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

Annual Performance Report FY 2017

October 1, 2016 – September 30, 2017
Feed the Future Innovation Lab for Collaborative Research on Sorghum and Millet
Annual Performance Report FY 2017

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Cover photo:
Cyril Diatta, researcher at the Centre d’Etudes Régional pour l’Amélioration de l’Adaptation à la Sècheresse, stands with a specially adapted sorghum variety on the center’s research station in Bambey, Senegal.
Photo credit: Kira Everhart-Valentin

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Executive summary

The Sorghum and Millet Innovation Lab’s research program continues on its established course with a few changes that are responsive to program evolution. The program currently has twelve projects, funding commitments to 24 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 (three 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 researchers from Mali, Niger and Senegal. These projects are associated with 18 collaborating institutions in West Africa and another 16 collaborating institutions in Ethiopia, as well as one collaborating institution in France and South Africa. During this year, the program initiated a new associate award project to develop a genomics assisted breeding program in Haiti that drew in two new institutions - CHIBAS, in Haiti, and Cornell University - in addition to collaborators at Kansas State University. This project started in late FY 2016 and conducted field and lab activities this year.

The Lab again surpassed target values for FY 2017 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 2017 also saw the advancement of 23 technologies and management practices – a significant increase from last year. In the area of policy, the AGP-II in Ethiopia that includes sorghum as a key crop in the country’s industry has now been passed and enacted.

The five-year funding period for the Feed the Future Innovation Lab for Collaborative Research on Sorghum and Millet ends on July 22, 2018. During the final nine months of the program that fall in FY 2018, the program will focus on consolidating research and development activities in preparation for termination or continuation. In several cases, technologies developed in the program are ready for transfer to implementing partners and these will naturally flow into mission-directed activities or into the private sector. Considerable investment in human and institutional capacity has created an environment where long-term breeding strategies can continue to flourish and generate new varieties and hybrids for small-scale farmers.

The Sorghum and Millet Innovation Lab is co-organizing with the University of Pretoria “Sorghum in the 21st Century” a global convening of sorghum research, development and private sector in the first meeting since the 1990’s. This conference will be held in April 2018 in Cape Town, South Africa. The Innovation Lab will use the meeting to showcase research and development findings and foster greater collaboration among the global sorghum research community. We will use the meeting as the final opportunity to convene our sorghum community. If funding permits, we will organize a small regional meeting in West Africa on pearl millet to strategize on future activities.

If funding is extended into a new five-year cycle, the Sorghum and Millet Innovation Lab will issue a new call for research proposals and develop a new portfolio of research projects by the end of the 2018 calendar year.
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Genetic enhancement of sorghum to promote commercial seed supply and grain market development in Ethiopia

Improving sorghum adaptation in West Africa with genomics-enabled breeding

Trait development pipeline for food and feed value in sorghum

Development of dual-purpose pearl millet varieties for the benefit of farmers and agro-pastoralists in the Sahelian and Sudanian zones of West Africa

Assessment of pearl millet production problems in West Africa and molecular diversity analysis of pearl millet parental lines

AREA OF INQUIRY: Productions systems management

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

Biological control of the millet head miner in Niger and Senegal

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

AREA OF INQUIRY: Added-value products and markets

Improving sorghum adaptation in West Africa with genomics-enabled breeding

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

Development of dual-purpose pearl millet varieties for the benefit of farmers and agro-pastoralists in the Sahelian and Sudanian zones of West Africa

Assessment of pearl millet production problems in West Africa and molecular diversity analysis of pearl millet parental lines

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FTFIL for Genomics-Assisted Sorghum Breeding

Human and Institutional Capacity Development

Short-term training

Table 1. Short-term trainees supported by the Sorghum and Millet Innovation Lab – FY 2017

Long-term training

Table 2. Long term trainees supported by the Sorghum and Millet Innovation Lab – FY 2017

Institutional development

Annual program review meetings

IAVAO (West Africa)

Private industry partnerships – Kansas Department of Agriculture

Gender in sorghum production research study debrief workshop

Innovation transfer and scaling partnerships

Phase I technologies – Under Research

1. Technology: Sorghum germplasm/variety development for food quality

2. Technology: Development of parental materials for disease resistance

3. Technology: Experimental hybrids for commercial sorghum seed industry

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Management entity information
The core management entity team did not see any changes in staffing this year, thus maintaining the same program staff members as follows:

1) Timothy J. Dalton – Director
2) Nathanael Bascom – Assistant Director
3) Kira Everhart-Valentin – Program Coordinator
4) Kimberly Suther – Fiscal Analyst

As Kimberly continued to fully transition onto the team following her FY 2016 hire, the management entity dynamic has strengthened. The team continues to experience a strong working relationship between all members with high priority placed on efficient distribution of duties and responsibilities.

In addition to the core management team, Wyatt Pracht was hired as a temporary student worker to assist in researching the economic impact of U.S. investment in international agricultural development. Wyatt graduated in May 2017 and left the Lab later in the summer to serve in the Peace Corps in Senegal.

The management entity’s in-country coordination team has remained stable, with the current team as follows:

1) Senegal - Ndiaga Cisse
2) Soumana Souley – Niger (supported by previous coordinator, Moustapha Moussa)
3) Getachew Ayana – Ethiopia

The Lab’s management entity continues to support agricultural economics Ph.D. student Tebila Nakelse during his program of study and associated contributions to the Lab’s market research in West Africa as well as Mengistu Kassie, Ph.D candidate in agricultural economics. Both are at Kansas State University.

Dr. Desalegn Serba, a Kansas State University pearl millet breeder hired during FY 2015, continues to make progress in his evaluation of pearl millet lines for stress tolerance and yield potential. He has been active in building relationships with the Lab’s West African breeding teams and is establishing priorities that will shape his future research.

External Advisory Board information
Since the 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 the life of the Lab, 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 Marilynn Thomas Chair at Oklahoma State University

In FY 2017, instead of holding separate meetings for the EAB and management entity only, the Lab decided to incorporate the EAB’s participation in the program-wide annual meetings that were held in Saly, Senegal. All EAB members, with the exception of Bettina Haussmann, were able to be present for those meetings and the resulting engagement and discussion between the EAB and research teams was extremely valuable for both the projects and the management entity. Side administrative meetings between the management entity and EAB allowed for in-depth discussions on project status and direction, as well as prioritization of the final remaining research funds.
As in previous years, the management entity continued to provide periodic updates on activities and research-related developments to the EAB throughout the year, as well as consult them for guidance when areas of challenge arose.

Focus countries

The Lab continues to work primarily in its focus countries – Ethiopia, Senegal and Niger – and secondarily in Burkina Faso, Mali and Haiti. Activities in Haiti are supported through an associate award initiated in FY 2016.

Ethiopia

Research in Ethiopia capitalizes on coordination between regional research centers, universities, and the Ethiopian Institute for Agricultural Research. Ethiopia continues to be the site of a large-scale sorghum phenotyping activity involving more than 2,000 accessions at multiple trial sites that represent a wide range of growing conditions and environmental stresses. In addition, research at Hawassa University on the performance of sorghum in doughs and baked goods – particularly rolls as well as injera – continues to demonstrate that the incorporation of improved high digestibility sorghum varieties is possible and can reduce dependence upon wheat and teff.

A multi-regional study on gender and sorghum production has been conducted with teams executing rural appraisal techniques in several regions of the country. An end of project meeting was held in August 2017, reports were presented and recommendations provided. Final reports were received at the end of the fiscal year and a meta-report will be synthesized in 2018.

Senegal

The Sorghum and Millet Innovation Lab continues to engage with the Senegalese Institute for Agronomic Research at the West African Center for Research on Adaptation to Drought Stress (CERAAS) in Thies, the regional center at Bambey and the headquarters in Dakar. Food product research and development is conducted with the Senegalese Institute for Food Technology (ITA) in Dakar. In addition, study on storage pests is conducted at ITA while field pest research is conducted at Bambey.

Niger

Activities in Niger continue to be led by INRAN, the national agricultural research service, at several key locations including Niamey, Maradi and Kollo in addition to filed sites at several additional locations. Research is concentrating on the genetic enhancement of sorghum and pearl millet, agronomic interventions to improve millet seed germination and establishment, and the biological control of the millet head miner (MHM). The millet head miner control project is being led by the ICRISAT Sahelian Center with collaboration from INRAN and the University of Maradi. Ph.D. student and junior researcher at INRAN, Laouali Amadou, received the BIFAD Award of Excellence for student research for his work on refining the biological control of the MHM.

