

Feed the Future Innovation Lab for Collaborative Research on Sorghum and Millet

Annual Performance Report FY2015



October 1, 2014 – September 30, 2015

Feed the Future Innovation Lab for Collaborative Research on Sorghum and Millet Annual Performance Report FY 2015

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Cover photo:

Millet for sale on a street market in Niamey, Niger, in March 2015.

Photo credit: Kira Everhart-Valentin.

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Executive summary

The Feed the Future Innovation Lab completed its second full year of activities in at the end of FY 2015 and the second season of field experimentation is now underway. This year can be characterized as a year of activity development and project consolidation after the successful start-up of the program. In Ethiopia, field trials are taking place to characterize biotic, abiotic and grain quality traits of over 2,100 varieties of Ethiopian sorghum in one of the most ambitious multi-localational trials in Ethiopian sorghum breeding. In West Africa, collaborators across the West African Sahel have assembled a smaller panel representative of the diversity of sorghum ranging from Senegal to Niger and includes materials from Senegal, Niger, Togo, Mali, and Nigeria. Both efforts are essential components in the program's strategy to develop national capacity to participate in cutting edge breeding techniques that will lead to genomics-enabled breeding capabilities and increased supply of high quality and nutritious sorghum adapted to the food, feed, fodder and multipurpose needs of farmers, processors and consumers in our host nations and beyond.

A new project was initiated on breeding pearl millet varieties for dual food and feed purposes with a special emphasis on improving forage quality. This project is led by a consortium of West African pearl millet breeders and directed out of the Burkina Faso national program. This project will be complemented with collaboration from a newly-hired pearl millet breeder at Kansas State University who will continue to build upon the university's global reputation in modern pearl millet breeding. Pearl millet management projects focusing on the control of the Millet Head Miner through IPM and improved stand establishment through the use of seed balls will complement genetic enhancement research. The IPM project is working towards wide-spread scale up while the seed ball project is entering in broad field-scale evaluation and refinement prior to extension.

Stimulating demand for sorghum and millet through value-added food product development is accelerating in West Africa and Ethiopia. In Ethiopia, novel parents with improved food quality attributes are being tested for adaptation and application for food processing needs such as *injera* against existing varieties found in-country. In addition, several sensory evaluation procedures were developed to systematically evaluate food quality hedonic attributes and the impact of food processing technologies on quality. In West Africa, the program continues to build upon INTSORMIL investments and expand collaborative activities with industry and other research and development programs. Initial activities have focused on developing extruded products to complement existing agglomerated foods and composite flours. This activity has been regarded as highly successful and has generated additional investment by the Nigerien government in the construction of a new food product incubation center at the national program in Niamey.

Long- and short-term training has accelerated. Twenty-three individuals are registered for advanced degrees surpassing 2015 targets. Forty-seven short-term trainings took place that impacted over 3,000 trainees. Fourteen technologies or technology components were advanced this year. The program continues to contribute to development of the Ethiopian agricultural policy and the Agricultural Growth Program II. Fifty-nine percent of our research and training budget is allocated to national programs, or students from national programs, and 34% to U.S. institutions. We still hold nearly 7% of our research and training budget in reserve for new activities in FY 2016 and beyond.

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Management entity information

The core management entity that was established in the Lab's first year has stayed consistent through FY 2015, and includes the following individuals:

- 1) Timothy J. Dalton – *Director*
- 2) Nathanael Bascom – *Assistant director*
- 3) Kira Everhart-Valentin – *Program coordinator*
- 4) Kristen Sanborn – *Business financial specialist*

The team continues to experience a strong working relationship, with organizational responsibilities well-defined and shared across the team members based on skill sets and interests.

In addition to the core management team, two student workers were also hired to support the Lab's mission, particularly in the area of communications and contact management. These individuals are:

- 1) Shelby Mettlen – *Communications assistant*
- 2) Shawn Wittkopf – *Information systems intern*

Mettlen's role has largely been comprised of communications-related responsibilities such as publication design, website updates, success story and e-blast writing, and social media updates. Wittkopf has focused his energies on the development of a 1,200+ person database of a variety of important actors in the sorghum research and development communities.

Additionally, the Lab recently welcomed Ph.D. student Tebila Nakelse to the team. Nakelse is originally from Burkina Faso, where he served as a research assistant in impact assistant with AfricaRice. While at Kansas State University as a part of the Lab's activities, he will be following a program of study in agricultural economics, and contribute to the Lab's mission by working on cereals policy research in West Africa.

Also hired on by the university as part of the Lab's activities was a pearl millet breeder. Dr. Desalegn Serba is based at the Western Kansas Agricultural Research Center in Hays, Kansas, and will revive a pearl millet breeding program first started at the university in the 1970s and continued into the late 1990s. Dr. Serba will focus on a variety of breeding priorities, including the development of stress-resistant varieties, improving agronomic characteristics and improving grain micronutrient densities and forage digestibility. Dr. Serba's program will be integrated into the West Africa pearl millet breeding program. Dr. Serba was hired as a result of Kansas State University's cost share commitment.

External Advisory Board information

Since the Sorghum and Millet Innovation Lab's inception, the External Advisory Board (EAB) has played a key role in ensuring that the Lab's research and management practices are both high-quality as well as relevant. The EAB members have remained consistent throughout FY15, and include:

- 1) Dr. Brhane Gebrekidan - *Ethiopian Academy of Sciences*
- 2) Prof. Bettina Haussmann - *University of Hohenheim, also serving as West Africa Liaison Scientist for the McKnight Foundation and Capacity Development Manager at the KWS SAAT SE*
- 3) Dr. Tim Lust - *Chief Executive Officer of the National Sorghum Producers*
- 4) Dr. Peter Matlon - *Adjunct Professor at Cornell University*
- 5) Prof. Barbara Stoecker - *Regents Professor and Marilyn Thomas Chair at Oklahoma State University*

All EAB members were present for an annual two-day meeting in December 2014 in Manhattan, KS. Also participating in that meeting were the management entity staff and USAID representative Angela Records. Over the two days,

participants discussed research project progress, reviewed management entity performance and goals, and explored future directions and priorities for the Lab.

The EAB also supported the Lab during FY 2015 by participating in the annual in-country review meetings as well as offering guidance and insight in project development. Brhane Gebrekidan was present for the Ethiopian meeting and was an active part of the trait development discussions among research teams. Bettina Haussmann attended the West Africa meetings and offered a variety of suggestions to the teams during the project review process. She also worked one-on-one with the Lab's newest project team (dual-purpose pearl millet development) to strengthen their research plan and improve how it fits into the broader context.

Focus countries

The Sorghum and Millet Innovation Lab has continued to work primarily in its focus countries – Ethiopia, Senegal and Niger. However, with the addition of the new pearl millet project, work has officially extended to include the West African countries of Mali and Burkina Faso.

Ethiopia

The Lab's overall approach to activities in Ethiopia has been defined by coordination with broader national goals in the sorghum sector and agricultural development spheres. There are a number of efforts currently underway in Ethiopia, including activities funded by the Bill and Melinda Gates Foundation as well as the definition and roll out of a new Agricultural Growth Plan (AGP-II) at the national level. The Lab has been an active participant in discussions and planning for AGP-II and has been proactive in coordinating its own activities with its strategic goals. In addition, the Lab has been exploring avenues to facilitate U.S-Ethiopia linkages in private industry around the area of food processing. One example of this has been relationships established between Addis Ababa-based injera production company EthioGreen (www.ethiogreen.com) and western Kansas-based sorghum processing facility, Nu Life Market (www.nulifemarket.com).

Senegal

Work in all three focus areas has been moving forward with particular success in Senegal. Field trials and associated research with the Senegalese Institute for Agricultural Research (ISRA) continue and food product development with the Food Technology Institute (ITA) continues to show progress and expansion into extruded products. There has been an additional focus on institutional capacity building at the Centre d'Etudes Régional pour l'Amélioration de l'Adaptation à la Sécheresse (CERAAS) through the identification of capacity gaps, short- and long-term training to fill those gaps and specialized equipment.

Niger

The Lab's work in Niger continues to have a particularly strong focus on private sector involvement. Through the support of incubation centers in the area of food processing, the Lab has enhanced a wider effort to explore the opportunities of food product development. The successes achieved by researchers in this area were accentuated by the Nigerien government's decision to support the construction of a new food processing center at the Institut National de la Recherche Agronomique du Niger (INRAN). The center will serve as a headquarters for the development of new food processing methods, technologies and products.

In addition, the Lab's genetic enhancement activities in West Africa continue to contribute to a regional genomics-enabled breeding strategy. In working with colleagues in Niger, Senegal, Mali, Burkina Faso and beyond, researchers are accessing genetic material and records that are building this truly international effort.

Mali and Burkina Faso

While efforts in the area of developing a regional West African genomics-enabled breeding strategy have already resulted in some research activities taking place in Mali and Burkina Faso, the two countries were officially added to the list of the Lab's activities with the contracting of the most recent project focused on dual-purpose pearl millet

development. Due to a variety of regional similarities and cross-connections, these two countries fit naturally into the Lab's portfolio and their addition will contribute to the cohesion of the Lab's research strategy in the region.

List of program partners

United States

Integrated Pest Management Innovation Lab
Kansas State University
Kansas State University – Western Kansas Agricultural Research Center, Hays
Purdue University
Texas A&M AgriLife Research
Texas A&M University
USDA-ARS
Virginia Tech University
West Texas A&M University

Ethiopia

Ethiopian Institute of Agricultural Research
Asosa Research Center
Bako Research Center
Melkassa Research Center
Pawe Research Center
Sirinka Research Center
Haramaya University
Hawassa University
Hollela Biotechnology Center
Oromia Regional Program
Tigray Agricultural Research Institute
Tigray Regional Program

Senegal

Centre d'Etudes Régional pour l'Amélioration de l'Adaptation à la Sécheresse
Centre National de Recherche Agronomique
FAPAL (farmer organization)
Institut Sénégalais de Recherches Agricoles
Institut de Technologie Alimentaire
University Cheikh Anta Diop de Dakar

Niger

Fuma Gaskiya (farmer organization)
HALAL (farmer organization)
Institut National de la Recherche Agronomique du Niger
International Crops Research Institute for the Semi-Arid Tropics
LSDS (farmer organization)
University of Maradi

Mali

Institut d'Economie Rurale

Burkina Faso

Institut de l'Environnement et de Recherches Agricoles

Germany

University of Hohenheim

France

Centre de Coopération Internationale en Recherche Agronomique pour le Développement

Republic of South Africa

University of Pretoria

Acronyms

AGP	Agricultural Growth Program
AOR	Agreement Officer Representative
ARS	Agricultural Research Service
ATA	Agricultural Transformation Agency
BMR	Brown Midrib
CC	Country Coordinators
CCRP	Collaborative Crop Research Program
CERAAS	Centre d'Etude Régional pour l'Amélioration de l'Adaptation à la Sécheresse
CGIAR	Consultative Group on International Agricultural Research
CIRAD	Centre de Coopération Internationale en Recherche Agronomique pour le Développement
CNRA	Centre National de Recherche Agronomique
CORAF/WECARD	West and Central African Council for Agricultural Research and Development
CRP	CGIAR Research Program
CRSP	Collaborative Research Support Program
EAAP	Ethiopian Association of Agricultural Professionals
EAB	External Advisory Board
EAS	Ethiopian Academy of Sciences
EIAR	Ethiopian Institute of Agricultural Research
EMMP	Environmental Mitigation and Monitoring Planning
EMS	Ethyl Methanesulfonate
DNA	Deoxyribonucleic Acid
FO	Farmer Organization
HX	Heterowaxy
HPD	High Protein Digestibility
ICRISAT	International Crops Research Institute for the Semiarid Tropics
IDIN	International Disease and Insect Nursery
IDL	International Drought Line Test
IEE	Initial Environmental Examination
IER	Institut d'Economie Rurale
IL	Innovation Lab
INERA	Institut de l'Environnement et de Recherches Agricoles
INRAN	Institut National de Recherches Agronomiques du Niger
INTSORMIL	International Sorghum and Millet CRSP
IPM	Integrated Pest Management
ISRA	l'Institut Sénégalais de Recherches Agricole
ITA	Institut de Technologie Alimentaire
KSU	Kansas State University
ME	Management Entity
MHM	Millet Head Miner
MIS	Management Information Systems
MLT	Midge Line Test
NAM	Nested Association Mapping
NARS	National Agricultural Research System
NSP	National Sorghum Producers
OSU	Oklahoma State University
PI	Principal Investigator
PMP	Performance Monitoring Plan
RFA	Request for Application
RFI	Request for Information

SICNA	Sorghum Improvement Conference of North America
SIIL	Sustainable Intensification Innovation Lab
SME	Small Medium Enterprises
SMIL	Sorghum and Millet Innovation Lab
TLL	Thunderbird Livestock and Land
USAID	United States Agency for International Development
USCP	United Sorghum Checkoff Program
UNDP	United Nations Development Program
USDA	United States Department of Agriculture
WAAPP	West Africa Agricultural Productivity Program
WACCI	West African Centre for Crop Improvement
WSI	Water Solubility Index
WX	Waxy

Program activities and highlights

The Sorghum and Millet Innovation Lab's research program is geographically divided between Ethiopia and West Africa. Within West Africa, our research is concentrated in Senegal and Niger, though in FY 2015 we initiated a new project under the genetic enhancement area of inquiry on pearl millet improvement that also includes plant breeders from Mali and Burkina Faso. Three projects focus on genetic enhancement of sorghum in Ethiopia, with associated activities in production systems management and added-value product development, and one project focuses solely on new food product development. In West Africa, three projects focus primarily on genetic enhancement of sorghum, one focuses on genetic enhancement of pearl millet, two focus on production systems management of pearl millet and one project focuses on added-value product development of sorghum- and millet-based foods. In August, a Ph.D. student in Agricultural Economics at Kansas State University initiated studies that will contribute research on consumer preferences for sorghum- and millet-based food products and food policy relevant to the Lab's operations. In September, Kansas State University hired a new professor, who is stationed at the Western Kansas Agricultural Research Center (which housed previous pearl millet improvement research), to reinvigorate the pearl millet improvement program and build upon past varietal improvement successes.

At the end of the fiscal year, all projects were nearing the end of the second cropping cycle. Extreme challenges were apparent in Ethiopia where widespread drought hampered crop development in rainfed trials especially in the north and east. Trials in the western lowlands did not suffer as much from the drought. Earlier in the year, flooding damaged irrigation infrastructure at the site where winter nurseries are planted, limiting research at that station. Despite these setbacks, considerable progress occurred because of the broad set of partners and testing sites where some trials flourished. Food product development research at Hawassa University is continuing and testing on varieties with better food processing characteristics advanced in the United States but was limited in Ethiopia due to the drought conditions. Student training in food chemistry and technology is taking place at Hawassa University, the University of Pretoria, and Texas A&M University. A study on the opportunities for gender-specific research and technology opportunities was commissioned and is underway.

Research in West Africa continued as planned. Off-season nurseries were planted in Senegal (primarily at the Bambe research station) and some activities were conducted in Niger. The off-season sorghum breeding activities in Niger were hampered by the lack of a fully functional irrigation system and investments have been made to improve the infrastructure. Both projects on pearl millet management—the IPM project led by Malick Ba and the seed ball project of Ludger Hermann—are advancing towards field implementation. In the case of the millet head miner control, optimization of rearing techniques of the parasitoid have advanced and study on the organizational structure of local execution has led to interest in broad scale implementation. The seed ball technology has been tested at field scale in multiple locations and continues to be refined based upon empirical evidence on agronomic efficiency and farmer feedback. Start-up meetings on food product development were held in Niger in November 2015 and product development continues in both Niger and Senegal. Parallel and complementary projects funded by the McKnight Foundation and USAID through the Feed the Future Innovation Lab on Food Processing and Post-Harvest Handling contribute to broadening scope and application into other geographical and topical areas.

Key accomplishments

The 2015 fiscal year saw a number of successes for the Sorghum and Millet Innovation Lab. Those of particular note include the hiring of a Kansas-based pearl millet breeder, the establishment of a gender integration consultancy in Ethiopia, and positive progress in research and Feed the Future indicators, including a very successful short-term training outreach.

Hire of K-State-based pearl millet breeder

As a part of Kansas State University's commitment to SMIL and research on drought-resistant crops, it recently hired Dr. Desalegn Serba as its new pearl millet breeder. Dr. Serba will be based at the Western Kansas Agricultural Research Center in Hays. Dr. Serba received his BSc in plant sciences from Alemaya University of Agriculture (now Haramaya University) in Ethiopia and MSc in Plant Breeding and Genetics from the University of Agricultural Sciences-Bangalore, India. He received his PhD in Plant Breeding and Genetics from the University of Nebraska-Lincoln in 2009. From 2010 to 2015 he worked as a Postdoctoral Fellow for the Department of Energy (DOE) Bioenergy Science Center (BESC) at the Samuel Roberts Noble Foundation, Inc. and for short time as a research scientist at the University of North Texas on switchgrass genomics and breeding. Dr. Serba's research interests center on improving crop plants for yield, stress tolerance and quality for human food and animal feed through the application of conventional and molecular breeding approaches. His pearl millet breeding at KSU focuses on developing early maturity hybrid cultivars improved for yield, drought tolerance, input use efficiency, and enhanced nutritional quality.

Gender integration consultancy established

In line with its commitment to a proactive approach to gender integration at a project and programmatic level, the Lab has entered into a consultancy contract with gender expert Yeshe Chiche for a country-specific exercise aimed at capacity building in the area of women in science as well as gathering gender-disaggregated data on sorghum production practices and uses in the major sorghum-producing regions of Ethiopia. Ms. Chiche has a long history as an agricultural economist working in gender issues and the farming systems approach, and spent much of her career tackling gender issues at EIAR. She will continue to collaborate closely with EIAR's gender focal person throughout the length of her consultancy. In this project, she has been building a team of female scientists to compile a comprehensive review of the available literature on sorghum production practices and uses in the major sorghum-producing areas. From that, a participatory rural appraisal tool will soon be developed to further research the regional differences (in particular, to obtain gender disaggregated data), with the team of women administering the tool on a selected household level. The Lab is very excited about investing in this capacity-building activity, as well as in the potentially rich data on Ethiopian sorghum production that will become available as a part of research study.

Feed the Future indicator performance

The Lab surpassed target values for FY 2015 in both short- and long-term training, with the number of individuals (particularly producers) that were reached through short-term training being significantly higher than expected. FY 2015 also saw the advancement of eight technologies and management practices and important developments in the inclusion of sorghum as a priority value chain in Ethiopia's Agricultural Growth Program.

4.5.2(6) – Long-term training

The long-term training initiated in FY 2015 surpassed target values as 23 individuals took part in long term training at either a bachelor's, Master's, Ph.D. or postdoc level. Ten of these students are receiving training at a U.S. institution, while the remaining are located in home country or 3rd country institutions and/or sandwich programs. The usage of home and 3rd country programs created more opportunities for projects to support long-term trainings as the cost per student is considerably less in some cases than for students training in the U.S. At least two additional long-term trainees are expected to begin their programs in the U.S. in FY16.

4.5.2(7) – Short-term training

The Lab's reported short-term trainings as reported by the research projects also far exceeded targeted values. There were a total of 47 reported trainings that took place in Ethiopia, Senegal, Niger, Mali, Burkina Faso, South Africa and the United States and reached nearly 3,000 reported trainees. Of these trainees, approximately 38 percent were female and 62 percent were male. Additionally, approximately 64 percent of those trained were producers, 11 percent were government affiliates, 11 percent were from the private sector, 8 percent were from the private sector and 6 percent were unknown. Large-scale trainings in relation to field testing of the

parasitoid for the millet head miner under Malick Ba's project accounted for nearly half of all of the reported trainees.

4.5.2(39) – Technologies and management practices

The Lab saw the advancement of fourteen technologies and management practices as a part of project activities. These technologies included food product development, integrated pest management practices with parasitoid rearing, seedball testing and genetic screening. All were in either Phase I (Under Research) or Phase 2 (Under Field Testing).

