Workers plant seeds in Puerto Rico in December; Peterson travels there to make crosses in late January and

Dr. Gary Peterson observing the performance of sorghum cultivars in a breeding plot.

Dr. Gary Peterson determines the health of a sorghum grain by cutting it in half.

returns in March to harvest the sorghum. In Corpus Christi, planting starts in late March, and harvest is in July. Planting in Lubbock starts in May, and harvest begins in September.

This schedule speeds up the breeding process, allowing Peterson to make observations on lines in Corpus Christi in July, to use those observations to make crosses that produce new breeding populations at Lubbock in August and then to send the crossed seed to Puerto Rico in time for the planting season there.

"Thus we are able to accomplish 2-3 years' activity in one year," Peterson wrote in an e-mail.

College students working for Peterson follow his directions to crossbreed top-notch sorghum varieties.

"Plant breeding is a numbers game," Peterson said. "The more people that you have working for you, the more crosses you can make, the more rows you can plant out, the higher probability you have of selecting something that's worthwhile."

"He is a good mentor and a great scientist. He is open-minded and believes that in a dynamic world researchers need to be dynamic and innovative."

– Lloyd Mbulwe

The crossbreeding process combines the genetics of two plants to create a new one, like humans do with reproduction. After four or five generations of crosses, Peterson selects two to four lines for sorghum farmers to use, in either the United States, Africa or Central America.

Peterson creates new sorghum varieties with a process called plastic-bag emasculation.

A sorghum plant is self-pollinating, which means it has both male and female sex organs. To cross sorghum varieties to create a new variety, Peterson selects one plant to use as a female and waits until the sorghum head starts to flower. He cuts the tip of the grain head off and puts a plastic bag on the remaining part of the grain head, followed with a paper bag the size of a small lunch sack.

The bags trap humidity so the plant doesn't shed pollen. After two or three days, Peterson returns with pollen from the plant he has chosen as the male, takes the bags off the female grain head and puts the pollen on the plant. He puts a new bag on the female plant and waits to harvest the grain.

Peterson's workers make 150 plastic-bag crosses a year, which can result in 75 to 100 successful, new sorghum types.

Two other INTSORMIL scientists, William Rooney—a Ph.D. plant breeder—and his father Lloyd—a Ph.D. food scientist—also work in the TAMU sorghum fields.

Although Peterson doesn't teach in a classroom, as an INTSORMIL principal investigator he participates in training students to become sorghum breeders. In more than 30 years, INTSORMIL scientists have trained about 1,200 graduate students, 431 of them at TAMU. Peterson, himself, has collaborated with 20 students—all except one were from Africa. Lloyd Mbulwe will be Peterson's newest graduate student when he comes to the U. S. from Zambia in 2011.

Mbulwe works as a sorghum breeder for the INTSORMIL sorghum-breeding program in Zambia. In an e-mail, Mbulwe wrote that INTSORMIL is extremely helpful with funding sorghum research in Africa.

Mbulwe visited Peterson in late July and early August 2010 and is excited to learn and work with Peterson.

"He is a good mentor and a great scientist," Mbulwe wrote. "He is open-minded and believes that in a dynamic world researchers need to be dynamic and innovative."

INTSORMIL will pay for Mbulwe's Ph.D. program if INTSORMIL receives funding to continue for the five years from September 2011 to September 2016.

It's fitting that Mbulwe is from Zambia, because Peterson coordinates INTSORMIL's southern Africa program, which includes South Africa, Botswana, Mozambique and Zambia.

In the 2009 INTSORMIL Annual Report, Peterson outlined his successes in developing better sorghum varieties: decreased drought damage, increased tolerance to insects and increased yield. He said he's grateful for the money that INTSORMIL provides for him to do his research and make an impact on farmers' lives.

"There is no question; if you look at the whole range of the program, yes it's been a success," he said.

Dr. Gary Peterson checks his electronic pad where he stores all the information about each sorghum type and where it is located in the fields.

Plant breeding methods explained: traditional vs. genetic engineering

Story by Caroline Brauer, Jenna Gibson, Carolyn Johnsen & Karoline Kastanek

In the reality TV show, Survivor, contestants try to outwit, outplay and outlast their competitors. This show is based on one of the principles of natural selection: The well-adapted player wins the game. Sorghum breeding is similar to this natural-selection game, except the process has a helping hand: a plant breeder.

For 30 years, INTSORMIL's plant breeders have used traditional methods to create grain-crop varieties that contribute to food security by resisting drought, disease and pests. INTSORMIL plant breeders also use a new technique called marker-assisted selection to improve efficiency in the breeding process. The two techniques have the same goal: to develop a plant that has a hardier or higher-yielding blend of genetic traits than the parent plants that produced it. The traditional plant-breeding process used by INTSORMIL scientists differs from genetic engineering—a process used widely, except in many INTSORMIL host countries.

In the traditional process, the plant breeder identifies parent plants with specific traits, crosses them and selects offspring with unique genetic combinations that neither parent plant possesses. In addition to ingenuity and experience, this traditional plant-breeding process requires time; creating a new sorghum line requires several years of work by a plant breeder.

First, a note about how reproduction occurs in a sorghum plant without the intervention of a plant breeder. Each sorghum flower has a stigma (female sex organ) and anthers (male sex organs). A protective layer within the flower encapsulates these sex organs until they mature. Once the anthers mature and produce pollen (male sex cells), the pollen falls into the stigma, down to the ovule (female sex cell) and fertilization occurs.

Cross-pollinated sorghum heads are enclosed in paper sacks in a greenhouse breeding-study.

Photo by Karoline Kastanek

A traditional plant breeder may intervene in this process by selecting plants for specific, desirable traits. The first step in selection is called cross-pollination. To cross-pollinate sorghum, a breeder finds a female plant with many of the desired qualities. Then the breeder finds a male sorghum plant with the desired trait or gene to cross to the female plant. This "insertion" requires additional steps involving paper bags, seed selection and a couple of months of waiting for plants to mature.

After finding suitable "parent" plants, the breeder either removes the anthers from the female or does not allow the anthers to shed pollen. The female plant's flower is then covered with a paper bag coated inside with pollen from the male plant's anthers. The pollen in the bag falls into the stigma and grows through the stigma to fertilize the ovary. The seed then matures; the result of this process is an F_1 (first generation) seed. Depending on what pollination technique is used, the number of seed produced can range from a few to several.

After the seeds mature, they're planted. Then the breeder determines which plant is actually an F_1. To do so requires knowledge of the appearance—or phenotype—of each parent and understanding of the

Farmers in Central America discussing the performance of hybrid sorghum cultivars.

Photo by INTSORMIL

inheritance of sorghum genes. In an F_1 plant, each parent contributes 50 percent of the genes. This is similar to a human child receiving half of his or her genes from each parent.

After identifying the F_1 plant, the breeder then plants the F_1 seed and makes additional selections from the progeny—which are the F_2 plants. Over several generations, the breeder selects for the traits of interest and eventually develops a line that does not segregate for any trait. The line is then ready to test and to be used as a parent to produce new lines.

Genetic engineering (GE) offers a faster method of developing new varieties with desirable qualities. GE allows genes to be transferred mechanically between plants and even from different species—such as from a bacterium to a plant—creating what's called a "genetically modified organism" (GMO). GMO crops dominate on U.S. farms, where more than 90 percent of soybeans and 70 percent of corn grown annually are GMOs. At present, there are no GMO sorghums grown.

Rather than using GE methods, INTSORMIL scientists create new varieties or lines of sorghum and millet through traditional plant-breeding. Both methods modify the genetic makeup of the offspring plants, but traditional plant-breeding methods are more acceptable to INTSORMIL's host countries.

Like the offspring of traditional breeding methods, GMOs have targeted qualities, such as resistance to the effects of certain pesticides—a quality that would be hard to produce in conventionally bred plants. And yet, much of the controversy about GMOs focuses on the safety of resulting offspring and the GE method used to create the offspring.

This controversy is one reason that INTSORMIL scientists use traditional plant-breeding methods, even though they take much longer to produce varieties with the desired qualities. In fact, most of INTSORMIL's host countries have banned genetic engineering. Out of the program's 14 African host countries, only six are affiliated with the U.N. group International Centre for Genetic Engineering and Biotechnology. Only two of the seven Central American countries where INTSORMIL works are signatories to the ICGEB.

One African scientist associated with INTSORMIL said some African countries are starting to shift their stance on GMOs because they recognize that attaining food security may require the use of genetic engineering.

Genetic engineering, however, is expensive, said John Yohe, Ph.D., INTSORMIL's director. With shrinking budgets, INTSORMIL has chosen to focus on more affordable ways to develop grain-crop varieties—all in the name of achieving food security.

Cross -pollinated sorghum heads waiting to be threshed.

Photo by E.A. "Short" Heinrichs

CREATING A SORGHUM LINE

Sorghum female parent

Has many favorable genes.

Sorghum male parent

Has one to several genes that need to be combined with genes from the female parent.

First generation (F_1 Seed)

Scientists cross-pollinate female and male plants and harvest the F_1 seeds. Then scientists confirm the F_1 plant's identity through field phenotyping or using DNA finger-printing techniques.

Selection

Beginning with the F_2 (second generation) plants are selected for the best combination of genes based on phenotype (appearance) and/or molecular markers.

Finding the superior sorghum plant

For several generations, the scientists repeat the selection process until they find plants that will produce the favorable genes from the mother plant and the favored genes from the father plant. Each growing cycle takes four to six months to complete.

Germplasm: Agriculture's insurance policy

Story by Karoline Kastanek

Germplasm is a piece of plant material suspended in growth. For example, scientists may collect a plant's seed, flower bud, cell or tissue and freeze or suspend its growth to preserve the genetic qualities of the plant. Varieties of germplasm provide some insurance that genetic diversity of a plant species will survive.

Genetic diversity is a crucial factor in food security. In fact, the U.S. Department of Agriculture's National Germplasm Resources Laboratory website says, "Well-documented plant genetic diversity in germplasm collections provides plant breeders and other scientists with the raw materials necessary for crop improvement and other research efforts."

After harvesting germplasm, scientists have several options to keep it alive in a dormant stage until they need it. According to Molecular Plant Biotechnology's website, scientists can use liquid nitrogen to lower the plant material's temperature and thus, suspend plant-material growth. Scientists can also reduce the oxygen concentration in the storage area or give hormones to germplasm to slow its growth.

To improve crop traits, scientists all over the world store germplasm.

"INTSORMIL scientists have stored and used germplasm as seed since inception of the program," said John Yohe, Ph.D., director of INTSORMIL. For example, these scientists preserve germplasm in seed form in dry, cold-storage places such as a facility in Lubbock, Texas. This collection of sorghum, millet and other small-grain plant material has helped INTSORMIL scientists develop new crop varieties that can survive adverse climate conditions such as drought, cold temperatures and soil low in nutrients.

Scientists know that the greatest genetic diversity of a plant can be found in its place of origin. Thus, INTSORMIL scientists harvest most of their sorghum and pearl millet germplasm from Africa. As more uses of sorghum and pearl millet develop, scientists are also constantly experimenting to find or develop varieties with higher yield potential for more uses than just food grain—such as for biofuel.

In effect, INTSORMIL scientists store germplasm to make better grain. It's like insurance for genetic diversity.

Biodiversity of sorghum in Kansas State University breeding plots in Manhattan, Kan.

Photo by E.A. "Short" Heinrichs

Seed companies take INTSORMIL science to the world

Story by Alia Conley & Carolyn Johnsen

Breeding sorghum is like solving a giant 1,000-piece puzzle. But it's a team effort.

The Texas AgriLife sorghum improvement program at Texas A&M University (TAMU) is the go-to place for seed companies large and small, who sell to farmers across the U.S. and the world. Gary Peterson, Ph.D., an INTSORMIL scientist, works with other INTSORMIL researchers to develop sorghum in fields in Puerto Rico and in Corpus Christi and Lubbock, Texas. Each scientist adds his or her expertise to the sorghum plant, until the puzzle is complete.

The INTSORMIL program involves scientists and farmers from Africa and Central America, but U.S. farmers also benefit from the research. Scientists use their discoveries to create new lines of sorghum, and the seeds are available for companies to buy.

According to Peterson, there's not a better group of people to help him solve the puzzle.

"There has always been very good camaraderie in the sorghum industry," said Peterson, a professor of grain-sorghum breeding at TAMU.

Companies who are INTSORMIL's clients help shape the breeding process with comments and suggestions. Donnie Swink, executive vice president of Crosbyton Seed Company in Crosbyton, Texas, buys sorghum germplasm (sorghum DNA in the form of seeds) for his company from TAMU.

"INTSORMIL is pretty important to us," Swink said. "It's just another tool to get better lines and better products out to the U.S. farmers and the rest of the world."

TAMU, a widely respected name in sorghum breeding, has the longest-running program in the United States. The program in Lubbock, Texas, celebrated its 100th anniversary in September 2010.

"TAMU has used the geographic diversity of Texas and knowledge of sorghum to produce germplasm that has been widely used in the industry," Peterson wrote in an e-mail.

Sorghum originating in the TAMU program and further developed by private seed companies has been extensively used by private industry. Firm statistics are not available, since companies can use the lines obtained from TAMU either directly as hybrid parents or as sources for their own breeding programs. TAMU-released lines with genes for improved grain yield, adaptation, and resistance to drought or disease or insects have been used directly as parents for many hybrids sold domestically or internationally.

Once Peterson and his colleagues create new sorghum with desirable characteristics, such as insect- or

Dr. Gary Peterson displays a sorghum hybrid generated in a breeding plot.
Photo by INTSORMIL

Sorghum breeding plots near Corpus Christi, Texas.

Photo by Alia Conley

disease-resistance, they plant the seeds in fields near Texas cities associated with TAMU, such as Lubbock and Corpus Christi. Using a program on his handheld computer, Peterson marks and documents the different sorghum plants in the fields to identify their particular traits.

When the sorghum grain is mature, seed company representatives visit the fields once or twice a year to go "shopping." They evaluate each type of sorghum and decide if they want to use the germplasm in their own breeding lines, which result in sorghum seed that the companies sell directly to farmers.

Peterson said varying sizes of companies use sorghum differently.

"If you're a larger company, you have your own breeding program and you would take germplasm and make crosses into your own germplasm and develop proprietary lines that are then used to make proprietary hybrids, something that only you have," Peterson said.

Companies must enter into an agreement with TAMU to commercialize a sorghum hybrid with TAMU germplasm. Under this "Material Transfer Agreement" (MTA), companies pay royalties and fees to TAMU.

TAMU germplasm is available to sorghum breeders throughout the world with an MTA.

"We can't send anything out to anybody without an MTA," Peterson said—even to INTSORMIL collaborators and other public workers. "Basically all they're acknowledging is that they got their material from us," Peterson said.

Peterson joined INTSORMIL in 1982, three years after the program started. He said the release policy has changed often, and the program must adapt to the changes.

"It used to be, if someone wanted seed we could just give it to them, but we can't do that anymore," Peterson said. "Now for the Texas program, if somebody requests a line, whatever the release policy was at the time that line was released is the procedure that they have to use to get that line."

At shopping time, two to four sorghum lines might be available for companies to look at. Each company looks for different traits, but all companies want to increase sorghum yield, because farmers receive money based on how much sorghum they produce.

"Seed quality is a big issue," said Swink, who is also general manager and owner of Crosbyton Seed. "You can have a good hybrid, but the seed quality can be poor."

After yield and seed quality, companies look for characteristics (or traits) such as maturity, sustainability, adaptation to other climates and resistance to insects.

Peterson said Corpus Christi is a good place for companies to pick out sorghum because of the climate.

"It's easier to select things in a sub-tropic environment like Corpus Christi

Dr. Gary Peterson holds two samples of sorghum grain: weathered sorghum (left) and non-weathered sorghum (right).

Photo by Alia Conley

has and move those into other sorghum areas," Peterson said. "We've been able to have an environment where the selections will look good in a number of other places."

Only a few active sorghum-breeding programs still operate in the U.S. The programs are at TAMU, Kansas State University, the University of Nebraska-Lincoln and Purdue University in Indiana. All are part of the INTSORMIL program, and all are land-grant universities.

Peterson said INTSORMIL allows scientists to complete stable and continuous research, something that's helpful because it can take six to ten years to produce a new sorghum variety.

"Agriculture research is a long-term endeavor," Peterson said. "You really can't run a program that needs long-term results on short-term grants. INTSORMIL has enabled us to have a long-term view."

In the last 30 years, the TAMU program has released a total of 1,115 sorghum lines to companies for sale to farmers around the world.

Communication between INTSORMIL and seed companies is important so scientists can create what companies are looking for. Swink said TAMU is a primary source when Crosbyton Seed Company looks for new sorghum.

For example, Swink said his company identifies what U.S., African and Central American farmers need—particularly to fight disease—and shares that information with INTSORMIL sorghum breeders.

"We give them information on what we need help on," Swink said.

Seed companies and farmers understand that a germplasm might not work out, and scientists will then try another type of sorghum. If a plant doesn't produce an acceptable yield, Peterson throws it away and plants something new.

"Failure's not a good word to use," Peterson said. "It's trial and error. If we knew exactly what plants to cross, we could solve all problems."

Although the risk for unsuccessful germplasm exists, seed companies still return to TAMU to buy sorghum because of the connection with the INTSORMIL program.

Sorghum cultivars in a breeding plot near Corpus Christi, Texas.

Photo by Alia Conley

"Agriculture research is a long-term endeavor...INTSORMIL has enabled us to have a long-term view."

– Gary Peterson,
Texas A & M University

International collaboration benefits sorghum farmers in the Nicaraguan Dry Zone

Story by E. A. "Short" Heinrichs

Scientists collaborating with INTSORMIL have developed an improved variety of sorghum that gives farmers in dry areas of Nicaragua a bright economic and food-secure future.

Tests in 40 farmers' fields showed that the new drought-tolerant variety, called INTA Segovia, yields 23 percent more grain than the best local variety currently planted by farmers. INTA Segovia should have a significant economic impact on rural income in Central American countries because it produces well in drought-prone regions—40 percent of the land area in Nicaragua alone.

INTSORMIL collaborated with scientists at INTA (Instituto Nicaraguense de Tecnologia), Texas A&M University and CENTA (Centro Nacional de Tecnologias Agropecuarias)-El Salvador to develop INTA Segovia.