Food product development continues at INRAN as does collaboration with the McKnight Foundation to develop rural food product incubation hubs.

Mali and Burkina Faso

Efforts and activities in Mali and Burkina Faso focus on a regional approach to the development of dual-purpose pearl millet varieties under the leadership of Roger Zangré. Based upon previous research, a set of best-performing dual purpose varieties were evaluated in farmers’ fields in each of the four countries (including Senegal and Niger).

Haiti

FY 2017 saw the startup of the Feed the Future Innovation Lab for Genomics-Assisted Breeding in sorghum in Haiti. This project, co-led by Kansas State University, CHIBAS and Cornell University, aims to develop a genomic-assisted breeding platform better tailored to the constraints and realities faced by NARS in smaller developing countries.
List of program partners

**United States**

Cornell University  
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-Agricultural Research Service  
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  
Holleta 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

Haiti

CHIBAS
Quisqueya University

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
ARS   Agricultural Research Service
BMR   Brown Midrib
CERAAS Centre d’Etude Régional pour l’Amélioration de l’Adaptation à la Sécheresse
CGIAR Consultative Group on International Agricultural Research
CHIBAS Centre de Recherche sur les Biocarburants et l’Agriculture Durable
CIRAD Centre de Coopération Internationale en Recherche Agronomique pour le Développement
CNRA Centre National de Recherche Agronomique
EAB   External Advisory Board
EIAR   Ethiopian Institute of Agricultural Research
EMMP Environmental Mitigation and Monitoring Planning
EMS   Ethyl Methanesulfonate
DNA   Deoxyribonucleic Acid
GBS   Genotyping-by-sequencing
HX    Heterowaxy
HPD   High Protein Digestibility
ICRISAT International Crops Research Institute for the Semi-arid Tropics
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
IPM   Integrated Pest Management
ISRA  l’Institut Sénégalais de Recherches Agricole
ITA   Institut de Téchnologie Alimentaire
KSU   Kansas State University
KDA   Kansas Department of Agriculture
ME    Management Entity
MHM   Millet Head Miner
MSB   Millet Stem Borer
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
SICNA Sorghum Improvement Conference of North America
SIIL  Sustainable Intensification Innovation Lab
SME   Small Medium Enterprises
SMIL  Sorghum and Millet Innovation Lab
USAID United States Agency for International Development
USDA United States Department of Agriculture
WAAPP West Africa Agricultural Productivity Program
WACCI West African Centre for Crop Improvement
WX    Waxy
Program activities and highlights

The Sorghum and Millet Innovation Lab entered into the final year of its five-year program. Research activities have matured and development results generated. Considerable investment has focused on genetic enhancement through better understanding of the diversity and opportunities harbored in the sorghum genome. The Ethiopian core collection, a sample of over 2,000 varieties and cultivars, has been phenotyped in multiple locations and more than 60 percent of the collection has been genotyped. These materials have been screened for drought tolerance, *Striga* resistance, nutritional quality, yield potential, disease resistance and other characteristics and will provided a breeding resource for Ethiopia and other partners from now and well into the future. In West Africa, collaboration with Senegal and Niger has led to the establishment of a “genomics informed” breeding program with several beneficial attributes such as improved fodder quality, higher protein digestibility and biotic stress resistance incorporated into preferred local materials. At the same time, new materials and breeding lines are being generated by established plant breeders and Ph.D. students. Dual purpose pearl millet varieties with high grain, fodder and nutritional yields are being evaluated in farmers’ fields in Senegal, Mali, Burkina Faso and Niger.

Agronomic research in Senegal and Niger has generated new opportunities to improve pearl millet seedling establishment through seed balls composed of organic materials and fertilizers. Seed ball trials were conducted on over 1000 farmer fields in Niger in 2017 and yield results, collected in October, are under study. Integrated pest management strategies to protect against insect damage caused by the millet head miner have been refined and the technology is being used in numerous locations. Mr. Laouali Amadou, a junior researcher at INRAN and Ph.D. student at the University of Maradi was honored with the BIFAD Award of Excellence for student research for his study on improving the efficiency of rearing the predatory wasp that is used to reduce millet head miner pressure.

Market development and added-value products continues with several advances in Ethiopia using waxy and highly digestible varieties of sorghum in the production of food products ranging from injera to bread and pastry products. Consumer tests indicate high acceptance of sorghum when blended with tef and the same for bakery products. Consumer tests and product presentations were conducted several times this year and publicized on national television. In West Africa, food product innovation continues in Niger and Senegal and new opportunities explored using extruded flour. Product evaluations have been very favorable and processors indicate excitement about market opportunities. Marketing studies have identified key product and packaging attributes through choice and hedonic taste experiments with urban consumers in Niamey.

The program continues to support a large number of students in the United States, host countries and in third-party countries such as South Africa and Germany. Resources have been invested in long-term degree training and also in providing opportunities for thesis and dissertation research. Over 60 students have benefited from the program’s investment in human capacity development.

A new project was established in Haiti that links researchers at CHIBAS, a Haitian NGO with scientists at Kansas State University and Cornell University. The objective of the project is to determine whether collaborative research activities between small countries like Haiti, and service providers, can be organized to harness the benefits of plant genomics and improve the speed and efficiency of sorghum breeding.

We continue to work with our partners to strengthen institutional capacity in environmental monitoring and compliance, financial research management. In addition, a major study on the gender-differentiated activities and norms in Ethiopian sorghum production was completed by a team of researchers in six different woredas.
Key accomplishments

Key accomplishments in the Lab continue to build upon previous investments and exceed expected targets in several categories. As the projects move into their final year of activities, concrete outputs are beginning to take form and key results are becoming available.

Program highlights

- Higher lysine content in tested improved highly digestible (IHD) sorghum lines was demonstrated, serving as an important development in regards to protein nutrition.
- New methods allowing identification of the heritability of the IHD trait were developed, and stability of the IHD traits across environments (Ethiopia and Texas) was confirmed.
- Approximately 1,600 sorghum accessions in Ethiopia were genotyped by sequencing (GBS) and data analyses on association genetics has started, which will be useful for current and future studies that focus on utilization of Ethiopian sorghum germplasm.
- Approximately 1,000 accessions in Ethiopia were characterized for grain biochemical characteristics, including zinc and iron content.
- A multi-locational study of gender roles in sorghum production and utilization was conducted across six different woredas in Ethiopia and results were presented at a post-study workshop in August 2017.
- A comprehensive survey of genomic diversity for sorghum from Senegal and Niger as well as Togo and Mali has been completed, which will serve as a major resource for development of genomics-enabled breeding tools.
- Millet head miner and stem borer egg parasitoids have been successfully reared in a laboratory setting all year round, and on-farm augmentative release of the egg parasitoids has been demonstrated as an effective mean for controlling the millet head miner.
- Further expansion of the incubator concept for the development of sorghum- and millet-based food products is serving as a platform for rural development in West Africa and is contributing to nutrition improvement in the associated areas.
- Seed ball technology has shown better germination rates and early vigor when correctly implemented, and in FY 2017 alone, more than 1,000 on-farm trials were conducted in Niger.
- A single recessive allele may be responsible for protein digestibility. Sequence analyses identified several SNPs and candidate genes that may be responsible for this mutation.
- The collection of sorghum mutants was screened for variation in increased amylose composition and reduced starch gelatinization temperature.
- Fifteen of the most promising dual-purpose pearl millet germplasm were selected for the Sudanian and Sahelian zones in Mali, Burkina Faso, Niger and Senegal while seed from these 120 dual-purpose millet varieties was produced for testing in on-farm trials.
- A select number of pearl millet hybrids with high grain yield, early maturity and moderate downy mildew resistance were identified.
- The genomics-assisted breeding project in Haiti saw the start-up of all activities across the three locations and program partners. Protocols and processes for sequencing and analysis of materials have been established, while holes in the currently-available analysis software have been identified and necessary modifications are being made. Initial analyses of the base germplasm at CHIBAS was conducted and first selections of GS populations have been made.