4.5.1(24) – Agricultural enabling policies

During the FY 2015, the Lab was an active player in moving one policy into Step 3: Drafting or Revision. This policy is in reference to Ethiopia's national agricultural policy prioritization: the Agricultural Growth Program (AGP) Phase II. The AGP I, which provided the framework for the government's investment plan, was focused on high-potential cropping areas and targeted value chain crops of maize, tef, wheat, coffee, honey and sesame. The sorghum value chain was not included. However, in the development of Phase II of the AGP, the importance of sorghum as the third largest crop in Ethiopia (by yield) and for its strategic role in food security were emphasized by the Lab country coordinator and other USAID players. As a result, sorghum is moving forward with a place as a value chain in Phase II of the AGP.

Beyond this policy, there have been no other strategic opportunities to advance additional policies where Lab activities take place, but we anticipate seeing more in the next fiscal year.

Research program overview and structure

Overall, the research program of the Sorghum and Millet Innovation Lab has not changed much from the previous year's program except for a few additions. The program held approximately 10% of the funding allocated to research projects in reserve for future opportunities. As of last year, approximately 57% of project funding was invested into genetic enhancement of sorghum, 20% in production systems management and 23% in added-value product development and markets. Of the funds invested in research, 42% of the total was invested in projects targeting Ethiopia and 58% in projects in Senegal and Niger.

The first important revision is that due to a reclassification of indirect costs at Kansas State University, additional money was reallocated to the pool of money set aside for research, increasing it to approximately 13% of the available research budget. Secondly, with the funding of the pearl millet improvement project, available funding for new research investments has been reduced but this was offset partially by the internal transfer leaving a remaining balance of approximately 7.5% of our research budget. After taking into consideration the allocation to the pearl millet improvement project, approximately 60% of our funding is allocated to genetic enhancement of sorghum and millet, 19% to production systems management and 21% to added-value product development and markets. Sixty percent of the total funding is allocated to West Africa and 40% to Ethiopia.

The program currently has eleven projects, funding commitments to 23 institutions and these institutions are responsible for pass-through agreements to approximately 25 additional organizations. Projects are led by several institutions including Purdue University (four projects), Kansas State University (two projects), Texas A&M, West Texas A&M, ICRISAT and the University of Hohenheim (one project each). The pearl millet improvement project is being led by the Burkina Faso national agriculture research program (INERA) and integrates new researchers from Mali, Niger and Senegal. These projects are associated with 18 collaborating institutions in West Africa and another 16 collaborating institutions in Ethiopia (Figure 1), as well as one collaborating institution in France.

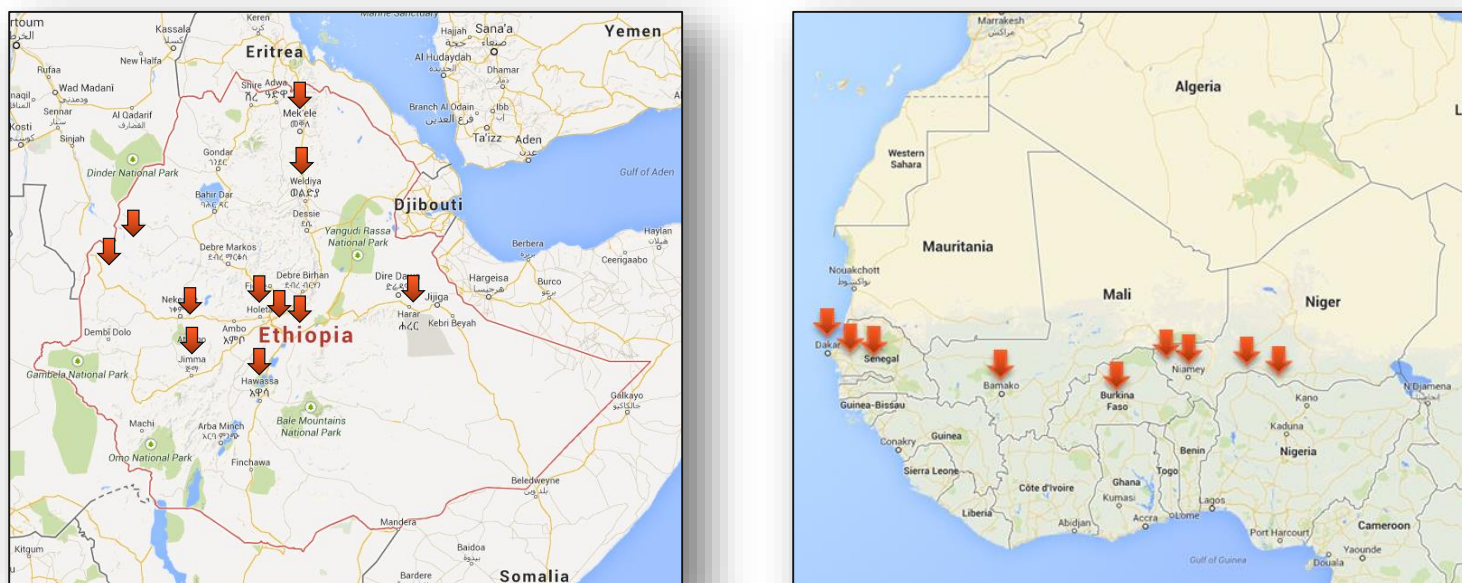


Figure 1. Sorghum and Millet Innovation Lab research activity locations in Ethiopia and West Africa

Research project reports

Geographic area: East Africa (Ethiopia)



Developing superior functionality in sorghum for food applications to promote sorghum value chain in Ethiopia
(Led by Dr. Joseph Awika – Texas A&M University)

Area(s) of inquiry:

Added-value products and markets
Genetic enhancement

Description

Two major bottlenecks on sorghum utilization for food in Ethiopia's growing urban markets are its inadequate functionality as a food ingredient and inferior protein nutritional quality (low lysine and poor digestibility). To combat these characteristics, Texas A&M University has developed a set of sorghum parental lines and hybrids that combine waxy and heterowaxy traits (WX/HX) with the high lysine, high protein digestibility (HPD) trait into high performing hybrids and inbred cultivars. The WX/HX-HPD sorghums have desirable end-use characteristics, including more efficient fermentation for ethanol, better protein quality co-product (high lysine) for feed and other uses, and better functionality in batters and dough systems. In this project, Dr. Awika and his research team will test the hypothesis that the improved WX/HX-HPD sorghums will demonstrate significantly better functionality as a food ingredient in dough and batter systems, producing superior quality grain-based products, and that products made with WX/HX-HPD sorghums will demonstrate superior protein nutritional quality for infants and young children from poor households.

The three research objectives for this project include:

- 1) Establish the effect of combining waxy-heterowaxy (WX/HX) with HPD sorghum traits on dough and batter rheology, food processing, and quality profile of selected traditional and commercial grain-based food products popular in Ethiopia;
- 2) Establish the suitability of the WX/HX-HPD sorghum hybrids for malting and commercial brewing; and
- 3) Evaluate the performance and adaptation of the WX/HX-HPD sorghum hybrids in Ethiopia.

Addressing these objectives will lead to development of superior quality sorghum-based food products that will open new markets and enhance the value-chain of sorghum, benefit small-scale sorghum producers and small- and medium-scale food enterprises (SMEs), and limit the effects of poor nutrition in children.

Collaborators

U.S. collaborating institution(s): Texas A&M University
Intl. collaborating institution(s): Ethiopia - Hawassa University
South Africa - University of Pretoria

Achievements

Waxy/heterowaxy (WX/HX) and high lysine, high protein digestibility (HPD) lines useful for human food products were grown in locations in Texas and Ethiopia and high environmental interaction with genetic background affected physicochemical properties and quality traits. All samples had higher water solubility index (WSI) than control, which suggests they may perform better as food ingredients. These materials were sent to Ethiopia and sown in three locations. Unfortunately, due to drought conditions in Ethiopia, only one site will produce grain for evaluation. Local sorghum varieties were collected from Mieso and Kobo research stations for initial injera experiments.

Food processing experiments were initiated at Hawassa University and a substitution of 65% of sorghum for tef in injera production was achieved with similar quality results. Substituting sorghum for tef appears to delay the growth of spoilage molds by one day, prolonging the keeping quality of injera. Protocols for hedonic evaluation of injera were developed including sensory attributes and descriptive terminologies. These protocols were tested on human panelists in late FY 2015 at Hawassa University. Student research at the University of Pretoria also examined the impact of microwave cooking on injera quality by grain type. The University of Pretoria has initiated evaluation of WX/HX-HPD lines for malting quality.

Capacity building

Three students are being trained under this project: one Ph.D. at Texas A&M University who began in September 2015, one Ph.D. at the University of Pretoria who began earlier, and a M.S. student at Hawassa University. All are making satisfactory progress.

In April 2015 Dr Abegaz and Mr. Mezgebe participated in two short practical training courses in South Africa. The first course (three days) on Sorghum Food Processing Technologies was held at the Ukulima Research Farm, in Limpopo province and was presented by Prof. John Taylor, Profs. Gary Peterson and Joseph Awika (Texas A&M University) and Dr. Medson Chisi (Golden Valley Research Trust, Zambia). The course (also three days) dealt with sorghum plant development, identification of sorghum types, simple methods for determining sorghum end-use quality and sorghum food and beverage processing technologies. The second course was presented by Prof. Henriette de Kock at the University of Pretoria's Sensory Science Unit. The course dealt with standard methods for food product sensory evaluation and focused on consumer hedonic sensory evaluation and descriptive panel sensory characterization of foods.

A poster highlighting the project goals, accomplishments, and anticipated benefits was presented at a scientific research conference held on June 22 to 24, 2015 at Hawassa University. This led to the creation of awareness about the project to government ministers, ambassadors, the diplomatic community, scientists, and international participants.

Lessons learned

The large interaction between physicochemical properties and environment indicates that the WX-HX/HPD lines can be optimized for performance in select geographies. The creation of a protocol to evaluate injera quality with clear terminology and metrics was challenging but doing so has created a uniform platform for systematic evaluation.

Presentations and publications

Elhassan, Mohammed S. M., et al. "Novel Biofortified Sorghum Lines with Combined Waxy (High Amylopectin) Starch and High Protein Digestibility Traits: Effects on Endosperm and Flour Properties." *Journal of cereal science*. 65 (2015): 132-9. Web.

Improved crop genetics, production practices and processing methods for increased productivity and nutrition for smallholder sorghum producers in Ethiopia

(Led by Dr. Tesfaye Tesso – Kansas State University)



Area(s) of inquiry:

Genetic enhancement
Production systems management

Description

This project focuses on developing and utilizing high-yielding, locally-adapted sorghum varieties and hybrids that are rich in highly-digestible protein and essential micronutrients, while at the same time suiting local processing methods and diverse production systems. Through collaborative sorghum research, new innovations including the recently

completed sequence of the sorghum genome, fine mapping of loci associated with Striga resistance, discovery of biochemical compounds associated with processing and utilization of sorghum grains, and the development of herbicide-resistant sorghum can be utilized and explored.

Multidisciplinary teams of scientists from a variety sorghum research institutions in Ethiopia, the USDA-ARS and U.S. land grant universities will work together to exploit the wide genetic resources for high yield potential, environmental stress tolerance and improved nutritional quality available among Ethiopian sorghum germplasm. The team also plans to optimize food processing methods in order to maximize availability of nutrients in sorghum-based local diets. A series of interrelated activities will be implemented both in the laboratory and at selected field locations in major sorghum producing regions of the country to discover unique phenotypes related to improved productivity, protein and micronutrient nutrition and develop and select the best variety or hybrid carrying these traits.

The team also plans to utilize genomic tools to locate genes associated with enhanced nutritional value and reduced anti-nutritional factors, such as low protease inhibitor and phytic acid, and enhance breeding efforts for the improvements of many of these traits. Additionally, the team will contribute to building the capacity of human resources and the institutional infrastructure of collaborating national organizations through training and mentoring graduate students to help build the critical mass of scientists capable of solving local and national problems.

Collaborators

U.S. collaborating institution(s): Purdue University, Kansas State University, USDA-ARS, KSU – Hays Research Station

Intl. collaborating institution(s): Ethiopia - EIAR (Melkassa Research Center, Sirinka Research Center, Pawe Research Center), Tigray Agricultural Research Institute, Haramaya University

Achievements

Building upon the sorghum population that was developed in FY 2014, 2,100 entries were planted at several locations in Ethiopia. Agronomic data are being collected by collaborators at respective locations and will be completed in Q1 FY2016. Though different data sets will be collected, the germplasm population in the field will be utilized by all the three SMIL breeding/genetics PIs for Ethiopia (Drs. Ejeta, Mengiste and Tesso). The PIs and collaborators at different research stations in Ethiopia have developed a data collection plan that will deploy a large number of people including the PIs and post-docs from the U.S., locally recruited graduate students and staff at collaborating stations. This strategy will continue in subsequent years.

In addition to characterization for nutritional, agronomic and disease traits, the collection is being tested for their fertility reaction at Melkassa. Some 2,100 hybrids were created from the population and the F1 progenies are growing at Melkassa. The PIs will evaluate the hybrids to determine their fertility reaction of the populations. Furthermore, genetic purification of the collections is being conducted at Arsi Negelle to prepare for the germplasm samples for genotyping and this will be completed during the 2015 crop season.

A large breeding population with improved quality attributes (primarily protein digestibility) has been developed using germplasm sources adapted to Ethiopia. These were developed between the renowned Ethiopian high lysine sorghum landraces, ISI1178 and ISI1267, and local improved varieties adapted to various regions of the country. The F2 population is currently growing in the field. Selected F3 families will be advanced using an off-season nursery and F4 families to enter preliminary yield evaluation at key locations across the country starting in 2016. Thus, 2016 will be the beginning of evaluation of large set of high protein digestibility (PD) materials in the field. A few elite pollinator parent releases with exceptionally high PD of about 80% and 18% protein content have been identified. This level of PD was known only in high PD mutants developed at Purdue University and never reported in normal endosperm type sorghums. These lines are currently being crossed to African adapted genotypes including SRN39 and other sources of high PD such as SC42.

Capacity building

A Ph.D. student from Haramaya University was admitted to Kansas State University and will begin his studies in January 2016. A M.S. level student will begin her program at Haramaya University.

Lessons learned

Given the massive nature of the activities, collection of data at all locations, grinding grain samples from 2000+ genotypes and shipping to U.S. in time for biochemical analysis will be a challenge.

Presentations and publications

Adrianos S., et al. "Factors Related to Reduced in-Vitro Protein Digestibility in a Diverse Sorghum Population". *American Chemical Society*. Mar 22, 2015, Denver, Colorado. 22 Mar. 2015. Conference Presentation.

Bean S., et al. "Grain Quality Traits in a Sorghum Association Mapping Panel". *Sorghum Improvement Conference of North America*. Manhattan, Kansas. 1 Sept. 2015. Conference Presentation.

Bean S., et al. "Grain Quality Traits in a Sorghum Association Mapping Panel". *American Chemical Society*. Denver, CO. 22 Mar. 2015. Conference Presentation.

Genetic improvement of sorghum and millet for resistance to fungal pathogens

(Led by Dr. Tesfaye Mengiste – Purdue University)



Area(s) of inquiry:

Genetic enhancement

Description

Sorghum is an important food security crop in Ethiopia, and is grown in diverse agroecologies with varying climatic characteristics. While some of the most favorable conditions for crop growth occur in west Ethiopia, these conditions are also accompanied by a variety of potentially devastating pathogens.

The goal of the project is to enhance sorghum productivity and improve the livelihood of sorghum farmers in western Ethiopia through a

collaborative research program focused on developing new, innovative interventions in crop disease resistance. Local varieties grown in the target regions have evolved under severe pathogen pressure and thus possess powerful alleles for a blend of novel resistance genes. Fungal diseases, anthracnose and grain mold are significant risk-causing pathogens in the target region that can result in significant loss of yield, grain quality deterioration, and are obstacles to growing high yielding varieties with shorter growth durations.

By utilizing the unique local gene pool and other sources of germplasm covering the spectrum of natural variation, this project aims to identify disease resistance to combine with other adaptive traits to create high yielding sorghum varieties and hybrids. This will be achieved through innovative phenotyping and resistance breeding, supported by molecular tools for identification and characterization of genes and alleles in key genomic regions underlying a higher level of disease resistance. The germplasm evaluations that make use of the unique environmental conditions of the target region will be strengthened by next generation sequencing and mapping approaches to identify genes underlying quantitative traits such as grain mold. In parallel, to guide the breeding effort and enhance resistance identification schemes, the prevalence and nature of fungal species causing grain mold and strains of anthracnose in the target area will be studied. Further, the project aims to strengthen the capacity of local research institutions by providing graduate education in critical areas that are likely to boost the capability of the next generation of breeders and plant pathologists.

Collaborators

U.S. collaborating institution(s): Purdue University, Kansas State University

Intl. collaborating institution(s): Ethiopia - EIAR (Asosa Research Center, Pawe Research Center, Bako Research Center), Holleta Biotechnology Center

Achievements

Diverse sorghum lines (over 2,100) from the Ethiopian germplasm collection were planted at Mieso, Arsi Negelle, Haramaya, Kobo, Pawe, and Bako under the joint germplasm evaluation activity described under Dr. Tesso's project (and not repeated here). Disease traits will be scored mainly at the two western sites Bako and Pawe because of the high disease pressure. In addition, this project moved forward with wider screening for disease resistance.

Several diseases were examined. Ninety-five sorghum lines from Purdue University and additional lines from Melkassa with some history of grain mold resistance were grown in Assosa, Bako, Jimma and Pawe. Data have been collected on general plant performance traits. Currently, disease and other scores are being followed by local staff from the EIAR and substations. Parallel studies funded by the Ethiopian government are being conducted at Assosa, Bako, Jimma and Pawe to determine important diseases for the region on sorghum. Such studies will have a synergistic effect on this Lab-funded project and demonstrate national commitment to the research area.

In addition, a separate trial for screening of genotypes against Anthracnose/grain mold was planted. This activity is being conducted by a graduate student working for his M.S. and supported by the Sorghum and Millet Innovation Lab. In this trial, 225 sorghum lines were tested for their resistance to grain and foliar diseases at Assosa, Bako and Pawe. In sum, a total of 320 genotypes are being screened for disease resistance at various sites in Western Ethiopia. Overall, these is a multi-year activity with the initial year focusing on the identification of resistant material through multi-location and multi-year tests. Once robust material are identified, breeding efforts will be initiated to introgress these traits into locally adapted cultivars. To date, we have identified multiple resistant germplasm but this resistance needs to be confirmed at multiple locations in the current and coming years.

Collection of *Colletotrichum sublineolum* strains from representative sites in Ethiopia was done last year during the cropping season. The collection of fungal strains and their isolation and characterization was initiated from sites around Assosa, Bako, Jimma and Pawe and their morphological characterization continued. New collections will be made from new locations in the target regions to make the collection as comprehensive as possible. Selected isolates will be imported to the US for whole genome sequencing and characterization of the fungal strains representative to the region. Dr. Mengiste obtained the APHIS permit to import the strains for laboratory studies. Grouping of about 20 isolates based on growth characteristics on culture media continued in the lab at Haramaya University. This activity will be repeated this growing season in October and November 2015.

Recombinant inbred populations derived by crossing resistant and susceptible accessions followed by many generations of selfing were used for mapping anthracnose-resistant loci. The RI population along with the parental lines were repeatedly tested for disease resistance and scored for their responses. Resistant or susceptible RI lines were identified and their reactions were confirmed. Then, DNA was extracted from all resistant and susceptible plants and pooled separately and sequenced at the Purdue genomics facility. Two loci were identified to be responsible for the resistance in the resistant parental line.

Capacity building

Demeke Bayable has been recruited to this project to conduct his graduate studies on disease resistance of sorghum.

Lessons learned

Several resistant germplasm lines have been identified but this resistance needs to be confirmed at multiple locations in the current and coming years.