Farmers participating in the seed-multiplication portion of this effort will be taught the scientific methods of seed production. The farmers producing this certified seed will use it to plant their own fields in 2012 and may sell the rest to other farmers, to continue the distribution process. Silverio Rios, who leads a farmers' association that has tested INTA Segovia and is producing more seed for distribution to other farmers, said he is excited about the variety's large heads, which contain an abundance of high-quality, nutritious grain.

Sorghum is an important crop grown on 59,000 hectares (about 145,800 acres) by 48,000 smallholder farmers on Nicaragua's drought-prone hillsides. Sorghum is a key crop in the battle against hunger in Central America because it provides both food for people and feed grain for poultry and pigs.

Silverio Rios, leader of an association of farmers.
Photo by E.A. "Short" Heinrichs

Rene Clara Valencia by tall INTA Segovia sorghum.

Photo by E.A. "Short" Heinrichs

U.S. Principal Investigators in Central America

Guatemala

William Rooney (Texas A&M University)

Honduras

William Rooney, Lloyd Rooney (Texas A&M University)

Nicaragua

Joe Hancock (Kansas State University), Lloyd Rooney, William Rooney

El Salvador

Joe Hancock, Lloyd Rooney, William Rooney

Costa Rica

William Rooney

Panama

William Rooney

Haiti

William Rooney

Plant Protection

A major goal of INTSORMIL plant breeders is to develop grain varieties with genetic traits that enable plants to resist or repel damage from insects, weeds, disease and drought. The scope of the threat is global: More than 100 insect pests attack sorghum and millet in the field and storage; insects that attack these crops in the field consume leaves, break stalks and kill young plants; larvae of the sorghum midge, for example, can cause 100 percent loss of grain. Worldwide, insect pests destroy 35 percent of stored grain. The seven stories in this section further quantify the challenges and profile INTSORMIL scientists who specialize in developing sorghum and millet varieties to resist the many threats to food security posed by insects, weeds, disease and drought. These stories explain or explore:

* Biotic and abiotic stress.

* The work of Bonnie Pendleton, Ph.D., West Texas A&M University professor and INTSORMIL's U.S. entomologist (insect scientist), who has collaborated with scientists in 10 African countries to develop "ecologically based technologies that will decrease loss by insects in the field and storage, reduce pesticide use, conserve soil and water without contamination by pesticides, and increase yield of food and feed for domestic use and income from marketing." Pendleton's distinguished career includes 186 publications and nearly 300 presentations at regional, national and international scientific meetings.

* Drought tolerance.

* The "internationally important disease" of downy mildew and what INTSORMIL scientists are doing to fight it.

* The work of INTSORMIL scientist John Leslie, Ph.D., a Kansas State University professor, to control mold in stored grain, particularly in finger millet, which is often used to produce a weaning food for children, whose development can be affected by exposure to mold toxins.

* The life and work of INTSORMIL scientist Gebisa Ejeta, Ph.D., a plant breeder at Purdue University who won the prestigious World Food Prize in 2009. (The World Food Prize Foundation gave INTSORMIL permission to reprint this story and its accompanying photographs.)

* The final story describes one focus of Ejeta's work—the parasitic weed *Striga* and the threat it poses to grain crops worldwide.

– By Carolyn Johnsen

Rene Clara Valencia, INTSORMIL Central America Host Country Regional Coordinator, observing the performance of elite sorghum cultivars in El Salvador.

Photo courtesy of Rene Clara Valencia

Biotic & abiotic stresses imperil INTSORMIL crops

Story by Alia Conley

Matthew comes home, stressed out because he's in a fight with his girlfriend and his boss yelled at him. Matthew throws his keys on the kitchen table, where a small plant is dying because insects are attacking and eating it.

Stress exists for plants just as for humans; while stresses for humans can include relationship problems and loud noises, stresses on crops include disease, insect pests and weather.

In physics, stress is pressure or tension applied to an object. For example, when a heavy weight pushes on a metal bar, a physical result should occur, like the bar bending. Likewise, a weak plant can wilt or break if a strong gust of wind hits it.

But stress is often more complicated for plants. In biology, the definition of stress is "a departure from optimal physiological conditions," according to Leon Higley and Robert Peterson, authors of the book "Biotic Stress and Yield Loss." Plant stress occurs when abnormal conditions force plants to change in order to survive.

The two types of plant stress—biotic and abiotic stress—are easy to distinguish: Think of "bio" (a prefix meaning "life") and "a" (a prefix meaning "not"). Biotic stress occurs when living organisms such as bacteria, viruses and fungi damage plants. Abiotic stress occurs when nonliving factors harm plants. Abiotic stress includes environmental elements, such as drought, excessive heat, high winds and nutrient deficiency.

Both biotic and abiotic stresses can harm sorghum, millet and other plants grown as crops in Africa, Central America and the U.S.

For INTSORMIL scientists, understanding how these stresses affect plants is essential in order to research ways to prevent stress on plants. So INTSORMIL scientists are at work breeding sorghum and millet with improved resistance to stresses like *Striga* and drought. This breeding effort is the focus of six INTSORMIL projects, according to the program's 2009 report. By creating top-notch, stress-resistant plants, INTSORMIL scientists can decrease the chances of biotic and abiotic stressors killing crops that are essential to food security.

Example of a termite tube, which is a biotic stress for crops.
Photo by INTSORMIL

The fight against insect pests

Photos and story by Jamie Klein

Bonnie Pendleton, Ph.D., lifted the large, pyramid-shaped cage to reveal three containers filled with soil and developing sorghum plants. She leaned low to peer closely at each plant. Pendleton, a professor of integrated pest management-entomology at West Texas A&M University, was checking for damaged leaves. Any red or yellow spots? Dead leaves?

"Not ready yet," she said of the growing plants. "It'll be a few more days before we rate them."

Pendleton then watered the plants and spoke to one of her graduate students, Suhas Vyavhare. Pendleton devotes much of her time to mentoring students and supervising their research, which supports her own research on insect pests of sorghum and millet. In this WTAMU greenhouse, Pendleton rates sorghum lines for resistance to greenbug aphids.

"What I mostly spend my time doing is trying to manage some of the worst pests without just using chemicals on them," Pendleton said.

Finding ways to manage insects without insecticides is an important INTSORMIL goal both in the U.S. and in the African countries where Pendleton works. Many African farmers can't afford pesticides or sometimes can't understand the directions and end up using the chemicals improperly, Pendleton said. Environmental factors, like drought, also come into play.

Pendleton's research team studies plant and insect biology to identify methods that farmers can use to control the pests, like clearing weeds near sorghum fields to keep insects away.

One of her students discovered that greenbug aphids—insects with piercing, sucking mouthparts that live on sorghum leaves—live longer and reproduce more offspring sooner in their lifetimes in the summer, when the sun is out longer. That means Pendleton can tell farmers that a mild, sunny winter could lead to an infestation of greenbug aphids—something that farmers can fight with methods other than insecticides.

Pendleton's project, "Ecologically-Based Management of Sorghum and Pearl Millet Insect Pests in Africa and the United States," focuses on the INTSORMIL goal to help farmers prosper economically by managing insects that damage the yield and quality of sorghum and millet. The project also aims to enhance the marketability of sorghum and millet by improving the nutritional quality of the grain.

Pendleton uses integrated pest management (IPM) strategies in developing ways to manage insects and increase the yield potential of crops. For example, she has learned that, to manage insect pests, knowledge about insect life cycles can help farmers choose IPM methods like intercropping (such as planting grasses among sorghum and millet plants to draw insect pests away from the crops), rotating crops and changing planting dates.

Pendleton and her team have studied millet head miner, sorghum midge, different types of aphids, stalk borers and storage beetles. Pendleton conducts her research in labs and fields in Texas and in western Africa, where she is one of two coordinators for INTSORMIL's regional program.

In addition to supporting Pendleton's IPM research, the INTSORMIL project also supports

Dr. Bonnie Pendleton waters sorghum seedlings.

pest-management research and education of scientists in African countries and students in both Africa and the U.S.

While working toward the INTSORMIL goals, Pendleton teaches her students as much as she can along the way. She wants them to know "it's possible to collect data, get a result and publish." Pendleton said she measures her project's progress through her students: If they are successful, she feels her mentoring, teaching and research are successful.

"I came here specifically for application research. It's one thing to tell farmers to wait five to 10 years for a seed," Eder said. "It's another when we can tell you when to plant and when to harvest just by telling you how the insect lives."

He studies yellow sugarcane aphids, which aren't a nuisance every planting season; when they do attack sorghum, they can create a lot of damage quickly, Eder said. The damage can sometimes be misdiagnosed as frost damage: The leaves have spots that turn bright purple and yellow and then die within only a few days of infestation.

"What I mostly spend my time doing is trying to manage some of the worst pests without just using chemicals on them."

– Bonnie Pendleton
West Texas A&M University

Suhas Vyavhare moved to Canyon, Texas, from India to work on his master's degree with Pendleton. His research concerns maize (corn) weevils, pests that damage stored sorghum grain. Maize weevils can also infest sorghum kernels in fields, but are most damaging in storage units. The insects can eat their way into sorghum grain and deposit eggs that hatch into larvae that eat the inside of the grain.

Vyavhare, whose master's work is partially sponsored by INTSORMIL, said he chose maize weevils as his research focus because, while growing up in India, he saw them attacking sorghum in storage facilities.

"Working with Dr. Pendleton is a great learning experience," Vyavhare said. "She always wants us to improve. She believes in the practical thing: You may make a mistake the first or second time, but she knows it will get better."

Pendleton's students typically have positive things to say about their soft-spoken mentor. Zachary Eder from Victoria, Texas, attended West Texas A&M University because of Pendleton. He wanted to do applied research—that is, research that could directly, and immediately, be helpful to farmers.

Of Pendleton, Eder said, "She's very down to earth and has a huge willingness to help." Vyavhare said even though Pendleton has other students, other projects and other assignments, she still finds time to help him with his research if he needs it.

"She does everything. She's everywhere," Eder said. "She has the heart of a teacher and she uses it." Pendleton's website says she has taught university courses for 30 years; at the same time, she has contributed to INTSORMIL's research and collaboration goals since she was a doctoral student in entomology at Texas A&M University in 1985.

Hamé Abdou Kadi Kadi, an entomologist in Niger, has worked with Pendleton on different levels for 26 years. Pendleton was a teaching assistant in classes he took at Texas A&M in College Station. Now she is his American collaborator for INTSORMIL projects. In her 2009 report, Pendleton credited Kadi Kadi for teaching farmers in Niger "identification, biology, and ecology of millet head miner and sorghum midge."

Kadi Kadi described his relationship with Pendleton as irreplaceable.

"From my perspective, I would say she is all to me," Kadi Kadi said. "You can't even describe how the person is to you, there is no such word. So to speak Africa language and say, 'She is all to me.'"

From critiquing his reports through e-mails to providing a computer for Kadi Kadi, Pendleton has tried to help him anyway she could. Pendleton said he helps her, too, by being another entomologist for her to bounce ideas off of or to learn about insects in different habitats. "For all of us to develop, you can't work by yourself," she said.

Pendleton's list of activities and interests is a long one. She teaches economic entomology, a class about insects and their effects on humans, to 56 students twice a week, supervises five graduate students' research and academic work, serves on 65 local and national professional committees, writes reports and works on her INTSORMIL research as a western Africa coordinator for INTSORMIL. She and Bruce Hamaker, Ph.D., of Purdue University coordinate the regional program with 21 scientists in five western African countries. Hamaker and Pendleton also collaborated to organize the 2010 INTSORMIL West Africa meeting, where U.S. scientists and their collaborators from the region met to update each other on research. Pendleton's presentation at the meeting included brief overviews of research by her African collaborators and by her students. She told scientists at the meeting about progress in studies of millet head miner, sorghum midge, aphids and stalk borers.

Despite all her work in academics and research, Pendleton said she is rarely stressed.

"What I do I never really find stressful mostly because I believe in what I do," Pendleton said. "I'm used

Dr. Bonnie Pendleton and Suhas Vyavhare, a master's student from India, examine sorghum seedlings for insect damage.

to being busy. I'd probably be stressed if I had nothing to do."

Pendleton said sorghum plants have 100-120 insect pests, so there is always something to study.

"There are so many insects in the world that it's difficult to know hardly anything about any insects, so there is plenty of work to be done," she said. Insects are always a part of Pendleton's life: For example, she founded and coaches the winning WTAMU Linnaean (entomology quiz) Team and presents educational programs on insects for school children and teachers and for 4-H and FFA.

Pendleton has insect books or small insect toys all over her office in Canyon, Texas. She also usually wears some type of an insect representation, like a ladybug ring or brooch. She collects more insect paraphernalia on her frequent travels—for example, to Africa two to four times a year.

"I'd have to look in my passport," she said. "I think I've been to Mali maybe 13 times." Pendleton's website says she has visited 40 countries and all U.S. territories and states except for New England.

Pendleton's mentor and major professor of her Ph.D. committee at Texas A&M University, Dr. George L. Teetes, was a part of INTSORMIL research before the name became official in 1979. After Teetes retired, Pendleton submitted her own proposal to INTSORMIL for funding, which was granted in 2002. Pendleton said she took over where Teetes left off and still follows many of the practices he taught her.

"He taught me all kinds of techniques," she said. "I even file my papers the way he used to file them. He was super efficient."

Pendleton said there were times when she had no idea how they could finish all their work. Teetes would simply say, "We'll get it all done." And they would.

"He taught me to be calmer because it all does work out," she said.

Pendleton said studying with Teetes and continuing his research was a natural result of what she had been working toward her whole life. When she was 13 and choosing what courses to take in high school, Pendleton knew she wanted to get a Ph.D. and teach science at the university level.

Pendleton received her bachelor's in biological sciences and chemistry and master's in anthropology from California State University, where many of her relatives also studied. She received her Ph.D. in entomology from Texas A&M University.

Drought tolerance

Story by Kate Veik

Sorghum is no Superman.

Sorghum has proved to be more tolerant of drought than cereals more common to the United States such as maize (corn), wheat and barley, but prolonged water shortage still affects sorghum crops.

In a sense, drought affects sorghum's ability to breathe. All plants have stomates--little pores like those on human skin. In the process of photosynthesis, plants use their stomates to exchange oxygen for carbon dioxide. The plant turns the carbon dioxide into sugar for energy, thus promoting plant growth.

Drought essentially plugs the stomates, stunting the growth and yield of the sorghum, according to William Rooney, Ph.D., an INTSORMIL scientist and professor of sorghum breeding and genetics at Texas A&M University.

"It's like closing your nose or your mouth," Rooney said. "You can't breathe."

When the stomates are plugged, the plant has less energy to burn. Instead of growing, sorghum's task becomes retaining water merely to survive, so the plant's growth either slows or the sorghum dies.

In his 2009 report for INTSORMIL, Rooney described sorghum as grown in Central America, where he is INTSORMIL's regional coordinator: "The crop is typically grown in the dry season due to its enhanced drought tolerance and ability to produce a crop under limited water availability."

INTSORMIL scientists like Rooney are increasing drought tolerance in sorghum by breeding sorghum lines with traits that scientists know enhance drought resistance.

For example, the staygreen trait keeps the sorghum plant alive in a drought after the plant has started to produce grain, or flowered. By integrating the staygreen trait into sorghum lines, INTSORMIL scientists can help to increase the yield and quality of sorghum crops in areas that experience consistent and crippling drought.

Sorghum in the highlands of Central America where drought is especially severe.

Photo by Rene Clara Valencia

Sorghum downy mildew

Story by Jamie Klein

Small white fuzzy splotches or light-and-dark streaks of green on sorghum leaves are disconcerting to farmers and crop scientists because they point to sorghum downy mildew, an infectious disease that reduces the amount of grain produced by a field of sorghum.

Growing sorghum that resists downy mildew is a goal that INTSORMIL scientists hope to achieve through worldwide research efforts.

Although sorghum is internationally grown, it is a staple food in the diets of many Africans.

Farmers in Africa grow sorghum to feed their families and livestock, so downy mildew's ability to reduce the crop's yield is a major concern, said Gary Odvody, Ph.D., an associate professor of sorghum and corn diseases at Texas A&M Research and Extension Center.

The fungus that causes sorghum downy mildew is borne in soil and, if sorghum plants aren't around to be infected, remains in the soil between farming seasons, said Odvody, a former INTSORMIL scientist. When a susceptible sorghum plant is nearby, spores from the fungus infect sorghum roots and grow with the plant.

Symptoms of downy mildew, including multi-colored leaves with fuzzy white spots underneath, are noticeable three or four weeks after the sorghum sprouts from the ground, Odvody said.

"We look at it as a mosaic pattern of light-colored cells and green cells of the host," he said.

The sorghum leaves may also have alternating parallel stripes of green and yellowish-green to white tissue; leaves with the lighter stripes eventually die, according to a website of the University of Nebraska-Lincoln Department of Plant Pathology.

Infected plants probably die without producing any grain, Odvody said.

"INTSORMIL sorghum breeders, other INTSORMIL scientists and their international collaborators are growing sorghum from various genetic backgrounds and testing them for downy-mildew resistance both in the U.S. and internationally," Odvody said. "If sorghum breeders can identify which types of sorghum are resistant to downy mildew, then it's possible to create resistant sorghums for farmers to use around the world. "

For that reason, Odvody said, sorghum downy mildew is an "internationally important disease."

An example of sorghum downy mildew.
Photo by Gary Odvody, former INTSORMIL scientist

Moldy grain

Story by Jenna Gibson, Carolyn Johnsen and Kate Veik

An African farmer looks over his yield. Most of the sorghum looks healthy, but a few grains are blackened with mold. The farmer can't sell the moldy grain, but he needs to get as much money as possible for his crop.

"Many times a grain trader comes to the village and is interested in buying grain that the farmers have harvested," said John Leslie, Ph.D., a plant pathologist at Kansas State University.

But the trader wants to buy only the good grain. The farmer needs cash, so he sells the good grain and saves the moldy grain for his animals and family to eat.

An example of healthy grain on the left and moldy grain on the right.
Photo courtesy of Gary Odvody, former INTSORMIL scientist

For African subsistence farmers, moldy grain may be the only option for food—a serious food-security concern.

Leslie and his INTSORMIL collaborators are researching ways to limit the effects of mold on sorghum and millet grain. This goal is directly related to INTSORMIL's efforts to increase food security in Africa.

Mold in grains can release poisonous chemicals called aflatoxins. Aflatoxins in the body affect particular organs, especially the liver. High doses of the toxins received over a few days or weeks can cause death, usually through liver malfunction. In small doses over a longer period of time, the chemicals can induce cancer or weaken the immune system, leaving people more open to other infections, Leslie said.