Feed the Future indicator performance

The Lab again surpassed target values for FY 2017 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 2017
also saw the advancement of 24 technologies and management practices – a significant increase from last year. In the area of policy, the AGP-II in Ethiopia that includes sorghum as a key crop in the country’s industry has now been passed and enacted.

**EG.3.2-2 (4.5.2-6) – Long-term training**

In FY 2017, the Lab saw a continued increase in total numbers of long-term trainees. The program now has a roster of 62 different trainees, 17 of which are new to the program this year. Among those 62 trainees, 42 are male and 20 are female. The group also represents a variety of degree levels with two agricultural engineers, four Bachelor’s, 26 Master’s 29 Ph.Ds and one post-doc. Several students graduated this year and went on to pursue further educational/training opportunities or secure employment.

**EG.3.2-1 (4.5.2-7) – Short-term training**

The Lab again exceeded target numbers for FY 2017 in the area of short-term training. There were a total of 29 reported trainings that took place in Burkina Faso, Ethiopia, Mali, Niger, Senegal, South Africa and the United States and reached over 2,500 reported trainees. Of these trainees, approximately 50 percent were female and 48 percent were male. Additionally, approximately 76 percent of those trained were producers, 5 percent were government affiliates, 4 percent were from the private sector, 13 percent were from civil society and 2 percent were unknown. Large-scale trainings in relation to testing and fabrication of millet seed balls in Niger under Ludger Herrmann’s project accounted for a large percentage of the trainings, as did rearing and deployment of parasitoid wasps to combat the millet head miner under Malick Ba’s project.

**EG.3.2-7 (4.5.2-39) – Technologies and management practices**

The Lab saw the advancement or continuation of 23 technologies and management practices in FY 2017 as a part of project activities, which exceeded the targeted output for this fiscal year. These technologies included food product development, integrated pest management practices with parasitoid rearing, seedball fabrication mechanization, genetic traits and varieties, rural incubation centers and genomic selection methods. Eleven of the technologies were in Phase 1 (Under Research), eight were in Phase 2 (Under Field Testing) and four have made it to Phase 3 (Made Available for Transfer).

**EG.3.1-12 (4.5.1-24) – Agricultural enabling policies**

During FY 2015, in partnership with the Ethiopian Institute of Agricultural Research, the Lab was an active player in the moving of an agricultural-enabling policy into Step 3: Drafting or Revision during FY 2015. The policy, which involved the inclusion of sorghum as a priority crop in the Agricultural Growth Program Phase II (AGP-II), saw continued forward progress during FY 2016 in the actual inclusion of sorghum listed as an important crop in the Ethiopian agricultural industry (as compared to the complete absence of sorghum in the previous AGP-I document). During FY 2017, the AGP-II was passed and officially enacted, moving the policy into Stage 4: Passed/Approved.
Research program overview and structure

The Sorghum and Millet Innovation Lab’s research program continues on its established course with a few changes that are responsive to program evolution. The program currently has twelve projects, funding commitments to 24 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 (three 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 researchers from Mali, Niger and Senegal. These projects are associated with 18 collaborating institutions in West Africa and another 16 collaborating institutions in Ethiopia, as well as one collaborating institution in France. During this year, the program initiated a new associate award project to develop a genomics assisted breeding program in Haiti that drew in two new institutions - CHIBAS, in Haiti, and Cornell University - in addition to collaborators at Kansas State University. This project started in FY 2017 and conducted field and lab activities this year.

The program is organized around three areas of inquiry: 1) Genetic enhancement, 2) Production systems management, and 3) Market development and added-value products. Since the program is commodity focused, more than fifty percent of our projects focus on sorghum and pearl millet crop improvement with the remaining projects split between production systems management and added-value products. Geographically, slightly more than 50% of our financial resources are focused on Ethiopia and the remainder in West Africa. The Associate Award focuses only on Haiti.
Research project reports

AREA OF INQUIRY: Genetic enhancement

*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)

**Additional area(s) of inquiry**
Production systems management

**Location (zonal level)**
Ethiopia - East Shewa, North Wollo, Addis Ababa, Arsi, East Harerge, West Gojam, South Tigray, East Tigray

**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 (Mekellassa Research Center, Sirinka Research Center, Pawe Research Center), Tigray Agricultural Research Institute, Haramaya University

**Achievements**
The core Ethiopian collection was replanted. About 1,000 accessions from the population have been characterized for grain biochemical characteristics with results for some 360 of them already received. Some of the accessions have as high Zn content and 3 to 4 times higher Fe content than tef. A second evaluation included populations at Manhattan derived from high protein digestible and high protein content breeding lines identified in our program. The crosses involved these lines and tropically adapted materials including Macia, Sureno and SRN 39 (a striga resistant variety) confirmed to have good adaptation to tropical environments including Ethiopia. The high protein content (PR868) and...
high protein digestible (PRS14) materials included in the cross are R-line releases from our program and have been confirmed to have protein content of 18% and protein digestibility of 78% as tested by USDA –ARS group using wet chemistry method. Moreover, these two lines produce hybrids with superior agronomic potential and restore fertility in A1 cytoplasm and hence were released as pollinator parents. Close to 1,000 families derived from these population were sent to Ethiopia for planting during 2017 season. Selection will continue for agronomic characteristics and the top agronomically desirable genotypes will be tested for protein digestibility and other nutritional traits.

**Capacity building**

Individuals trained under this project include:

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<thead>
<tr>
<th>Name</th>
<th>Institution</th>
<th>Degree</th>
<th>Field</th>
</tr>
</thead>
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<tr>
<td>Alemnesh Bekele</td>
<td>Haramaya University</td>
<td>Master’s</td>
<td>Plant pathology/breeding</td>
</tr>
<tr>
<td>Yemane Belayneh</td>
<td>Kansas State University</td>
<td>Ph.D.</td>
<td>Plant breeding and genetics</td>
</tr>
<tr>
<td>Diriba Hika Chere</td>
<td>Kansas State University</td>
<td>Ph.D.</td>
<td>Plant pathology/breeding</td>
</tr>
</tbody>
</table>

**Lessons learned**

Protein digestibility is a very complex trait. The standard pepsin assay alone may not be enough to understand all of the biological processes associated with breakdown of proteins in the gut. There is remarkable opportunity for enhancing protein digestibility by following certain pre-processing steps and treatments to precipitate compounds interfering with protein nutrition. Increased Fe and Zn, in addition to increasing the availability of these minerals in the diet, will help increase the concentration of phytase in the grain that may breakdown phytic acid, one of the pepsin inhibitory compounds.

**Presentations and publications**

None reported.
Genetic improvement of sorghum and millet for resistance to fungal pathogens
(Led by Dr. Tesfaye Mengiste – Purdue University)

Location (zonal level)
Ethiopia – East Shewa, North Wollo, Addis Ababa, Arsi, East Harerge, West Gojam, South Tigray, East Tigray

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
About 1,600 accessions of the Ethiopian collection were genotyped. The genotyping by sequencing (GBS) procedure was conducted and data analyses on association genetics has started. The quality and coverage of the data is sufficient for association genetics when phenotypic data are available. The GBS data is a milestone for future sorghum improvement research in Ethiopia. The available GBS sequences will be useful for current and future studies that focus on utilization of the Ethiopian sorghum germplasm. It will be a good training tool for locals who would like to use the genotypic data. The results of the various GWAS studies will be published in the immediate future. Disease resistance breeding advanced in 2017. Development and evaluation of segregating lines for anthracnose and grain mold resistance continued in 2017 seasons by including new crossings and generation advance of previously generated crosses. During the 2017 season, 58 F1 generations were selfed and advanced to F2 generation for upcoming field screening for anthracnose and grain mold in 2018 season. Among the previously generated F1 crosses, 24 F1s were backcrossed with their 7 recurrent local landraces to regain the adaptive traits of the landraces. The aim of this work is to introduce new resistant genes
into the local landraces and also keep the beneficial traits of the landraces. This work is underway currently in 2017 season and about 24 BC1F1 crosses are expected.