Presentations and publications

Mengiste, Tesfaye. "Induced resistance to post harvest plant pathogens." *Induced Resistance to Plant Pathogens*. Schwan-Estrada, KR, et al. Maringa, Brazil: UEM. 2014. 141. Print.

Genetic enhancement of sorghum to promote commercial seed supply and grain market development in Ethiopia

Led by Dr. Gebisa Ejeta -- Purdue University)



Area(s) of inquiry:

Genetic enhancement

Added-value products and markets

Description

Ethiopian sorghum landraces exhibit native genetic variation for drought and Striga resistance which this project aims to exploit in the development of sorghum cultivars with resistance to these important stresses. The project employs biotechnology, breeding and agronomy to unleash the potential of the crop for Ethiopian farmers. The team is

developing a core set of sorghum germplasm population to characterize the inherent variability through large-scale, high-throughput genotyping and coupling this practice with phenotyping of valuable traits under target environments. Data is then treated with appropriate bioinformatics and statistical procedures to identify useful allelic variation for drought and Striga resistance. This will be enhanced by the development of local capacity and the restoration of rigor and discipline to the Ethiopian sorghum breeding program to produce superior sorghum on a regular basis. Project researchers will cooperate with agronomists and economists to develop a package of genetic and crop management practices to control stresses and optimize yields.

At the highest level, the project aims to develop a functional sorghum breeding program in Ethiopia focused on the development of adapted, high-yielding sorghum varieties and hybrids for broad societal impact. The use of hybrid cultivars will be promoted to strengthen the seed supply value chain and catalyze the development of a commercial sorghum seed enterprise system in the country. These activities will serve as part of the larger national effort in building local capacity, strengthening the institutions of education, research, extension, and input systems for development, and for advancing science-based development to impart livelihood change for smallholder sorghum farmers of Ethiopia.

Collaborators

U.S. collaborating institution(s): Purdue University, Kansas State University

Intl. collaborating institution(s): Ethiopia - Ethiopian Institute of Agricultural Research (EIAR), (Melkassa Research Center, Sirinka Research Center), Holleta Biotechnology Center, Tigray Regional Program, Oromia Regional Program, Haramaya University

Achievements

In addition to participating in the joint multi-locational germplasm evaluation activity described under Dr. Tesso's project (not repeated here), the project moved forward in evaluating experimental hybrids to catalyze the emergence of a commercial sorghum seed industry. To this end, experimental hybrids were evaluated across several ecologies in 2015. From evaluation of the first year tests, 29 stay green hybrids (of 50 evaluated) were selected as promising in Mieso; of 114 early hybrids evaluated as Chiro and Kobo for mid-season drought, 43 were selected as promising. Of 173 seed parents and 267 pollinator parents introduced to Ethiopia, 62 seed parents and 120 R lines, respectively were selected as promising for subsequent testcrossing to produce experimental hybrids. These results were derived from a set of 762 experimental hybrids synthesized at Purdue University.

Capacity building

This project is supporting Adedayo Adeyanju, a post-doc researcher in plant genetics at Purdue University.

Lessons learned

The project is ambitious, its sheer size presents numerous challenges. The team has done a yeoman's job in facing up the challenges and teaming up to do a great job with an otherwise very challenging project that requires exacting phenotyping data.

Presentations and publications

Ejeta, G. "Research for Development (R4D): Mantra or Practice?" *EIAR Crop Conference*. Addis Ababa, Ethiopia. 24 October 2014. Conference Presentation.

Geographic area: West Africa (Niger, Senegal, Mali, Burkina Faso)

Improving sorghum adaptation in West Africa with genomics-enabled breeding

(Led by Dr. Geoffrey Morris – Kansas State University)



Area(s) of inquiry:

Genetic enhancement

Description

Improving the productivity, resilience and quality of cereal crops is a major leverage point for development in West Africa because of the potential for impacts in regional trade, rural food security, and the health of women and children. As the starting point for a major agriculture value chain, enhanced sorghum varieties with greater yields and improved yield stability can support agricultural and economic development at regional scale.

This project will use new genomic tools to accelerate marker-assisted breeding and expand its impact in West Africa, with six integrated objectives:

- 1) Genomic characterization of Senegalese and Nigerien landraces and breeding lines to connect West African breeding programs to global sorghum breeding efforts;
- 2) Development of a simplified genomics toolkit to increase access to marker-assisted breeding tools in West Africa;
- 3) Development of multi-parent populations for more efficient trait mapping and breeding which combine traits from locally-preferred varieties and elite global lines;
- 4) Improved genetic mapping of stress resistance/tolerance traits to generate more effective trait-associated markers;
- 5) Implementation of Marker Assisted Recurrent Selection to develop more resilient locally-preferred varieties;
- 6) Long-term and short-term training on genomics-enabled breeding for West African crop scientists.

As sorghum is a major component of the diet of many of sub-Saharan Africa's poorest rural people, the acceleration of sorghum breeding will have numerous outcomes that support Feed the Future objectives. In particular, the proposed project will directly address the USAID strategy for climate-smart agriculture in West Africa by accelerating the development of sorghum varieties with increased resilience to abiotic and biotic stressors.

Collaborators

U.S. collaborating institution(s): Kansas State University

Intl. collaborating institution(s): France - Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD)
 Senegal - Institut Sénégalais de Recherches Agricoles (ISRA), Centre d'Etudes Régional pour l'Amélioration de l'Adaptation à la Sécheresse (CERAAS), Centre National de Recherche Agronomique (CNRA)
 Niger - International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Institut National de la Recherche Agronomique du Niger (INRAN), LSDS (farmer organization), HALAL (farmer organization)

Achievements

The largest genomic source for West African sorghum breeding materials has been assembled from Senegal, Mali, Niger and Togo. Seedling growth and DNA extraction has taken place on over 800 entries from this West African Sorghum Association Panel. Library preparation, Illumina sequencing, SNP discovery and typing has taken place through Genotyping-by-Sequencing. Genotyping is currently in progress for an additional 500 sorghum lines from Niger, 500 sorghum lines from Senegal, and 500 sorghum lines from Nigeria. The raw data from this is being processed and the first country and program set of markers are being identified.

For the mini-NAM population one generation has been advanced in the off-season nursery, so a total 600 F4 families have been produced from three crosses (Nganda crossed with CSM63, Macia, and Sureno) in Senegal. In Niger, initial crosses have been made and will be confirmed during the rainy season nursery. The putative F1 hybrids will be genotyped with SSRs (CERAAS), and KASP markers (KSU) to confirm hybrid status. Trait mapping is ongoing with a large scale screening of drought-related traits taking place during the rainy season in Bambey. Analysis of the phenotype data is underway. In Niger, the irrigation facilities at Tillabéri have been installed and the first testing of managed drought stress phenotyping has been carried out. For Striga, local collections of Striga seed has been made and the first testing of the enhanced Striga field began this rainy season (sowing on July 23rd). Fifteen lines have been selected for testing of the Striga screen facility, with five replicate plots for each line.

Capacity building

Two Ph.D. level students began training in January 2015: Fanna Maina from Niger and Jacques Martin Faye from Senegal. Both began with English language training and Ms. Maina tested sufficiently high in May to graduate from the program. Both Maina and Faye have actively participated in research and training in the sorghum genetics lab (lab meeting, genotyping, phenotyping) when not occupied with ELP. Maina is now a full-time PhD student in Agronomy as of May 2015. Faye has been conditionally admitted to the PhD program for January 2016.

INRAN sorghum breeding technician Ardaly Oussenni has taken a 3-week training course at ICRISAT-Mali on striga phenotyping and data management with the Breeding Management System software (Acitivity 2.1). ICRISAT-Niger co-PI has provided a half day training to SMIL PhD trainee of drought phenotyping. One BSc student from Senegal, Aicha Guèye, is working at Darou on the phenotyping of the marker-assisted recurrent selection (MARS) population for grain mold resistance. She started in July 2015 and will finish on November 2015.

Lessons learned

The great diversity of flowering time and photoperiod sensitivity makes it difficult to phenotype an association panel during the rainy season (when there are long days) because it is impossible to apply a stress at a consistent growth stage for all lines. This was anticipated, and now preliminary data on maturity and photoperiod sensitivity classes is being used to refine the panel to a small set of ~500 accessions

On training, the uncertainty of the timing for the shift from English language training to graduate studies has been difficult for project budgeting, since the ELP is substantially more expensive than graduate school.

Presentations and publications

Lasky, J.R., et al. "Genome-Environment Associations in Sorghum Landraces Predict Adaptive Traits." *Science Advances*. 1.6 (2015): doi: 10.1126/sciadv.1400218.

Hu, Z., et al. "Population Genomics of Pearl Millet (*Pennisetum glaucum* (L.) R. Br): Comparative Analysis of Global Accessions and Senegalese Landraces." *BMC Genomics*. (submitted)

Development of biotic stress-resistant sorghum cultivars for Niger and Senegal

(Led by Dr. Bonnie Pendleton – West Texas A&M University)



Area(s) of inquiry:

Genetic enhancement
Production systems management
Added-value products and markets

Description

This multi-disciplinary research project includes entomology, breeding, and agricultural economics to develop, evaluate, and deploy sorghum genotypes resistant to abiotic and biotic stresses and adapted to indigenous production and storage systems in West Africa. An

integrated approach will increase agricultural productivity and economic growth, with attention to human nutrition, environmental conservation, development of host-country capacity, and gender equity.

In this project, sorghum genotypes with resistance to important stressors in West Africa and the U.S will be selected for managing abiotic and biotic constraints. Sorghums that flower when sorghum midges are present in the field will be evaluated to develop resistance to sorghum midge. Research on sorghum time of flowering in relation to environmental factors will be used to verify the genetic basis of resistance.

Additionally, germplasm resistant to grain mold and weathering in a range of environments will be introgressed into sorghums adapted to Niger and Senegal. To protect stored grain, environmentally friendly methods including hermetic storage and plants with natural insecticidal properties will be evaluated. Scanning electron microscopy of the structure of sorghum kernels resistant to storage insects will be used to increase efficiency for evaluating sorghum genotypes for resistance.

Extension will assist in teaching farmers to identify and manage biotic constraints in the field and storage. Human capacity will be improved by educating scientists in conventional and molecular research methodology and in graduate degree programs. Production profitability and marketing opportunities for sorghum cultivars with increased resistance to abiotic and biotic stresses will be assessed to ensure farmer adoption in West Africa. In all, this project is improving human nutrition, human capacity, and environmental conservation while increasing productivity and economic growth for sorghum.

Collaborators

U.S. collaborating institution(s): West Texas A&M University, Texas A&M AgriLife Research
Intl. collaborating institution(s): Senegal - ISRA, CNRA, CERAAS
Niger - INRAN

Achievements

Nurseries were established in Senegal and Niger to evaluate resistance against biotic stresses. Data were received from Niger for the three nurseries planted. The nurseries were for resistance to sorghum midge, drought tolerance, and standard elite lines. A diverse set of lines was provided to collaborators in Niger and Senegal to evaluate for adaptation, grain yield potential, and reaction to biotic and/or abiotic stress in indigenous cropping systems.

A larger quantity of additional germplasm, 103 lines, was provided to Senegal collaborators for local increase to provide grain for research on insect pests of stored grain. The increase when combined with seed for other trials will provide sufficient seed for the local methodology for stored grain research.

The scanning electron microscopy procedure was simplified and refined to better correlate resistance of stored sorghum grain to maize weevils. Sorghum is being produced to evaluate for resistance to insect pests of stored grain. Farmers were taught to identify insect pests of stored grain. Literature review is underway for technologies on storage pests.

Capacity building

A graduate student from Dakar, Senegal, began studying sorghum midge in relation to sorghum resistance. A scientist from Niger was identified for training and the student came to the U.S. and started his Ph.D. program at West Texas A&M University in August 2015. Three women are studying for graduate degrees with Dr. Ibrahima Sarr in Senegal. As planned, a Master's student in agricultural business and economics is being identified from West Africa to come to the U.S. in 2016. One male from Niger earned his Master of Science degree from Burkina Faso University and worked as an intern with the entomologist at INRAN in Niger.

Lessons learned

Nurseries were hindered by poor germination of some lines resulting in high CV. Packaging and seed treatment for the current year was changed based on lessons learned.

Presentations and publications

Pendleton, Bonnie, et al. "Using Environmental Scanning Electron Microscopy to Predict Resistance of Sorghum to Storage Weevils". *63rd Annual Meeting of the Southwestern Branch of the Entomological Society of America and Annual Meeting of the Society of Southwestern Entomologists*. Tulsa, Oklahoma. 26 May. 2015. Conference Proceedings.

Pendleton, Bonnie, et al. "Using Environmental Scanning Electron Microscopy to Predict Resistance of Sorghum to Storage Weevils". *63rd Annual Meeting of the Southwestern Branch of the Entomological Society of America and Annual Meeting of the Society of Southwestern Entomologists*. Tulsa, Oklahoma. 24 Feb. 2015. Conference Presentation.

Pendleton, Michael, et al. "SEM Imaging Combined with SEM-EDS Analysis Enables Prediction of Resistance of Sorghum to Storage Insects". *Entomological Society of America 62nd Annual Meeting*. Portland, Oregon. 18 Nov. 2014. Conference Presentation.

Pendleton, Bonnie, et al. "Development of Biotic Stress-Resistant Sorghum Cultivars for Niger and Senegal". *SMIL Annual Meeting in West Africa*. Niamey, Niger. 25 Mar. 2015. Meeting Presentation.

Hame, Abdou Kadi Kadi. "Développement Des Variétés De Sorgho Résistantes Aux Contraintes Biotiques Au Niger". *INRAN/Niger SMIL Program launching workshop*. Niamey. 26 Sept. 2014. Meeting Presentation.

Pendleton, Bonnie. "Not an Apocalypse: Perspectives on Pest Potential of Aphids and Lessons from the Past". *Annual Meeting of the Southwestern Branch of the Entomological Society of America and the Annual Meeting of the Society of Southwestern Entomologists*. Tulsa, Oklahoma. 24 Feb. 2015. Conference Presentation.

Sarr, Ibrahima and Thiam, Adja Nene. "Développement De Cultivars De Sorgho Résistant Aux Stress Biotiques Au Niger Et Sénégal". *Internal seminar at CNRA*. Bambey, Senegal. 15 Sept. 2015. Meeting Presentation.

Peterson, Gary, et al. "Approaches to Management of Sugarcane Aphid on Sorghum: Host Plant Resistance Sources and Potential". *63rd Annual meeting of the Southwestern Branch of the Entomological Society of America and Annual Meeting of the Society of Southwestern Entomologists*. Tulsa, Oklahoma. 24 Feb. 2015. Conference Presentation.

Trait development pipeline for food and feed value in sorghum

(Led by Dr. Mitchell Tuinstra – Purdue University)



Area(s) of inquiry:
Genetic enhancement

Description

Some of the most important regional research issues highlighted by scientists in Niger and Senegal as related to sorghum include the need to develop locally-adapted guinea and non-guinea sorghum varieties and hybrids with improved grain quality characteristics. This project leverages new genetic technologies to address these sorghum crop improvement needs through targeted research, short- and long-term training and education, and technology transfer to promote and enhance sorghum

production and impact.

The genetic research and technology transfer in this project makes use of the sorghum genome sequence and a proven population of sequence-indexed mutants as tools to identify and characterize allelic variation in genes that influence four specific grain quality traits, which include protein digestibility, reduced phytic acid content to improve iron bioavailability, modified starch composition, and designer starches with altered gelatinization temperatures. Collaborators in West Africa are conducting research to target modification of grain protein digestibility and forage quality. Those alleles that condition improved end-use value will then be incorporated into locally adapted cultivars and hybrids.

The project's training activities will strengthen sorghum breeding programs across the region and contribute to capacity building in host-country programs while germplasm-enhancement activities will result in technology transfer that contributes to the development of sorghum varieties and hybrids with enhanced food- and feed-quality traits. Farmer participation in evaluation and selection of these varieties will promote acceptance and production of new cultivars and the increased production of high-quality grains will stimulate and support development of new markets.

Collaborators

U.S. collaborating institution(s): Purdue University

Intl. collaborating institution(s): Senegal - Institut de Technologie Alimentaire (ITA), CERAAS, ISRA, CNRA
Niger - INRAN

Achievements

The project has continued to pursue high throughput analysis of a mutant population by forward and backward genetic strategies to identify mutations that change protein digestibility. A set of 30 genetically diverse sorghum genotypes including parent lines and varieties from West Africa were evaluated for variation in protein digestibility. No highly digestible variants were identified among these lines. A forward genetic screen of more than 500 DNA sequence indexed EMS mutants identified a mutant with highly digestible protein in the kernels. A forward genetic screen of approximately 5,000 additional unsequenced EMS mutants identified two additional mutants with highly digestible protein in the kernels. These mutants are being characterized to determine the causal variation and associated phenotypes. Additionally, EMS

families with mutations in genes associated with low Phytic Acid (LPA) were identified. No mutants with a clear LPA phenotype were discovered.

Seeds for selected EMS lines and other genetic materials were sent to collaborators in West Africa for phenotype evaluation as requested for protein digestibility (Senegal) and brown midrib (BMR) forage (Niger) quality traits. A set of 136 genotypes representing elite breeding lines, sequenced lines and varieties, highly digestible protein mutants, and forage parents were sent to CERAAS in Senegal. A set of 66 lines and 18 hybrids representing elite breeding lines, sequenced lines and varieties, elite forage parent lines, SbEMS mutants with BMR mutations, and commercial forage hybrids were sent to INRAN in Niger. Forward and reverse genetic screens were conducted at Purdue to identify additional EMS mutations in genes for protein digestibility and brown midrib forage quality traits as described above. A set of three mutants with highly digestible protein were identified and 14 mutants with brown midrib phenotypes. These mutants are being characterized to identify causal mutations and associated phenotypes.

Genetic crosses between mutants with highly digestible protein and mutants with BMR have occurred with elite parent lines and varieties from West Africa. These breeding populations are being shared with collaborating NARS programs as they become available. Purdue PIs continue to initiate breeding programs to introgress new food- and feed-value traits into West African sorghum varieties. The sorghum breeding program at Purdue advanced 11 breeding populations to the F3 generation in 2015. Crosses and plant breeding populations segregating for key target traits will be sent to NARS collaborators for selection. In 2015, two breeding populations derived from crosses with N223 were sent to INRAN to introgress the BMR trait into locally adapted hybrids in Niger.

Capacity building

Mr. Ousmane Seyni Diakite, a technician at the Institut National de la Recherche Agronomique du Niger (INRAN) based in Niamey, Niger, and Mrs. Elizabeth Diatta from Centre d'Etudes Régional pour l'Amélioration de l'Adaptation à la Sécheresse (CERAAS), Thiès, Senegal were identified to begin Ph.D. programs in plant breeding at the West Africa Centre for Crop (WACCI), University of Ghana, Legon. The students initiated study at the WACCI in January, 2015. With input from researchers from INRAN, Mr. Ousmane Seyni Diakite will conduct research to develop brown midrib forage varieties to enhance feed value of sorghum for farmers in Niger. With input from researchers from CERAAS, Mrs. Elizabeth Diatta will conduct research on mutations that contribute to highly digestible protein in the grain.

Short-term training was conducted on the use of functional genomics in sorghum crop improvement. On 27 March 2015, the training was conducted at CERAAS in Thiès, Senegal. Tuinstra delivered genomic resource data and provided overview of use in plant genetics and breeding. Ideas for research and education in 2015 were discussed and priorities identified. The same approach was followed in Niger and on 31 March 2015, the training was conducted at INRAN in Niamey, Niger and concluded with brainstorming.

Lessons learned

Some EMS mutants proved to be difficult to propagate in Niger and Senegal. These mutants are being crossed to local varieties to improve adaptation characteristics. Many of the important breeding lines from West Africa are photoperiod sensitive. These crosses and breeding populations can only be advanced at a rate of one generation per year.

Presentations and publications

Addo-Quaye, C., et al. "Utility to the Maize Community of a Functional Gene Discovery Platform for Sorghum Improvement". *Maize Genetics Conference*. St. Charles, Illinois, USA. 12 Mar. 2015. Conference Paper.