Mold can cause problems even for people who don't directly eat contaminated cereal grains. Some of the toxins produced by fungi in moldy grains, if eaten by animals, can be passed on. So a cow that eats moldy grain can produce contaminated milk that makes people sick. Mothers can pass on these toxins to infants through breast milk.

Mold is particularly a problem in Africa because of the climate. Aflatoxin-producing mold commonly grows in places where daytime temperatures are greater than 90 degrees Fahrenheit, where humidity is above 80 percent or where plants are particularly stressed by insects or drought.

Worldwide, losses due to grain mold are estimated at $130 million annually, according to one INTSORMIL report. Leslie said another study showed a cost of $1.5 billion to the U.S. economy for controlling mycotoxin, the food-contaminant category that includes aflatoxin. But sorghum and millet—grains traditionally grown in Africa—may offer some hope.

Leslie said dangerous mold affects sorghum and millet less than other grains like maize (corn). In studies with colleagues from INTSORMIL and the International Institute for Tropical Agriculture, Leslie measured aflatoxin levels in grain samples. The international cutoff for acceptable levels of aflatoxin in grain is 20 parts per billion. The studies, which looked at grain from plants grown side by side in a field in Nigeria, found 74 percent of the harvested maize samples were unacceptable. But only 13 percent of sorghum samples and none of the millet samples were too highly contaminated to be sold in the international market.

"In terms of food safety, these results are potentially very important because it means, in general, that sorghum and millet are safer food than maize," he said. "Effectively, it looks like sorghum is a healthier diet than maize, at least in terms of toxin consumption."

Scientists may not know why mold attacks maize more than other cereal grains, but they do know that in African climates, reducing mold exposure and educating farmers is essential to preventing mold-related health problems.

A recent complicating factor is that some agricultural development agencies are encouraging African farmers to plant short-season maize crops in drier areas.

A close-up of healthy grain on the left and moldy grain on the right.

Photo courtesy of Gary Odvody, former INTSORMIL scientist

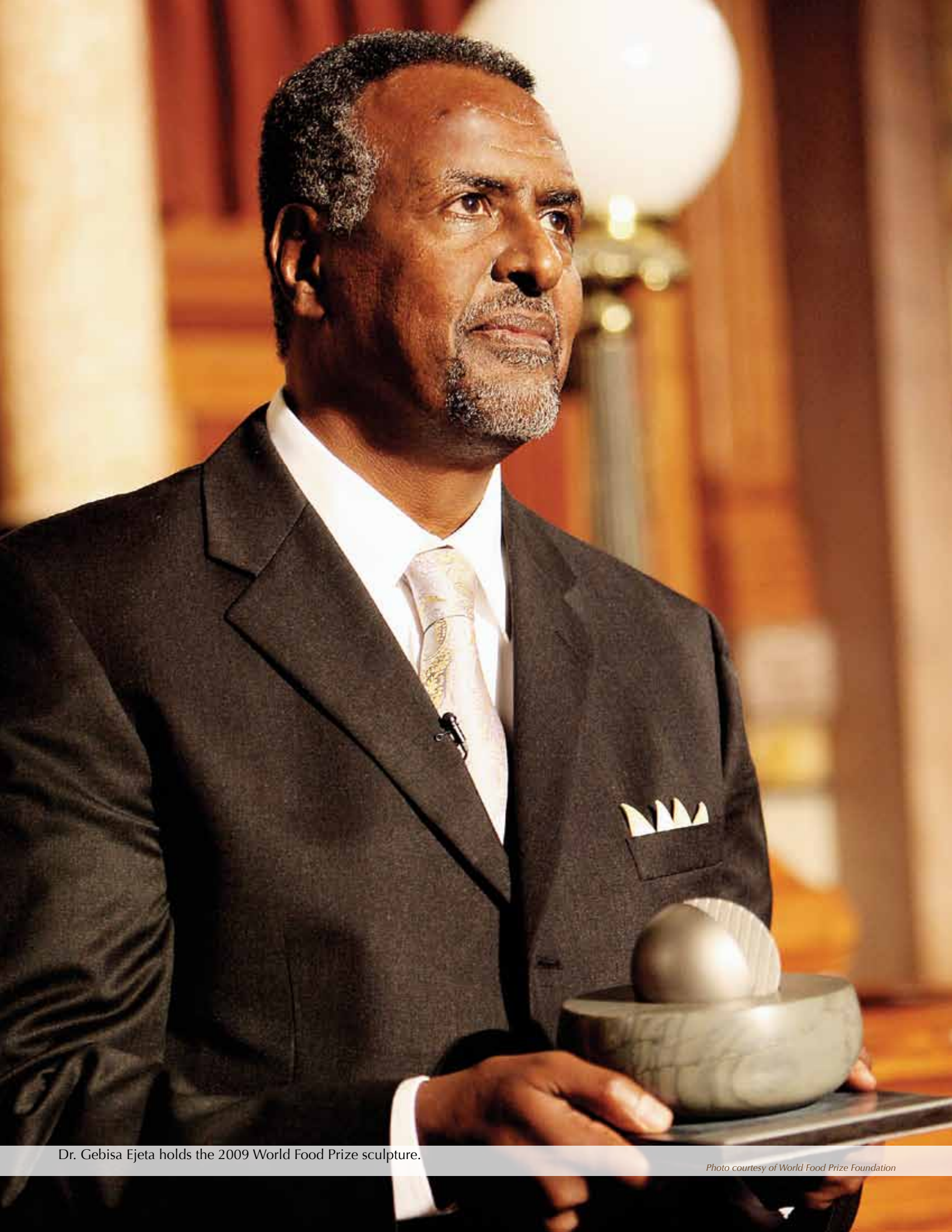
"We've been trying to tell the aid agencies that it's not a good idea to encourage this practice," Leslie said. "And we've been trying to develop crystal-clear evidence to document that."

The more that maize becomes the food staple, the more people will be exposed to moldy grains and the toxins they contain, Leslie said. An important focus for INTSORMIL researchers, he said, is to convince farmers and food processors to use sorghum and millet rather than maize.

Farmers can identify and separate moldy grains from good ones, Leslie said, and by avoiding the blatantly moldy grains, farmers can reduce their toxin exposure by 90 to 95 percent.

Despite the warnings, many farmers will continue to sell all their good grain because they need the money. As long as food security is an issue, someone will be willing to eat the contaminated grain and risk health problems later to avoid starving today. So INTSORMIL researchers like Leslie are focusing on increasing the resistance of sorghum and millet to mold and reducing the reliance on maize.

"The general conclusion is that sorghum and millet are preferable to maize because maize poses such a health risk due to toxin contamination in these hot dry areas," Leslie said. "That should be the main message that comes through."



Dr. Gebisa Ejeta holds the 2009 World Food Prize sculpture.

Photo courtesy of World Food Prize Foundation

World food prize confirms impact of scientist's research

Story courtesy of the World Food Prize Foundation

Ethiopia

The 2009 World Food Prize was awarded to Gebisa Ejeta, Ph.D., of Ethiopia, whose sorghum hybrids resistant to drought and the devastating *Striga* weed have dramatically increased the production and availability of one of the world's five principal grains, enhancing the food supply of hundreds of millions of people in sub-Saharan Africa.

Background on Problem

The greatest biological impediment to food production in Africa – the deadly parasitic weed *Striga*, known commonly as witchweed – devastates yields of crops, including maize (corn), rice, pearl millet, sugarcane and sorghum, thus severely limiting food availability. A 2009 U.N. Environmental Programme report estimated that *Striga* plagues 40% of arable savannah land, affecting the food security of 100 million people in Africa.

Personal Background

Born in 1950, Gebisa Ejeta grew up in a one-room thatched hut with a mud floor, in the rural village of Wollonkomi in west-central Ethiopia. His mother's deep belief in education and her struggle to provide her son with access to local teachers and schools provided the young Ejeta with the means to rise out of poverty and hardship. She made arrangements for him to attend school in a neighboring town. Walking 20 kilometers every Sunday night to attend school during the week and then back home on Friday, Ejeta rapidly ascended through eight grades and passed the national exam qualifying him to enter high school.

Ejeta's high academic standing earned him financial assistance and entrance to the secondary-level Jimma Agricultural and Technical School, which had been established by Oklahoma State University under the U.S. government's Point Four Program. After graduating with distinction, Ejeta entered Alemaya College (also established by OSU and supported by the U.S. Agency for International Development) in eastern Ethiopia. He received his bachelor's degree in plant science in 1973.

In 1973, his college mentor introduced Ejeta to a renowned sorghum researcher, John Axtell, Ph.D., of Purdue University, who invited him to assist in collecting sorghum species from around the country. Axtell was so impressed with Ejeta that he invited him to become his graduate student at Purdue University. This invitation came at a time when Ethiopia was about to enter a long period of political instability which would keep Ejeta from returning to his home country for nearly 25 years.

Ejeta entered Purdue in 1974, earning his Ph.D. in plant breeding and genetics. Upon completing his graduate degree, Ejeta accepted a position as a sorghum researcher at the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) office in Sudan.

Ejeta later became a faculty member at Purdue, where today he holds a distinguished professorship (Distinguished Professor of Plant Breeding & Genetics and International Agriculture).

Achievements

During his time at ICRISAT, Ejeta developed the first hybrid sorghum varieties for Africa, which were drought-tolerant and high-yielding. With the local importance of sorghum in the human diet (made into breads, porridges and beverages), and the vast potential of dry-land agriculture in Sudan, Ejeta's drought-tolerant hybrids brought dramatic gains in crop productivity and also catalyzed the initiation of a commercial sorghum seed industry in Sudan.

His Hageen Dura-1, as the hybrid was named, was released in 1983 following field trials in which the hybrids out-yielded traditional sorghum varieties by 50 to 100 percent. Its superior grain qualities contributed to its rapid spread and wide acceptance by farmers, who found that yields increased to more than 150 percent greater than local sorghum, far surpassing the percentage gain in the trials.

Ejeta's dedication to helping poor farmers feed themselves and their families and rise out of poverty propelled his work in leveraging the gains of his hybrid breeding breakthrough. He urged the establishment of structures which could monitor production, processing, certification and marketing of hybrid seed — and farmer-education programs in the use of fertilizers, soil and water conservation, and other supportive crop management practices.

By 1999, one million acres of Hageen Dura-1 had been harvested by hundreds of thousands of Sudanese farmers, and millions of Sudanese

Dr. Gebisa Ejeta, Dr. John Yohe and two Ethiopian farm boys in a field at an integrated *Striga* management workshop field trip.
Photo by INTSORMIL

had been fed with grain produced by Hageen Dura-1.

Another drought-tolerant sorghum hybrid, NAD-1, was developed for conditions in Niger by Ejeta and one of his graduate students at Purdue University in 1992. This cultivar has had yields 4 or 5 times the national sorghum average.

Using some of the drought-tolerant germplasm from the hybrids in Niger and Sudan, Ejeta also developed elite sorghum inbred lines for the U.S. sorghum hybrid industry. He has released over 70 parental lines for the U.S. seed industry's use in commercial sorghum hybrids in both their domestic and international markets.

Ejeta's next breakthrough came in the 1990s, the culmination of his research to conquer the *Striga* weed. Previous attempts by African sorghum farmers to control the deadly weed, including crop management techniques and application of herbicides, had failed until Ejeta and his Purdue colleague Larry Butler, Ph.D., formulated a novel research paradigm for genetic control of this scourge. With financial support from the Rockefeller Foundation and USAID, they developed an approach integrating genetics, agronomy and biochemistry that focused on unraveling the intricate relationships between the parasitic *Striga* and the host sorghum plant. Eventually, they identified genes for *Striga* resistance and transferred them into locally adapted sorghum varieties and improved sorghum cultivars. The new sorghum also possessed broad adaptation to different African ecological conditions and farming systems.

The dissemination of the new sorghum varieties in *Striga*-endemic African countries was initially facilitated in 1994 by Ejeta, working closely with World Vision International and Sasakawa 2000. Those organizations coordinated a pilot program with USAID funding that distributed eight tons of seed to Eritrea, Ethiopia, Kenya, Mali, Mozambique, Niger, Rwanda, Senegal, Somalia, Sudan, Tanzania and Zimbabwe. The yield increases from the improved *Striga*-resistant cultivars have been as much as four times the yield of local varieties, even in areas of severe drought.

In 2002-2003, Ejeta introduced an integrated *Striga* management (ISM) package, again through a pilot program funded by USAID, to deploy in Eritrea, Ethiopia and Tanzania along with the *Striga*-resistant sorghum varieties he and his colleagues had developed at Purdue. This ISM package achieved further increased crop productivity through a synergistic combination of weed resistance in the host plant, soil-fertility enhancement and water conservation.

Honors, Awards & Positions Held

Less than a month after receiving the 2009 World Food Prize, Gebisa Ejeta received his home country's highest honor: Ethiopia's President, H.E. Ato Girma Woldegiorgis awarded Ejeta the National Hero Award, the first time the nation's highest honor had been given to an Ethiopian for work in science and technology.

Ejeta has served on various science and program review panels, technical committees, and advisory boards of major research and development organizations. These include the international agricultural research centers (IARCs), the Rockefeller Foundation, the Food and Agriculture Organization (FAO) of the United Nations, and numerous national and regional organizations in Africa. He was a member of the team that launched the Alliance for Green Revolution in Africa and has served as a member of the Science Council and Consortium Board of CGIAR. He is a board member of the Sasakawa Africa Program and currently serves as special advisor to USAID Administrator Rajiv Shah, Ph.D.

Ejeta is a Fellow of the American Association for the Advancement of Science, a Fellow of the Crop Science Society of America, and a Fellow of the American Society of Agronomy.

Legacy

By partnering with leaders and farmers across sub-Saharan Africa and educational institutions in the U.S. and abroad, Ejeta has personally trained and inspired a new generation of African agricultural scientists that is carrying forth his work.

Ejeta's scientific breakthroughs in breeding drought-tolerant and *Striga*-resistant sorghum have been combined with his persistent efforts to foster economic development and the empowerment of subsistence farmers through the creation of agricultural enterprises in rural Africa. He has led his colleagues in working with national and local authorities and nongovernmental agencies so that smallholder farmers and rural entrepreneurs can catalyze efforts to improve crop productivity, strengthen nutritional security, increase the value of agricultural products and boost the profitability of agricultural enterprise – thus fostering profound impacts on lives and livelihoods on a broader scale across the African continent.

"Dr. Ejeta's accomplishments in improving sorghum illustrate what can be achieved when cutting-edge technology and international cooperation in agriculture are used to uplift and empower the world's most vulnerable people," said Norman E. Borlaug, Ph.D., founder of the World Food Prize. "His life is as an inspiration for young scientists around the world.

In response to the National Hero Award, Ejeta announced that he will use his $250,000 World Food Prize to establish an educational foundation aimed at assisting Ethiopian and other African children.

Four graduate students work with Dr. Gebisa Ejeta in a Purdue University greenhouse.

Photo by Agricultural Communications, Purdue

Striga infests sorghum

Story by Alia Conley

Farmers hope that *Striga*, a parasitic plant, never attacks their crops.

Acting like a leech, *Striga* steals nutrients from a host plant. *Striga* is deadly because of the aggressive, unique way it weakens crops directly, unlike other weeds, which compete with crops only for space, water, sunlight and soil nutrients.

Also known as "witchweed," *Striga* is one of the worst enemies for cereal crops such as maize (corn), millet, rice and sorghum, said Charles Wortmann, Ph.D., an INTSORMIL scientist at the University of Nebraska-Lincoln.

"Many sub-Saharan African countries have it. It's common in Asia," Wortmann said. "It's widely occurring in warmer areas from 25 degrees latitude or closer to the equator."

Striga (pronounced "STRY guh") spreads to sorghum crops through "contaminated seed and equipment, surface run-off, eroded soil, wind, animals and people," according to the African Agricultural Technology Foundation. Each *Striga* plant can produce up to 50,000 seeds, which are tiny and easily scattered.

Striga seeds can stay inactive for up to 20 years, and become active only in the presence of roots of plants, such as sorghum, that stimulate germination.

The battle starts once *Striga* attaches itself to a sorghum root. *Striga*'s own roots use a special tip called a haustorium to invade the sorghum root and suck nutrients from the plant, like a straw.

Striga weakens sorghum because the crop wastes energy by providing the weed with nutrients, according to the U.S. Department of Agriculture. *Striga*-infested sorghum is less productive, weaker and yields less grain because *Striga* robs all the crop's resources. *Striga* also inhibits plant height and discolors sorghum.

Striga infests about 100 million hectares (247 million acres) of field crops in sub-Saharan Africa, says a report by Gebisa Ejeta, Ph.D., an INTSORMIL scientist and professor of agronomy at Purdue University.

Striga grows best in low-moisture climates and in soils with low fertility. The weed was once a problem in the U.S., but U.S. farmers have mostly eradicated it, said Wortmann, an associate professor of soil science at UNL. The USDA website identifies only three states in the U.S. that have a form of *Striga*: North Carolina, South Carolina and Florida.

But the situation is much different in Africa where, according to the U.N., *Striga* causes crop losses of 40 percent, and reduces the food security of 100 million African people.

One sign of *Striga*'s presence in a sorghum field is plants that fold and wither even though they are receiving enough moisture. When farmers plant sorghum year after year on the same land without rotating crop types, *Striga* can attack more easily. The U.N. Development Program reports that *Striga* is spreading, at least in part because of farming practices: "land pressures cause farmers needing to feed their families to opt for continuous cropping of the higher yielding cereal crops without rotation or moving to other land."

As *Striga* matures, yellow-green stems will emerge above ground four to seven weeks after the first attack on the sorghum, according to the Pan-African *Striga* Control Network. The stems produce red flowers two weeks later, and numerous seedpods develop. When seeds scatter, the cycle begins again.

"You can get quite high densities of *Striga* in the field," Wortmann said. "The seed does persist for a number of seasons and a number of years so it's a problem that's difficult to get rid of once you have it."