**Capacity building**

Individuals trained under this project include:

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<tr>
<th>Name</th>
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<tr>
<td>Chemeda Berhanu</td>
<td>Haramaya University</td>
<td>Master’s</td>
<td>Plant pathology/breeding</td>
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<tr>
<td>Kebede Dessalgn</td>
<td>Haramaya University</td>
<td>Master’s</td>
<td>Plant pathology/breeding</td>
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<tr>
<td>Demeke Bayable</td>
<td>Purdue University</td>
<td>Ph.D.</td>
<td>Plant pathology</td>
</tr>
<tr>
<td>Habte Nida</td>
<td>Purdue University</td>
<td>Ph.D.</td>
<td>Plant breeding and pathology</td>
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**Lessons learned**

As we identify new resistant lines from the screening, development of new populations are being made each season. The identification of the anthracnose resistance loci will help design molecular markers to transfer the resistance genes into widely adapted materials which are often deficient in resistance. The QTL-seq analysis was completed for two of the loci based on sequencing reads of deep sequenced resistant and susceptible bulks at F2 generation. One resistance gene was clearly mapped to an arm of chromosome 5 while the second was mapped to Chromosome 8. The 2017 season new crossing included 14 parents with 2 newly selected disease resistant lines, therefore from this cross 28 new F1 crosses are expected for generation advance in 2018 season.

**Presentations and publications**


Review of Genetic Basis of Protein Digestibility in Grain sorghum (*To be submitted to Crop Science*).

Genetic enhancement of sorghum to promote commercial seed supply and grain market development in Ethiopia
(Led by Dr. Gebisa Ejeta - Purdue University)

Other area(s) of inquiry
Added-value products and markets

Location (zonal level)
Ethiopia – East Shewa, North Wollo, Addis Ababa, Arsi, East Harerge, West Gojam, South Tigray, East Tigray

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
Our work on selection of sorghum cultivars with drought tolerance has focused on developing and evaluating experimental hybrids from inbred lines that have been selected for drought tolerance. We have been working with EIAR sorghum breeders in synthesizing experimental sorghum hybrids, with on the job training of technical staff in managing the development of seed parents and pollinator parents carefully. A running list of the classes of sorghum hybrids that have been evaluated in Ethiopia include: Striga resistant hybrids; Stay green (late season drought tolerant) hybrids; Mid-season drought tolerant hybrids; Dual-purpose (grain and biomass) hybrids; Brown-midrib (low lignin) forage hybrids.

Capacity building
Individuals trained under this project include:

<table>
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<th>Name</th>
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<th>Field</th>
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<tbody>
<tr>
<td>Patrick Ongom</td>
<td>Purdue University</td>
<td>Ph.D.</td>
<td>Plant Genetics</td>
</tr>
<tr>
<td>Xiaochen Xu</td>
<td>Purdue University</td>
<td>Ph.D.</td>
<td>Plant breeding and genetics</td>
</tr>
</tbody>
</table>
Lessons learned
There is considerable potential to develop a broad range of sorghum hybrids meeting multiple production objectives, including forage needs, and incorporate Striga resistant into those hybrids.

Presentations and publications

**Improving sorghum adaptation in West Africa with genomics-enabled breeding**  
(Led by Dr. Geoffrey Morris – Kansas State University)

**Location (department level)**  
Niger – Aguie, Bkonni, Kollo, Niamey, Tillaberi, Say  
Senegal – Thies, Bambey, Tambacounda

**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  
Int'l. 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**  
A comprehensive survey of genomic diversity for sorghum from Senegal and Niger (African and US-based collections), as well as Togo and Mali (African-based collections only) was completed by PhD trainees Maina, Faye, and Akata. This is major resource for development of genomics-assisted breeding tools. This was achieved due to completion of
genotyping the West African collection. Several breeding populations from the nested association mapping population have been advanced as high as the F6 level as planned in Senegal and to the F5 level in Niger. Students are advancing towards their degrees.

**Capacity building**

Individuals trained under this project include:

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<tr>
<th>Name</th>
<th>Institution</th>
<th>Degree</th>
<th>Field</th>
</tr>
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<tr>
<td>Nadre Gbedié</td>
<td>CERAAS</td>
<td>Master’s</td>
<td>Breeding</td>
</tr>
<tr>
<td>Eyanawa Akata Atchozou</td>
<td>CERAAS</td>
<td>Ph.D.</td>
<td>Agronomy (Breeding &amp; Genetics)</td>
</tr>
<tr>
<td>Cyril Diatta</td>
<td>CERAAS</td>
<td>Ph.D.</td>
<td>Plant breeding and genetics</td>
</tr>
<tr>
<td>Jacques Faye</td>
<td>Kansas State University</td>
<td>Ph.D.</td>
<td>Agronomy (Plant Breeding &amp; Genetics)</td>
</tr>
<tr>
<td>Fanna Maina</td>
<td>Kansas State University</td>
<td>Ph.D.</td>
<td>Agronomy (Plant Breeding &amp; Genetics)</td>
</tr>
</tbody>
</table>

**Lessons learned**

Phenotyping capacity is still the major limitation for identification of trait-associated markers. For quantitative trait locus mapping of grain mold, visual rating of naturally-occurring grain mold infection in F3/4 generation mini-NAM lines was inconsistent across years/sites and did not lead to highly predictive trait-associated markers. In future work, reduced genetic variability of RILs and improved phenotyping protocols may produce better trait-associated marker.

**Presentations and publications**


Trait development pipeline for food and feed value in sorghum
(Led by Dr. Mitchell Tuinstra – Purdue University)

**Location (department level)**
Niger - Ague, Bkonni, Kollo, Niamey, Tillaberi, Say
Senegal – Thies, Bambey

**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**
Genetic analyses of SbEMS1613 and derived F2 progeny showed a binomial distribution for protein digestibility with a segregation ratio of 3:1 suggesting a single recessive allele. Sequence analyses identified several SNPs and candidate genes that may be responsible for this mutation. Dr. Kane was able to set up the protein digestibility testing facility at CERAAS and is now screening sorghum breeding lines for improved protein digestibility. The collection of EMS mutants was screened for variation in ASV and 11 mutants were discovered. Sequence analysis showed these genotypes have mutations in SBEIIb, starch DBE, and SSIIa. Some of these mutant exhibit increased amylose composition and others exhibit reduced starch gelatinization temperature. Forage quality was also evaluated in Niger in 2017. The BC1F3 bmr breeding trials are being conducted at 2 localities (Tillaberi and Konni). Families with good stover yield will be submitted for NIRS analysis to determine feed quality. The F3 breeding populations are also being evaluated based on earliness, good biomass, and stay-green.

**Capacity building**
Individuals trained under this project include:
Lessons learned

More than one candidate gene was identified for increased protein digestibility in SbEMS1613. It may be challenging to identify the causal SNP for this phenotype. Quality assessment is now possible at CERRAS as the lab is fully operational.

Presentations and publications


Kane, K. (December 2016). Biochemical phenotyping for the development of improved grain quality varieties. Presentation at Innovation et amélioration variétale en Afrique de l'Ouest (IAVAO), Saly (Senegal).


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)

Location (department level)
Niger - Aguié, Kollo, Boboye,
Senegal – Bambey, Nioro du Rip
Mali – Segou, Koutiala
Burkina Faso – Ouahigouya, Ougadougou

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
Based upon the results from screening in previous years, fifteen of the best performing dual purpose pearl millet varieties were planted in farmers’ fields in each country. Breeder seed was also increased on station. Open field days involving 20 to 30 farmers by country and zone were conducted where experiences were exchanged and feedback elicited in October 2017. There is wide variability in characteristics; grain yield is from 1766 kg/ha to 2066 kg/ha, fodder yield is from 6654 kg/ha to 7328 kg/ha. Fodder quality ranges from 2.51 to 6.47mg/kg for proteins content, from 39.99 to 53.42 for ADF, from 46.68 to 77.25 for NDF, from 60.16 to 92.33 for RFV. Grain quality attributes range from 29.20 to 44.20 for iron content and from 16.95 to 44.80 for zinc. Around 600 preliminary crosses were made during the 2017
off-season in the project countries between good cultivars for dual purpose. Around 400 farmers and agropastoralists (100 per country) participated in short term training on good practices on varietal participatory selection, seed production, good field management and fodder conservation techniques.