Tuinstra, M. R., et al. "Detection of Induced Mutations in the Resequenced Genomes of 600 EMS Mutagenized Sorghum BTx623 Individuals". *Maize Genetics Conference Abstracts*. 57:P57. St. Charles, Illinois, USA. 12 Mar. 2015. Conference Paper.

Massafaro, M., et al. "Mapping and Identification of Increased Protein Digestibility in Sorghum". *Sorghum Improvement Conference of North America*. Manhattan, KS. 2 Sept. 2015. Conference Presentation.

Massafaro, M., C. Weil, and M. R. Tuinstra. "Mapping and Identification of Increased Protein Digestibility in Sorghum". *Maize Genetics Conference*. St. Charles, Illinois, USA. 12 Mar. 2015. Conference Paper.

Mofini, Marie Therese. "Phenotypic and Genotypic Characterization of a Sorghum Mutant Collection." *University Cheikh Anta Diop of Dakar*. 30 Sept. 2015. Thesis.

Biological control of the millet head miner in Niger and Senegal

(Led by Dr. Malick Ba – ICRISAT, Niger)



Area(s) of inquiry:

Production systems management

Description

The Millet Head Miner (MHM) is a major chronic insect pest of millet in the Sahel. This project will serve to develop technologies for controlling the MHM, with intentions to significantly decrease the devastating losses that it can inflict (often ranging from 40-85%) on millet yields. Improved management of this key pest will result in increased pearl millet productivity and greater income and food security among millet farmers.

The proposed project includes three primary components:

- 1) Biological control of the MHM with releases of larval parasitoids to significantly increase on-going mass rearing of the larval parasitoid *Habrabracon hebetor* Say (Hymenoptera: Braconidae) and fine-tune release techniques for improved control of the MHM.
- 2) Test the *Trichogrammatidae* egg parasitoid as bio control agents of the MHM.
- 3) Establishing parasitoid cottage industry for rearing and commercialization of parasitoids in the Sahel with particular attention to having those businesses owned and operated by individuals or groups of women.

The project will train one M.S. and two Ph.D. students at Virginia Tech as well as the University Cheikh Anta Diop in Senegal. Farmers will be trained on biological control of the millet head miner and links will be made with a McKnight-funded project in Burkina Faso, Mali and Niger, a West-Africa Agricultural Productivity Program-funded project in Senegal and the CGIAR research program on Dryland Cereals to scale up the technologies in all Sahelian countries. Outcomes of this project will include a reduction in pearl millet grain losses, an increase in food production and security among Nigerien and Senegalese millet farmers, as well as the establishment of a cottage industry to rear and sell natural enemies, which will provide revenue to farmers and women's cooperatives.

Collaborators

U.S. collaborating institution(s): Virginia Tech University, IPM Innovation Lab

Intl. collaborating institution(s): Senegal - ISRA, CERAAS, University Cheikh Anta Diop de Dakar
 Niger - University of Maradi, INRAN

Achievements

Important progress is being made to strengthen the biocontrol process by searching for egg parasitoids in addition to refining larval control processes. A total of 5,957 eggs of the MHM were collected in Western Niger in the districts of Tera, Dantchandou, Filingue and Say and monitored until emergence of parasitoids. In Senegal a total of 421 eggs were

collected in the district of Niore du Rip. The parasitoid, *Trichogrammatidae armigera* has been recorded emerging from eggs of the millet head miner. On average 4% eggs were parasitized in Western Niger and 11.88% in Senegal. Emerging parasitoids were given healthy eggs of the MHM. The parasitoids developed within 7.11 ± 0.6 days and inflicted 34% mortality to the eggs of the MHM. Difficulties were encountered in rearing the egg parasitoids on factous hosts under controlled conditions.

Rearing and release of the *H. hebetor* parasitoid was refined through field experimentation in several sites. The release of the parasitoids significantly increased ($P < 0.05$) the parasitism of MHM as compared to control villages, which did not, receive any parasitoids. Parasitism ranged from 15 to 50% in the Zinder district and from 35 to 67% in Tera district. The highest parasitism was recorded in villages where 1,600 parasitoids were released. Concurrently, focus group discussions with farmers in villages have established the "public good" nature of distributing the parasitoids. If one farmer adopts, his/her neighbors benefit which affects willingness to adopt the technology. Baseline survey instruments have been developed and will be soon administrated to farmers. This season, the University of Maradi is leading a World Bank project to train farmers in 500 villages to use the jute bags with parasitoids. The project is training technicians and sending them to train the farmers on bag placement. The World Bank has provided parasitoids to certain villages by channeling money through the pilot-tested businesses associated with our SMIL project.

Capacity building

Short term training has been provided to five parasitoid production managers for pilot testing of parasitoid commercialization. Seven bachelor's students, including one female from the University of Maradi, are being trained.

Lessons learned

Additional research to improve the efficacy of rearing egg parasitoids will be required before any assessment of parasitism.

Presentations and publications

Ba, Malick, et al. "IPM for Pearl Millet in the Sahel: Augmentative on-Farm Releases of Parasitoids to Control the Millet Head Miner in the Sahel". *The 8th International IPM Symposium, "IPM: Solutions for a Changing World"*. Salt Lake City, USA. 23 Mar. 2015. Conference Presentation.

Sarr, Ibrahima and Goudiaby, Mame Fatoumata. "Lutte Biologique Contre La Chenille Mineuse De l'épi Du Mil Au Niger Et Sénégal". *Internal seminar at ISRA CNRA*. 15 Sept. 2015. Meeting Presentation.

Optimization of the seed ball technology for pearl millet, and agronomic and socio-economic evaluation in the context of smallholder farmers in Senegal and Niger

(Led by Dr. Ludger Herrmann - University of Hohenheim)



Area(s) of inquiry:

Production systems management

Description

Pearl millet farmers in Senegal and Niger face many challenges related to crop production, one of which is seedling survival. Technologies that enhance seedling survival in the Sahel present the potential of an important contribution to reduce overall cropping risks in the region, thereby enhancing pearl millet productivity and yield stability.

This project pursues the seed ball technology as a valid option to reduce cropping risks and improve farmers' yields - particularly for female

farmers - by using low-cost resources that are readily available. The seed ball technology represents a special form of seed pelleting with natural loam and additives including wood ash from cooking places and chemical fertilizers in micro-dosages, to enhance early plant establishment and plant development. In a highly interdisciplinary and participatory approach the team's research activities will:

- 1) Further optimize the seed ball technology for pearl millet;
- 2) Validate the seed ball technology under Sahelian field conditions and determine the agronomic and socio-economic benefits for farmers; and
- 3) Strengthen local capacity for seed ball research and application in Senegal and Niger.

These objectives are being achieved by including smallholder farmers, farmer organizations, local and international research institutions and multimedia in a continued process of seed ball development, refinement, validation and adaptation to local conditions. At least four local Master's students will be trained and results will be communicated widely. The overarching project objective will be achieved when Sahelian subsistence farmers are able to create seed balls independently and can benefit from a reduced likelihood of cropping failures, improved early plant establishment and grain yield formation.

Collaborators

Intl. collaborating institution(s): Senegal - ISRA, FAPAL (farmer organization)
Niger - INRAN, Fuma Gaskiya (farmer organization)

Achievements

This project initiated activities in FY 2015 first with greenhouse experiments and then in the field during the cropping season. The seedballs were physically optimized. Optimum diameter appeared to be 1.5-2.0 cm with random distribution of seeds. Chemical optimization was also successful. The basic composition as a gravimetric ratio is as follows: 80 parts sand, 50 parts loam, 25 parts water, and 3 parts wood ash or 1 part NPK fertilizer.

In 2015 two identical on-station trials were successfully conducted, one each at ISRA station, Bambey, Senegal and the other at INRAN Maradi station, Niger. Factors were seeding time (before-season sowing vs. in-season sowing), seeding depth (surface vs. 3cm depth), and type of additive (wood ash vs. NPK fertilizer).

On-station trials were complemented by regional on-farm trials. Thirty trials were conducted in three villages of the Serkin Haoussa district. In Senegal, only one "central" trial site was chosen by the local farmers. Post season assessment of the technology led to the result that most (>90%) farmers want to continue testing in the 2016 season. In Niger, first volunteer adopters were observed who did not officially take part in the project's on-farm testing program.

One survey in Senegal was conducted by a B.Sc. student (Konni Biegert) from Hohenheim University. The B.Sc. thesis is available and detected no ex-ante reasons for non-adoption of the seedball technology. Fuma Gaskiya performed an informal survey during the introduction of the project to farmer groups. As in Senegal, no ex-ante reason for non-adoption were raised.

At present a first English draft of the seedball manufacturing guide is available but needs further update after the on-farm experiences of this season. A first poster on the seedball technology was presented at Tropentag 2015. Another one is planned for next year. Training for seedball was opened to men and women farmer. Data collection concerning on-farm trials will be gender separated.

Capacity building

Capacity building in 2015 addressed NARS scientists as well as farmers from local farmer organizations (FO). At ISRA in Bambey, Senegal, three scientists were trained with respect to the seedball technology and its application. Thirty farmers from the FAPAL FO in Louga took part in a workshop on seedball processing. Farmers decided afterwards to provide a

central seedball testing plot. In addition, one Master's student was introduced to the technology and took responsibility for the field testing on-station and on-farm.

Similarly, in Niger four INRAN scientists took part in a workshop on seedball technology. Together with 30 farmers, three animators of Fuma Gaskiya (FO in Maradi area) were trained in seedball production and the latter also on trial conduction and supervision on-farm. Unfortunately, no students could be enrolled in Niger in 2015 due to too late engagement of NAR in finding one.

Lessons learned

The first on-farm applications of the seedball technology have shown that 1) the materials for the technology are locally available and affordable, 2) the technology can be easily learned by local farmers, 3) and the technology is competitive with normal seeding practices.

Presentations and publications

Herrmann, L., C.I. Nwankwo, J. Mühlana, D. Butzer, K. Biegert, G. Neumann. "Saatkugeln als Managementoption zur Verbesserung des Auflaufverhaltens von Perlhirse (*Pennisetum glaucum*) auf sandigen Böden im Sahel." *Berichte der DBG*. 2015. Online Publikation ID 1082.

Herrmann, L., et al. "Seedball as Management Option to Improve Pearl Millet (*Pennisetum Glaucum*) Seedling Development during Early Growth Stages on Sandy Sahelian Sites". *Jahrestagung der Deutschen Bodenkundlichen Gesellschaft 2015*. Munich, Germany. 7 Sept. 2015. Conference paper.

Nwankwo, C. I., et al. "Optimisation of Seedball Technology for Pearl Millet Production in the Sahel". *Tropentag 2015*. 9/15/2015, Berlin, Germany. 15 Sept. 2015. Conference Presentation.

Nwankwo, Charles Ikenna, et al. "Optimization of Seedball Technology for Pearl Millet; Agronomic and Socio-Economic Evaluation in the Context of Smallholder Farmers in Senegal and Niger." Internal meeting with ISRA. Bambey, Senegal. 10 April 2015. Meeting presentation.

Awards

The poster presentation related to the publication Nwankwo et al. (2015) was awarded the Agrinatura Best Poster Award worth 500€ during the Tropentag conference 16th-18th of September in Berlin, Germany.

Expanding markets for sorghum and millet farmers in West Africa through strengthening of entrepreneur processors and nutrition-based promotion of products

Led by Dr. Bruce Hamaker – Purdue University)



Area(s) of inquiry:

Added-value products and markets

Description

This project expands activities with entrepreneurial processors at local incubation centers to develop strategies to fabricate new extruded products, innovative ways to promote processed sorghum and millet products, and nutrient fortification of food products through sustained market demand. The specific project objectives include:

- 1) To further develop and optimize food items made from sorghum and millet for market expansion with a focus on high quality

flour-based and agglomerated products, and newly developed technology for the production of nutritionally-enhanced extruded instant flours for thin porridges target at infant/young children.

- 2) To strengthen the capacity of Senegalese and Nigerien micro-, small- and medium-sized agribusinesses through existing incubation centers and to identify development partners for business management training and assistance to entrepreneurs, through improved branding, marketing and promotional activities.
- 3) To leverage nutritional factors in marketing and promotion of sorghum and millet products in rural and urban centers.
- 4) Integrate with other actors in the value-chain to benefit smallholder farmers through development of output markets.

While addressing the area of inquiry, “Development of added-value products and market development,” the research team aims to create successful models using food and nutrition-related technologies to expand markets and improve nutrition and health of vulnerable groups. Scientific and technological research is being used to generate advancements in sorghum and millet utilization while capacity building is incorporated through short-term and graduate degree training.

Collaborators

U.S. collaborating institution(s): Purdue University
 Intl. collaborating institution(s): Senegal - ISRA, CNRA, ITA
 Niger - INRAN

Achievements

This project continues to build upon previous investments in the food product incubation centers developed under the INTSORMIL program. In Senegal, several formulas made up with millet and sorghum with local fruits such as baobab fruit flour, cowpea, and peanut were developed in this period. Sensorial analyses have been run for each new product to assess their potential in the urban and rural markets. Local purported nutrient-rich plant materials were collected in Niger and Senegal, and analyzed for pro-vitamin A carotenoids and minerals (iron and zinc through the Food Processing Innovation Lab project component at University of Pretoria). They were baobab (“bouy” *Adansonia digitata*), bali (*Parinari macrophylla*), bambara nut (*Vigna subterranea*), lam (*Moringa oleifera*), cowpea (*Vigna unguiculata*), oule (*Parkia biglobosa*), gum arabic (*Acacia senegal*), nere (*Parpkia africana*), palm nut (*Hyphaene thebaica*), roselle (*Hibiscus sabdariffa*), tiger nut (*Cyperus esculentus*). The purpose is to identify potential fortifying agents for processed millet and sorghum products. An instant cereal product was made at Purdue using the same extruder as is at ITA in Senegal, and that has been shipped in August 2015 to Niger for installation at the INRAN incubation center. The selected plant materials were added into the instant cereal product to evaluate their impact on the delivery of provitamin A carotenoids. Full analysis of the plant materials was completed in the 2014-2015 reporting period. Based on the mineral analysis data, baobab, moringa, and hibiscus were selected as potential sources of iron and zinc. The porridge formulation containing baobab and hibiscus appeared to enhance the carotenoid accessibility. Baobab increased carotenoid bioaccessibility from 18.3 to 31.7% as its amount added in the dry mix was increased from 5% to 25%. This increase in bioaccessibility was found to be ~3x higher than the control. On the other hand, higher amounts of moringa and hibiscus seemed to have a negative impact on carotenoid bioaccessibility compared to the control. Next steps are to make formulated milled, agglomerated, and instant products for sensory, further bioaccessibility, and market testing.

In Niger, there were two main advancements in the use of the incubation center concept at INRAN, and as extended to rural areas through the partnership between the Sorghum and Millet Innovation Lab and the McKnight Foundation projects. First, the INRAN Food Lab received funding from the Niger government UEMOA program to build a new and larger incubation center and food laboratory at INRAN. With SMIL support, an extruder for developing and processing nutrient-enriched instant flours was purchased, as well as a flour sieving machine and other minor processing accessories. The center will soon be fully functional and will allow for an increased level of training and support of urban and rural processors.

There were increased outreach activities from the incubation center to smallholder farmer women processors in conjunction with the McKnight Foundation project. This project is designed to provide rural women access to markets

through processing. Processed products development and optimization was done on five indigenous popular rural millet processed foods: 1) an agglomerated millet-based couscous-like product, 2) a steamed millet raw grain product generally mixed with moringa leaves called "Tousme", 3) a millet thick porridge-like pasta/macaroni product called "Bibita", 4) a millet-based thin porridge beverage drink called "Toukoudi", and 5) a composite millet or sorghum-based bread. The five products are being made and tested using 20 millet varieties with the objective to identify their suitability for making each of these food products. Parameters being tested and monitored include semi and final product yield, color, moisture, and sensory properties. Similar tests will be initiated on sorghum varieties as well. A contracting partnership was initiated between urban processors operating in Niamey and local grain growers from two farmer organizations: Moribeen/Western Niger (Tillabery and Dosso) and Fuma Gaskiya/Eastern Niger (Maradi), with the objective to produce about 25 tons of consistent quality and clean grain from improved sorghum and millets for making agglomerated products, fortified flours for porridges, and composite bread.

Capacity building

In this reporting year, fifteen women processor groups of 20-30 women each were involved in training activities to make agglomerated sorghum and millet foods including popular couscous, boulettes and degue, porridges, and nutrient-enriched food products.

In the Lab and McKnight Foundation partnership, incubation activities were expanded to three additional villages (Agué, Tchadoua, and Tessaoua) in Maradi where more than 30 women were trained in millet and sorghum processing, with further support from a World Bank-funded project (Passadem).

In Senegal, a firm partnership was established with Maria Distribution, a Dakar-based mid-level cereal processor. The entrepreneur processor is now working closely with the ITA incubation center to extend the instant flour technology to the private sector.

Lessons learned

This project needs to find a better way to connect entrepreneur processors with potential financiers to improve their chance to use the technologies developed at INRAN and ITA. In some cases, policy matters affect the ability of processors to grow their businesses and the Lab may try to strategize whether it could facilitate change to benefit small- and medium-scale millet and sorghum processors.

Presentations and publications

Cisse, Fatimata. "African Starchy Foods, Gastric Emptying, and Starch Digestion." Purdue University, 8 Feb. 2015. Dissertation.

Moussa, Moustapha, Bruce Hamaker, and et al. "Expansion Des Marchés De Mil Et Sorgho En Afrique De l'Ouest par Le Renforcement Des Transformateurs Et La Promotion De Produits Nutritionnels". *Atelier d'Information/Sensibilisation sur le Développement et l'Innovation de Technologies Post-Récoltes et de Transformation de Grain de Mil et Sorgho*. Hotel Sahel, Niamey, Niger. 13 Nov. 2014. Conference Presentation.

Moussa, Moustapha, et al. "A Technology-Based Incubation Center for Establishing Food Processing Enterprises in Niger, a Case Study". *WORLD FOOD CEREAL (WFC)*. U.S. 10 June 2015. Conference Paper.

Moussa, Moustapha, et al. "SMIL Processing and Nutrition Update". *SMIL Annual Review Meeting*. Niamey, Niger. 1 Apr. 2015. Meeting Presentation.

Moussa, M., et al. "Transformation De Grain De Mil Et Sorgho Pour Etendre Les Marchés Le Long De La Chaîne De Valeurs au Niger Et Burkina Faso". *8th Annual Regional Workshop, Community of Practice (CoP)/CCRP/ West Africa/ McKnight Foundation*. Ouagadougou, Burkina Faso. 15 May 2015. Conference Presentation.

Ndiaye, Maty Diop. "Fabrication De Farines Infantiles Enrichies Instantanées à Base De Produits Locaux Par Extrusion." *Université Cheikh Anta Diop*, 15 Sept. 2015. Thesis.

Ndiaye, Maty Diop, and Dr Djibril Traoré. "Development of Instant Fortified Flours from Local Cereals". *Symposium Sur Les Programmes de Recherche Financés Par Le Project USAID/ERA*. Ngor Diarama. 13 Jan. 2015. Conference Presentation.

NEW PROJECT: Development of dual-purpose pearl millet varieties for the benefit of farmers and agro-pastoralists in the Sahelian and Sudanian zones of West Africa
(Led by Dr. Roger Zangré – INERA)



Area(s) of inquiry:
Genetic enhancement

Description
This project aims to tackle the challenges of both human and animal malnutrition by setting the foundation and developing a strategy for farmer-participatory breeding of highly nutritious, dual-purpose pearl millet varieties in the target countries Senegal, Mali, Burkina Faso and Niger. The development and cultivation of dual-purpose pearl millet varieties with enhanced grain nutritional quality and stover digestibility is

expected to contribute to better crop-livestock integration and improved incomes and even nutritional security of smallholder farming families, as called for by the Millennium Development Goals (MDGs).