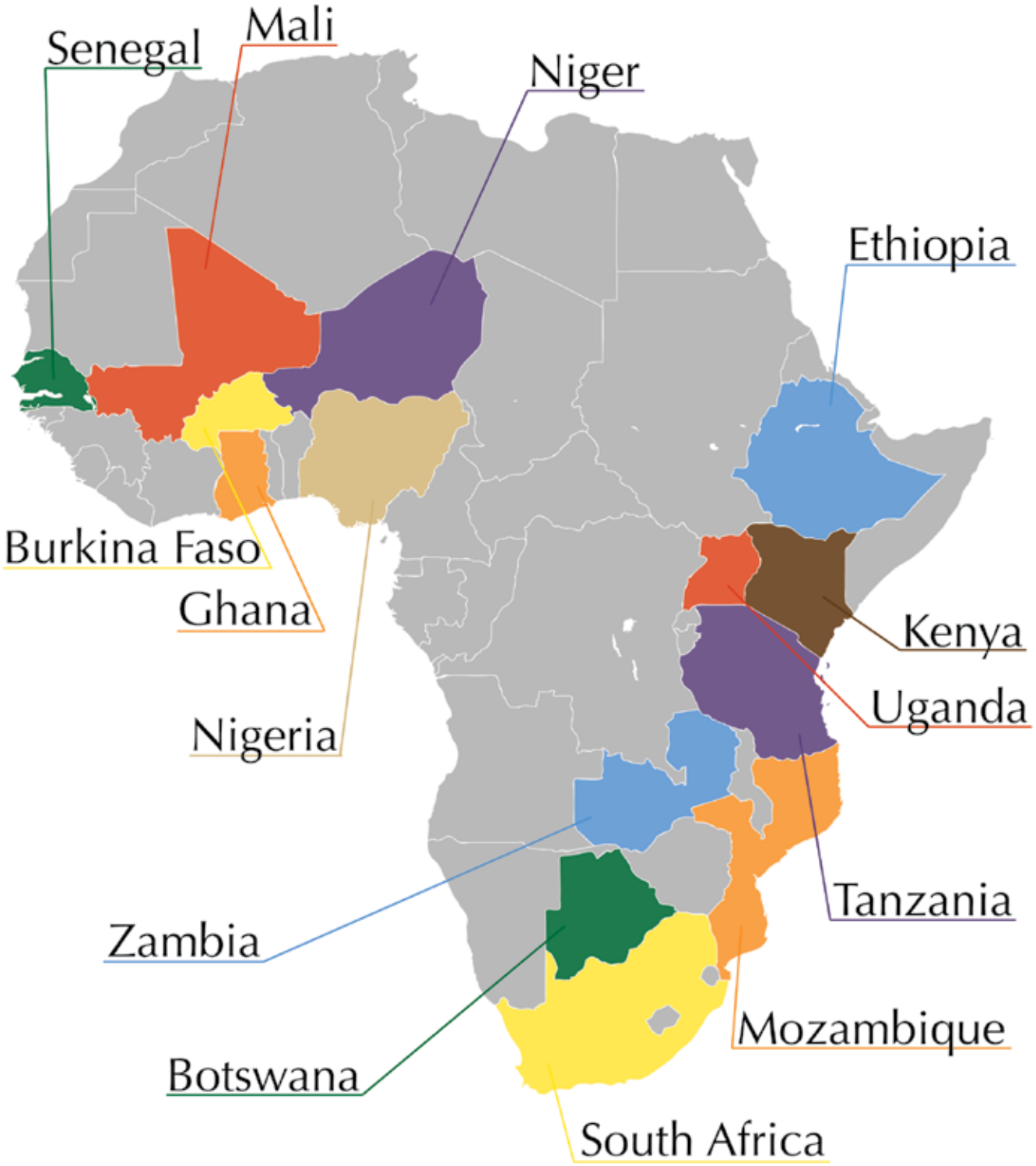
Consequently, INTSORMIL scientists are developing *Striga*-resistant strains of sorghum. In fact, Gebisa Ejeta won the World Food Prize largely because his sorghum hybrids "resistant to drought and the devastating *Striga* weed have dramatically increased the production and availability of one of the world's five principal grains, enhancing the food supply of hundreds of millions of people in sub-Saharan Africa."

Striga infesting a sorghum plant.
Photo by INTSORMIL

Flowering *Striga*.

Photo by INTSORMIL

U.S. Principal Investigators in Africa



Mali

Bruce Hamaker, John Sanders & Mitchell Tuinstra (Purdue University); Joe Hancock, John Leslie, Vara Prasad, Scott Staggenborg & David Mengel (Kansas State University); Bonnie Pendleton (West Texas A&M University); Jeffrey Wilson (U.S. Department of Agriculture)

Senegal

Bruce Hamaker, Joe Hancock, John Sanders, Jeffrey Wilson

Burkina Faso

Bruce Hamaker, Vara Prasad, Scott Staggenborg, David Mengel, John Sanders, Mitchell Tuinstra, Jeffrey Wilson

Ghana

Vara Prasad, Scott Staggenborg, David Mengel

Nigeria

Bruce Hamaker, Joe Hancock, Iro Nkama (University of Maiduguri), Ignatius Angarawai (Lake Chad Research Center)

Zambia

Mark Erbaugh & Donald Larson (The Ohio State University), David Jackson (University of Nebraska-Lincoln), Gary Peterson (Texas A & M University), Jeffrey Wilson

Botswana

Joe Hancock, Bonnie Pendleton, Gary Peterson, Mitchell Tuinstra, Jeffrey Wilson

Niger

Bruce Hamaker, Joe Hancock, Bonnie Pendleton, Vara Prasad, Scott Staggenborg, David Mengel, John Sanders, Mitchell Tuinstra

Ethiopia

Gebisa Ejeta (Purdue University), Charles Wortmann (University of Nebraska-Lincoln)

Kenya

Gebisa Ejeta, John Leslie

Uganda

Gebisa Ejeta, Charles Wortmann

Tanzania

Gebisa Ejeta, Mark Erbaugh, Curtis Weller (University of Nebraska-Lincoln), David Jackson, John Leslie, Don Larson, Charles Wortmann

Mozambique

Bonnie Pendleton, Gary Peterson, Charles Wortmann

South Africa

Gary Peterson, Don Larson, Mark Erbaugh, John Leslie, Lloyd Rooney, Bonnie Pendleton

Farming Practices

In some cases, farmers using INTSORMIL techniques got three times more yield than farmers using traditional methods of growing and harvesting sorghum, according to a 2008 report by INTSORMIL economist John Sanders, Ph.D., of Purdue University.

Despite the chance of increased yield and income, loyalty to traditional methods and the expense involved with new methods of farming are two reasons why subsistence farmers may resist some methods recommended by INTSORMIL scientists. Two examples: Hand-hoe tillage is labor-intensive but less expensive than cultivators pulled by tractors. Although smallholder farmers have traditionally planted every part of their fields, INTSORMIL scientists may recommend skip-row planting, that is, planting every other row and leaving the others empty to act as reservoirs, storing moisture and nutrients throughout the growing season.

To improve the stability and yield of farmers' food crops—an INTSORMIL objective—INTSORMIL supports research into ways to manage the crops themselves and the soil and water needed to grow them, in Central America, the U.S. and Africa. This research is most significant if farmers agree to participate in it and to apply the results of the research to their own circumstances.

To that end, INTSORMIL scientists at Kansas State University have designed their research around the stated needs of farmers who grow food crops. KSU scientists Scott Staggenborg, Ph.D., and Vara Prasad, Ph.D., have described their goals to "transform sorghum and millet from subsistence to cash crop status, generate more income and provide food security"—a goal shared by all INTSORMIL scientists.

The first story in this section describes these KSU scientists' efforts to persuade farmers to use integrated crop-management systems in their fields. Intercropping and crop rotation—two other promising farming practices advanced by INTSORMIL scientists—are the topics of the second and third stories. The final story in this section describes threats to harvested grain crops in storage, including heat, humidity, insects and rodents—threats that can inhibit many efforts to increase food security.

Scientists expect climate change to add more challenges to small farmers' efforts to produce and store crops to feed their families and to sell grain for a profit. Drought and heat are obvious challenges resulting from climate change; so efforts by INTSORMIL scientists to help farmers manage crops with limited water are important ingredients in efforts to improve food security.

– By Carolyn Johnsen

Sorghum seedlings in Central America.
Photo by INTSORMIL

KSU scientists research cropping systems in Kansas and Africa

Story by Kate Veik

Two INTSORMIL scientists at Kansas State University hope to make Africa the breadbasket it was decades ago.

Scott Staggenborg and Vara Prasad, both Ph.D. agronomy professors at KSU, believe that reshaping crop, water and soil management in Africa will do the trick by increasing the quality and yield of sorghum and millet grown by African farmers.

The pair work out of rural Kansas, an ideal place for their research because of its similarity to Africa. Western Africa is a tropical environment with limited rain, and tropical soils are notoriously bad at retaining any rain that does fall. Kansas has, by and large, good soil, but it also is a very dry, or semi-arid, environment.

So Prasad and Staggenborg are able to transfer some of their conclusions to Africa because, like Africa, Kansas gets very hot and dry during the growing season.

"There's a relationship there with how to deal with stressful water-limiting environments," Staggenborg said. "We have a lot of experience with that compared to, say, someplace like upstate New York where it's cool and it rains a lot."

The men's research will also be useful for developing stress tolerance in crops in Kansas—although Kansas farmers and African farmers use very different methods.

"It's much more mechanical management here, whereas there it is mostly done by human labor, whether planting or weeding or harvesting," Prasad said.

This INTSORMIL research at KSU focuses on integrated cropping systems management or "ICSM." The systems are "integrated" in that they incorporate three components: crop, soil and water management.

This integrated approach is essential for obtaining better crop quality and yield, Prasad said.

"If you don't have water, you apply nitrogen but it has no value," Prasad said. "For the plant to absorb nitrogen, it needs water." On the other hand, abundant water in the absence of nitrogen is of limited use to plants.

Thus Prasad and Staggenborg base their research on the assumption that managing crops, soil and water together will increase yield.

Crop Management

Among other things, crop management involves determining the order in which to plant crops.

Food crops can be divided broadly into two groups. Cereals include sorghum, millet, rice, wheat and maize (corn). Legumes include soybeans, peanuts and cowpeas.

The roots of legumes have nodules that "fix" atmospheric nitrogen. That is, they convert nitrogen in the air to nitrogen in the soil and make it available to plants that use nitrogen as an organic (naturally available) fertilizer.

"If you have less nitrogen, your leaves are going to be yellow, and that

Dr. Vara Prasad in a field of a local sorghum cultivar in Ghana.

Photo courtesy of Vara Prasad

INTSORMIL investigators Dr. Vara Prasad (center) and Dr. Jesse Naab (right), and a field technician examine native land race sorghum in Ghana
Photo courtesy of Vara Prasad

means they are not photosynthesizing efficiently—that is, converting the light energy into the sugars," Prasad said. "So if you have less photosynthesis, then your growth and yield and everything thereafter are going to be lower. So nitrogen is an essential element required by the crops and plants for producing biomass and yield."

Biomass (the stalks and leaves of plants) can be used as a raw material in ethanol production; so, in addition to doing research on food crops, the KSU team and their collaborators also look for lines of sorghum and other grains suitable for ethanol production, both in the U.S and in Africa. But even a cereal grain crop that works well for this use needs ample sources of fertilizer.

"By doing that (crop management) you are minimizing the use of inorganic fertilizers in the places where there is a shortage of fertilizer or the fertilizer costs are too high."

- Vara Prasad
Kansas State University

Cereals cannot fix nitrogen like legumes can. So one crop-management practice studied by the KSU team and their African collaborators in Niger is to alternate planting cowpea, a legume that fixes nitrogen in the soil, with millet, a cereal that uses the nitrogen to grow.

"By doing that, you are minimizing the use of inorganic fertilizers in the places where there is a shortage of fertilizer or the fertilizer costs are too high," Prasad said.

Inorganic—or commercial—fertilizers are often too pricey and unavailable for African farmers.

As another alternative to alternating legume and cereal crops, INTSORMIL scientists have also urged farmers to leave the leaves and stalks of legumes on the soil after harvest. This residue acts as a natural fertilizer and improves soil quality, which relates to another part of INTSORMIL's research into ICSM: soil management.

Soil Management

Among other things, good soil management involves adding organic material and fertilizer to the soil with as little cost and waste as possible.

African farmers traditionally use crop residue to build houses and storage bins and to feed their animals. Although Prasad and Staggenborg have encouraged farmers to leave crop residue in the fields, African farmers have been hesitant to do so because they have alternative uses for the residue or because cows from neighboring farms typically graze on it.

"There are people who have herds of cows who will go around eating residue off of anyone's field," Staggenborg said. "It's a foreign concept to us. If we wanted to graze a neighbor's field, we'd go over and ask him and then pay him to graze his stalks because they're his stalks," he said, comparing a U.S. farming practice with one in Africa.

Water Management

Water management is also part of ICSM and, thus, part of INTSORMIL's effort to improve or alter traditional farming techniques for improved crop quality and yield.

Some African farmers traditionally trap runoff water in ponds and use

buckets to scoop water out of the pond onto their crops—a labor-intensive method of irrigating crops. So INTSORMIL scientists are looking for more effective ways for farmers to manage water. For example, in one report to INTSORMIL, Staggenborg and Prasad described their evaluation of various tillage practices on sorghum's use of both water and nitrogen. In research with a collaborator, Jesse Naab, Ph.D., in Ghana, these practices included both no-till methods and traditional tillage, like plowing. In that same report, the INTSORMIL scientists described their research on Kansas test plots, where they grew selected sorghum varieties in both rain-fed and irrigated plots.

Most of Prasad and Staggenborg's research in Africa is done on farmer's fields, where INTSORMIL typically provides the seed and inorganic fertilizer and the farmer provides the labor. At harvest, the farmer gives a sample of the crop to INTSORMIL scientists who then take the necessary measurements and tests of the crop. The rest of the harvest belongs to the farmer.

Once the farmer has evidence that recommended methods are working, INTSORMIL will usually cut all contributions because the farmer is now benefiting from the science on his or her own.

Little of this science will have an impact unless farmers agree to use it. So before doing their research in Africa, Prasad and Staggenborg conducted a baseline survey of farmers in Ghana, Mali, Burkina Faso and Niger. The scientists wanted to identify the constraints farmers see on crop quality and yield, such as drought and soil fertility.

After surveying the concerns of the farmers, the INTSORMIL scientists began designing their research "to establish integrated multi-factor experiments which will have important components of the farmers' priorities and needs."

With efforts like this, INTSORMIL scientists hope to help Africa regain the title "Breadbasket of the World."

Agronomist Dr. Vara Prasad checks the health of sorghum plants in a Kansas State University greenhouse.

Photo by Kate Veik

Crop rotation

Story by Jenna Gibson

For farmers in Africa, every dollar counts. Every harvest can make or break a family's livelihood for the year.

One problem that can cause poor harvests is soil depletion, which results when plants suck up nutrients in the soil, leaving fewer nutrients for the next year's crop. Farmers can ease soil depletion by leaving their fields empty – or fallow – for a season, to give the soil time to rest and replenish nutrients. But for farmers in African countries where INTSORMIL scientists work, skipping a year of planting and losing that year's profit is not an option. Some INTSORMIL scientists are helping African farmers use a time-tested process called crop rotation as a way to give the soil a break without leaving a field barren for a whole season. Crop rotation involves planting one crop one season and a different, complementary crop the next season.

Plants need certain nutrients, such as nitrogen, to grow. Over time, the soil is like an hourglass, with the nitrogen nutrients slowly leaking out of the soil into plants. Planting a crop that creates nitrogen in the soil turns the hourglass over, putting nutrients back into the soil. For example, cowpeas create nitrogen in the soil, while sorghum sucks up nitrogen to grow. Planting cowpeas one season can add nitrogen to the soil to sustain the next season's crop of sorghum.

One INTSORMIL scientist who is using crop rotation to help increase yields and therefore increase profits for farmers in Uganda is Charles Wortmann, Ph.D., an associate professor of agronomy and horticulture at the University of Nebraska-Lincoln. In this research, Wortmann and his INTSORMIL collaborators compared results from different crop-rotation plans. The scientists found that planting sorghum after planting cowpeas resulted in a 60 to 70 percent increase in sorghum yield over planting sorghum two seasons in a row.

Farmers who want to plant only sorghum would have to buy nitrogen fertilizer to put enough nitrogen back in the soil to keep the second year's harvest healthy, Wortmann said. Crop rotation can therefore cut the cost for farmers to prepare their fields and ensure a profit.

"We got quite good yield responses because of crop rotation with lower investment and more profit."
– Charles Wortmann, University of Nebraska-Lincoln

"We got quite good yield responses because of crop rotation with lower investment and more profit," he said.

Not only does crop rotation help solve problems caused by soil-depletion, it also limits the effects of a pest that hurts sorghum in Africa—a weed called *Striga*. Merely clearing out the *Striga* plants and replanting sorghum is like doing a cursory cleaning job—the hard-to-reach spots behind the refrigerator will still be filthy; that is, the *Striga* seeds will remain. But planting a new crop of cowpeas is like full-on spring-cleaning, clearing out all the furniture and making sure even the hidden pests are gone; in this case, even if *Striga* seeds sprout, cowpeas will resist the weed and thrive. Wortmann said his research shows that rotating *Striga*-resistant cowpeas with sorghum offers farmers a way to manage *Striga*; that is, the practice can reduce the weed's effects on grain crops planted in the field.

Farmers can also plant sorghum and cowpeas together in a field in one season (that is, "intercrop") and rotate with other crops the following season. This technique of combining crop rotation and intercropping helps farmers get the most out of their fields, providing more than one harvest each year. When combined with intercropping, crop rotation can increase farmers' profits and can lower the risk of losing profit in case of a natural disaster, such as drought.

The risk-management aspect of crop rotation is a big sticking point for David Mengel, Ph.D., a professor of soil fertility and nutrient management at Kansas State University who trains INTSORMIL-sponsored students. In many countries where fertile soil is rare, where water is scarce or where natural disasters threaten crops, crop rotation can help ensure a decent yield each year, Mengel said.

INTSORMIL scientists say crop rotation, along with intercropping and other INTSORMIL-recommended techniques, can decrease farmers' investments in their fields while increasing their profit from higher sorghum yields.

Intercropping of mature maize (corn) and green sorghum on the sides.

Photo by INTSORMIL

Intercropping

Story by Caroline Brauer

The earliest inhabitants of the United States used intercropping when they planted maize (corn) and beans in the same field. Today, some small farmers in Africa use the same farming method to make money and feed their families.

Farmers who use intercropping grow more than one type of crop in the same field at the same time. This method maximizes yields by providing more than one crop to be harvested in a season, prevents some soil erosion by putting more plants and roots in the ground, and controls pests by stimulating them to grow and complete their lifecycles in one crop before the farmer plants the next crop.