**Capacity building**

Individuals trained under this project include:

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<th>Name</th>
<th>Institution</th>
<th>Degree</th>
<th>Specialization</th>
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<tr>
<td>Siby Boubacar</td>
<td>Universite Prive de Segou Agri SUP</td>
<td>Bachelor’s</td>
<td>Agronomy</td>
</tr>
<tr>
<td>Abdou Illiassou</td>
<td>Universite Dan Dicko Dankoulodo</td>
<td>Master’s</td>
<td>Agronomy</td>
</tr>
<tr>
<td>Benoit Ouedraogo</td>
<td>University of Ouagadougou</td>
<td>Master’s</td>
<td>Breeding and conservation of seed</td>
</tr>
<tr>
<td>Zongo Rachelle Yvonne</td>
<td>INERA</td>
<td>Master’s</td>
<td>Seed selection and conservation (SELCOSE)</td>
</tr>
</tbody>
</table>

**Lessons learned**

Considerable variation in quantitative and qualitative traits provides a new resource for pearl millet improvement in West Africa.

**Presentations and publications**


Assessment of pearl millet production problems in West Africa and molecular diversity analysis of pearl millet parental lines

(Led by Dr. Desalegn Serba – Kansas State University)

Location (department level)
Niger - Aguie, Boboye
Senegal – Bambey

Description
Pearl millet is an important staple food and fodder crop in West Africa especially in Mali, Senegal, Niger, and Burkina Faso. However, the productivity is still low as compared to the genetic potential of the crop. Different biotic and abiotic constraints are expected to contribute to the low productivity. To identify a priority area for future research a professional assessment will be conducted through informal survey and preliminary evaluation nursery of germplasm. A total of 100 entries comprising of inbred lines, experimental hybrids, and open pollinated germplasm were assembled and being evaluated in Niger and Senegal. Informal survey of the production problems will be conducted in all four countries to identify a boarder-cutting production problem that need a collaborative research intervention.

Pearl millet breeding research at the Agricultural Research Center-Hays developed several parental lines in the 1980s and 1990s using mainly phenotypic evaluation. The newly initiated breeding program also assembled germplasm from various sources. The level of diversity of these materials has not been documented well. Molecular diversity analysis of these materials will aid to identify novel alleles for different important traits. Therefore, a next-generation sequencing technology called genotyping-by-sequencing will be used to genotype the materials and diversity analysis will be conducted using high throughput SNP markers. The outcome of this diversity analysis will apparently help in founding preliminary heterotic groups and conduct efficient hybrid breeding program.

Collaborators

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

Achievements
A single season evaluation was conducted in Niger and Senegal. High downy mildew pressure in the testing environment wiped out most of the test materials. A few hybrids with high grain yield, earlier maturing than the local cultivars and moderately resistant to downy mildew, were identified. DNA extraction of more than 384 samples (4 plates) was successfully conducted. Library constructed using two enzymes (PstI-MspI) combination for genotyping by sequencing (GBS) of reduced representation libraries is completed. The sample is in queue for sequencing.

Capacity building
No students at this time.

Lessons learned
Top cross hybrids are the way to go for the region as it maintains variability in the cultivar for any stresses.

Presentations and publications
None reported.
AREA OF INQUIRY: Productions systems management

Development of biotic stress-resistant sorghum cultivars for Niger and Senegal
(Led by Dr. Bonnie Pendleton – West Texas A&M University)

Other area(s) of inquiry
Genetic enhancement
Added-value products and markets

Location (department level)
Niger - Aguie, Bkonni, Kollo, Tillaberi
Senegal – Thies, Bambey

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
Diverse sets of breeding lines were 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 total of 115 lines with excellent resistance to abiotic (drought) and biotic (selected disease or insects) stresses were evaluated in Niger. Dozens of sorghum lines were evaluated for resistance to sorghum midge in the field in West Africa.
Scanning electron microscopy was used to determine mechanisms of resistance to maize weevil and other insect pests in stored sorghum grain in Texas. Four sorghum varieties were evaluated for resistance to Tribolium sp. and Corcyra sp. storage insect pests in Niger. Five treatments were evaluated for a hermetic bagging technique to control Tribolium castaneum and Corcyra cephalonica in West Africa. Four botanicals were evaluated for control of Tribolium castaneum in sorghum grain in Niger. In Texas, botanicals were evaluated for control of maize weevil, Sitophilus zeamais, in stored kernels of Malisor 84-7 sorghum from Mali, West Africa. One hundred stake-holders were educated to identify and manage pests of stored sorghum grain in West Africa.

**Capacity building**

Individuals trained under this project include:

<table>
<thead>
<tr>
<th>Name</th>
<th>Institution</th>
<th>Degree</th>
<th>Field</th>
</tr>
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<tbody>
<tr>
<td>Mame More Kasse</td>
<td>ISFAR/University of Thies</td>
<td>Engineer</td>
<td>Agricultural Engineering</td>
</tr>
<tr>
<td>Adama Sarr</td>
<td>ISFAR/University of Thies</td>
<td>Engineer</td>
<td>Agricultural Engineering</td>
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<tr>
<td>Omar Kendji</td>
<td>University Cheikh Anta Diop</td>
<td>Master’s</td>
<td>Pest Management</td>
</tr>
<tr>
<td>Marietou Ly</td>
<td>ENSA/University of Thies</td>
<td>Master’s</td>
<td>Sustainable development and society/agriculture</td>
</tr>
<tr>
<td>Gnilane Sene</td>
<td>University Cheikh Anta Diop</td>
<td>Master’s</td>
<td>Pest management</td>
</tr>
<tr>
<td>Hame Abdou Kadi Kadi</td>
<td>West Texas A&amp;M University</td>
<td>Ph.D.</td>
<td>Plant, Soil and Environmental Science - Insect Pest Management</td>
</tr>
<tr>
<td>Adja Thiam</td>
<td>University of Thies</td>
<td>Ph.D.</td>
<td>Pest management</td>
</tr>
<tr>
<td>Fatou Welle</td>
<td>University Cheikh Anta Diop</td>
<td>Ph.D.</td>
<td>Pest management</td>
</tr>
</tbody>
</table>

**Lessons learned**

The focus of research on sorghum resistance to sorghum midge by determining the daily time when sorghum midges are present in sorghum fields cross-referenced against the flowering time of spikelets of sorghum was diverted to recording data on resistance to sorghum midge, diseases, and other factors in Senegal because of difficulties in measuring midge presence and flowering time.

**Presentations and publications**


Hamé, A. (March 2017). *Improving sorghum production by using sorghum midge-resistant varieties*. Presentation at West Texas A&M University 23rd Annual Student Research Conference, Canyon, Texas, USA.

Hamé, A. & Pendleton, B. B. (September 2016). *Assessing efficacy of botanicals to control maize weevil (Coleoptera: Curculionidae) in stored sorghum grain*. Presentation at 25th International Congress of Entomology, Orlando, Florida, USA.

Hamé, A. & Pendleton, B. B. (November 2016). *Efficacy of botanicals to control maize weevils in stored sorghum grain*. Presentation at 13th Annual Texas A&M University System Pathways Program, College Station and Prairie View, Texas, USA.

Hamé, A. & Pendleton, B. B. (April 2017). Efficacy of botanicals for control of maize weevils in stored sorghum. Presentation at Annual Meeting of the Southwestern Branch of the Entomological Society of America and the Annual Meeting of the Society of Southwestern Entomologists, Austin, Texas, USA.


Kandji, O., Thiam, A. N., Sarr, I., Cisse, N., Pendleton, B. B., Peterson, G., Ndiaye, S., Kane, A. (March 2017). Dynamique de population de la ceclidomyie (Stenodiplosis sorghicola, Diptera: Cecidomyiidae) et degats sur le sorgho dans la zone de Mbour de Senegal. Presentation at Sorghum and Millet Innovation Lab Annual Review meeting, Saly, Senegal.


Pendleton, B., Pendleton, M., & Peterson, G. (March 2017). Variable-pressure scanning electron microscopy images of sorghum predict resistance to storage insect pests. Presentation at the 12th Annual Faculty Research Poster Session and Research Fair, Canyon, TX.