The project will gather and characterize at least 100 accessions of germplasm from the countries involved and other millet breeding programs to determine the genetic diversity for stover quality and digestibility traits, grain mineral content, grain and stover yield performance. It will also assess relationships between stover nutritional quality and digestibility and agro-morphological traits, as well as grain micronutrient contents, to understand potential trade-offs in selection of nutritious dual-purpose pearl millet cultivars, validate superior germplasm accessions in a participatory manner with women and men farmers in large-scale on-farm trials in the target regions, and identify farmer-preferred accessions for use in future dual-purpose pearl millet breeding programs.

The genetic material will be multiplied to make seed available for farm multi-location trials and complementary grain chemical analyses. At least five superior dual-purpose varieties with good yield and good quality for grain and stover/fodder will finally be selected by country and seed multiplication system involving breeder-foundation and certified seed, will be put in place to make seed available to the users (farmers, agro-pastoralists and others). Capacity building will include stakeholders training on quality seed production techniques, identification of diseases, insects, parasitic weeds and other biotic millet production constraints.

Collaborators

U.S. collaborating institution(s): Kansas State University
Intl. collaborating institution(s): Senegal – CERAAS/ISRA
Niger – INRAN, ICRISAT
Burkina Faso – INERA
Mali - IER

Achievements

Research began on the first objective to gather landraces and breeding materials from countries participating in the project and characterize for genetic diversity concerning stover quality/digestibility traits, grain mineral content and agronomic performance. Implementation of the activity resulted in the collection of 100 entries of West Africa pearl

millet germplasm assembled by the four-country members: 34 from Burkina Faso, 20 from Mali, 23 from Niger, and 23 from Senegal. These materials were sown on the following dates: 1) Senegal-- 15th July at Niore and 27th July at Bambey; 2) Burkina Faso: 14th July at Gampela and 25th July at Katchari; 3) Mali: 8th July at Cinzana and 11th July at N'Tarla, 4) Maradi (date not known). Harvest and final evaluation of these materials will take place in Q1 FY 2016.

Capacity building

Due to the recent launch of this project late in the fiscal year, no formal short-term or long-term training has yet taken place. However, Dr. Zangre, Dr. Sy, Dr. Issaka, Moussa Daouda, were active participants in the Sorghum and Millet Innovation Lab annual meeting in March in Niamey, Niger, which involved approximately 50 researchers from a variety of regional and national research stations in the region. Together, they dedicated nearly two days to forming a solid, collaborative research project that would address the most compelling issues in the development of dual-purpose pearl millet.

Lessons learned

This is the first year of this project and limited information is available since the field trials have not been harvested.

Presentations and publications

Zangré, Roger. "Development of dual-purpose pearl millet varieties for the benefit of farmers and agro-pastoralists in the Sahelian and Sudanian zones of West Africa." *Sorghum and Millet Innovation Lab Annual Review Meeting*. Grand Hotel, Niamey, Niger. 2 April 2015. Project Presentation.

Associate award project reports

The Sorghum and Millet Innovation Lab did not have any associate awards in FY 2015.

Human and Institutional Capacity Development

Human and Institutional Capacity Development (HICD) continues to be a cornerstone of the Lab's research portfolio and program, and FY 2015 saw a number of exciting developments in this area. In addition to a total number of short-term trainees that significantly exceeded expectations, the Lab funded (either partially or in-full) 23 long-term training programs at institutions around the world. Institutional support was also seen in all focus countries with a particular focus on private industry and food product development.

Short-term training

Lab-funded short-term training during FY 2015 far exceeded expectations with 47 separate trainings taking place in Ethiopia, Senegal, Niger, Mali, Burkina Faso, South Africa and the United State. There were nearly 3,000 reported trainees, 38 percent of which were female.

Ethiopia

- 1) Title: Operational procedures for germplasm characterization
 - a. Number of individuals trained: 4
 - i. Male: 4
 - ii. Female: 0
 - b. Purpose: Orientation for field breeding staff on germplasm characterization protocols
 - c. Training institution/mechanism: Traditional learning as provided by Dr. Tesfaye Tesso
- 2) Title: SMIL Environmental Mitigation and Monitoring Plan (EMMPs)
 - a. Number of individuals trained: 27

- i. Male: 24
 - ii. Female: 3
 - b. Purpose: The objective is to guide the monitoring evaluation team, researchers and field technicians at a research station on proper follow up of EMMP module for project implementation in Ethiopia.
 - c. Training institution/mechanism: Traditional learning as provided by Dr. Getachew Ayana and Dr. Gashawbeza Ayalew
- 3) Title: EMMPs and Electronic Data Capture Training
- a. Number of individuals trained: 14
 - i. Male: 13
 - ii. Female: 1
 - b. Purpose: To provide EMMPs concept and practice for SMIL project implementing centers in Ethiopia
 - c. Training institution/mechanism: Traditional learning as provided by Dr. Getachew Ayana and Habte Nida
- 4) Title: 2015 Sorghum and Millet Innovation Lab Annual Review Meeting
- a. Number of individuals trained: 55
 - i. Male: 45
 - ii. Female: 10
 - b. Purpose: An annual meeting organized by the Lab in Adama, Ethiopia to provide updates on research progress and results, as well as share future activities. Involved project partners and other sorghum value chain actors from the U.S., Ethiopia and South Africa.
 - c. Training institution/mechanism: Traditional learning as provided by SMIL with partnership of INRAN of Niger

Senegal

- 1) Title: Farmer enrolling and training on the identification of the millet head miner and larval parasitoid (B. hebetor) for release and saving them
- a. Number of individuals trained: 304
 - i. Male: 204
 - ii. Female: 100
 - b. Purpose: Identification of the pest of millet (millet head miner) as well as the larval parasitoid for rearing and release or saving
 - c. Training institution/mechanism: Traditional learning as provided by ISRA
- 2) Title: Senegal insect and disease training
- a. Number of individuals trained: 12
 - i. Male: 9
 - ii. Female: 3
 - b. Purpose: Teach laboratory and field technicians to identify insects and diseases and their symptoms for field evaluation
 - c. Training institution/mechanism: Traditional learning as provided by Ibrahima Sarr
- 3) Title: Identification of insects and diseases of sorghum
- a. Number of individuals trained: 11
 - i. Male: 6
 - ii. Female: 5
 - b. Purpose: Evaluate sorghum germplasm in Senegal. Participants are trained on site how to recognize diseases and insects of sorghum
 - c. Training institution/mechanism: Traditional learning as provided by ISRA/Entomology Unit
- 4) Title: Cereal food product consumer preference assessment

- a. Number of individuals trained: 13
 - i. Male: 9
 - ii. Female: 4
 - b. Purpose: ITA staff and three students took part in a food preference consumer assessment to better understand markets for sorghum and millet
 - c. Training institution/mechanism: Traditional learning as provided by the Institut Technologie Alimentaire (ITA), Dakar
- 5) Title: Seedball fabrication workshop with Louga farmers in Senegal
- a. Number of individuals trained: 5
 - i. Male: 5
 - ii. Female: 0
 - b. Purpose: Farmers of the local FO were trained to fabricate seedballs to be used in later on-farm trials.
 - c. Training institution/mechanism: Traditional learning as provided by C.I. Nwankwo, University of Hohenheim
- 6) Title: Introduction into seedball technology
- a. Number of individuals trained: 2
 - i. Male: 2
 - ii. Female: 0
 - b. Purpose: Preparing ISRA personal and master student for seedball research.
 - c. Training institution/mechanism: Traditional learning as provided by C.I. Nwankwo, University of Hohenheim
- 7) Title: Functional Genomics Platform Resource Review
- a. Number of individuals trained: 15
 - i. Male: 12
 - ii. Female: 3
 - b. Purpose: Provided CERAAS researchers with USB drives containing the Purdue sorghum sequence database and training on how to use this genetic resource for functional genomics studies
 - c. Training institution/mechanism: Traditional learning as provided by Mitch Tuinstra

Niger

- 1) Title: Functional Genomics Platform Resource Review
- a. Number of individuals trained: 5
 - i. Male: 4
 - ii. Female: 1
 - b. Purpose: Delivered genomic resource data and provided overview of use in plant genetics and breeding
 - c. Training institution/mechanism: Traditional learning as provided by Mitch Tuinstra
- 2) Title: Seed ball production
- a. Number of individuals trained: 50
 - i. Male: 15
 - ii. Female: 35
 - b. Purpose: The main objective of training on seed ball production was to bring the new technology to farmers in Niger in order to reduce millet production problems
 - c. Training institution/mechanism: Traditional learning as provided by Mr Charles Nwankwo
- 3) Title: Seedball fabrication workshop with Fuma Gaskiya farmers
- a. Number of individuals trained: 18
 - i. Male: 5

- ii. Female: 13
 - b. Purpose: Farmers of the local Fuma Gaskiya branch were introduced to the making of seedballs as a pre-requisite for later on-farm trials.
 - c. Training institution/mechanism: Traditional learning as provided by C.I. Nwankwo, University of Hohenheim
- 4) Title: Introduction of INRAN scientists and technicians to the seedball technology
 - a. Number of individuals trained: 3
 - i. Male: 1
 - ii. Female: 2
 - b. Purpose: Help the collaborators get acquainted with the seedball technology
 - c. Training institution/mechanism: Traditional learning as provided by C.I. Nwankwo, University of Hohenheim
- 5) Title: Local Partners Training Workshop in Collaboration/Synergi with McKnight Foundation on elaboration/reviewing of Project Theory of Change (TOC) and Research Methods
 - a. Number of individuals trained: 25
 - i. Male: 15
 - ii. Female: 10
 - b. Purpose: To review and elaborate Grain Processing Project Theory of Change Training institution/mechanism: Traditional learning as provided by McKnight Foundation & University of Reading, UK
- 6) Title: Training and technical support to Sorghum and Millet Women Processors Groups in Niamey during Ramadan 2015
 - a. Number of individuals trained: 40
 - i. Male: 5
 - ii. Female: 35
 - b. Purpose: Give hands-on training to local women processors to make agglomerated sorghum and millet foods including couscous, boulettes and degue products. These products are highly demanded during Ramadan. Facilities of processors incubation center installed at INRAN with SMIL-USAID funds are used to reinforce women processors groups to face demand in urban city of Niamey during Ramadan. As well, training modules including food processing equipment optimization and innovation, process control, food safety and hygiene management, packaging and marketing are provided to participating groups working at the INRAN incubation center
 - c. Training institution/mechanism: Traditional learning as provided by Institut National de la Recherche Agronomique du Niger (INRAN)
- 7) Title: Salon National de l'Agriculture
 - a. Number of individuals trained: 600
 - i. Male: 250
 - ii. Female: 350
 - b. Purpose: Inform/communicate/expose to the public on new innovation and technology development in agriculture. These include improved seeds, foods products, equipment and processes and technics to improve agricultural productivity and market expansion for processed products along value chains of local crops in Niger and West Africa
 - c. Training institution/mechanism: Traditional learning as provided by Ministere de l'Agriculture in collaboration with le Reseau des chambres d'Agriculture (RECA)
- 8) Title: Public Launch Ceremony/Workshop of Grain Processing Project/Communication-Information
 - a. Number of individuals trained: 50

- i. Male: 20
 - ii. Female: 30
- b. Purpose: Overall goal is to inform local grain processors about new innovation and development on local based grain processing with objective to use food and nutrition-related technologies to develop value added sorghum and millet foods to expand markets and improve nutrition and health of vulnerable groups in West Africa for local community. Specifically inform participants on :
 - i. Innovative technology on millet and sorghum grain threshing at a household level
 - ii. Introduction of extrusion technology as a potential means of adding value to sorghum and millet grain in West Africa
 - iii. Use of nutrition/health attributes in strategy of marketing and promotion of foods along the sorghum and millet value chain in West Africa
 - iv. Innovative technology for roasting, grinding, agglomerating, filtering, pasteurizing, mixing and packaging millet, sorghum, cowpea and peanut grain based foods to improve nutrition and expand market
- c. Training institution/mechanism: Traditional learning as provided by Institut National de la Recherche Agronomique Du Niger (INRAN)

9) Title: 2015 Sorghum and Millet Innovation Lab Annual Review Meeting

- a. Number of individuals trained: 70
 - i. Male: 50
 - ii. Female: 20
- b. Purpose: An annual meeting organized by the Lab in Niamey, Niger to provide updates on research progress and results, as well as share future activities. Involved project partners and other sorghum value chain actors from the U.S., Europe and West Africa.
- c. Training institution/mechanism: Traditional learning as provided by SMIL with partnership of INRAN of Niger

10) Title: New post-harvest threshing technology training

- a. Number of individuals trained: 65
 - i. Male: 20
 - ii. Female: 45
- b. Purpose: Demonstrated and trained farmers on a new grain threshing technique
- c. Training institution/mechanism: Traditional learning as provided by INRAN, Hampshire College

11) Title: Sorghum and millet product marketing

- a. Number of individuals trained: 45
 - i. Male: 10
 - ii. Female: 35
- b. Purpose: Exposition and marketing of local agricultural products
- c. Training institution/mechanism: Traditional learning as provided by RECA (Reseau de Chambres d'Agriculture du Niger)

12) Title: Sorghum and millet grain processing and food safety training

- a. Number of individuals trained: 20
 - i. Male: 5
 - ii. Female: 15
- b. Purpose: Training women processors from Niamey on grain processing (cleaning, washing, decortication, milling, mixing, agglomeration, steaming, drying, and packaging) and food safety (personal hygiene, good manufacturing practices).
- c. Training institution/mechanism: Traditional learning as provided by INRAN

- 13) Title: Sorghum and millet new food processing technologies
 - a. Number of individuals trained: 55
 - i. Male: 20
 - ii. Female: 35
 - b. Purpose: Inform processors and farmers of new cereal processing technologies, e.g. extrusion, roasting, pasteurization, filtration, mixing, packaging, agglomeration, drying, threshing.
 - c. Training institution/mechanism: Traditional learning as provided by INRAN
- 14) Title: Provided information on insect pests of sorghum and millets and other crops to different stakeholders
 - a. Number of individuals trained: 85
 - i. Male: 53
 - ii. Female: 32
 - b. Purpose: Provided information biology and IPM control methods of insect pests of sorghum and millets and other crops
 - c. Training institution/mechanism: Traditional learning as provided by Hame Abdou Kadi Kadi
- 15) Title: Evaluation de variétés de sorgho pour la résistance à la cécidomyie
 - a. Number of individuals trained: 1
 - i. Male: 1
 - ii. Female: 0
 - b. Purpose: Field practical training on sorghum for his Thesis research activities and writing results; conduct host plant resistance studies to evaluate sorghum for resistance reliance; Collect data, analyze and write up the thesis
 - c. Training institution/mechanism: Traditional learning as provided by Hame Abdou Kadi Kadi
- 16) Title: On-farm training of producers to identify and determine control measures to apply
 - a. Number of individuals trained: 12
 - i. Male: 8
 - ii. Female: 4
 - b. Purpose: Help the producers/farmers recognize insect pests as constraints to production. Teach them how they can use alternative management methods as opposed to only insecticides.
 - c. Training institution/mechanism: Traditional learning as provided by Hame Abdou Kadi Kadi
- 17) Title: Training of Niger National Assembly councils on the use of sustainable technologies to control insect pests
 - a. Number of individuals trained: 35
 - i. Male: 22
 - ii. Female: 13
 - b. Purpose: Provide information that will help them draft documents for the National Assembly. Create awareness of research and results available. Building a network between scientists and policymakers.
 - c. Training institution/mechanism: Traditional learning as provided by Hame Abdou Kadi Kadi et al.
- 18) Title: Training of technicians on conducting field experiments and data recording
 - a. Number of individuals trained: 12
 - i. Male: n/a
 - ii. Female: n/a
 - b. Purpose: Technicians conducting the experimentation on host plant resistance to insect pests, diseases and drought were trained on the field on identification of the constraints and record data as provided in the protocol data recording sheet.
 - c. Training institution/mechanism: Traditional learning as provided by Hame Abdou Kadi Kadi
- 19) Title: Biological control of millet head miner at village level

- a. Number of individuals trained: 216
 - i. Male: 197
 - ii. Female: 19
 - b. Purpose: The training of farmer related prevention and control of millet head miner. During the process of parasitoid release farmers are involved to place the release bags in their farm or granaries and should be sensitized and trained on how to handle the parasitoid release bags
 - c. Training institution/mechanism: Traditional learning as provided by INRAN/University of Maradi
- 20) Title: Training for parasitoids production for implementing private unit for Habracon hebetor production
- a. Number of individuals trained: 18
 - i. Male: 17
 - ii. Female: 1
 - b. Purpose: The objective of training is to build farmers capacity about the process of rearing the parasitoid and it alternate host in other to prepare the release bags and scaling the parasitoid to farmers communities. Fourteen persons from farmer federation (Mooriben, FCMN et FUMA) attended the training.
 - c. Training institution/mechanism: Traditional learning as provided by University of Maradi and INRAN
- 21) Title: Training farmers on biological control of the millet head miner – Tera District/Tillabery Region
- a. Number of individuals trained: 150
 - i. Male: 120
 - ii. Female: 30
 - b. Purpose: Training was provided to farmers before releases of parasitoids in 15 villages
 - c. Training institution/mechanism: Traditional learning as provided by Laouali Karimoune and Malick Ba
- 22) Title: Training farmers on biological control of the millet head miner – Zinder Region
- a. Number of individuals trained: 216
 - i. Male: 197
 - ii. Female: 19
 - b. Purpose: The objective of the training was to provide farmers with information about the biological control program of the millet head miner. Since parasitoids were going to be releases in their respective farm/villages for research purpose farmers needed to be briefed on the purpose of the research.
 - c. Training institution/mechanism: Traditional learning as provided by University of Maradi and INRAN
- 23) Title: Biological control of the millet miner: concept and methods
- a. Number of individuals trained: 240
 - i. Male: 160
 - ii. Female: 80
 - b. Purpose: The training explained to farmers the purpose of the release of parasitoid wasps and to get farmers acceptance of the control methods.
 - c. Training institution/mechanism: Traditional learning as provided by Malick Ba
- 24) Title: Biological control of the millet miner: concept and methods
- a. Number of individuals trained: 240
 - i. Male: 160
 - ii. Female: 80
 - b. Purpose: The training at explaining to farmers the purpose of the releases of parasitoid wasps and to get farmers acceptance of the control methods.
 - c. Training institution/mechanism: Traditional learning as provided by Malick Ba

Mali

- I) Title: Striga phenotyping training for INRAN breeding technician
 - a. Number of individuals trained: 1
 - i. Male: 1
 - ii. Female: 0
 - b. Purpose: The objectives of this training were for INRAN sorghum technician Ardaly Abdou Ousseini to gain technical expertise on:
 - i. Trial set-up, and Striga data collection
 - ii. Understand and learn new approaches used on Striga collection and seed extraction
 - iii. Initiation and control of analysis tools (GenStat and Breeding Management System)
 - c. Training institution/mechanism: Traditional learning as provided by ICRISAT-Mali

Burkina Faso

- I) Title: Train farmers to seed production and good field techniques
 - a. Number of individuals trained: 70
 - i. Male: 50
 - ii. Female: 20
 - b. Purpose: To provide farmers the capacities for: Identification and putting in place of good seed plots, identification and epuration of off-types and seek plants in seed plots and management of harvesting and post harvesting of seed
 - c. Training institution/mechanism: Traditional learning as provided by Dr Roger G. ZANGRE (INERA)
- 2) Title: Diversifying Uses of Legume and Cereal By Grain Processing to Improve Nutrition and Expand Market on the value-added chain to benefit smallholder farmers in West Africa
 - a. Number of individuals trained: 45
 - i. Male: 35
 - ii. Female: 10
 - b. Purpose: 8th Annual Regional Workshop, Community of Practice (CoP)/CCRP/ West Africa/ McKnight Foundation. Objectives :
 - i. Review of projects activity reports
 - ii. Country reports
 - iii. Exchange of information (display of projects new findings and sharing of experience, new challenges, etc.) that include building partnerships within and between projects that address regional constraints to sustainable agricultural intensification, food security, processing, nutrition, income, and mitigation of land degradation and climate change; empowering farmers' organizations; strengthening value chain links and particularly those that most directly affect producers; storage, quality; management and marketing bargaining and access to new technologies, credit, markets, etc.
 - c. Training institution/mechanism: Traditional learning as provided by the McKnight Foundation

South Africa

- I) Title: Short Training Courses in Sorghum Food Processing Technologies and in Sensory Evaluation
 - a. Number of individuals trained: 2
 - i. Male: 2
 - ii. Female: 0
 - b. Purpose: Hands-on Training Course in Sorghum Quality and Sorghum Food Processing Technologies - The course dealt with sorghum plant development, identification of sorghum types, simple methods for determining sorghum end-use quality and sorghum food and beverage processing technologies. Hands-on Training Course in Sensory Evaluation - The course dealt with standard methods for food product sensory evaluation and focused on consumer hedonic sensory evaluation and descriptive panel sensory characterization of foods.