Plant architecture refers to the crops' shape and size, which will help farmers decide which crops to plant. For example, farmers growing a short crop that needs a lot of sunlight wouldn't plant it with a taller crop that blocks the sun.

Choosing crops that mature at different times staggers harvest and may ease a farmer's workload. In India, for example, sorghum matures and is harvested before flowering begins for the pigeon peas that are intercropped with the sorghum.

Plant density affects the yield at harvest. Farmers who intercrop decide how much of each crop to plant, depending on which crop they want a better yield from and on the competition they can expect between crops. Staggenborg said intercropped plants always compete in some fashion. For example, all crops need water and soil nutrients, and two crops planted in one field will compete for a limited supply of these resources. As a result, the yield of one crop will suffer, but any drop in yield depends upon the density of plants for both crops.

"They're already going through the field. This way they get a little bit of a bonus."

– Scott Staggenborg, Kansas State University

"Every system's a little different," said Scott Staggenborg, Ph.D., an agronomy professor and INTSORMIL scientist at Kansas State University who has worked on intercropping systems in West Africa. He said intercropping involves more than just deciding to plant a field with half one crop and half another.

"You have to weigh the choice properly," he said.

Farmers who intercrop do a lot of planning before planting begins. In "Intercropping Principles and Practices," the National Sustainable Agriculture Service says farmers planning to use intercropping should consider four things: plant architecture, maturity dates, plant density and spatial arrangement.

Finally, farmers consider which spatial arrangement to use:

* Relay: Farmers plant a second crop before harvesting the first.

* Mixed: Subsistence farmers in Mexico and Central America use mixed intercropping when they plant corn, beans and squash with no particular spatial arrangement.

* Row: Niger's farmers row intercrop when they alternate a row of one crop (such as millet) with a row of another crop (like cowpeas).

* Strip: Farmers alternate several rows of one crop with several rows of another. But Staggenborg said strip isn't always considered intercropping because only the plants on the edges of the strips interact. The center rows of plants in each strip grow as if they were in a single-crop field.

Intercropping's effectiveness depends, in part, on the type of farm. For example, small farmers in Niger use their time efficiently by planting cowpeas between rows of millet plants while hoeing weeds in the millet fields.

"They're already going through the field," Staggenborg said. "This way they get a little bit of a bonus."

U.S. farmers who use intercropping can plant both crops with machinery, but mechanized harvest is more difficult. If the crops are similar in size, like cowpeas and millet, machines may not be able to harvest the crops separately, and the grains might mix.

Niger's farmers, however, plant and harvest by hand—a method with some advantages in an intercropping situation. Because the cowpeas were planted later and harvested first, their yield may be less than if the cowpeas had been raised in their own field. But the early cowpea harvest gives the farmers a small cash crop to sell. The farmers harvest the millet second to feed their families and sell any extra grain. Harvesting the crops separately prevents mixing the grains from the two different crops.

Grain-storage problems in Africa

Story by Karoline Kastanek

Cookies are kept in a cookie jar to preserve their chewy, soft texture and to keep them from spoiling.

Grains need a "cookie jar," too. Accordingly, farmers in the U.S. and most developed countries have dependable storage bins that prevent grain from retaining too much moisture and keep pests from eating it.

In Africa, some small-scale farmers store their grain in termite-resistant wooden structures called granaries. According to the International Research and Development Centre's Web site, the termite-resistant wood supply is depleting rapidly. As a result, farmers find it hard to repair existing storage granaries and build new structures. In fact, some African farmers use plant stalks for contruction material, including to build grain-storage facilities.

Many countries in Africa have problems storing grain, primarily because of climate conditions. Heat and high humidity can cause grain to spoil or rot at a faster rate because, combined, they offer ideal growing conditions for bacteria and mold. In "Mycotoxins," John Leslie, an INTSORMIL scientist at Kansas State University, wrote that *Fusarium*, *Penicillium* and *Aspergillus* are commonly found on maize (corn), sorghum and cassava in eastern and southern Africa and can attack grain while it is stored.

Infiltration by insects and rodents adds to farmers' difficulties in storing grain over a long period of time.

No matter how abundant the harvest and nutritious the grain, without proper storage, African farmers can't use sorghum, pearl millet and other small grains efficiently—either for their families' food or to sell for a profit. INTSORMIL researchers are finding ways to reduce grain loss during storage.

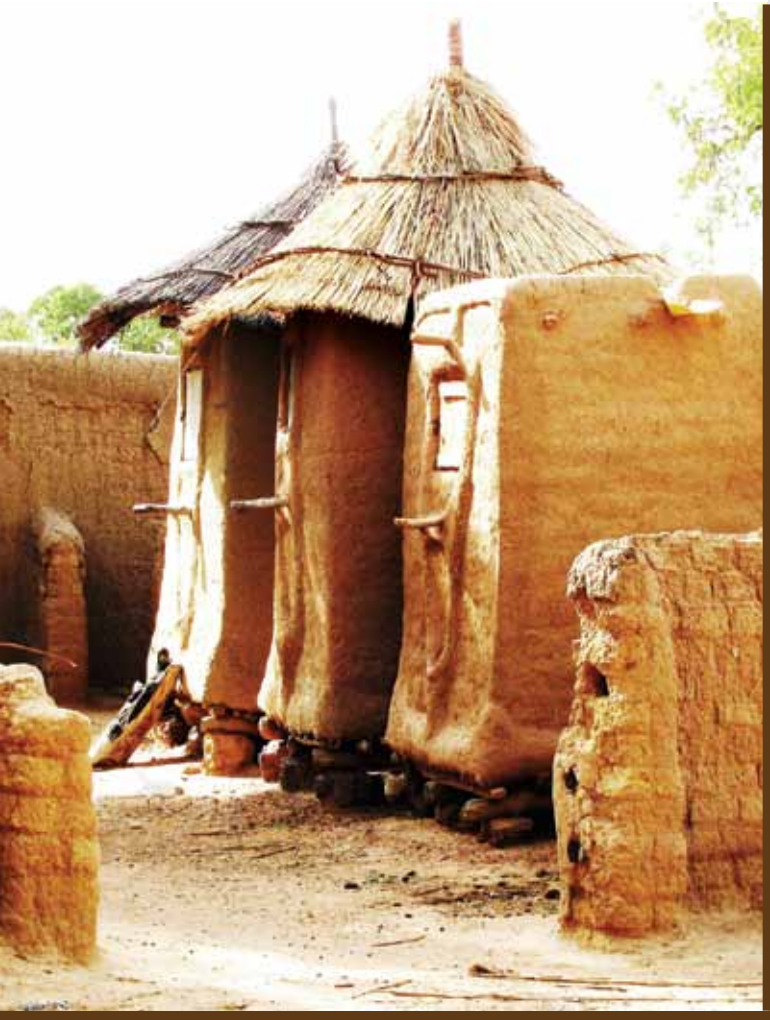
Top Right: Two different types of storage structures in Mali.

Photos by E.A."Short" Heinrichs

Bottom Left: Sorghum storage enclosure. Note the sagging canvas roof.

Bottom Right: Godwin Kaula collects sorghum from a Zambian farmer's grain-storage enclosure while another local farmer looks on. Note the walls made of wooden beams and sorghum stalks.

Photos by Kate Veik

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Marketing

INTSORMIL scientists encourage farmers to adopt "technology" developed in the program's more than 30 years of research, including hardy varieties of sorghum and millet, farming practices like crop rotation and food products made from the grain.

The "smallholder" farmers to whom INTSORMIL science is directed typically own or plant very small areas of land. Historically, these farmers have used grain crops to feed their families, leaving little or no grain to sell.

INTSORMIL scientists expect that improved technology will give these farmers harvests beyond the subsistence level—that is, grain to sell and provide more income. With more income, families will likely supplement their grain-rich diets with meat.

The first story in this section describes an INTSORMIL project to encourage poultry raising in West Africa.

INTSORMIL scientist Joe Hancock, Ph.D., and his collaborators report, "Poultry production is particularly well suited to a rapidly growing demand for animal products because of relatively low expenditures . . . to enter into the industry."

Like people, these domestic birds—mostly chickens—need to eat. If grain farmers sell grain to poultry farmers for a profit, grain farmers can afford to add poultry to their families' diets, increasing demand for both the poultry and the grain to feed them.

The second story identifies another market developing from a dietary staple—bread—an effort led by INTSORMIL scientist Bruce Hamaker, Ph.D. With the help of at least 16 collaborators, including food scientists and plant breeders in the U.S. and western Africa, Hamaker is trying to perfect a recipe for bread made from sorghum flour. The effort involves African women who make food products to sell in the marketplace.

The experience of a Zambian graduate student in developing a market for sorghum clear-beer is the topic of the third story.

The next story describes how an INTSORMIL team of economists explores the value-supply chain that follows a raw material like sorghum grain through each step of its use in Zambia and Tanzania—from seed supplier to farmer's field to processor to consumer.

The final story reports on two Zambian economists' study of the factors that influence farmers' decisions to adopt INTSORMIL technology. This 2005 study is one example of how INTSORMIL develops important skills among the citizens of host countries—an effort called "capacity building."

– By Carolyn Johnsen

Malian women carry harvested pearl millet to their village for storage.

Photo by E.A. "Short" Heinrichs

Poultry project

Story by Kate Veik

In 2005, INTSORMIL broadened its focus to include marketing sorghum and millet as cash crops rather than solely as subsistence crops.

One indicator of this shift in focus is INTSORMIL's poultry project, which started in 2007 in western Africa in the countries of Niger, Mali, Burkina Faso, Senegal and Nigeria.

"The poultry project is more about marketing grain than strictly about the development of new varieties of grains" said Joe Hancock, Ph.D., an animal scientist at Kansas State University. Through this project, INTSORMIL helps to support the poultry market, although the project has also led to the development of some new grain varieties.

Hancock, the poultry project's principal investigator, collaborates with many animal scientists in western Africa, Central America and the U.S. For several years, scientists in these INTSORMIL projects have compared maize (corn) and sorghum as feed grain for broiler chicks.

"Economic development is what it's all about."
– Joe Hancock
Kansas State University

In 2007, 2008 and 2009 nearly 2,000 chicks from farms of all sizes were used in the project.

"We're trying to support anyone with a need for technical help… anyone who will listen," Hancock said. "Typically, somebody with anywhere from 50 to several hundred birds."

The farms are incredibly small by U.S. standards, Hancock said.

"We do interact with some large farms, but our primary target audience would be small grain and poultry producers in underdeveloped regions of the world," he said.

Hancock explained the protocol and results from one recent experiment in the INTSORMIL poultry project. For 42 days, chicks were fed a diet either maize-based or sorghum-based. Then some birds were killed and their carcasses were checked for any differences in weight of intestines, gizzards, liver and fat.

The scientists found that birds fed sorghum had equal or greater growth performance and carcass value compared with those fed maize. This finding improves sorghum's marketability as a feed, which will help sorghum producers.

Commercial poultry facility near Dakar, Senegal.

Photo by Joe Hancock

The team is currently working to promote the results of their experiments to increase the worth of sorghum as feed for poultry.

Through promoting sorghum as a poultry feed, INTSORMIL scientists hope to increase the use of sorghum as a cash crop rather than solely as a subsistence crop in western Africa.

INTSORMIL plant-breeding programs, if successful, will create excess sorghum production for farmers.

Instead of excess sorghum production hitting the market and driving down grain prices, farmers can sell the excess grain into the poultry market as feed, Hancock said, thus creating a demand for the grain as feed while maintaining a stable price for sorghum throughout the crop year.

The team hopes to develop millet into a cash crop as well.

By increasing the value and use of sorghum and millet as cash crops, INTSORMIL will help farmers generate additional household income by selling eggs, poultry meat and other poultry products.

"Economic development is what it's all about," Hancock said.

On the whole, farmers in western Africa have been receptive to the new developments by the poultry project team, Hancock said.

The team hosts seminars for farmers each year to teach the new systems that incorporate sorghum and millet as animal feed.

"We keep the seminars pretty fundamental and basic," Hancock said. "These aren't large U.S. integrated systems; these guys have pretty limited budgets."

The poultry project team itself also works within a tight budget. The western Africa team, comprised of handpicked animal scientists from throughout western Africa, met face to face for the first time during the Regional West Africa INTSORMIL conference in Burkina Faso in May 2010.

Hancock said the meeting "drained our budget for the year, but I think it was a very good investment."

Laying hens used to supply eggs to consumers in Burkina Faso.

Photo by Joe Hancock

The network of scientists has proved to be an efficient use of resources, Hancock said. The scientists communicate with each other through e-mail or Skype, and all produce data in their specific countries.

"We get a huge data set and something truly applicable throughout West Africa," Hancock said.

The network of scientists also helps with getting the science into use on farms because, in countries where they work, the scientists share the data with farmers.

"There still is a fair amount of concern about use of a sorghum-based diet for poultry. This concern results primarily from a lack of information, and we try to address that," Hancock said. "It's like any other outreach activity; you always hope they [the farmers] go home and use the suggestions."

He said the team uses farmers' feedback to make sure its recommendations are working.

Move over wheat; bread has new flour–sorghum

Story by Karoline Kastanek

Bruce Hamaker makes the most of his time—even if that means sitting in an airport for a good long phone chat about the very reason he's in the airport: work. On his way to Mali in late February 2010, Hamaker did just that.

Hamaker, a Ph.D. food science professor at Purdue University and director of the Whistler Center for Carbohydrate Research, studies carbohydrates. In addition, Hamaker serves as one of two coordinators for INTSORMIL's West Africa Regional Program. Hamaker studies bread characteristics and consumption trends in western Africa. Although he claims he is not a prize-winning bread maker, he is perfecting a unique bread recipe—one calling for sorghum flour.

Hamaker's current INTSORMIL research focuses on increasing the almost non-existent demand for western African-grown sorghum. Although sorghum is an easy crop for farmers to grow in western Africa's climate, especially in comparison to wheat, it has a very small market in Africa because of consumer preferences for bread made with wheat flour.

"Our goal is to increase the amount of sorghum flour that can be incorporated into composite breads and associated products, both to increase market opportunities for local sorghum farmers and to reduce need for imported and often high-priced wheat."

– Bruce Hamaker
Purdue University

In his 2009 report for INTSORMIL, Hamaker wrote, "Our goal is to increase the amount of sorghum flour that can be incorporated into composite breads and associated products, both to increase market opportunities for local sorghum farmers and to reduce need for imported and often high-priced wheat."

Accordingly, Hamaker looks for ways to substitute sorghum for wheat in foods like couscous and bread. In Africa, bread made from wheat flour is often expensive because Africa imports most of its wheat, Hamaker said. And farmers in western Africa need a profitable crop that will bump their production up from subsistence farming to allow small farmers access to markets.

Hamaker said he can achieve these goals by creating a sorghum bread that tastes and looks similar to the standard wheat bread that appeals to western Africa consumers.

Taste is on the tongue of the beholder. Today's Africans eat bread, but bread consumption varies by country and region of the continent. For example, urban people have a higher income than rural villagers and can afford to buy bread, which is often costly because of the high price of wheat and the additional cost of importing it.

But bread isn't a traditional food in Africa. Its origins date back to when England and France occupied

In El Salvador, Vilma Calderon, CENTA food technologist, observes a mill grinding sorghum grain into flour.

Photo by E.A. "Short" Heinrichs

Whole sorghum grain (left), coarse and fine sorghum flour (right). *Photo by E.A. "Short" Heinrichs*

colonies on the continent; thus, people in different regions of Africa have different preferences. For example, France occupied Niger, so, the bread served there may resemble a French baguette. In countries formerly occupied by England, the bread may have a fluffy texture and taste much like the bread eaten in England or the United States.

As Hamaker tries to increase the demand for sorghum in Africa, his bread needs to taste, look and feel just like its competitor, wheat bread. Some similarities between sorghum and wheat do exist. For example, Africans have storage problems with flour made from both grains.

"They can't use whole wheat flour because it doesn't have good shelf life in the hot, humid climates of Africa," Hamaker said. Sorghum shares in this problem because much like wheat, it has a bran layer. This hard, nutritional outer layer is usually removed during the milling process.

Sorghum flour and wheat flour differ in their bread-making properties. Wheat bread is often light and airy in texture, a byproduct of gluten protein in wheat flour.

When wheat flour is mixed with yeast and water, the gluten protein in the flour gives the dough a viscoelastic structure or a stretchy composition.

"It is this elastic gluten framework which stretches to contain the expanding leavening gases during rising," Nebraska Extension Food Specialist Julie Albrecht said.

These leavening gases created from combining yeast, flour and water, make small air pockets in wheat bread, giving it a porous look after it is baked.

Instead of gluten, sorghum has weaker analogous proteins that exist in hard, small bodies that make them inaccessible to each other during mixing. When these proteins are

A layer cake made from sorghum flour. *Photo by E.A. "Short" Heinrichs*

Pastries made from sorghum flour.
Photo by E.A. "Short" Heinrichs

mixed in dough with wet yeast, the proteins cannot create a viscoelastic structure stable enough to give the dough stretchiness. Instead, the dough becomes a sticky pile of glop, that when baked, becomes a dense crumbly cake-like substance.

So rather than using 100 percent sorghum flour, Hamaker is working to develop a bread that has as much sorghum flour as possible in a blend of sorghum and wheat flour. When scientists first used conventional sorghum flour, it could comprise only 15 to 20 percent of the flour in the bread; the other the 85 percent of the flour had to be wheat flour to make a good bread indistinguishable from 100 percent wheat bread. Hamaker's research shows the possibility of increasing sorghum flour in this ratio of flours.

Hamaker uses flour made from a variety of sorghum that contains proteins that exist outside the confines of the protein body, making it different than conventional sorghum flour and allowing it to contribute to the dough's viscoelastic structure. Hamaker's recipe uses a 50:50 ratio of the new sorghum flour to wheat flour. He says this ratio could result in a new market for African sorghum farmers.

"Imagine if you could replace half of the wheat flour used to make bread with sorghum flour," Hamaker said.

Then half the cost of bread flour could be returned to African sorghum farmers. According to the U.S. Department of Agriculture's Foreign Agriculture Service, Africa consumed 69,950 metric tons of wheat in 2009. In a large-scale market, Hamaker's small changes to a recipe could mean changes in the varieties of sorghum that farmers plant and big changes in demand for sorghum.

As with most food products, Hamaker's research and development move slowly and there is more research to do.

"Like everything, if you're trying to change a grain or make a hybrid…it takes time," Hamaker said.