Biological control of the millet head miner in Niger and Senegal
(Led by Dr. Malick Ba – ICRISAT, Niger)

Location (department level)
Niger - Aguie, Say, Tahou, Dosso, Magaria, Tera
Senegal – Thies, Bambey
Burkina Faso - Ouahigouya

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
Millet head miner egg parasitoid were mass reared in the laboratory all year around and on-farm augmentative release of the egg parasitoid is an effective mean for controlling the head miner. In the laboratory, the MHM eggs parasitoid Trichogrammatidae armigera was able to complete development on eggs of the following species: the cotton bollworm, Helicoverpa armigera, the millet stem borer Coniesta ignefusalis, the millet head miner Heliocheilus albipunctella, the Moringa leaf defoliant, Noorda blitealis, the rice moth, Corcyra cephalonica; the floor moth, Ephestia Kuehniella Zeller; and the grain moth Sitotroga cerealella. The three-storage host species, C. cephalonica, E. Kuehniella and S. cerealella were all suitable for mass culturing of T. armigera. The parasitoid parasitized up to 65% of the eggs of C. corcyra compared to 53% and 42% for E. Kuehniella and S. cerealella respectively. When put in a choice situation T. armigera parasitized 36-47 % of eggs of the three species with no significant difference. Colonies of T. armigera have been established all year round in both ICRISAT and INRAN laboratories.
Capacity building

Individuals trained under this project include:

<table>
<thead>
<tr>
<th>Name</th>
<th>Institution/University</th>
<th>Degree</th>
<th>Field</th>
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<tbody>
<tr>
<td>Michael Guerci</td>
<td>Virginia Tech</td>
<td>Master’s</td>
<td>Agricultural Economics</td>
</tr>
<tr>
<td>Hamidou Idrissa</td>
<td>Université Abdou Moumouni de Niamey</td>
<td>Master’s</td>
<td>Entomology</td>
</tr>
<tr>
<td>Said Laminou</td>
<td>Université Abdou Moumouni de Niamey</td>
<td>Master’s</td>
<td>Entomology</td>
</tr>
<tr>
<td>Oumou Moumouni</td>
<td>Abdou Moumouni University of Niamey with Short Training at Virginia Tech</td>
<td>Master’s</td>
<td>Agricultural Economics</td>
</tr>
<tr>
<td>Baye Thiam</td>
<td>University of Thies</td>
<td>Master’s</td>
<td>Agricultural engineering</td>
</tr>
<tr>
<td>Laouali Amadou</td>
<td>University of Maradi</td>
<td>Ph.D.</td>
<td>Entomology</td>
</tr>
<tr>
<td>Mame Fatoumata</td>
<td>University Cheikh Anta Diop</td>
<td>Ph.D.</td>
<td>Entomology</td>
</tr>
<tr>
<td>Goudiaby</td>
<td>ICRISAT – Niger</td>
<td>Ph.D.</td>
<td>Entomology</td>
</tr>
</tbody>
</table>

Lessons learned

We are yet to identify a suitable host for a second MHM egg parasitoid (Telenomus spp) to enable carrying out studies on interspecific competition.

Presentations and publications


Goudiaby, M. F. Techniques d’elevage et de lacher des parasitoides Bracon hebetor: Formation des produteurs dans le Bassin arachidier (Factsheet).


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)

Location (department level)
Niger - Ague
Senegal – Bambey

Description
Pearl millet farmers in Senegal and Niger face many challenges related to crop production, one of which is seeding 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
The key achievement is that it can be shown that seedballs can be locally produced and that they work out in the field. When the protocol is followed, seedballs show sufficient germination rates and early vigour better than in farmer control plots. However, the small nutrient amount that can be added to seedballs only supports the small plantlings during the first two to three weeks after germination. Further nutrient application is necessary thereafter. After the great success of seedballs in Niger during the dry year 2016, many farmers were keen to test this technology. In total, more than 1000 on-farm trials were facilitated by the farmer federation Fuma Gaskiya in Niger.

Capacity building
Individuals trained under this project include:

<table>
<thead>
<tr>
<th>Name</th>
<th>Institution</th>
<th>Degree</th>
<th>Field</th>
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<tr>
<td>Iro Ousseini</td>
<td>INRAN</td>
<td>Bachelor's</td>
<td>Agronomy</td>
</tr>
<tr>
<td>Daouda Abassa</td>
<td>INRAN</td>
<td>Master's</td>
<td>Socio-economy</td>
</tr>
<tr>
<td>Cheikh Dieng</td>
<td>ENSA Thies</td>
<td>Master’s</td>
<td>Production Végétales</td>
</tr>
</tbody>
</table>
Lessons learned

Large on-farm trials present the opportunity to identify benefits under uncontrolled situations but it is not easy to implement clear counterfactuals to determine the benefit.

Presentations and publications


Nwankwo, C. I. & Herrmann, L. (2017) Viability of the seedball technology to improve pearl millet seedling establishment under Sahelian conditions - a review of pre-requisites and environmental conditions. *Agriculture, Ecosystems and Environment*. Submitted

Nwankwo, C. I., Herrmann, L., & Neumann, G. (September 2015). Seedball presentation by PI. Presentation at Tropentag, Berlin, Germany

AREA OF INQUIRY: Added-value products and markets

*Developing superior functionality in sorghum for food applications to promote sorghum value chain in Ethiopia*

(Led by Dr. Joseph Awika – Texas A&M University)

**Location (department level)**
Ethiopia - Sidama

**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**
A new reliable method to identify the presence of the IHD trait in sorghum, based field emission electron microscopy (FESEM), was developed. With this method we will be able to clearly identify the heritability of the IHD trait which will be highly valuable to future breeding efforts. Stability of IHD trait across environments (Ethiopia and Texas) was confirmed. We applied the injera making methods we standardized in the previous year in collaboration with local women enterprises to assess the effect of the IHD sorghum traits on injera processing and quality parameters. Key parameters assessed were fermentation efficiency, and injera texture, shelf stability, and consumer acceptability. Sorghum was substituted for teff at rates from 20 – 80%, with 100% sorghum and 100% teff used as controls. Key
findings: 1) Process efficiency: The Improved HD sorghum with waxy endosperm fermented a lot quicker (24 h) than other sorghums or teff alone (48 – 72 h). This is likely due to the combined easier access to starch by microbial enzymes (due to the HD trait), and the better swelling power of waxy starches which make them easier to ferment by the microflora. The quicker fermentation is practically important because it improves fermentation efficiency and can reduce processing cost by a significant margin. This superior processing quality attribute was highly liked by the women entrepreneurs who prepared the injera. 2) Product quality: Blind test on day-old injera revealed consumers preferred 50% blend of improved waxy sorghum with teff, over 100% teff and other substitutions. The IHD/waxy sorghum injera had better appearance, texture and taste score compared to teff alone or teff with non IHD/non waxy sorghum. This finding is important, because sorghum is usually perceived as inferior ingredient for injera processing. 3) Shelf life: The waxy trait in sorghum significantly improved the shelf life of injera. The waxy sorghum based injeras remained pliable longer than other treatments, and were comparable to or better than teff alone. This indicates the waxy trait slows staling of injera, and thus addresses one of the major problems with sorghum functionality – rapid staling leading to a ‘dry’ texture.

**Capacity building**

Individuals trained under this project include:

<table>
<thead>
<tr>
<th>Name</th>
<th>Institution</th>
<th>Degree</th>
<th>Field</th>
</tr>
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<tr>
<td>Getahun Adane</td>
<td>Hawassa University</td>
<td>Master’s</td>
<td>Food science and postharvest technology</td>
</tr>
<tr>
<td>Loza Mengistu</td>
<td>Hawassa University</td>
<td>Master’s</td>
<td>Food Processing and Preservation</td>
</tr>
<tr>
<td>Abadi Mezgebe</td>
<td>University of Pretoria</td>
<td>Ph.D.</td>
<td>Food Science</td>
</tr>
<tr>
<td>Tadesse Teferra</td>
<td>Texas A&amp;M</td>
<td>Ph.D.</td>
<td>Food Science</td>
</tr>
</tbody>
</table>

**Lessons learned**

Achieving equitable enrollment of females in the different training activities remains an on-going challenge.

**Presentations and publications**


Mengistu, L. (2017) *Process Optimization and Quality of Injera from White, Red and Yellow Sorghum (Sorghum bicolor) in Comparison to Kuncho Teff (Eragrostis tef) and Its Blend* (Master’s thesis).