- c. Training institution/mechanism: Traditional learning as provided by University of Pretoria
- 2) Title: Sensory evaluation techniques for food quality assessment
- a. Number of individuals trained: 2
 - i. Male: 2
 - ii. Female: 0
 - b. Purpose: Training on sensory methods that will be used to evaluate quality and preference of products made with improved sorghum hybrids relative to traditional sorghums and tef in Ethiopia.
 - c. Training institution/mechanism: Traditional learning as provided by Henriette DeCock, University of Pretoria
- 3) Title: Sorghum milling, malting and small scale food processing techniques
- a. Number of individuals trained: 5
 - i. Male: 5
 - ii. Female: 0
 - b. Purpose: Hands on training on using local technology and resources to mill sorghum and process sorghum flour into food products that meet traditional and modern food needs. Demonstrations and hands-on learning on fermentation, and thin porridge and biscuit processing. Demonstration and training on sorghum malting and malt quality assessment. A separate project was leveraged to cover most of the cost for this training.
 - c. Training institution/mechanism: Traditional learning as provided by John Taylor, University of Pretoria

United States

- 1) Title: Breeding for resistance to insects
- a. Number of individuals trained: 5
 - i. Male: 4
 - ii. Female: 1
 - b. Purpose: Coordinate with entomologist on correct approach to identify resistance and methodology to advance resistance to hybrids and farmers' fields.
 - c. Training institution/mechanism: Traditional learning as provided by Gary Peterson
- 2) Title: Semester of coursework and research planning
- a. Number of individuals trained: 1
 - i. Male: 0
 - ii. Female: 1
 - b. Purpose: Moumouni Oumou who is completing a masters' degree in agricultural economics on the millet head miner biocontrol project came to Virginia Tech for four months to participate in a course on economic theory and another in econometrics. She also prepared for her research on the project.
 - c. Training institution/mechanism: Traditional learning as provided by Virginia Tech
- 3) Title: Tour and discussion of sorghum nursery
- a. Number of individuals trained: 3
 - i. Male: 2
 - ii. Female: 1
 - b. Purpose: Show and explain sorghum nursery for resistance to stress
 - c. Training institution/mechanism: Traditional learning as provided by Dr. Gary C. Peterson, Texas A&M AgriLife Research, Lubbock
- 4) Title: Training on rearing and evaluating maize weevils in stored sorghum
- a. Number of individuals trained: 2
 - i. Male: 1

- ii. Female: 1
 - b. Purpose: Teach how to rear maize weevils and evaluate stored sorghum for resistance
 - c. Training institution/mechanism: Traditional learning as provided by Dr. Bonnie Pendleton, West Texas A&M University
- 5) Title: Discussion on maize weevil and insect pests of stored sorghum
- a. Number of individuals trained: 71
 - i. Male: 43
 - ii. Female: 28
 - b. Purpose: Teach the biology and management of maize weevil and other insect pests of stored grain
 - c. Training institution/mechanism: Traditional learning as provided by Dr. Bonnie Pendleton, West Texas A&M University
- 6) Title: Discussion on sorghum midge
- a. Number of individuals trained: 71
 - i. Male: 43
 - ii. Female: 28
 - b. Purpose: Teach students the biology and cultural management of sorghum midge
 - c. Training institution/mechanism: Traditional learning as provided by Dr. Bonnie Pendleton, West Texas A&M University
- 7) Title: Drought ecophysiology concepts for SMIL PhD trainees
- a. Number of individuals trained: 2
 - i. Male: 1
 - ii. Female: 1
 - b. Purpose: Falalou Hamidou from ICRISAT-Niger provided an introduction to advanced concepts and methods on drought ecophysiology for dryland crops to SMIL PhD trainees Fanna Maina and Jacques Faye. Topics covered included infrared leaf canopy temperature measurements for estimating transpiration, rainout shelters and precision irrigation for managed drought stress, and lysimetric systems for whole-plant water budgets.
 - c. Training institution/mechanism: Traditional learning as provided by ICRISAT-Niger

Long-term training

This year saw the start of a number of long-term trainings, both U.S.-based, in-country and third country. Currently, a total of 23 individuals are involved in long-term training under the support of the Sorghum and Millet Innovation Lab.

Table 1. Long term trainees supported by the Sorghum and Millet Innovation Lab

Name	Sex	University	Degree	Major	Graduation Date	Home Country
Zongo Yvonne	Female	INERA	Bachelor's	Seed selection and conservation (SELCOSE)	Dec-15	Burkina Faso
Loza Mengistu	Female	Hawassa University	Master's	Food Processing and Preservation	Jul-16	Ethiopia
Kebede Dessalgn	Male	Haramaya University	Master's	Plant pathology/breeding	Dec-15	Ethiopia
Nadre Gbedié	Male	CERAAS	Master's	Breeding	Mar-16	Côte d'Ivoire
Oumou Moumouni	Female	Abdou Moumouni University of Niamey with Short	Master's	Agricultural Economics	May-16	Niger

		Training at Virginia Tech				
Michael Guerci	Male	Virginia Tech	Master's	Agricultural Economics	May-16	United States
Gnilane Sene	Female	University Cheikh Anta Diop	Master's	Pest management	Sep-15	Senegal
Abadi Mezgebe	Male	University of Pretoria	Ph.D.	Food Science	Jul-18	Ethiopia
Tadesse Teferre	Male	Texas A&M	Ph.D.	Food Science	Dec-18	Ethiopia
Demeke Bayable	Male	Purdue University	Ph.D.	Plant pathology	Aug-19	Ethiopia
Patrick Ongom	Male	Purdue University	Ph.D.	Plant Genetics	May-16	United States
Jacques Faye	Male	Kansas State University	Ph.D.	Agronomy (Plant Breeding & Genetics)	Mar-18	Senegal
Eyanawa Akata Atchozou	Male	CERAAS	Ph.D.	Agronomy (Breeding & Genetics)	Jan-17	Togo
Laouali Amadou	Male	University of Maradi	Ph.D.	Entomology	Jan-18	Niger
Adja Thiam	Female	University of Thies	Ph.D.	Pest management	Dec-15	Senegal
Fatou Welle	Female	University Cheikh Anta Diop	Ph.D.	Pest management	Dec-15	Senegal
Hame Abdou Kadi Kadi	Male	West Texas A&M University	Ph.D.	Plant, Soil and Environmental Science - Insect Pest Management	Jul-18	Niger
Charles Nwankwo	Male	University of Hohenheim	Ph.D.	Agriculture	Jun-17	Nigeria
Ousmane Seyni	Male	West African Center for Crop Improvement	Ph.D.	Plant Breeding	Dec-18	Niger
Elizabeth Diatta	Female	West African Center for Crop Improvement	Ph.D.	Plant Breeding	Dec-18	Senegal
Tebila Nakelse	Male	Kansas State University	Ph.D.	Agricultural Economics	Jul-18	Burkina Faso
Fanna Maina	Female	Kansas State University	Ph.D.	Agronomy (Plant Breeding & Genetics)	Mar-18	Niger
Adedayo Adeyanju	Male	Purdue University	Post-doctoral Studies	Plant Genetics	Jun-16	Nigeria

Additional long-term trainees from both Niger and Ethiopia are expected to start their program of study in January 2016.

Institutional development

Strengthening the institutional capacity of our national agricultural research partners is a priority for the Lab, with the goal of a long-term engagement in multiple areas such as technical research support, communications, environmental compliance, gender in development, project monitoring, financial administration, resource mobilization and information knowledge management.

Addressing capacity gaps – CERAAS

The Lab's largest partner in Senegal, CERAAS, is also a major player in the area of climate resilient crop research in West Africa. During the initial project phases, specific capacity gaps in personnel, training and available technologies have been identified. Through efforts from across the numerous Lab projects that partner with CERAAS, some of these gaps are being addressed through the support of short- and long-term training and specialized equipment. Pathology remains a need for the center and the region according to CERAAS' director.

Food incubator - INRAN

As mentioned previously, in supporting local incubation centers in the area of food processing, the Lab has enhanced a wider effort to explore the opportunities of food product development in West Africa. The successes achieved by researchers in this area were accentuated by the Nigerien government's decision to support the construction of a new food processing center at the Institut National de la Recherche Agronomique du Niger (INRAN). The center will serve as a headquarters for the development of new food processing methods and technologies.

Additionally, thanks to the Lab's support, an extruder for developing and processing nutrient-enriched instant flours, as well as a flour-sieving machine and other minor processing accessories were purchased and are being housed at INRAN's food processing center. The center will soon be fully functional and will allow for an increased level of training and support of urban and rural processors.

Private sector linkages – EthioGreen and Nu Life Market

Development of corporate partnerships is a key method to incubate a new wave of feed and food products in order to stimulate demand. The Lab ME assisted in catalyzing a partnership between Nu Life Market - a gluten-free/sorghum food product company in the U.S. (<http://www.nulifemarket.com/>) - and EthioGreen, an Addis Ababa-based food product company with domestic market and injera export sales (<http://www.ethiogreen.com>). A first phase of exchange of product formulations has occurred and site visits to each other's manufacturing facilities is planned for in the first half of the 2016 fiscal year. In addition, the two companies applied in partnership to the Partnering for Innovation (PI-EOI-04) expression of interest. Though unsuccessful, the application process assisted Nu Life Market and EthioGreen with sharing formulations and equipment ideas, planning for exchange visits, and the development of a stronger business/marketing plan.

Partner support in management issues

Partnering institutions have repeatedly requested opportunities for training and support in the area of administration and finance as well as general project management. The ME has begun to seek out opportunities to provide such support through hands-on training and webinars on pertinent issues. During the FY 2015, the ME provided one-on-one training to country coordinators in the area of environmental compliance and continues to support and encourage them in disseminating this information to technicians and researchers. The country coordinator in Ethiopia proceeded to host two separate training sessions on environmental compliance with the various implementing centers in-country. The ME also hosted an administration and finance webinar for the accounting contacts at the subaward institutions to discuss specific regulations and best-practices, as well as to address any challenges they might be facing. Future opportunities for broader management or soft skills trainings will be explored in the coming fiscal year.

Technology transfer and scaling partnerships

The Sorghum and Millet Innovation Lab has a diversified research program that focuses on seed technology development, crop and resource management interventions and food product development. Concurrent with this strategy is the diversified technology development pipeline with variety, hybrid and seeds targeted at the long-term, with near to intermediate term delivery of crop and resource management interventions, and a more continuous delivery of food products.

Genetic enhancement

Technology: Sorghum germplasm/variety development for food quality

Project PI: Tesfaye Tesso

Category: Biological

Phase: I – Under Research

Description: Over 10 new populations initiated between sources of high protein digestibility/high grain quality and locally preferred varieties are being advanced at Melkassa, Ethiopia. Moreover, F3 families derived from about 15 populations initiated in the U.S. are being advanced at Kansas State University. Selected F4 families will be shipped to Ethiopia in the fall for seed increase in off-season nursery. The most promising F5 families will be included in multi-environment yield trial beginning 2016 main season.

Partnerships made: Local partner institutions from three major sorghum growing regions of the country, namely, Amhara Regional Agricultural Research, Institute (Amhara), Oromia Agricultural Research Institute (OARI), Tigray Agricultural Research Institute (TARI) and Haramaya University.

Next steps: To complete a multi-environment yield evaluation

Technology: Development of parental materials for disease resistance

Project PI: Tesfaye Mengiste

Category: Biological

Phase: I – Under Research

Description: Evaluations of diverse sorghum lines for resistance against both grain and foliar diseases are in progress. Once the most promising resistant lines are identified, these traits will be introgressed into locally adapted cultivars to produce parental materials for the development of adapted disease-resistant lines.

Partnerships made: Local partner institutions from major sorghum growing regions including Asosa, Pawe and Bako research centers (EIAR) and Holleta Biotechnology Center.

Next steps: Continue screening activities for further evaluation of disease resistance.

Technology: Experimental hybrids for commercial sorghum seed industry

Project PI: Gebisa Ejeta

Category: Biological

Phase: I – Under Research

Description: Seventy-two experimental hybrids (out of a pool of 164) were advanced for continued evaluation at multiple locations.

Partnerships made: Local partner institutions including Melkassa and Sirinka research centers (EIAR), and Holleta Biotechnology Center, Tigray Regional Program, Oromia Regional Program and Haramaya University.

Next steps: Continue screening activities for further hybrid evaluation

Technology: Genomics-enabled breeding platform

Project PI: Geoffrey Morris

Category: Management Practices

Phase: I – Under Research

Description: The genomics-enabled breeding platform will include a genomic diversity database of West African germplasm (traditional varieties and breeding material), analysis tools for identifying useful genetic markers based on genomic diversity data, diagnostic genetic markers for useful traits and the locally-preferred genetic background, and network of trained geneticists and breeders that can take advantage of these resources in crop improvement.

Partnerships made: We anticipate establishing a partnership with the Integrated Breeding Platform based at CIMMYT and the CGIAR Genomics Back Office based at Cornell University (when launched).

Next steps: In the coming year we will analyze the genomic diversity data (genotyping-by-sequencing) for the West African Sorghum Association Panel, and the U.S.-based collections of Senegalese and Nigerian germplasm. We will identify and test new genetic markers for drought-related traits and locally-preferred genetic backgrounds.

Technology: Locally-preferred sorghum varieties with improved adaptive traits

Project PI: Geoffrey Morris

Category: Biological

Phase: I – Under Research

Description: Our goal is to further the development of several new locally-improved sorghum varieties. These will have locally-preferred genetic backgrounds with additional adaptive traits (drought tolerance, mold resistance, striga resistance) introgressed from other regional or international germplasm sources.

Partnerships made: In the final stage of the project, when new varieties have been developed and are ready for initial field testing, it is anticipated that the project team will partner with the Senegalese farmer cooperative RESOOP (Le Réseau des Organisations Paysannes et Pastorales du Sénégal), current partners of project co-PI Ndiaga Cisse for field testing, seed production, and marketing.

Next steps: In the coming year, the team will continue marker-assisted recurrent selection of existing breeding populations at CERAAS, and continue the early generation population development for new breeding populations at INRAN.

Technology: Insect-resistant sorghum cultivars

Project PI: Bonnie Pendleton

Category: Biological

Phase: I – Under Research

Description: Parental materials consisting of insect resistant lines have been developed.

Partnerships made: ISRA, CNRA, CERAAS, INRAN

Next steps: Continue screening activities for further evaluation of insect resistance.

Technology: Disease-resistant sorghum cultivars

Project PI: Bonnie Pendleton

Category: Biological

Phase: I – Under Research

Description: Parental materials consisting of disease resistant lines have been developed.

Partnerships made: ISRA, CNRA, CERAAS, INRAN

Next steps: Continue screening activities for further evaluation of disease resistance.

Technology: Food quality traits in sorghum

Project PI: Mitch Tuinstra

Category: Biological

Phase: I – Under Research

Description: Parental materials consisting of crosses of elite West Africa breeding lines with mutants having high protein digestibility have been generated. This platform has allowed for the advancement of 11 additional breeding populations to the F3 generation.

Partnerships made: ITA, CERAAS, ISRA, CNRA, INRAN

Next steps: Continue screening activities for further evaluation of food quality traits.

Technology: Forage digestibility traits in sorghum

Project PI: Mitch Tuinstra

Category: Biological

Phase: I – Under Research

Description: Parental materials consisting of crosses of elite West Africa breeding lines with mutants having BMR traits have been generated. Two new populations derived from crosses with N223 that were sent to INRAN.

Partnerships made: ITA, CERAAS, ISRA, CNRA, and INRAN

Next steps: Continue screening activities for further evaluation of forage digestibility.

Production systems management

Technology: Seed balls to reduce risk and improve yield in Sahelian pearl millet based farming systems

Project PI: Ludger Herrmann

Category: Management practices

Phase: I – Under Research

Description: Seed balls are a sowing technique for semi-arid areas, especially aiming at the improvement of plant establishment with dry sowing. Seed balls represent a mixture of soil material, seeds and additives (e.g. nutrients, pesticides). They aim at small-grain cereal cropping system with wide spacing (seed pockets).

Partnerships made: Fuma Gaskiya - Maradi, Niger (farmer organization); FAPAL - Louga, Senegal (farmer organization)

Next steps: Currently chemical optimization is in progress. Next step is the optimization with respect to water uptake and germination.

Technology: Mass rearing of parasitoids for biological control

Project PI: Malick Ba

Category: Management practices

Phase: I – Under Research

Description: The type of diet needed for increasing of parasitoid mass production was identified.

Partnerships made: None at this time

Next steps: Preliminary results indicated that adding of cowpea flour in the millet-based diet enhances mass production of parasitoids. The rearing methods are now being refined to identify the balance proportion of cowpea needed to complement the diet.

Technology: Direct release of *Habrobracon hebetor* adults for controlling the millet head miner

Project PI: Malick Ba

Category: Management practices

Phase: 2 – Under Field Testing

Description: Progress was made in the identification of numbers of *H. hebetor* adults needed per acreage of pearl millet for controlling the millet head miner.

Partnerships made: Activities are being undertaken with farmer unions in Western and Eastern Niger.

Next steps: The preliminary result have to be confirmed from the 2015 rainy season trials.

Added-value products and markets

Technology: Improved endosperm sorghum for protein quality and processing functionality

Project PI: Joseph Awika

Category: Biological

Phase: 2 – Under Field Testing

Description: Combining high digestible, high lysine sorghum trait with modified starch profile (waxy trait) to improve sorghum functionality as a food ingredient in traditional and modern processes in Ethiopia. This will result in higher food use of sorghum and thus higher crop value for small scale farmers. The high lysine trait will also improve nutritional status in children.

Partnerships made: None yet established

Next steps: Evaluating performance of the improved sorghums in various environments in Ethiopia.