In fact, putting sorghum bread onto the market is more complex than marketing most food products. There are more people to train in the process of introducing a new sorghum variety.

"Farmers have to adopt it, and they have to have a good reason to do it," Hamaker said. INTSORMIL scientists must also teach millers how to achieve the texture the new sorghum flour needs for good baking qualities, an effort underway in Central America. And finally, bakers must learn how to develop a quality product using the proper sorghum-to-wheat flour ratio.

Developing a new food product from its most basic level, the seed, is one of the reasons Hamaker says that INTSORMIL's influences on Africa's flour markets in the past 30 years have come slowly.

"But with persistence you see changes," Hamaker said.

When Hamaker joined the INTSORMIL team in 1992, the food laboratories he started working with were supporting only plant-breeding programs. These laboratories conducted tests on varieties of sorghum to examine the fat and protein content, among other properties. Today, these same laboratories are trying to bring the changes of sorghum production and flour processing to farming cooperatives and millers.

Hamaker isn't quite ready to pitch this new sorghum bread to Africa. He is collaborating with the Institut de Technologie Alimentaire in Senegal to do research on improving sorghum and millet processing to expand markets in West Africa. Hamaker and the Institute have plans to do taste tests on new sorghum-wheat breads. If these tests prove that African consumers are willing to buy high-sorghum bread, scientists will start teaching farmers, millers and bakers how to produce and process this new sorghum.

Until then, Hamaker will continue to perfect his sorghum-bread recipe.

Pastries made from sorghum flour.
Photo by E.A. "Short" Heinrichs

Vilma Ruth Calderon (left), a food technologist with CENTA (Centro Nacional de Tecnologia Agropecuaria y Forestal) in El Salvador, and an assistant examine the quality of sorghum flour used as a partial substitute for wheat in bread-baking.

Photo by E.A. "Short" Heinrichs

Sorghum and millet foods

Story by Caroline Brauer

Bruce Hamaker sat at the round table in his office and proudly held out the small bag of proof: couscous, made in Africa from African sorghum.

Hamaker, Ph.D., a food-science professor at Purdue University, studies carbohydrates; as an INTSORMIL scientist, he also studies bread characteristics and consumption trends in western Africa. Hamaker's work, complemented by related INTSORMIL research in Central America and southern Africa, contributes both to the development of more acceptable and healthful foods

"In the rural areas that's (sorghum and millet) their staple food,"
– Bruce Hamaker
Purdue University

and to markets for farmers' grain.

"In the rural areas that's their staple food," he said.

Most sorghum and millet consumption occurs in Africa, India and Asia. Some sorghum is consumed in the United States, but usually as an alternative for people with celiac disease who can't handle wheat and gluten.

Sorghum and millet can be cooked in a variety of ways. One cooking method decorticates (removes the hull) of the grain. Annam, a dish common in India, contains decorticated sorghum and millet that are boiled and served like rice. Cooks may supplement the dish with real rice or beans and add spices or nuts for flavor.

Another cooking method for sorghum results in a snack that closely resembles movie goers' favorite food: popcorn. Making popsorghum involves heating whole sorghum grains until the grains explode in a manner similar to popcorn. According to "Sorghum and Millets in Human Nutrition" by the Food and Agriculture Organization of the United Nations (FAO), popped sorghum is more tender than popped corn, has less outer grain covering or hull, isn't as likely to get stuck in the eater's teeth and is quieter than popcorn to consume.

Popped sorghum even comes in a variety of flavors. Popghum, a company that makes popped sorghum and is based in Arlington, Va., offers nine different flavors including original, caramel and green curry.

However, popped sorghum isn't a staple food that many people in the Eastern Hemisphere rely on. Porridge is. The names for porridge change with each location and the porridge's consistency. Porridge can be thick or thin.

According to Hamaker, Africans tend to prefer thick porridge and often consume it before a long day in the fields. Porridge makes people feel full and gives extended energy release, he said.

"I'm over there, I eat one of those things and I think, goll, it's 7 o'clock and I'm full," he said.

Porridge consumption in the cities is less common than in rural areas. Hamaker said the decrease in

Baker in El Salvador prepares cookies made partially from sorghum flour.
Photo by E.A. "Short" Heinrichs

consumption occurred partly because of the perception of sorghum as a grain for the lower class—a stigma that INTSORMIL is working to eliminate.

In Mali, the efforts to change perception will soon include educational workshops and TV spots. In other areas, the perception-change efforts involve producing a high-quality food product.

Hamaker said he knows that people who are unfamiliar with the situation may think Africans just need food and may consider the focus on quality as a waste of time.

Hamaker, however, said quality is equally as important as quantity.

"The reason you have to care about that is because if you don't care about it, no one's going to buy it," he said.

People everywhere are particular about the food they eat, Hamaker said. Even at the village level, Africans are careful about the consistency of their porridge and the grains that go into it.

Hamaker picked a small bag off the shelf by the table and presented it as an example. The bag of couscous was made in a special processing unit that INTSORMIL helped develop.

INTSORMIL food scientist Dr. Lloyd Rooney takes a drink of atole, a thick beverage made from sorghum.

Photo by E.A. "Short" Heinrichs

Couscous is a popular dish that's often served in the cities and at parties in Africa. It's a precooked, granulated dish made from agglomerated flour. Cooking couscous is time-consuming. Women in Africa often agglomerate (wet the flour so it clumps) and sift the couscous into small pieces by hand. Hamaker said much of the couscous eaten in African countries comes from Algeria, Morocco or France.

To help develop local sources for the food, Hamaker and INTSORMIL helped place about five metric tons of sorghum couscous on the market in various African cities. Then they followed some of the couscous as it was sold and surveyed the buyers.

"People were surprised," Hamaker said. "They couldn't believe it was made from sorghum."

Another INTSORMIL scientist, David Jackson, Ph.D., at the University of Nebraska-Lincoln, also works with sorghum foods in Africa. He operates an educational-assistance program for entrepreneurs in eastern Africa. The program focuses on training

Two young girls in El Salvador serve atole.

Photo by INTSORMIL

Popped sorghum.
Photo by E.A. "Short" Heinrichs

participants in running a sorghum-based business, processing methods for sorghum and personal follow-up meetings at the entrepreneurs' places of work.

Hamaker isn't the only INTSORMIL scientist exploring and advocating the benefits of baked goods made from sorghum flour. In southern Africa and Central America, consumers, food processors and farmers benefit from the work of a team led by Lloyd Rooney, Ph.D., a food-science professor at Texas A&M University.

In a 2009 INTSORMIL report, Rooney described the health benefits of foods made with specially developed sorghums. These sorghums, for example, "are quite high in anti-inflammatory compounds" and have "high antioxidant levels." Rooney wrote, "Our research on these special sorghums has stimulated many major research institutions around the world to initiate research on sorghum as a health food."

Rooney also reported, "Large bakeries as well as small ones are utilizing sorghum composite flours for baked products." Bakers' continued use of sorghum flour means that farmers who grow high-quality sorghum will have a market for their grain.

A woman in El Salvador pulls fresh, sorghum flour made bread from an oven.

Photo by E.A. "Short" Heinrichs

Ohio State's INTSORMIL research

Story by Karoline Kastanek

Sorghum has the potential to improve food security and incomes in southern Africa.

In this region, farmers grow sorghum as a famine-reserve crop—that is, as a backup in case their other crops fail to produce.

A marketing and agricultural economics Ph.D. duo at The Ohio State University are working both in the U.S. and in southern Africa to make sorghum a more commercially important crop instead of a subsistence or backup crop. Mark Erbaugh and Donald Larson serve as the principal investigators for INTSORMIL's sorghum-market development project in Tanzania and Zambia. Erbaugh and Larson recall joining the INTSORMIL team four or five years ago as the only economists working with the program in southern Africa. Their primary study: value-supply chain analysis.

Value-supply chain analysis at a glance

A value-supply chain includes numerous variables – everything between the farmer planting and harvesting sorghum to the consumer buying and eating food products containing sorghum. Erbaugh and Larson analyze value-supply chains of sorghum in both new and emerging markets. And that task becomes even more challenging when they try to build a completely new value chain.

Because the value-supply chain involves so many variables, economists must break it down into small segments—or chainlinks—for analysis.

One of the first steps these INTSORMIL scientists take to analyze sorghum value-supply chains is to gather information.

Left to right: Dr. Mark Erbaugh, Dr. Donald Larson and Bernadette Chimai review Chimai's research in the clear-beer study.

Photo by Karoline Kastanek

"Social scientists need to see the numbers," Erbaugh said.

Tanzania and Zambia have very few records of sorghum varieties planted, on-farm crop yields and prices that buyers are willing to pay for sorghum. Without records, the INTSORMIL economists face a huge problem in analyzing sorghum markets.

Erbaugh and Larson also ask why people in Tanzania and Zambia don't already eat more sorghum. So far, these economists have learned from survey responses that African consumer behavior and attitudes toward sorghum and sorghum food products are among the main hindrances impeding demand for sorghum. Erbaugh and Larson said that African consumers tend to associate sorghum with a lower income and with villagers who live in poverty. As consumers' income increases, their demand for a variety of foods high in protein—such as meat or poultry—also rises, replacing other foods in the diet.

Negative consumer attitudes toward sorghum make the task of building new value-supply chains challenging for Larson and Erbaugh. They must look for ways that sorghum can be integrated into existing markets, such as the beer market, and find ways to create new markets.

Farmers in need of connection

At the same time that Larson and Erbaugh analyze consumer trends and demands, they also study the supply on the producer end of the value chain. It is important for them to understand why farmers raise sorghum as a subsistence or backup crop instead of as a cash crop.

The problem is complex. New improved varieties of sorghum seed are more expensive than seeds from older varieties of local sorghum. One comment from government officials that irritates Erbaugh most is, "Technology's on the shelf; all we have to do is move it out." Erbaugh responds to that statement: "Much of the seed developed in Africa doesn't

make it off the shelf." Most farmers realize there is no profitability in sorghum production, especially compared to maize (corn), which is subsidized by the governments of both Tanzania and Zambia.

"If farmers don't see a demand for their crop, they aren't going to pay extra money for better varieties of sorghum," Larson said.

Even if farmers in southern Africa eventually do see increased demand for sorghum, they still may not have the collateral or the capital necessary to help them get a bank loan to buy the newly developed seed. In contrast, farmers in developed countries who own the ground they farm often use that land as a source of collateral to receive bank loans. In Tanzania and Zambia, the governments or local tribes own most of the land.

Like improved seed, fertilizer is also expensive for farmers. According to INTSORMIL's 2008 Annual Report, none of the 2006 sorghum crop in Zambia had synthetic fertilizer applied to it. The difference between the constraints on using fertilizer and those on buying the best seed is that farmers in southern Africa have found ways to grow sorghum – often poor quality sorghum – without expensive synthetic fertilizers.

Another major problem on the producer end of the value-supply chain is the absence of market linkages – connections or relationships between farmers and processors. With few records of the price and few records of crop yield, it is hard to connect farmers with markets. So Larson and Erbaugh are collaborating with INTSORMIL scientists in Zambia and Tanzania to obtain prices and yields.

In comparison, the U.S. has accurate records, thanks to federal and state governments and farmer organizations.

Although the production side of the value-supply chain seems problematic in southern Africa, Erbaugh and Larson are optimistic. The future holds many opportunities. Larson says, for example, that if African farmers can arrange contracts with grain processors before planting the sorghum, they may be able to use those contracts as leverage for loans to buy fertilizers and new varieties of seed.

Before Erbaugh and Larson can get to this point, however, they have a lot of data to collect. So they keep analyzing all factors across the spectrum of the value-supply chain—from seed sources and costs, to sorghum yields to trends in consumer preference.

Examples of clear-beer made from sorghum.

Photo by Karoline Kastanek

Sorghum clear-beer in Zambia

Story by Karoline Kastanek

When Bernadette Chimai started college at the University of Zambia, she never would have guessed she would be where she is today.

Chimai is now an agricultural economics graduate student.

"I became curious. How could economics and agriculture work together?" said Chimai as she recalled switching her undergraduate major.

Initially, Chimai wanted to study in the field of medicine. Eventually, as she worked her way through her last years of college, Chimai found herself on the path of agriculture, one of the primary reasons why she is now involved with INTSORMIL.

Chimai spent the 2009-2010 school year working directly with Mark Erbaugh, Ph.D., and Donald Larson, Ph.D., at The Ohio State University. Chimai analyzed the sorghum clear-beer value chain in Zambia to see how consumers respond to sorghum.

"People see sorghum as a food for poor villagers," Chimai said.

Zambian people, especially urban dwellers and even the government, see maize (corn) and wheat as more prestigious foods than sorghum. The major problem with this view is that maize and wheat are not easily grown in drought-prone areas of Zambia. The Zambian government favors maize so much that it subsidizes maize farmers, so they can afford to grow maize in their fields.

Farmers often grow sorghum for personal use, mixed in with food made from maize and in home-brewed traditional beer.

This home-brewed sorghum beer is typically unfiltered and very cloudy. Even most sorghum beer sold on the market has sorghum sediments in it. This sorghum beer is usually sold in cartons and has a cloudy appearance.

In contrast, commercially made sorghum clear-beer, like that made by Zambian Breweries, has been filtered for a clear look, and it is sold in, as Chimai says, "a pretty bottle," meaning it stands out at the market next to its cloudy sorghum-beer competitors.

Chimai says the sorghum clear-beer is priced reasonably so that almost anyone can afford to drink it. The Zambian government has even lowered the tax on sorghum clear-beer to make it even more affordable and more popular, thus increasing the demand for sorghum.

The increased demand for sorghum now means that Chimai, Erbaugh and Larson must look for ways to strengthen the relationship between farmers and sorghum millers. The three economists hope eventually to create a more stable flow of sorghum from farmers to millers and then to breweries. Much like fine wine, this value-supply chain will take time to mature.

SABMiller Nile Breweries, located in Uganda, is where clear sorghum lager beer started. The famous Eagle Lager is also brewed in Zambia, Tanzania and Zimbabwe.

Photo by JRN Taylor, University of Pretoria

Top: Employees of Lusaka National Breweries package Chibuku beer.

Right: Shake Shake Sorghum Beer is popular in Zambia.

Photos by INTSORMIL

Technology adoption study

Story by Kate Veik

Science does no good sitting on the shelf.

That is why INTSORMIL has begun to focus on disseminating new technologies and developments to farmers. A recent study evaluated the adoption of INTSORMIL science by farmers in Zambia.

Two economists at the University of Zambia, Gelson Tembo, Ph.D., and Priscilla Hamukwala, collaborated with two INTSORMIL principal investigators at The Ohio State University to study 270 smallholder farms with an average size of about 2.9 hectares (about seven acres).

In the study, the economists considered socioeconomic factors that they believed might influence a farmer's decision to adopt technology developed by INTSORMIL research. These socioeconomic factors included farm size, off-farm income, education levels within the household, the farmer's marital status, and access to financial information, such as loans and credit, and to extension information, such as training workshops.

To determine whether a farm family was fully traditional or fully modern, the study also looked at indicators of wealth such as accessibility to roads and storage sheds and materials the farmers' homes were made of.

Tembo, Hamukwala and their team kept all these factors in mind while they surveyed and observed farming practices of Zambian farmers to determine what factors influenced them to adopt or not to adopt farming techniques recommended by INTSORMIL.

Some examples: To do field work such as plowing and planting, INTSORMIL scientists recommend the use of draught animals, like oxen. To increase yields of sorghum and millet, INTSORMIL scientists recommend high-yielding grain varieties and some form of fertilization, with either organic or inorganic fertilizer. To conserve water for crops, INTSORMIL scientists recommend conservation-tillage techniques, including planting basins to regulate the flow of water, and zero tillage—a farming practice that doesn't disturb the soil where crops are planted.

Tembo and Hamukwala found that 30 percent of the participating farmers used animal draught power, 40 percent used improved seed varieties, and 27 percent used conservation tillage.

The economists believe the relatively low adoption rates of these technologies are caused partially by these farmers living in remote areas and having poor access to new

Sorghum farmers in the Singida region of Tanzania with INTSORMIL colleague and student Jeremia Markindara (right).

Photo courtesy of Mark Erbaugh

Zambia Technology Adoption study team: Dr. Medson Chisi (left), Priscilla Hamukawala and Dr. Gelson Tembo, University of Zambia, and Dr. Mark Erbaugh, The Ohio State University.

Photo courtesy of Mark Erbaugh

information and markets.

The economists say another reason for the relatively low adoption rates is that farmers prefer to eat maize (corn) and they consider sorghum and millet to be "poor man's" food.

Donald Larson, Ph.D., a collaborating economist from The Ohio State University, said that, because the Zambian government subsidizes maize production, farmers can buy seed and fertilizer at half of the market price. The subsidies are not available for sorghum, although sorghum is more drought-tolerant and performs better than maize in drier areas.

The economists have contacted the Zambian government to show sorghum's improved performance in drier areas.

"We are trying to point out the distortions created by the maize subsidies," Larson said.

Sample size may also have affected the study's conclusions, Tembo and Hamukwala said.

"The larger the sample, the more reliable the results," Tembo said.

Hamukwala added, "But the results are true of the families" that the study did cover.

With information like that provided in the study, INTSORMIL is broadening its efforts to promote new technologies and to open more markets for sorghum and millet crops in Zambia.

"Marketability is very important because farmers are more willing to adopt new technology and produce more if they have some confidence that a market exists for their products," Larson said.

The study confirmed that adoption of practices recommended by INTSORMIL "was directly related . . . to access to production and market information." The study also found that adoption of these practices "was directly related" to the marital status of the head of household, the education level of males in the household and the number of people living in the household.

Tembo and Hamukwala say they hope their adoption findings will influence policymakers and help improve agriculture in Zambia.

"Doing research is one thing," Hamukwala said. "But getting your findings to be used is another."

Putting new technologies in the hands of farmers is a big challenge to INTSORMIL and one that African governments and nongovernmental organizations could play a key role in achieving.

It's difficult for INTSORMIL and similar programs to develop new technologies and disseminate the information for free because this process is very expensive.

Governments may have resources to help promote the accomplishments of agricultural research, but Tembo said, "Politicians are in one world and researchers in another."

Hamukwala added, "Getting the two worlds to meet takes a lot of advocates."

Collaboration and Training

In the past 30 years, INTSORMIL has collaborated with many so-called "stakeholders" to do research and to move the products of that research into the hands of African and Central American farmers who will benefit from it. In 2010, a USAID officer told INTSORMIL's advisory committee that the agency expects half of the program's work to be in "tech transfer," that is, moving research from INTSORMIL scientists to farmers. The first story in this section describes important elements of INTSORMIL's collaboration with host governments and charitable organizations.