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

Location (department level)
Niger - Niamey, Tera, Tchirozerine, Magaria
Senegal - Dakar
Burkina Faso - Kaya

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
Instant flours from three millet improved varieties and a local control were prepared with the extruder to make thin and thick porridges. They were tested for consumer perception and acceptability and willingness-to-pay in six locations in Niamey to about 214 consumers, including urban women processors. This was done in collaboration PhD student Tebila Nakelse and INRAN staff including food scientists, an agricultural economist; a professor (Prof. Zakou), and local partners (processor group, nutritionist, communication and extension people). A second study determined the perception and acceptability of labeling and packaging for processed millet foods. The focus was on nutrition labeling. The results from this study will be used to incorporate nutrition labeling for the last part of the current project, to study whether nutritional information can be used to drive products and increase profit for processors. In rural areas, locally made composite flours transformed into porridges were preferred over corn and soy blends. Optimization of the extruded millet couscous product was done for improve the quality (texture, taste, color) and efficiency of the equipment (improved yield); thus shortened the steps of the process (tempering the grain with water was reduced from...
24 hour to a 30 minute step). It was found that both hot and cold water to prepare or reconstitute the couscous. Surprisingly, the cold water reconstitution was better than the hot water, in terms of texture and yield of product (no chunks, etc. with little waste). Nutritional fortification of millet-based foods has been achieved and is being used to make local products that children prefer to eat.

**Capacity building**

Individuals trained under this project include:

<table>
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<tr>
<th>Name</th>
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<th>Degree</th>
<th>Major</th>
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<tr>
<td>Abdourahmane Diop</td>
<td>Universite de Thies</td>
<td>Master’s</td>
<td>Agricultural Economics</td>
</tr>
<tr>
<td>Aminata Diouf</td>
<td>ITA</td>
<td>Master’s</td>
<td>Agricultural Economics</td>
</tr>
<tr>
<td>Hawi Debelo</td>
<td>Purdue University</td>
<td>Ph.D.</td>
<td>Food science</td>
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<tr>
<td>Eliasse Dieme</td>
<td>Cheikh Anta Diop University/ITA</td>
<td>Ph.D.</td>
<td>Microbiology</td>
</tr>
<tr>
<td>Maty Diop</td>
<td>Cheikh Anta Diop University</td>
<td>Ph.D.</td>
<td>Food Science and Nutrition</td>
</tr>
<tr>
<td>Anna Hayes</td>
<td>Purdue University</td>
<td>Ph.D.</td>
<td>Food Science and Nutrition</td>
</tr>
<tr>
<td>Moustapha Moussa</td>
<td>INRAN</td>
<td>Ph.D.</td>
<td>Food Science</td>
</tr>
</tbody>
</table>

**Lessons learned**

Study on product attributes and packaging has determined that urban consumers place the greatest value on knowing the expiration date of the product and knowing that it is locally made. There was less value placed on micronutrient fortification. Processors are highly interested in developing extruded products.

**Presentations and publications**


Moussa, M., Bugusu, B., & Hamaker, B. R. (July 2017). Post-harvest Innovations. Presentation at Mandela Washington African Young Entrepreneurs Fellows, Purdue University, W. Lafayette, IN, USA.


Moussa, M. & Hamaker, B. R. (August 2017). Added Value Product Development and Markets Model in rural areas to empower women & young as a Solution to Development & Security as part of contribution to Sorghum and Millet Innovation Laboratory (SMIL) Presentation. Presentation at International seminar on State Partnership Program (SPP) of Indiana National Guard and Niger, Indianapolis, IN, USA.


Description
Globally, there is great interest in applying new genomic technologies to accelerate genetic gains in developing country breeding programs. However, these methods have not been adopted in developing country NARS due a mismatch between available genomic selection approaches and the existing operations of NARS breeding programs. This project aims to develop genomic approaches from within a NARS breeding program to reduce barriers for adoption. Specifically, these improved genomics selection approaches will be deployed to address several key constraints for dual-purpose sorghums used by smallholders in Haiti. The targets will be improving grain yield while maintaining forage yield and quality, improving tolerance to low/high pH soils, and improving tolerance to post-emergence and post-flowering water limitation.

By designing genomics-assisted breeding approaches in a NARS, the resulting technology will be better suited for adoption by other NARS globally. The tools and resources developed in this project will facilitate adoption of genomics-assisted breeding by partner programs in West and East Africa and will be diffused globally via breeding informatics initiatives (GOBII and BMS).

Collaborators
U.S. collaborating institution(s): Kansas State University, Cornell University
Intl. collaborating institution(s): Haiti – CHIBAS

Achievements
We have been successful at getting both rAmpSeq and Nextera based protocols to work with low quality DNA preps in the US. We will work in the coming year to get these running in Haiti using off-the-grocery shelf reagents. The bioinformatics to use rAmpSeq as anonymous markers work quite well, but it does not integrate seamlessly with other marker systems. We have established the software for the practical haplotype graph in maize, and will be implementing a sorghum version in the coming year. The nature of DNA sequencing is changing with low cost pore based sequencing, and we feel that we should be migrating genotyping to these systems in the coming year. We will experiment with genomic selection by random sequencing of the next few months, and then evaluate the strengths and weaknesses of these approaches. Basic analysis of population structure and diversity for Chibas germplasm is complete. Based on the GBS data, Muleta and Rigaud are now working to estimate the effective population size for the Chibas breeding program, which is the key value needed to reparameterize the genomic selection simulations. Initial simulations confirm improved genetic gain based on GS versus conventional recurrent selection. Further details of breeding plan (e.g. size of populations, intensity of selection, generations to genotyped) remain to be determined.

Capacity building
Individuals trained under this project include:

| Charles Rigaud | CHIBAS | Master’s | Genetics |
| Sarah Jensen | Cornell University | Ph.D. | Plant breeding and genetics |
Lessons learned

Shipping DNA, tissue, and some reagents into Haiti has been challenging. We have developed a number of strategies to make this more efficient, and are hoping these efforts will make the first round of genomic selection go smoothly. Long term, we will work to reduce the number of shipping exchanges needed between the US and Haiti.
Human and Institutional Capacity Development

As in previous years, human and institutional capacity development was kept at the forefront of priorities for the Lab, which resulted in important progress being made in the area, most notably in human capacity development.

Short-term training

The Lab again surpassed the anticipated target number of short-term trainees for FY 2017, overall training 2,590 individuals across all programs. This included 1,306 females and 1,248 males, with 36 individuals of unreported gender. Of the nearly 2,500 trainees, producers made up the largest group with 1,981 trained, followed by 325 civil society members (predominantly researchers and students), 140 people in government and 115 in private sector firms.

The types of short-term trainings conducted varied, and included farmer trainings, professional workshops, on-the-job capacity-building exercises and academic courses. One project in particular accounted for the largest percentage of all short-term trainees by training approximately 1,160 producers in Niger was a farmer training on seedball production and testing. Another large training that included 450 producers in Niger and Senegal was on the rearing and deployment of parasitoid wasps to combat the millet head miner.

Table 1. Short-term trainees supported by the Sorghum and Millet Innovation Lab – FY 2017