Technology: Extruded sorghum- and millet-based food products

Project PI: Bruce Hamaker

Category: Mechanical and Physical

Phase: 2 – Under Field Testing

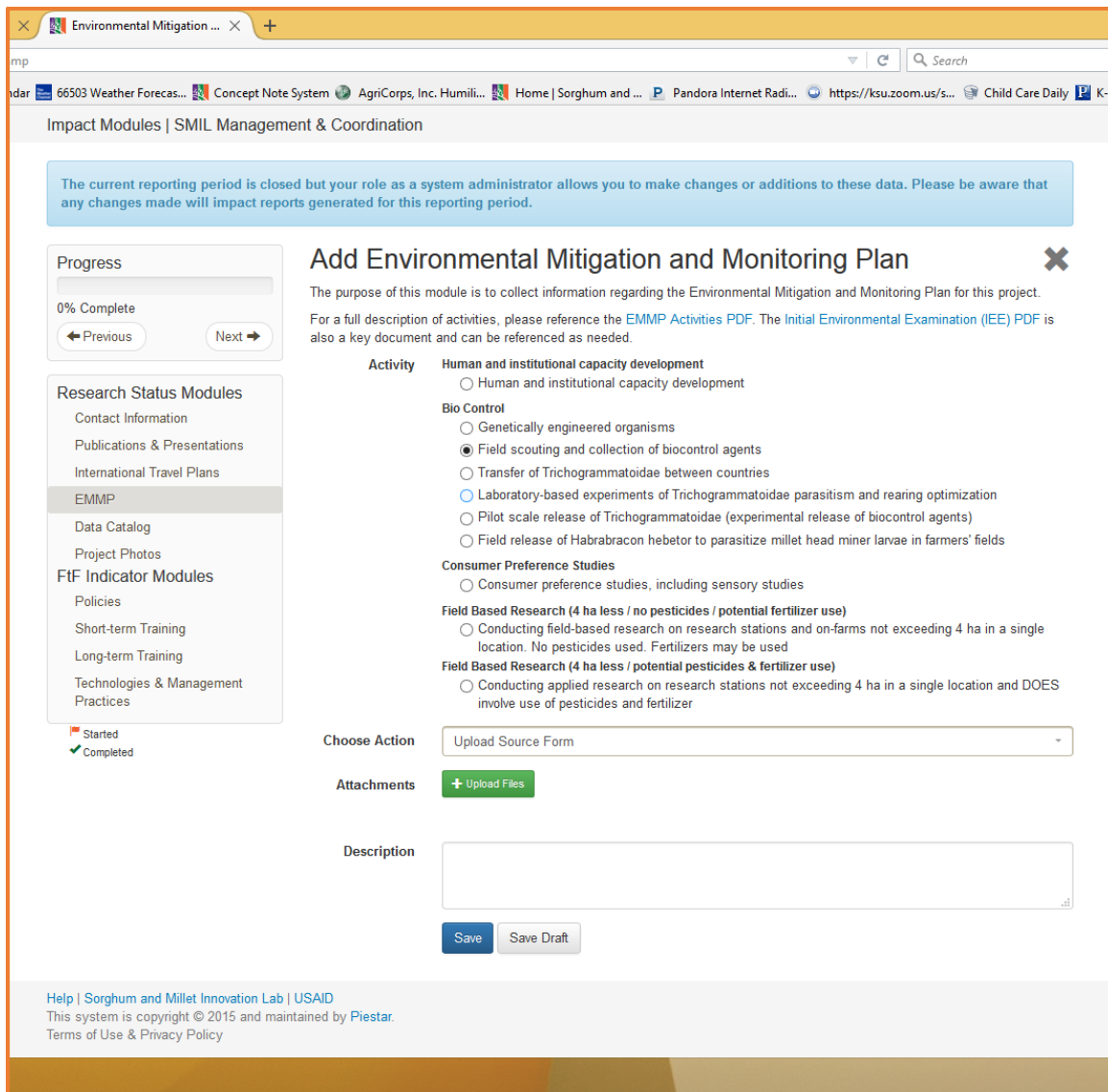
Description: Formulas for extruded sorghum- and millet-based products that incorporate local plant products for the purpose of nutrient fortification have been developed. These formulations are being utilized in extruded infant cereal production.

Partnerships made: Moribeen/Western Niger (Tillabery and Dosso) and Fuma Gaskiya/Eastern Niger (Maradi), McKnight Foundation, ISRA, CNRA, INRAN

Next steps: Continue testing on the products for nutrient delivery efficiency as well as product consumer feedback

Environmental Management and Mitigation Plan (EMMP)

The Sorghum and Millet Innovation Lab continued to strengthen the Environmental Mitigation and Monitoring Planning (EMMP) during this implementation period. An EMMP module was developed for the SMIL Resource & Reporting Hub. This web-based module provides an easily-accessible method to report monitoring visits in relation to the project activities as defined in the USAID approved Initial Environmental Examination (IEE). The module also provides a file upload feature to log relevant training information, national standards, national environmental compliance committee minutes, etc. Web links to key resource documents and contacts for environmental officers at USAID mission level are also provided (Figure 2).



Environmental Mitigation ...

mp

66503 Weather Forecas... Concept Note System AgriCorps, Inc. Humili... Home | Sorghum and ... Pandora Internet Radi... https://ksu.zoom.us/s... Child Care Daily K-5

Impact Modules | SMIL Management & Coordination

The current reporting period is closed but your role as a system administrator allows you to make changes or additions to these data. Please be aware that any changes made will impact reports generated for this reporting period.

Progress

0% Complete

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Research Status Modules

- Contact Information
- Publications & Presentations
- International Travel Plans
- EMMP**
- Data Catalog
- Project Photos

FtF Indicator Modules

- Policies
- Short-term Training
- Long-term Training
- Technologies & Management Practices

Started
Completed

Add Environmental Mitigation and Monitoring Plan

The purpose of this module is to collect information regarding the Environmental Mitigation and Monitoring Plan for this project.

For a full description of activities, please reference the [EMMP Activities PDF](#). The [Initial Environmental Examination \(IEE\) PDF](#) is also a key document and can be referenced as needed.

Activity

- Human and institutional capacity development**
 - ☐ Human and institutional capacity development
- Bio Control**
 - ☐ Genetically engineered organisms
 - ☒ Field scouting and collection of biocontrol agents
 - ☐ Transfer of Trichogrammatidae between countries
 - ☐ Laboratory-based experiments of Trichogrammatidae parasitism and rearing optimization
 - ☐ Pilot scale release of Trichogrammatidae (experimental release of biocontrol agents)
 - ☐ Field release of HabraBracon hebetor to parasitize millet head miner larvae in farmers' fields
- Consumer Preference Studies**
 - ☐ Consumer preference studies, including sensory studies
- Field Based Research (4 ha less / no pesticides / potential fertilizer use)**
 - ☐ Conducting field-based research on research stations and on-farms not exceeding 4 ha in a single location. No pesticides used. Fertilizers may be used
- Field Based Research (4 ha less / potential pesticides & fertilizer use)**
 - ☐ Conducting applied research on research stations not exceeding 4 ha in a single location and DOES involve use of pesticides and fertilizer

Choose Action

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Attachments

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Description

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Figure 2. EMMP data interface on the SMIL Resource and Reporting Hub

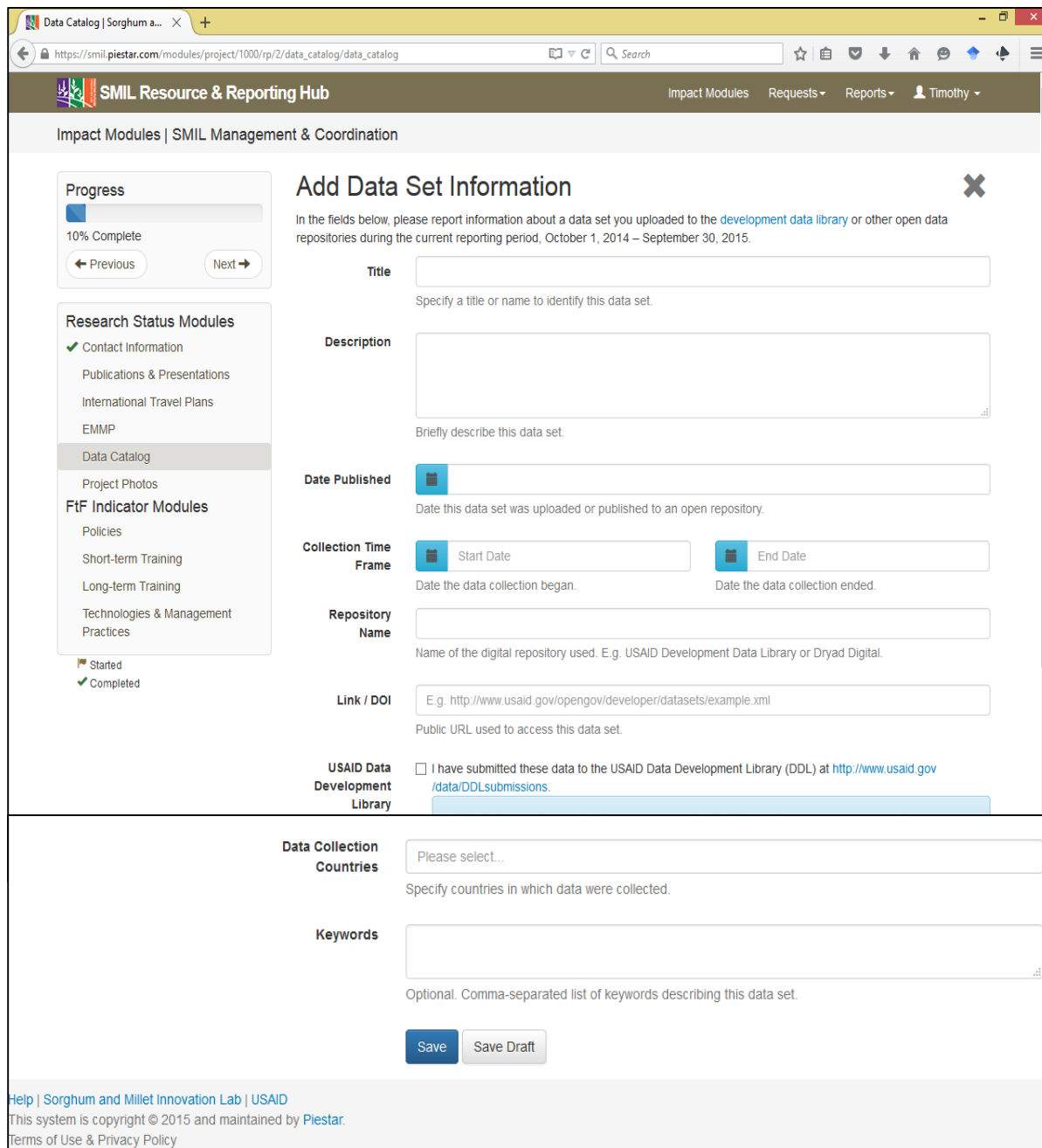
Additional environmental compliance capacity development is ongoing in each country. In Ethiopia, the Lab's program coordinator has linked with the existing monitoring and evaluation committees of the EIAR research stations to provide an environmental compliance orientation and training. Ongoing monitoring at research stations will be facilitated by these existing committees in cooperation with the Lab program coordinator. In Niger, the Lab coordinator initiated discussions with the senior leadership of INRAN as regards to environmental compliance. The director general of INRAN created and identified an environmental compliance focal person for the entire organization. Further to this, an external consultant has been identified and the terms of reference for an initial environmental scoping, gaps analysis, and orientation of research station staff has been developed for implementation in quarter one of the next implementation year. Lab partner ISRA in Senegal is pursuing ISO certification. The ISRA leadership and the Lab are investigating how environmental compliance will be considered during the certification process.

Open Data Management Plan

The Sorghum and Millet Innovation Lab began developing a data management plan in 2014 as part of our overall monitoring and evaluation platform contained in the SMIL Resource and Reporting Hub (<https://smil.piestar.com/login>). The module that is used to track datasets is referred to as the “Data Catalog” module. A screenshot of the Data Catalog module is presented in Figure 3. The Lab does not store any data that is collected in our projects but we use the module to link to the locations where the data is archived. During the 2015 annual meetings with our projects in Ethiopia and West Africa, a training was conducted to familiarize all collaborators about the requirements of ADS Chapter 579 and the importance of complying with the directive. In addition, we illustrated the “Data Catalog” module of the Resource and Reporting Hub and provided participants with guide sheets as well.

The Data Catalog module, as well as all other modules of the SMIL Resource and Reporting Hub, is accessible to the Lab’s AOR. We will enhance the functionality of the Data Catalog to send an email to the AOR when any new data set is entered into the system and then she (or he) can review the submission and determine whether any additional action is required. This system is much more functional than a static reporting document. All of our projects will be collecting data as part of their research activities and data will be collected at multiple points in time in multiple locations.

To keep track of the data, and as part of the Lab’s research program development strategy, each project developed and “Operational Plan” which is annually updated. In these plans, each data collection activity is described and the time when that data will be collected is denoted in the log frame. Each of these documents is available on the SMIL Resource and Reporting Hub and can be reviewed by the AOR in case greater information is required on what kind of data is being collected, for what objective, under what conditions and locations and when.



Data Catalog | Sorghum a...

https://smil.piestar.com/modules/project/1000/rp/2/data_catalog/data_catalog

SMIL Resource & Reporting Hub | Impact Modules | Requests | Reports | Timothy

Impact Modules | SMIL Management & Coordination

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Add Data Set Information ✕

In the fields below, please report information about a data set you uploaded to the [development data library](#) or other open data repositories during the current reporting period, October 1, 2014 – September 30, 2015.

Title
Specify a title or name to identify this data set.

Description
Briefly describe this data set.

Date Published
Date this data set was uploaded or published to an open repository.

Collection Time Frame
 Start Date
 End Date
 Date the data collection began. Date the data collection ended.

Repository Name
Name of the digital repository used. E.g. USAID Development Data Library or Dryad Digital.

Link / DOI
E.g. <http://www.usaid.gov/opengov/developer/datasets/example.xml>
Public URL used to access this data set.

USAID Data Development Library
☐ I have submitted these data to the USAID Data Development Library (DDL) at <http://www.usaid.gov/data/DDLsubmissions>.

Data Collection Countries
Please select...
Specify countries in which data were collected.

Keywords
Optional. Comma-separated list of keywords describing this data set.

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Figure 3. Data catalogue interface on the SMIL Resource and Reporting Hub

Governance and management entity activity

Activities in the ME have focused refining of management practices and expanding in additional directions that enhance the Lab's mission.

Strengthening relationships with partners

The Lab has continued to strengthen working relationships with all domestic and foreign partner management teams. Webinars were held with the administration and finance teams of the Lab's domestic partners to orientate them in the areas of sub award management, timelines, reporting requirements, web hub reporting tools, and post award accounting. Administration and finance support visits were organized to each of domestic university to meet with the principal

investigators and their administration and finance support teams. Additional guidance notes have also been developed where relevant to address common issues.

Country coordinator activity

The Lab's country coordinators (CC) are a key part of the ME team and regularly interface with the USAID mission offices and in the field. In Ethiopia and Niger, the CC have attended and continue to be invited to USAID quarterly development partner meetings. This provides a forum for the CC to represent the sorghum and millet value chain research and interface with large USAID multiyear funded projects. At a recent quarterly meeting in Addis Ababa, it was suggested that all Innovation Labs working in Ethiopia be involved in the development of a Mission-issued RFA to help strengthen the agricultural research aspects in the final version.

Continued expansion of reporting hub tools

The SMIL Resource and Reporting Hub developed by Piestar has seen continued development throughout this fiscal year. The development team added several new management tools to the system, including more sophisticated data export commands, an environmental compliance module, a photo upload module, travel report submission and automated e-mails to help remind users to submit their reporting data. Other aspects currently under development include a burn rate financial dashboard for both project and ME use.

Global sorghum contact database

The need for a multi-functional segmented database was identified as another area of support for building a stronger sorghum and millet network coalition. A student employee with a management information systems background was hired to develop an MS Access database to manage contacts and information. This database has approximately 1,200 current entries and is searchable and sortable by multiple defined fields. Occasional exports to MailChimp keep contacts fresh and forms within MailChimp help end users to self-segment. Future deployments include online web services that connect with an Access database.

Internal annual review

In December 2014, the Lab conducted an internal annual review and planning session as per outlined in the Plan for Monitoring Performance (PMP). The primary objectives of this review were to evaluate research performance, overall management effectiveness and emerging future priorities. The ME staff held a one-day meeting around these issues and documented key observations, which were presented along with recommendations for future directions to the EAB for further consideration and guidance.

SICNA

The Lab was a key player in the organization and coordination of the 2015 Sorghum Improvement Conference of North America (SICNA), which was held in Manhattan, Kansas on September 1-3. This year's conference had nearly 200 registrants, as well numerous exhibitors for an industry expo on Day 2. The conference activities and session topics were centered on the theme of "tackling today's grand challenges" in sorghum production and research, while enhanced interaction between production, industry and research were encouraged among participants. The Lab also offered registration scholarships (\$200 each) for graduate students from low- to middle-income countries that were interested in attending the conference. Plans are currently being made in regards to next year's organizers, and it is anticipated that the Lab will take some role in that planning committee. Dr. Dalton provided a keynote presentation and chaired the session on added-value products and new markets.

Industry linkages

In order to stay knowledgeable of the various opportunities and challenges in the sorghum and millet industries, the Lab has been proactive in establishing linkages with key players in those industries.

Sorghum

The Lab continues to collaborate with U.S. industry through participation on the High Value Markets Committee of the United Sorghum Checkoff and indirectly through interaction with other members on the crop improvement

committee to understand where complementary investments are being made. There has also been effort to communicate with the U.S. industry about the Lab's international activities. In early February 2015, Dr. Dalton presented a seminar at the monthly Center for Sorghum Improvement series at Kansas State University that was streamed to numerous other institutions. The Lab also initiated research to document the spillover effects of INTSORMIL research on U.S. industry, especially how previous research on insect tolerance and host plant resistance has generated new parental lines and hybrids that better tolerate the sugarcane aphid.

Millet

Proso millet is grown on more than 700,000 acres each year in the arid Great Plains as an alternative rotation or main grain crop in parts of Colorado, North Dakota, Nebraska, Minnesota, South Dakota and Kansas. Proso's market focus has been traditionally for bird seed but there are expanding human food markets to be explored both in the U.S. and internationally. Thunderbird Livestock and Land (TLL) is a large family owned producer of proso and pearl millet in eastern Colorado with plans to build phase one of de-hulling processing plant in 2016. The Lab ME has been networking with this company and Nu Life Market to explore the potential for common interests. Additionally, TLL is interested in facilitating on-farm millet trials in cooperation with the newly hired K-State pearl millet breeder based at the Hays, Kansas agricultural research center.

Other Topics

To enhance its overall impact, the Lab's activities in FY 2015 also extended into the cross-cutting areas of gender and environment while aligning itself with country-level strategies in the areas of sorghum and millet research.

Gender

A proactive approach to gender integration has been followed by the Lab. In order to achieve the greatest impact in this area, the Lab has taken a three-tiered approach that includes addressing both more specific project-level opportunities, as well as broader opportunities at the program level.

Gender integration action plans

While each research project within the Lab's portfolio differs significantly in terms of its "on-the-ground" activities, each has specific areas where the role of gender has the potential to impact the science being completed. This may be in interactions and preferences of an end-user group (i.e. women entrepreneurs or producers), or it may be at the national level of female participation within research in agriculture.

In order to address these potential impacts from the start of each project and avoid gender integration being approached as an afterthought, each project was asked to develop a gender integration action plan as part of their annual operational plan revisions. These plans were designed with ME support and include practical, obtainable steps that address HICD issues, feedback session design and end-user preferences. These plans were then integrated into the overall project operational plan and will be reported on by the research teams each reporting period.

Gender and sorghum production consultancy in Ethiopia

As a way to address the specific needs identified in Ethiopia, the Lab entered into a consultancy contract with gender expert Yeshi Chiche for a country-specific exercise aimed at capacity building in the area of women in science as well as gathering gender-disaggregated data on sorghum production practices and uses in the major sorghum-producing regions of Ethiopia. Ms. Chiche has a long history as an agricultural economist working in gender issues and the farming systems approach, and spent much of her career tackling gender issues at EIAR.

The project has launched initial activities, including identifying female scientists from key sorghum regions (and some male scientists in areas where a female scientist could not be identified) to participate in the preliminary

stages of a comprehensive literature review on sorghum production practices and uses in the major sorghum-producing areas. The group has completed initial meetings and a first draft of the literature review.

Future steps will include the development of a rapid assessment tool to further research the regional differences (in particular, to obtain gender disaggregated data), with the team of scientists administering the tool on a selected household level. The Lab is very excited about the potentially rich data on Ethiopian sorghum production that will become available as a part of research study.

Women in science – Ethiopia

In the first year of project meetings in 2014, it became very apparent that the participation of women in science was going to be a very real challenge for Lab activities – the only females present of the more than 50 attendees were USAID and Lab representatives. Therefore, in order to encourage greater female participation in project activities and discussions, the Lab worked with project PIs to identify junior-level female scientists whose research interests aligned with the project activities. These women, along with two female senior scientists, were invited to take part in the meetings. Strong discussions around gender were generated during the meetings, and opportunities for long-term training and project involvement for the women also resulted.