Every INTSORMIL project includes a training component—both for scientists completing their undergraduate and graduate degrees and for short-term training for those already at work in Central America and Africa. Two stories in this section demonstrate the efforts of INTSORMIL scientists in the U.S. to advise and direct promising students from host countries in their academic preparations. In the past 30 years, this effort has received about $28.4 million—about 30 percent of the project's total funding from USAID.

Charles Wortmann, Ph.D., an agronomist at the University of Nebraska-Lincoln said that, although UNL faculty have the responsibility to mentor graduate students, he does his work as a mentor in support of his own "career passion" to address the needs of small farmers in Africa. In an e-mail, Wortmann wrote, "African scientists conducting research to fill important information needs and enabling delivery of the information to farmers in their home countries are essential to addressing these challenges." Wortmann has mentored four INTSORMIL-supported graduate students at UNL and has provided advice to others at universities in Ethiopia and Uganda. He said, "Enabling such scientists to enhance their ability through higher degree education and collaboration in research are important activities of INTSORMIL."

The fourth story in this section describes the work of INTSORMIL scientists in diverse but related fields at Purdue University, including efforts to create food that "people want to eat," to quote Purdue's Bruce Hamaker, Ph.D., at the 2010 West Africa scientific meeting. In an important way, this final story summarizes the program's efforts to improve food security and, in the words of USAID's "Feed the Future" campaign, "to build a foundation for investments in health, education and economic growth."

– By Carolyn Johnsen

Nicaraguan sorghum breeders Nury Gutierrez (left) and Rafael Obando in a breeding study supported by INTSORMIL

Photo by E.A. "Short" Heinrichs

Collaboration

Story by Jenna Gibson

INTSORMIL helps to develop and release new varieties of sorghum and millet, to research and apply new methods of planting and harvesting and to train scientists from around the world. But INTSORMIL can't do all this work alone.

To conduct field research in African and Central American partner countries, INTSORMIL forms ties with researchers and governments in each country. And to get their work into the hands of farmers, researchers sometimes need to turn to non-governmental organizations (NGOs).

Examples of researchers and governments that collaborate with INTSORMIL in African partner countries include the Ethiopian Agricultural Research Institute in Ethiopia, the Institut de l'Environnement et de Recherches Agricoles in Burkina Faso and the Zambia Agriculture Research Institute (ZARI) in Zambia. At ZARI, researchers work with INTSORMIL to develop new varieties of sorghum and millet and provide seeds to local farmers.

Governments form agreements with INTSORMIL that lay out what each organization can contribute to and gain from the collaboration.

With ZARI, for example the agreement includes INTSORMIL support for scientists to get master's or doctoral degrees and for training scientists to use new research technology. INTSORMIL also provides ZARI with resources for research such as computers, plows, threshers, pollination bags and money to restore cold rooms and to buy gasoline.

The collaboration between ZARI and INTSORMIL, which started in 1982, has provided resources for dozens of projects, said Medson Chisi, Ph.D.

"Whatever it takes to get a breeding program going, whatever research going, and (ZARI) cannot find the resources, INTSORMIL provides," said Chisi, a national coordinator with ZARI.

"Working with NGOs is a way that we can get the output from our program out to the field."
– John Yohe, INTSORMIL program director

For any given project, a researcher may receive financial support from both ZARI and INTSORMIL, Chisi said. For example, he said, a scientist wants to do a research project but ZARI doesn't have the money to support the work. So the scientist appeals to INTSORMIL and receives funding to buy research supplies and to train workers to help with the research. The government provides a car for the scientist to get to the field.

Once the researcher has finished the study and created a new crop variety, he or she should be able to hand the work off to another group, usually a private seed company, to generate more improved seed and get the crop to market, Chisi said. In developed countries like the United States, the chain between research and use of a new variety works, Chisi said. But in Zambia and other developing countries, he said, things aren't so clear-cut. Sometimes the companies will not grow additional seed properly or will not work on getting the seed out to farmers.

"So you develop a variety and then what do you do? Do you leave it on the shelf or do you find a way to get it to the user?" Chisi asked.

In the United States, teaching, research and extension – getting new developments to the field and persuading farmers to actually use the new methods – are grouped together in one entity at land-grant universities. But in Africa, many of the government systems are based on European systems—holdovers from colonialism. So in many African countries the research and extension services are separate divisions under a ministry of agriculture.

INTSORMIL's agreements are mostly with the government research divisions, said John Yohe, Ph.D., director of INTSORMIL, headquartered at the University of Nebraska-Lincoln. This arrangement brings a lot of collaboration and progress in research, but leaves a gap in extension.

But agreements with a government's extension division may be ineffective, said John Sanders, Ph.D., an INTSORMIL principal investigator at Purdue University. For example, some international organizations recently worked to bulk up extension services in developing countries, Sanders said. But this effort basically meant hiring more and more people rather than strengthening the divisions' ability to get technology to farmers, he said.

"You ended up with many extension offices which were sort of skeleton agencies. They had people working but they didn't have enough gasoline or anything," Sanders said. "And as a result, when people would come in and try to work through extension agencies, they'd be just like a black hole – money would go in and nothing would come out."

This is where NGOs come in. If extension offices are ineffective at

getting research to farmers, working with effective NGOs can help INTSORMIL scientists accomplish that goal.

INTSORMIL makes agreements with NGOs like CARE, the Bill and Melinda Gates Foundation and Sasakawa Africa Association (SAA) – an organization that works with agriculture in Africa – to bridge the gap between the lab and the field.

"Working with NGOs is a way that we can get the output from our program out to the field," Yohe said.

NGOs can also benefit from this cooperation, said Abou Berthe, the country director for SAA in Mali. For example, INTSORMIL's scientists are more knowledgeable than the average non-profit worker and are more keyed in to new developments in agriculture, Berthe said. Collaborating with these knowledgeable scientists can provide helpful expert insight for the NGO's projects, he said. Berthe added that he wants to see the connections among all parties strengthened.

"Every step of the process we should see how we can develop some partnership between the researchers and other stakeholders," Berthe said.

Those stakeholders can include local farmers' organizations, private-sector seed companies, governments and NGOs.

Any given project could involve cooperation among half a dozen different entities in Zambia, Medson Chisi said. But these groups work together smoothly because they all have a job, he said.

"Each one knows what they want for the project," he said. "Each one of the entities has a specific role."

This is true, Sanders said, when INTSORMIL works with the right organizations. INTSORMIL needs to choose groups that are financially stable and can get the job done, he said. And it's important to work with organizations that understand agriculture so researchers don't have to waste time arguing about the technical side of the research, he said.

F.P. Muuka, a pearl millet breeder with ZARI, said the link between development and implementation of a new technology is like a chain, which is only as strong as its weakest link.

But when stakeholders collaborate effectively, their efforts can bring research results into the field for farmers to use.

Dr. John Sanders, Purdue ag economist (right with tan cap), and Bahiru Duguma, USAID/Washington (next to tree) and two Malian scientists (rear) discussing plans for the pearl millet production-marketing project with farmers and collaborating NGO representatives in a village in northern Mali.

Photo by E.A. "Short" Heinrichs

"Every step of the process we should see how we can develop some partnership between the researchers and other stakeholders."
– Abou Berthe of Sasakawa Africa Association

Mentorships fulfill INTSORMIL goals

Story by Jamie Klein

May in Burkina Faso can mean scorching temperatures all day, where relief comes in the evening when it cools only to about 90 degrees. While seated outside the restaurant Chez Simon in Ouagadougou in May, 2010, several U.S. INTSORMIL scientists and staff ordered dinner and started the jet-lag-recovery process. The INTSORMIL West Africa meeting would begin the following morning.

As the food started to arrive, so did many collaborators from countries throughout western Africa. Most U.S. scientists rose to greet the newcomers.

"How are you?"

"How's your family?"

"It's good to see you."

Smiles passed all around, and old friends exchanged many hugs and handshakes.

Research is a vital component of INTSORMIL, but creating bonds and building relationships is another important aspect of the program. Many relationships start when a U.S. scientist becomes a mentor for a student from a country where INTSORMIL has a presence.

"You can't do science alone. You have to have somebody. You learn by being with the other person."
– Hamé Abdou Kadi Kadi, Nigerian entomologist

INTSORMIL has helped hundreds of young scientists further their education by providing full and partial sponsorships for bachelor's, master's and doctorate degrees.

John Yohe, Ph.D., INTSORMIL's program director at the University of Nebraska-Lincoln, said one of INTSORMIL's major accomplishments is the training and continued mentor relationships between U.S. scientists and their students. He said this accomplishment contributes to food security in Africa and Central America.

"The best way to do that, if we want to make a long-term impact, is to be able to train people and mentor people so they have the capacity to solve their own problems," he said.

In more than 30 years, INTSORMIL has trained 1,156 collaborating scientists, which include U.S. students and other students from around the world:

46 bachelor's students
443 master's students
428 Ph.D. students
109 post-doctoral students
130 visiting-scientist programs

Dr. Fredy Kilima (right), INTSORMIL collaborator from Sokoine University of Agriculture, Tanzania with Dr. Mark Erbaugh, The Ohio State University. INTSORMIL provides mentorship and supports academic training at the Sokoine University of Agriculture.

Photo courtesy of Mark Erbaugh

INTSORMIL mentors from left to right: Dr. Brhane Gebrekidan (Virginia Tech, currently in Ethiopia) Dr. Gebisa Ejeta (Purdue University) , Dr. Mitch Tuinstra (Purdue University), Dr. Tesfaye Tesso (Kansas State University) and Taye Tadesse (Ethiopia).

Photo by John Yohe

Most INTSORMIL mentors are U.S. scientists while mentees hail from all over Africa, Central America and the U.S.

For four years, Bonnie Pendleton, Ph.D., an entomology professor at West Texas A&M University in Canyon, Texas, has been a mentor to Hamé Abdou Kadi Kadi, an entomologist with the Institut National de Recherches Agronomiques du Niger (INRAN) in Niger. But the two have known each other far longer.

They met in 1984 at Texas A&M University when Pendleton was a teaching assistant and taught a few of Kadi Kadi's undergraduate classes. Now Pendleton is a principle investigator for INTSORMIL and one of the program's two western Africa coordinators, and Kadi Kadi is a collaborating scientist in Pendleton's research on pests of sorghum and pearl millet.

Kadi Kadi said Pendleton's interactions with him are vital to his research.

"You can't do science alone," Kadi Kadi said. "You have to have somebody. You learn by being with the other person."

Pendelton and Kadi Kadi usually correspond by e-mail, which they find to be the fastest, most reliable way to communicate. For example, Kadi Kadi sends Pendleton first drafts of reports or proposals and asks for her opinion.

F. P. Muuka, a plant breeder with the Zambia Agricultural Research Institute and Medson Chisi, Ph.D., a sorghum breeder with ZARI and director of the Golden Valley Research Station in Zambia, are two former students who maintained relationships with their INTSORMIL mentors for several years after receiving their graduate degrees.

Both Muuka and Chisi said their experiences with their mentors still affect their own professional work.

Chisi's relationship with INTSORMIL began in 1982 when he was the first person in Zambia to undergo training sponsored by INTSORMIL. He worked on his master's under Fred Miller, Ph.D., now retired, at Texas A&M University.

"Naturally I was excited to go to add to the knowledge I had. It was a challenging move," Chisi said. "It was really good to go there. Everything I did there was exciting."

Later, after Chisi finished his

doctorate at Kansas State University, INTSORMIL scientists and staff began a concentrated effort to maintain links with students in their home countries. After Chisi went back to Zambia for two years, he would receive calls or letters from Miller asking how he was doing on his own.

"Whatever resources I needed, (he) assisted and we maintained collaboration," Chisi said.

Chisi said Texas A&M University had a great technical staff; and although Miller had eight or ten other graduate students, he still found time to talk to Chisi.

"He was always open to questions and things like that, but he was not there to spoon-feed me. He wanted you to work independently, but if you got stuck he'd be there," Chisi said.

Because Chisi was fully sponsored by INTSORMIL, he didn't need to do some of the things non-sponsored students did—like teach classes. But Miller thought teaching was an important part of the master's degree experience, so he went to the head of the department and asked for Chisi to be allowed to teach.

"He thought it would be good for me to teach. He called me to his office and said, 'Next Monday this is what I want you to do. It'll be good for you,'" Chisi recalled.

Chisi had never taught a class before, and suddenly he was faced with preparing Agronomy 101 lesson plans and speaking in front of a class full of American college freshman.

F.P. Muuka, who earned a graduate degree with INTSORMIL support, proudly shows a local sorghum variety growing in a test plot at the Golden Valley Research Trust in Zambia.
Photo byKate Veik

Reluctantly, Chisi took the job.

He was apprehensive at first, but at the end of the semester Miller approached him and said he "came up top," Chisi said. "I'm happy he gave me that opportunity. I'm told he'd never done that to an African student. He took a chance and it worked."

When Chisi was leaving A&M, Miller allowed him to select plant materials to take back with him to Zambia and then kept in touch with Chisi, asking how he was fitting in and how the plant material was doing.

"I'm still in the same profession and I love it," Chisi said. "That experience of teaching is coming in handy now."

For example, Chisi organizes programs for ZARI guests intended to educate them about ZARI research.

Muuka also kept in touch with his degree mentor, David Andrews, Ph.D., who was an agronomy professor at the University of Nebraska-Lincoln until his retirement.

John Yohe had visited Zambia and wanted more Zambians to be trained with INTSORMIL. Muuka was one of those selected.

Muuka said he was excited to visit the U.S. because he had studied its geography since his high school years.

"I knew all those states, even the highways. I knew them. I was looking forward to physically being there," Muuka said.

When Muuka landed in Lincoln in January 1987, Andrews was there to greet him—and to take him straight to a store to buy warm clothes.

Muuka worked with Andrews, who asked him to be a team leader of eight or so students in the research lab.


Agronomy master's students from Mali at Kansas State University studying with Profs. Vara Prasad and Scott Staggenborg.
Photo by Vara Prasad

Muuka said after he returned to Zambia in 1989, Andrews would contact him about twice every six months until he retired.

"Our goal is to help people and train people. To help them get a broad view of their research areas and apply technology in their own national program, and to apply what they learn to contribute to solving food-security problems in their countries.

– John Yohe, INTSORMIL program director

"We used to write each other letters," Muuka said.

Many collaborating relationships begin and are fostered by INTSORMIL because educating and training students is part of INTSORMIL's overall strategy. In a proposal submitted to USAID in 2006, the strategy involves "graduate-degree education (which also includes bachelor's degrees), short-term training, and distance education that link researchers, policy makers and development practitioners." The proposal said all projects will have either an education or training component or both. The advanced-degree programs will provide technical expertise required to develop new production packages from the lab or research fields to farmers' fields. The proposal also said training in a range of disciplines is a continuous need.

"Our goal is to help people and train people. To help them get a broad view of their research areas and apply technology in their own national program," Yohe said. "And to apply what they learn to contribute to solving food-security problems in their countries."

Ph.D. student Ostilio Portillo from Honduras (right) with mentor Dr. Bill Rooney, a Texas A&M sorghum breeder.

Photo courtesy of Bill Rooney

INTSORMIL mentorship at UNL

Story by Jenna Gibson

Charles Wortmann sat in his office, bent over a proposal on his desk. Occasionally he paused, staring out the window and thinking, before offering suggestions on how to improve the proposal. His protégé, Ricardo Maria, would nod, scribbling notes in his notebook, occasionally asking for clarification.

Maria is a doctoral student at the University of Nebraska-Lincoln researching how plants absorb nutrients from low-fertility soil. He wants to use this information to help improve agriculture in his native country, Mozambique, where farm soil is often low in nutrients that are necessary for healthy crops.

Wortmann, Ph.D., a UNL professor of agronomy and horticulture and a primary investigator for INTSORMIL, is Maria's adviser for the project. During the 2010 spring semester, the two scientists met once every two weeks or so. Wortmann helped edit the proposal for Maria's thesis and offered suggestions to improve and broaden the project.

Wortmann said he provides more guidance with Maria than he has with some of his more experienced students in the past, but he doesn't mind being more involved to ensure that Maria has a good learning experience.

"I try to have myself and the student's thesis committee very involved," he said. "Some professors really expect their students to do a lot on their own, but I prefer that it's more of the student being a member of a team."

Ricardo Maria has always been interested in farming, a natural choice, since he grew up on a farm in central Mozambique, a country in southern Africa where agriculture is integral to life.

Dr. Charles Wortmann (right) works with graduate student Ricardo Maria.
Photo by Jennifer Seefeld

About 80 percent of Mozambique's people work in agriculture, and 90 percent of those people are family and subsistence farmers, according to a report by the International Institute for Applied Systems Analysis, a non-governmental organization that studies public policy issues worldwide. Maria's family is among that 90 percent of traditional farmers in Mozambique, most of whom are desperately poor, growing enough to feed themselves but not enough to turn a profit.

A big problem in Mozambique is that the government doesn't devote enough time and money to improving the lives of farmers, Maria said. Mozambique has to import food from other countries to support its population, despite the fact that agriculture is so common throughout the country.

From a young age, Maria knew that something had to change.

"I really felt I needed to gain knowledge and skills in order to improve their life," Maria said. "We need to use knowledge and experience and collaborate with international institutions to support those farmers."

This international collaboration would bring in more knowledge from countries with a longer history of agricultural research. Plus, Maria said, international knowledge and involvement could pressure the Mozambique government to focus more energy on agricultural issues.

"As researchers we need to also do advocacy so the government can understand that research is important for growth," he said.

So after completing his undergraduate degree in Mozambique, Maria applied to an intensive English-language program funded by USAID. He couldn't get an education in soil management in Mozambique, so he knew he had to learn English and come to the United States.

In 2001, Maria and nine other students arrived in Lincoln, Neb., for the intensive language program. Maria didn't know a word of English, but he was ready to learn. It was difficult at first, he said, but worth the effort.

Maria met Charles Wortmann while in Lincoln, but didn't get to know him well. A friend told him to keep in touch with Wortmann, Maria said, and luckily he did. The

two later collaborated on a project in Mozambique that went well, and now Wortmann is Maria's adviser.

Wortmann also got his start in agriculture early.

He grew up on a farm in northeast Nebraska, and many of his family members are in the agriculture industry.

"The connection to agriculture and crop production has been there all my life," Wortmann said.