Future activities

Additional needs and opportunities will continue to be monitored. The Lab is following closely with the progress of GENNOVATE with hopes of aligning future gender integration activities in West Africa along the GENNOVATE platform.

Environment

The ME strategy in regards to strengthening environmental compliance across the program has been by addressing three key areas:

- 1) An orientation and training in relation to environmental compliance (EC) was integrated into the country project initiation and annual planning meetings. Mission level EC officers and the Lab AOR assisted in providing these presentations.
- 2) The ME then worked with principal investigators to seek feedback, reference documents, and input in the development of environmental planning for the overall portfolio of research activities.
- 3) Lastly, the ME developed an interactive space and process in which an EMMP module was created within the existing Reporting Hub. This module provides Mission contacts, resource materials, and a platform for reporting monitoring visits and uploading relevant documents.

The SMIL Resource and Reporting Hub has continued to be a key management tool and appreciated at all levels of the research and management teams. There will be consistent follow up with the Hub developers to further strengthen the EMMP module and its utilization.

National strategy alignment

In Ethiopia, the Lab country coordinator worked in partnership with EIAR to interface with the Agricultural Transformation Agency (ATA) as they developed a government-commissioned sorghum sector strategy. Five key value chain components were identified: 1) research and technology development, 2) access to inputs, 3) on-farm production, 4) post-harvest processing and storage, and 5) trade and marketing demand sinks. On-farm production, trade and marketing demand sinks, and research and technology development were established as key priorities to the national strategy and central bottlenecks for each component were identified. USAID-funded research, including some Lab activities, is addressing some of these bottlenecks and further country-level planning is anticipated to continue to align with this national planning framework where relevant.

Additionally, Ethiopia's initial Agricultural Growth Program (AGP) Phase I did not include sorghum as a value chain. AGP-I has been reviewed and the AGP-II priorities and geographic focus have been identified. Agricultural

commercialization zones which consist of clustered 10-15 woredas will be a key framework within the AGP-II to support a strong value chain and value-addition approach for all relevant crops. Thanks to active involvement by a variety of agricultural and development players (including USAID), sorghum has now been included in the AGP-II framework.

Issues

Financial Management

The SMIL ME guided the initial proposal budgeting and submission process to increase the percentage of research project funding directly into country national research system (NRS) partners. Table 2 describes the current unaudited allocation of resources expected over the five year program horizon, based upon current spending patterns. Approximately 38% of the research project funding is being contracted under sub awards to non-US based institutions and 22% towards student support in long-term training for an overall sum of 60% of the research budget. U.S.-based institutions (operating expenses and facilities and administration charges) receive slightly more than one-third of the research budget. Seven percent of the research and training budget is unallocated. Overall, 70% of the total program budget is allocated to research and long-term training. Support for the program accounts for approximately 30% of the total budget. A more detailed presentation of the financial allocation, broken down by country is presented in Appendix 2 but neither table includes cost-share contributions that may amount to \$4,227,676, well above Kansas State University's contracted commitment of \$2,565,000.

Table 2. Approximate funding allocations and projections

Category of spending	\$US	Share of	
		Research Budget	Total Budget
Research and Training			
Non-US collaborating institutions	3,623,602	38%	26%
U.S.-based and WACCI Student Training	2,104,270	22%	15%
U.S. Institutions	3,251,601	34%	24%
Unallocated research and training	657,433	7%	5%
<i>Sub-total</i>	<i>9,636,906</i>	<i>100%</i>	<i>70%</i>
Management Entity	2,659,248		19%
Facilities and Administration	1,403,846		10%
<i>Grand Total</i>	<i>13,700,000</i>		<i>100%</i>

TraiNet and Exchange Visitors

As the Lab and its partners have moved forward in the launch of a number of long-term training programs, it has run into several challenges for those involved in U.S.-based programs and therefore require the application of the TraiNet/VCS system. The system has a tendency to work in conflict with the already-present University immigration practices and create numerous complications. However, recent developments within USAID in regards to its policies on requirements for Exchange Visitors have resolved these issues.

Future directions

The overall programmatic structure will not change much in FY 2016 but we will attempt to add new elements to enrich the program. The Sorghum and Millet Innovation Lab will increase the collaboration between West African pearl millet breeders and the Kansas State University pearl millet breeder. This collaboration will be initiated in the Q2 FY2016 at the annual meeting. We anticipate that the meeting will be followed up by visits to some of the winter pearl millet nurseries that are in place in Senegal and other nations. Based upon these visits, the team will develop a strategy for collaboration and plans for future interaction and the interaction will be supported with a noncompetitive grant.

Discussions have been started on how to encourage collaboration between Innovation Labs. The Sorghum and Millet Innovation Lab sees several strategic opportunities to interact with the Legume Innovation Lab, the Peanut and Mycotoxin Innovation Lab, the Sustainable Intensification Innovation Lab and the newly established Livestock Innovation Lab. These Labs are working in the West African Sahel region and Ethiopia and provide an opportunity for contributing resources to joint objectives that focus on interactions between the system components. This may impact the unallocated research and training budget.

In FY 2015, the Sorghum and Millet Lab facilitated interaction between private sector processors in the United States and Ethiopia. This led to an expression of interest by Nu Life Markets, a Kansas-based sorghum food product manufacturing firm, and Ethiogreen, an Ethiopian-based manufacturer of *injera* and other products. Funding is being sought from the Kansas Department of Agriculture for exchange of knowledge and for exploring partnership opportunities. We do not anticipate budget implications for this activity.

At the same time, we will be working with U.S.-based extrusion equipment manufacturers to identify appropriate scale / partnership opportunities to support product development in West Africa, initially with ITA in Senegal. An exploratory visit to the Kansas State University Bioprocessing and Industrial Value Added Program by ITA is scheduled for Q1 FY 2016 and training courses are under discussion for Q3 FY 2016. This will impact the unallocated research and training budget.

The Sorghum and Millet Innovation Lab will continue in its objective to build a coalition of science and industry by interacting with the United Sorghum Checkoff program, the Dryland Cereals and Legumes Agrifood Systems CGIAR Research Program as well as cultivate new partnerships where possible, for example through public-private partnerships in plant breeding and added-value product development. In 2016, we will co-host the Sorghum Improvement Conference of North America. This will not impact the unallocated research budget.

Appendix I – Success Stories

Tiny package, big impact

Giving seeds an added boost to survive harsh Sahelian climates

Home to the harshest cropping environment in the world, the Sahel region of Africa hosts poor, sandy soils, low and erratic rainfall, and excessive soil surface temperatures. Ludger Herrmann, a researcher from the University of Hohenheim whose project is funded by the Feed the Future Innovation Lab for Collaborative Research on Sorghum and Millet, is working to improve seeding success rates and combat these harsh conditions with a tiny capsule that may revolutionize Sahelian cropping systems: the seedball.

The tiny seedball, a technology that is part of a long-term collaborative research effort with farmer organization Fuma-Gaskiya in the Maradi region of Niger, is small enough to fit in the palm of your hand, but holds the power to change the lives of farmers in the Sahel.

According to Herrmann, the greatest challenge faced by the research team is how to improve major staple cropping in the region in order to increase food security and resilience. Sahelian farmers often have limited space for cropping, very low incomes and restricted access to inputs such as fertilizer and pesticides. This combination of limitations makes it difficult for farmers to subsist on their cropping operations, and nearly impossible to sell their crops for income.

“Millet stand establishment is often a problem with emergence followed by intermittent drought so seedlings die, which forces the farmer to sow again, and then even a third time,” said Timothy J. Dalton, Director of the Feed the Future Innovation Lab for Collaborative Research on Sorghum and Millet.

By creating microenvironments that can capture moisture and make nutrients more readily available, the seedball has the potential to break this cycle.

Herrmann and his team invested in “local fertilizer” to create the seedballs, using a combination of products that are easily accessible to subsistence farmers in the Sahel. Wood ash, a resource available in every household, provides water soluble phosphate while urine is used to close the nitrogen gap. Potassium from wood ash also allows for stomal closure in the emerging plant, which allows for higher water use efficiency. Because of this, Herrmann said it is expected that plants emerging from seedballs have a higher drought tolerance and can survive longer dry spells than plants that are dry scattered as seeds. If so, he said, seedballs will increase labor efficiency and reduce seed demand.

“These fields often fail to produce yield due to the fact that plants emerge after little rain that is followed by drought,” he said. “The nutrient formulation of the seedballs should support early plant growth, root growth in particular, so that seedlings are able to exploit a larger soil volume.”

While physical optimization of seedballs may be a challenge, Herrmann said the long-term goal is to define additives so seedball seeds germinate with a defined minimum amount of rainfall.

“We believe that seedballs can improve the local millet and sorghum cropping systems by reducing seed expenditures, increasing seedling survival, enhancing nutrient and water use, and finally by reducing cropping risk, increasing yield and thus income and resilience,” Herrmann said.

The key will be to show that the seedballs are an effective measure to enhance seeding survival and growth in the very early growth stages. Final yield is determined by the length of the growing season, and each day that a crop emerges earlier will increase yield, Herrmann explained.

The seedball is a powerhouse in its miniscule packaging. It is a low-cost technology with low application risk for farmers, particularly women who are often even more limited in their access to inputs. With its low investment requirements, the seedball offers exciting potential in semi-arid landscapes with sandy soils like those found throughout the Sahel.



Seedball preparation workshop in Niger in April 2015. Photo credit: Ludger Herrmann

Revolutionizing Sorghum

Scientists from Purdue, K-State team up to revolutionize sorghum stress resistance

Each year, sorghum is planted by millions of farmers across Africa's semi-arid regions as a key staple crop that will serve as food for household members, fodder for livestock and materials for construction. Due to the harsh climate in these areas, only a fraction of the planted crop typically survives, often leaving smallholder farmers with little food, fewer resources and no income.

In partnership with the Feed the Future Innovation Lab for Collaborative Research on Sorghum and Millet, three research teams are working together to improve sorghum's adaptation and resilience to help farmers manage risk in Africa's difficult growing conditions. Researchers Gebisa Ejeta and Tesfaye Mengiste of Purdue University and Tesfaye Tesso of Kansas State University have teamed up to head the initiative.

In 2014, the three teams planted 2,500 different sorghum lines in test nurseries across Ethiopia. Perhaps the largest screening of sorghum resistance in Ethiopia, the test plots represent the broad range of climatic and environmental stressors present in the target area. Considered the genetic origin for sorghum, Ethiopia's numerous landraces offer access to a diverse bank of genetic material. Because many of the lines being evaluated as part of the teams' research are not part of the U.S. germplasm collection, the initiative offers an exclusive opportunity to explore Ethiopian sorghum germplasm and identify areas of growth and innovation for new stress-resistant varieties.

Tesso, an associate professor of sorghum breeding and genetics, said the ongoing research is based on enhancing productivity through deploying high yielding drought-tolerant hybrids, increasing resistance to leaf and panicle diseases and enhancing nutritional value of the crop with emphasis on improving protein availability.

"Our projects attempt to address these key components," Tesso said. "Any breakthrough in these efforts will have monumental effects on the lives of farmers who depend on this crop both in terms of enhancing productivity and income and in reducing protein malnutrition and building a healthy society."

The improvement in protein availability in grain sorghum may also have significant impacts on the sorghum industry globally, Tesso said.

"It can increase feed value where the crop is primarily used as animal feed and, through reducing protein malnutrition it can also significantly contribute to improved health of communities where sorghum serves as a staple," he said.

The teams rely on partnerships with the Ethiopian Institute of Biological Diversity and the Ethiopian Institute for Agricultural Research (EIAR) along with regional programs and universities to gain access to the many landraces the country has to offer. Screening of planted germplasm has begun for characteristics including grain quality, drought resistance, disease resistance and Striga resistance. These screenings will be followed by genotyping to compare each plant's expressed characteristics with its DNA to locate specific genes that are linked to favorable traits in resistance or grain quality.

"We have assembled about 2,000 sorghum germplasm accessions and they are being characterized for various traits," Tesso said. "Given the richness in genetic diversity among the accessions, this effort may lead to major discoveries on several traits and the results have the potential to go beyond Ethiopia and positively impact the global sorghum industry."

Ejeta, Mengiste and Tesso and their teams are paving the way for sorghum breeders across the globe in the development of more resilient sorghum varieties. These new lines have the potential of providing sorghum farmers in Ethiopia and around the world with greater stability, income and food security.



Sorghum experiment fields at the Werer Research Station in central Ethiopia. Photo credit: Kira Everhart-Valentin

Battling sorghum's newest enemy

Using 30 years of science to fight a modern pest

Recently, the sugarcane aphid has had sorghum farmers and breeders biting their nails as the tiny green pest bullies its way from Louisiana to Kansas, destroying sorghum fields along the way. The aphid was originally identified in Florida in 1977, but it wasn't a major sorghum pest in the U.S. until just two years ago. A known pest in some parts of Africa, the sugarcane aphid got its first taste of American sorghum 2013 and didn't look back.

After crossing into the Beaumont area of South Texas in late 2013, the aphid worked its way through the Rio Grande Valley in northern New Mexico and devastated sorghum. In fact, growers lost up to 50 percent of grain sorghum yield in infested fields during 2013. This represented a nearly \$8 million loss for growers in 2013 alone.

The sugarcane aphid has been progressively expanding its range ever since. It has proven to overwinter well in the sorghum-producing areas of the U.S., and is now identified as a pest in the entire sorghum production region south of the Mason Dixon Line and east to the Atlantic Ocean. Its impact has been seen in all major sorghum-producing states, including Texas, Oklahoma and Kansas.

The most promising line of defense against the sugarcane aphid is in the development of resistant sorghum lines. However, breeding for resistance is a slow and painstaking process that can take years. Luckily for U.S. sorghum producers, breeders have been working on this problem for nearly 30 years through germplasm exchange and international collaboration, long before the aphid began wreaking havoc on American soil.

Investing in research for future benefit

This isn't the first time long-term research investments have paid off for the sorghum industry. In the 1980s, a similar pest called the greenbug aphid infested U.S. sorghum fields, leaving significant economic losses in their wake. However, thanks to the INTSORMIL* program and the exotic germplasm collection it funded, host plant resistance was developed, saving an estimated \$389 million in economic losses for the United States in 1989 alone (equivalent to nearly \$750 million in 2015 dollars). The investments made in Kansas, Texas and Nebraska on greenbug resistance is estimated to have generated a 48.2 percent rate of return on investment.

INTSORMIL was a USAID-funded program aimed at improving opportunities for sorghum and millet throughout the developing world and was in existence from 1979-2013 before being transitioned into the Feed the Future Innovation Lab for Collaborative Research on Sorghum and Millet (SMIL). Its existence supported the work of researchers like Gary Peterson, a sorghum breeder who first started working on sorghum pest resistance under the program.

Peterson's first area of focus was on the greenbug sorghum pest, and he, along with numerous other researchers, conducted countless screenings of thousands of sorghum lines in search of resistance. While screening for greenbug resistance, they also identified some of the best lines for sugarcane aphid resistance, a quality that is now proving to be very important in addressing the needs of today's sorghum industry.

Solutions from abroad

With the rise in prevalence of the sugarcane aphid, Peterson and a long list of other breeders have been looking harder at the sorghum lines they have developed and screened, and they have found those that show great promise for resistance. The origin of many of these lines is far from American soils.

According to Peterson, investment by INTSORMIL supported significant amounts of germplasm exchange from around the world, and it was through the lines introduced from Africa that breeders identified sugarcane aphid resistance.

The main line of focus for this resistance now is the Tx2783, which was developed in majority from Ethiopian sorghum lines. Already known for its greenbug resistance, Peterson and his team had Tx2783 sent to Botswana for evaluation and, as hoped, it showed sugarcane aphid resistance as well.

Many of the experimental lines currently being evaluated for resistance derive from Tx2783 or a Tx2783 derivative, and breeders are hopeful that the resistance found in Tx2783 can be applied in the development of new sorghum varieties to combat the devastating pest.

Making the sugarcane aphid a problem of the past

Peterson is actively working with other researchers to evaluate these lines and identify those that are the most promising. Just as many of the genetics originate in African countries that have been dealing with the sugarcane aphid for decades or centuries, U.S. researcher partnerships also extend to the African and international experts in the area.

The hope, says Peterson, is to pull together all the resources possible to develop sorghum varieties that display resistance and make the economic devastation caused by the sugarcane aphid a thing of the past. Because of the years of investment by INTSORMIL and SMIL the focus they have placed on international collaboration and information sharing, the development of those varieties may not be far away.

No one knew when the sorghum breeding research first started that screenings for aphid resistance would be so needed three decades into the future. But the investments that were made and sustained now have important implications to sorghum growers and their bottom line. Likely, future investments in such research will yield similar benefits.

**The International Sorghum and Millet Collaborative Research Support Program (INTSORMIL) is the predecessor to the Feed the Future Innovation Lab for Collaborative Research in Sorghum and Millet.*



The sugarcane aphid has spread rapidly across the sorghum-producing states, leaving behind millions of dollars in crop losses. Researchers are working tirelessly to make this destructive pest a thing of the past. Photo credit: Gary Peterson

Appendix 2 – Financial Information

(See the following page that is oriented to display the financial table.)

Appendix 2 Table. Research and training financial commitments by country and project

		Country Total										Project Total
		Non-US based								US-based		
Project Title	Principle Investigator	Burkina Faso	Ethiopia	Ghana*	Mali	Niger	Senegal	South Africa	Germany	Int'l Student Training	U.S.	
Country Coordination (Ethiopia, Niger, Senegal)		-	214,500	-	-	189,329	55,200	-	-	-	-	459,029
Improving sorghum adaptation in West Africa with genomics-enabled breeding	Geoff Morris	-	-	-	37,197	199,640	289,221	-	-	246,941	317,094	1,090,093
Combining high digestible protein trait with waxy/ heterowaxy endosperm traits to develop superior functionality in sorghum for food applications to promote sorghum value chain in Ethiopia	Joseph Awika	-	200,003	-	-	-	-	90,000	-	141,012	378,926	809,941
Biological control of the millet head miner in Niger and Senegal	Malick Ba	-	-	-	-	306,426	120,175	-	-	140,816	71,371	638,788
Development of biotic stress-resistant sorghum cultivars for Niger and Senegal	Bonnie Pendleton	-	-	-	-	108,721	90,000	-	-	345,057	332,506	876,284
Expanding markets for sorghum and millet farmers in West Africa through strengthening of entrepreneur processors and nutrition-based promotion of products	Bruce Hamaker	-	-	-	-	153,990	134,000	-	-	249,681	278,657	816,328
Genetic improvement of sorghum for resistance to fungal pathogens	Tesfaye Mengiste	-	117,700	-	-	-	-	-	-	278,226	447,037	842,963
Optimization of the seed ball technology for pearl millet, and agronomic and socio-economic evaluation in the context of smallholder farmers in Senegal and Niger	Ludger Herrmann	-	-	-	-	68,334	55,770	-	48,496	-	-	172,600
Genetic Enhancement of sorghum and millets to promote commercial seed supply and grain market development in Senegal and Ethiopia	Gebisa Ejeta	-	159,500	-	-	-	-	-	-	171,513	581,690	912,703
Improving crop genetics and processing methods for increased productivity and nutrition for smallholder sorghum producers in Ethiopia	Tesfaye Tesso	-	191,400	-	-	-	-	-	-	120,000	510,021	821,421
Sorghum trait development pipeline for improved food and feed value	Mitch Tuinsta	-	-	210,000	-	149,500	149,500	-	-	201,024	334,299	1,044,323
Development of dual-purpose pearl millet varieties for the benefit of farmers and agro-pastoralists in the Sahelian and Sudanian zones of West Africa	Roger Zangre	133,650	-	-	120,450	120,450	120,450	-	-	-	-	495,000
Program Total		133,650	883,103	210,000	157,647	1,296,390	1,014,316	90,000	48,496	1,894,270	3,251,601	8,979,473

*Funding to Ghana is to the West African Center for Crop Improvement at the University of Legon for Ph.D. student training.