But he wanted to get out and see the world before settling down. So Wortmann applied for jobs outside of his home state and ended up in Tanzania.

"In the interest of doing something different, I tried to apply some agricultural knowledge to a different part of the world," he said.

In Tanzania and Uganda, he studied different areas of agriculture from bean development to dairy production. Wortmann did his first project with INTSORMIL in 2002 focusing on water conservation in Ethiopia and soil fertility in Uganda. His prior work gave him a good background in issues that African farmers have to deal with, something that he uses in his INTSORMIL work.

In the spring of 2010, Maria was still trying to select a topic for his Ph.D. work. He had two options: to explore how plants efficiently get nitrogen from Mozambique's overused soil, or to study nutrients in the soil to determine how sorghum plants will respond to nutrient-management techniques such as adding fertilizer.

One of INTSORMIL's main objectives is to provide higher education for students from partner countries, with the hope that those students will get a quality education and take their knowledge back to their home country.

Maria hopes to do just that.

His work with INTSORMIL follows in the footsteps of his previous work with the Alliance for the Green Revolution in Africa, an organization working to improve the lives of farmers across Africa. Maria had postponed the start of his Ph.D. work in Lincoln so he could spend a year working with the alliance to analyze and start fixing some problems facing farmers in Tanzania. He hopes to take that knowledge and the experiences from his collaboration with Wortmann back to Mozambique to fix some of the big problems with agriculture there, especially nutrient depletion.

Because Mozambique is in the tropics, Maria said, the soil there is low in nitrogen and phosphorus, which are important nutrients for many plants, including sorghum.

"Farmers in Mozambique have been using soil since they learned how to farm, which means they have been depleting the soil since they knew how to farm," Maria said.

"So does that give you something to work with?" Wortmann asked, handing Maria back the draft of his thesis proposal.

"Ok, yeah, I'm going to work on this," Maria answered, packing up his things. "I'm going to spend quite a bit of time on (it) this week."

Maria would take Wortmann's advice, continue revising his thesis proposal and start getting to work both in Nebraska and in Mozambique, hoping to make a difference for farmers in both countries.

The two scientists work well together, Wortmann said, even though he has been a bit more hands-on than with some other students.

"The collaboration has been going quite well," Wortmann said. "I think we click pretty well."

Maria agreed.

"He is knowledgeable about the situation in Africa, the challenges we face," he said. "I'm blessed, I would say. Dr. Wortmann has been very good."

At an INTSORMIL-sponsored workshop in eastern Uganda, Dr. Charles Wortmann (standing, tan cap) addresses challenges of soil-fertility management with local farmers.

Photo courtesy of Charles Wortmann

Purdue's INTSORMIL team

Story by Caroline Brauer

Four Ph.D. professors, three buildings on different parts of campus and one goal: Help the sorghum and millet farmers of Africa and the United States. This is the INTSORMIL team from Purdue University.

Gebisa Ejeta, Bruce Hamaker, John Sanders and Mitchell Tuinstra work in different INTSORMIL disciplines. Ejeta and Tuinstra work in plant-breeding and genetics. Hamaker is a food scientist. Sanders' specialty is marketing economics. Occasionally their research lets these men cross paths and work together, but the real thing that unites them is their commitment to educating students and their desire to help others. Such commitment and service is evident in the work each does with INTSORMIL.

Growing up, Tuinstra, a Michigan native, was always interested in plants. Even his name illustrates that interest: Tuinstra is Dutch for "garden." Tuinstra began working for INTSORMIL while he was a professor at Kansas State University, where he worked on developing markets for sorghum as a poultry feed. In 2007, Tuinstra joined the Purdue faculty.

When he arrived at Purdue, Tuinstra was already familiar with the hallways of the agronomy building because he had earned both his master's and his Ph.D. at Purdue, studying under Peter Goldsbrough and Gebisa Ejeta.

"My office was right down the hall when I was a student," Tuinstra said.

Now Tuinstra focuses on helping students rather than on being a student. He dedicates about a third of his time to classroom teaching and advising of undergrad and graduate students. But Tuinstra does more than just teach and advise students; he builds relationships with them. For example, immediately after his interview for this story he hosted a farewell party for one of his students.

Tuinstra said training students creates one of INTSORMIL's greatest impacts in Africa. While doing graduate work, students develop ties with INTSORMIL scientists in the U.S. Once the students receive their degrees, they continue these collaborations when they go home to Africa and engage in research.

"Once they're there, you've got hands and feet on the ground all year round. They know what their problems are, and they're trying to solve them," Tuinstra said.

Sanders also said training students is a fundamental goal.

"The university is sort of based on training," he said. "So the idea is the outside funding and research we do, we would try and find at some point, ways to bring in students."

Sanders is no stranger to working with students. One of his first teaching jobs was with a master's program for agricultural economics in Brazil.

"I was advising all 15 students in the masters program," Sanders said. He paused, chuckled and said, "That was fun. It was good for my Portuguese."

Sanders started working at Purdue in 1981 and joined INTSORMIL in 1985. Currently, he advises three graduate students: one each from Ivory Coast, Niger and Ecuador. Each student also works for INTSORMIL.

Jeanne Coulibaly, Sanders' student from Ivory Coast, came to Purdue on a Fulbright Scholarship.

"I decided, with my desire to help, I should have some kind of skills in agriculture economics to help our poor farmers," Coulibaly said.

Her Ph.D research focuses on how new sorghum technologies affect women's welfare in Mali.

"It's a massive performance because women are so involved," she said.

Bruce Hamaker also noted the involvement of women in agriculture, although the women he works with in western Africa focus on producing sorghum and millet foods rather than on planting or breeding.

With INTSORMIL, Hamaker developed a processing center in Niger. Ten different groups of women have assigned times when they use the center's equipment to make sorghum and millet food products, like flour, semolina, grits and couscous. Then,

Fatimata Cisse, food processing graduate student from Mali working with Dr. Bruce Hamaker.

Photo byBruce Hamaker

In Niger, Dr. Issoufou Kapran (right) shows his new sorghum hybrids to Dr. John Sanders of Purdue University. Kapran is a sorghum breeder who did his INTSORMIL-supported graduate work at Purdue.
Photo courtesy of John Sanders

every Saturday morning, the groups divide the products and sell them.

Hamaker joined INTSORMIL in 1992. He said the biggest change he's seen within the program is a conceptual change. INTSORMIL once focused primarily on how to produce more food.

"That's certainly an important consideration," Hamaker said. "It still is today, but you also have to look at what drives food production and where it goes, and that concept now is very much into our overall goals."

More Africans are moving into cities, where they tend to stop eating sorghum because urban dwellers consider sorghum as a grain for the lower class, Hamaker said. As a result, INTSORMIL and Hamaker work to develop high-quality sorghum and millet foods that defy the lower-class label. He said the primary goal of his work is to introduce relevant technologies.

"I don't know anybody that is, like, trying to put a square peg into a round hole purposefully," he said. He tells a story to illustrate his point.

When Hamaker went to Niger in 1992, he encountered an analytical lab where people worked to test proteins and various characteristics of grains.

"That was the most dejected group of people," he said. "They didn't have anything that they could make happen."

Hamaker's encounter with the lab inspired him and one of his graduate students to develop the processing lab with INTSORMIL's help. The processing lab changed the Africans' attitudes almost immediately, Hamaker said.

"Those people, all of a sudden in the institute, saw they could do something and have an impact on their own," he said.

Besides developing the processing center, Hamaker has also helped develop a marketable form of high-quality, packaged couscous made from sorghum. He's also worked with a graduate student, Moustapha Moussa, to develop an instant sorghum flour that consumers in each of four testing sites preferred when the flour was made into porridge, a staple in African diets.

Hamaker is not the only Purdue INTSORMIL scientist to find success. Gebisa Ejeta won the 2009 World Food Prize. In 2007, Mitch Tuinstra teamed up with DuPont to develop a sorghum variety that can handle being treated with a herbicide that helps control a weed called *Striga*. DuPont is now looking to hire people in Nigeria to help to commercialize the variety.

"They're hiring western Africans in westerm Africa," Tuinstra said. "They're investing in the continent in a way they haven't before, and that's purely a product of INTSORMIL engaging with large, multinational ag industries."

John Sanders has a similar success story. Before he and INTSORMIL introduced "bache" (tarps) for African farmers to thresh their grains on, the grain that farmers were selling included up to 13 percent dirt, gravel and other impurities. Now Sanders is helping farmers who sell cleaner grain to get price premiums from food processors.

"You know," Hamaker said, "we just hope we can contribute something."

"It's about the people we train," Tuinstra said. "They come here; in many cases they speak terrible English. They learn English; they learn science; they learn how to do science; we become colleagues, and then they go home and we can support them and they can have an impact on the ground solving their own problems. We develop technologies but we also develop institutions, and that's very, very important in my opinion."

Everyone attending the West Africa meeting in Ouagadougou, Burkina Faso, in May 2010, gathered for this group shot.

Photo courtesy of Carolyn Johnsen

A *special thanks...*

•to the busy staff at the INTSORMIL office at UNL for all your efforts on behalf of our work on this report—for checking our work for accuracy and for tracking down facts we needed, including numbers, dates, names and information about photographs and photographs themselves;

•to the INTSORMIL scientists who answered our e-mail queries, reviewed stories for accuracy, provided photographs and took time for interviews;

•to scientists and other staff members who looked after us in Africa and gave us such important insight into the nature of farming and of INTSORMIL's work there; and

•to USAID for providing the funding that made this report possible.

--the INTSORMIL reporting & design team
University of Nebraska-Lincoln
College of Journalism and Mass Communications

Credits

Reporter Caroline Brauer traveled to Purdue University to complete her work for this project. An agricultural journalism major, Brauer will graduate from UNL in December 2011 with focuses in news-editorial and public relations. In 2010, Brauer served as the agricultural reporter on a team of students developing an in-depth report on Bolivia. Brauer interned with the Nebraska Wheat Growers Association in the summer of 2009 and the Nebraska Wheat Board from the fall of 2009 through the winter of 2010. In January 2011, Brauer began working for the Nebraska Wheat Board full time.

Reporter Alia Conley, a journalism and Spanish major who will graduate from UNL in May 2012, traveled to Texas A&M University for this project. For the summer of 2011, Conley is a city-desk intern at the Philadelphia Inquirer. She has also worked as a features reporter for the Omaha World-Herald and on the city desk for the San Antonio Express-News. Originally from Omaha, Conley enjoys "the good life" but loves to explore other cities. For the Spring 2011 semester, she studied in Salamanca, Spain, where she saw a bullfight, ate Spanish tortilla every day and learned the "real" language with the locals.

For this project, reporter Jenna Gibson traveled to Zambia, Ethiopia and Burkina Faso to learn more about INTSORMIL's work with agriculture around the world. Majoring in news-editorial journalism, French and international studies, Gibson graduated from UNL in May 2011. Gibson worked for UNL's student newspaper, the Daily Nebraskan, throughout her time at the school and was the paper's editor-in-chief during her senior year. In 2011-2012, Gibson will teach English in South Korea as a Fulbright Scholar.

Marilyn Hahn is a communications specialist in the UNL College of Journalism and Mass Communications (CoJMC). She is the recipient of Poynter Institute paid fellowships in print, Internet and multimedia and served on the university's Web development committee. She has contributed to numerous depth-reporting projects at the college, including layout and design, editing, toning and final production.

Managing editor Carolyn Johnsen helped develop the concept and write the grant that funded this project; see the introduction for more on her role. She has been a lecturer in UNL's CoJMC, where she taught science writing, beginning reporting and depth reporting. Johnsen, who will retire in 2011, finished her UNL career as an assistant professor of practice in the Institute of Agriculture and Natural Resources. For the Nebraska Public Radio Network, Johnsen reported on issues related to agriculture and the environment. She edited "Taking Science to the People: A Communications Primer for Scientists and Engineers," NU Press, 2010.

Reporter Karoline Kastanek traveled to The Ohio State University for this project. She graduated from UNL in December 2010 with a Bachelor of Science in agricultural economics and agricultural journalism and a minor in international agriculture and natural resources. Kastanek currently works for John Deere as a marketing representative in Lenexa, Kan. While at UNL, Kastanek was a communications intern for U.S. Wheat Associates and a public relations and advertising intern for John Deere. She also worked for the Nebraska Tractor Test Laboratory and was active in UNL's National Agri-Marketing Association Student Organization.

Reporter Jamie Klein traveled to West Texas A&M University and to Zambia, Ethiopia and Burkina Faso for this project. A news-editorial major, she received a bachelor's in journalism from UNL in May 2011. In college, she was active in the Daily Nebraskan, Nebraska Press Women and Multicultural Students in Media and interned for the Papillion (Neb.) Times Weekly, San Antonio Express-News, Omaha World-Herald and the Arkansas Democrat-Gazette. After graduating, Klein landed a summer internship with the St. Petersburg (Fla.) Times in its New Port Richey bureau.

Rob McLean was a graduate assistant who aided in the early planning and completion of this report and made many of the arrangements for student travel to INTSORMIL universities and Africa. He graduated from the University of Nebraska-Lincoln in 2010 with a master's in journalism. Previously, he earned his bachelor's in English from Creighton University. McLean has contributed to The Reader alternative weekly in Omaha, Neb., and now works as the local editor for Maryland Heights Patch (http://marylandheights.patch.com). He lives in suburban St. Louis, Mo.

Graphic designer Jennifer Seefeld, a graduate assistant, was in charge of all the graphic and layout design for the report. Upon receiving her masters' in advertising from UNL's CoJMC in August 2011, Seefeld plans to continue working in graphic design. She currently holds a graphic-design position with Alpha Dog Marketing. Previously she earned her bachelor's in business administration with minors in photography, communication and sociology from UNL. In her spare time, Seefeld enjoys shooting photography for her personal business, Studio J Photo & Design (http://www.studiojphotodesign.com). She also enjoys traveling and recently took a three-month backpacking trip through western Europe.

Amy Struthers helped develop the concept and write the grant that funded this project. She then served as project marketing-communications manager, working with senior and graduate advertising and public relations students to develop creative and innovative plans for sharing INTSORMIL's message. Struthers is an associate professor and sequence head of Advertising and Public Relations in the UNL CoJMC. She teaches promotional strategy, copywriting and integrated marketing-communication campaigns. Struthers' research interests focus on effective communication strategies to teens about science and public-health issues.

Photographer and reporter Kate Veik traveled to Kansas State University, Zambia, Ethiopia and Burkina Faso to complete her work for this project. In May 2011, Veik received a bachelor's in journalism from UNL, where she had participated in depth-reporting teams exploring poverty in Kosovo, xenophobia in South Africa and lithium prospects in Bolivia. Veik now has an internship as a reporter for Catholic News Agency.

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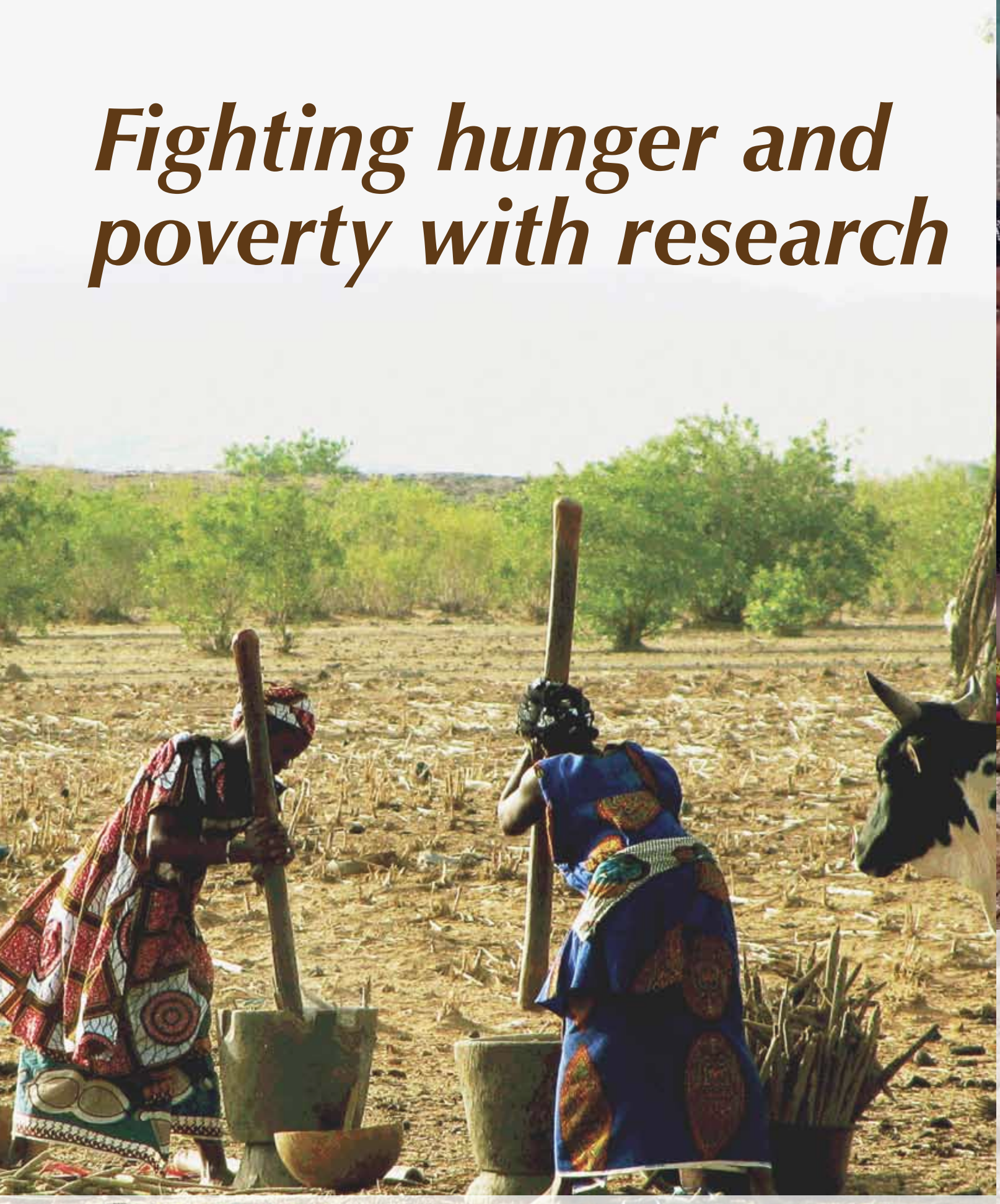

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