<table>
<thead>
<tr>
<th>Country of Training</th>
<th>Purpose of Training</th>
<th>Who was trained</th>
<th>Number trained</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burkina Faso</td>
<td>Annual McKnight CoP Training Workshop/CCRP/West Africa</td>
<td>Producers: 10</td>
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<td></td>
<td></td>
<td>Civil society: 29</td>
<td></td>
</tr>
<tr>
<td>Burkina Faso</td>
<td>Pearl millet production and seed multiplication techniques</td>
<td>Producers: 26</td>
<td>23 F 13 T 36</td>
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<td>Ethiopia</td>
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<td>Government: 1</td>
<td>11 F 10 T 21</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Private sector: 12</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Civil Society: 8</td>
<td></td>
</tr>
<tr>
<td>Ethiopia</td>
<td>Technical training on food analysis equipment use and maintenance</td>
<td>Government: 11</td>
<td>9 F 2 T 11</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>Participatory research appraisal training for SMIL Ethiopian gender study</td>
<td>Government: 26</td>
<td>23 F 3 T 26</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>Validation workshop on findings of participatory gender analysis of sorghum production, processing and utilization in selected sorghum-growing areas of Ethiopia</td>
<td>Government: 40</td>
<td>35 F 6 T 42</td>
</tr>
<tr>
<td>Location</td>
<td>Activity Description</td>
<td>Producers</td>
<td>Government</td>
</tr>
<tr>
<td>----------</td>
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</tr>
<tr>
<td>Mali</td>
<td>Participatory selection training to identify varieties that meet farmers’ needs/expectations</td>
<td>30</td>
<td>1</td>
</tr>
<tr>
<td>Niger</td>
<td>Building capacity of producers in sorghum seed multiplication techniques</td>
<td>30</td>
<td>10 (5 unknown)</td>
</tr>
<tr>
<td>Niger</td>
<td>Building capacity of producers in sorghum breeding, seed production, seed management and seed multiplication techniques</td>
<td>25</td>
<td>5</td>
</tr>
<tr>
<td>Niger</td>
<td>Capacity building for parasitoid private unit managers</td>
<td>21</td>
<td>1 (2 unknown)</td>
</tr>
<tr>
<td>Niger</td>
<td>Training farmers on biological control of the millet head miner</td>
<td>450</td>
<td></td>
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<tr>
<td>Niger</td>
<td>Student training on biological control of the millet head miner</td>
<td></td>
<td></td>
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<tr>
<td>Niger</td>
<td>Training on food safety and data collection surveys (perception/acceptability; socio-economic and quantitative evaluation) on extruded millet and sorghum foods</td>
<td>35</td>
<td>6</td>
</tr>
<tr>
<td>Niger</td>
<td>Training workshop and project monitoring tour/exchange field trips organized by INRAN and local partners</td>
<td>90</td>
<td>10</td>
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<tr>
<td>Niger</td>
<td>Short-term training/workshop on perception/acceptability and willingness to pay of extruded millet food products</td>
<td></td>
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<tr>
<td>Niger</td>
<td>Fuma Gaskiya animator training on seedball technology</td>
<td></td>
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**Sorghum and Millet Innovation Lab Annual Performance Report – FY 2017**
<table>
<thead>
<tr>
<th>Country</th>
<th>Description</th>
<th>Producers</th>
<th>Government</th>
<th>Private sector</th>
<th>Civil society</th>
<th>Total</th>
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<tr>
<td>Niger</td>
<td>Farmer training on seedball production and testing</td>
<td>Producers: 1157</td>
<td>264</td>
<td>893</td>
<td>1160</td>
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<tr>
<td>Niger</td>
<td>Training on sorghum breeding techniques for students at National Agricultural School (IPDR de Kolo)</td>
<td>Producers: 34; Government: 2; Civil society: 1</td>
<td>23</td>
<td>14</td>
<td>37</td>
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<tr>
<td>Niger</td>
<td>Cultural technique training in pearl millet production</td>
<td>Producers: 36; Government: 9; Private sector: 2; Civil society: 2</td>
<td>44</td>
<td>5</td>
<td>49</td>
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<tr>
<td>Senegal</td>
<td>Genomics-enabled breeding seminars</td>
<td>Civil society: 18</td>
<td>10</td>
<td>8</td>
<td>18</td>
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<tr>
<td>Senegal</td>
<td>SMIL Annual meetings and research update</td>
<td>Producers: 2; Civil society: 93</td>
<td>77</td>
<td>18</td>
<td>95</td>
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<tr>
<td>Senegal</td>
<td>Farmer field day around seedball production</td>
<td>Producers: 30; Government: 6</td>
<td>25</td>
<td>11</td>
<td>36</td>
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<tr>
<td>Senegal</td>
<td>Protein digestibility assey with technicians</td>
<td>Civil society: 2</td>
<td>0</td>
<td>2</td>
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<tr>
<td>Senegal</td>
<td>Student training on dual-purpose millet varieties</td>
<td>Government: 42</td>
<td>25</td>
<td>17</td>
<td>42</td>
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<tr>
<td>USA</td>
<td>Molecular tools in plant pathology and methods to assess mycotoxins</td>
<td>Civil society: 1 (Ethiopian co-PI training)</td>
<td>1</td>
<td>0</td>
<td>1</td>
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<tr>
<td>USA</td>
<td>Short training of Young African Entrepreneurs Leaders/Mandela Washington Fellowship</td>
<td>Producers: 5; Government: 2; Private sector: 15; Civil society: 5</td>
<td>13</td>
<td>14</td>
<td>27</td>
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<tr>
<td>USA</td>
<td>Buckler Lab Java Programming School 2017</td>
<td>Civil society: 8</td>
<td>5</td>
<td>3</td>
<td>8</td>
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<tr>
<td>USA</td>
<td>Bucker Lab Hackathon – June</td>
<td>Government: 2; Civil society: 13</td>
<td>10</td>
<td>5</td>
<td>15</td>
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<tr>
<td>USA</td>
<td>Bucker Lab Hackathon – August</td>
<td>Government: 2</td>
<td>10</td>
<td>5</td>
<td>15</td>
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</table>
**Long-term training**

In FY 2017, the Lab saw an increase in total number of long-term trainees. The program now has a roster of 62 different trainees, 17 of which are new to the program this year. Among those 62 trainees, 42 are male and 20 are female. The group also represents a variety of degree levels with two agricultural engineers, four Bachelor's, 26 Master's 29 Ph.Ds. and one post-doc.

**Table 2. Long term trainees supported by the Sorghum and Millet Innovation Lab – FY 2017**

<table>
<thead>
<tr>
<th>Name</th>
<th>Sex</th>
<th>University</th>
<th>Degree</th>
<th>Major</th>
<th>Graduation Date</th>
<th>Degree granted?</th>
<th>Home Country</th>
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<tbody>
<tr>
<td>Mame More Kasse</td>
<td>Male</td>
<td>ISFAR/University of Thies</td>
<td>Engineer</td>
<td>Agricultural Engineering</td>
<td>July 2017</td>
<td>Yes – on an internship with an agricultural entreprise</td>
<td>Senegal</td>
</tr>
<tr>
<td>Adama Sarr</td>
<td>Female</td>
<td>ISFAR/University of Thies</td>
<td>Engineer</td>
<td>Agricultural Engineering</td>
<td>July 2016</td>
<td>Yes – has been recruited by agricultural firm, SODAGRI</td>
<td>Senegal</td>
</tr>
<tr>
<td>Siby Boubacar</td>
<td>Male</td>
<td>Universite Prive de Segou Agri SUP</td>
<td>Bachelor's</td>
<td>Agronomy</td>
<td>December 2018</td>
<td>No</td>
<td>Mali</td>
</tr>
<tr>
<td>Aissatou Diao</td>
<td>Female</td>
<td>CERAAS</td>
<td>Bachelor's</td>
<td>Agronomy</td>
<td>January 2017</td>
<td>Yes – Pursuing Master’s degree at University Cheikh Anta Diop</td>
<td>Senegal</td>
</tr>
<tr>
<td>Iro Ousseini</td>
<td>Male</td>
<td>INRAN</td>
<td>Bachelor's</td>
<td>Agronomy</td>
<td>November 2017</td>
<td>No</td>
<td>Niger</td>
</tr>
<tr>
<td>Anna Thiam</td>
<td>Female</td>
<td>CERAAS</td>
<td>Bachelor's</td>
<td>Agronomy</td>
<td>January 2017</td>
<td>Yes – Searching for employment</td>
<td>Niger</td>
</tr>
<tr>
<td>Daouda Abassa</td>
<td>Male</td>
<td>INRAN</td>
<td>Master's</td>
<td>Socio-economy</td>
<td>January 2018</td>
<td>No</td>
<td>Niger</td>
</tr>
<tr>
<td>Getahun Adane</td>
<td>Male</td>
<td>Hawassa University</td>
<td>Master's</td>
<td>Food science and postharvest technology</td>
<td>February 2018</td>
<td>No</td>
<td>Ethiopia</td>
</tr>
<tr>
<td>Alemnesh Bekele</td>
<td>Female</td>
<td>Haramaya University</td>
<td>Master's</td>
<td>Plant pathology/breeding</td>
<td>May 2018</td>
<td>No</td>
<td>Ethiopia</td>
</tr>
<tr>
<td>Name</td>
<td>Gender</td>
<td>Institution</td>
<td>Degree</td>
<td>Field</td>
<td>Year</td>
<td>Nationality</td>
<td>Position</td>
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<tr>
<td>Chemeda Berhanu</td>
<td>Male</td>
<td>Haramaya University</td>
<td>Master’s</td>
<td>Plant pathology/breeding</td>
<td>October 2017</td>
<td>No</td>
<td>Ethiopia</td>
</tr>
<tr>
<td>Kebede Dessalgn</td>
<td>Male</td>
<td>Haramaya University</td>
<td>Master’s</td>
<td>Plant pathology/breeding</td>
<td>December 2015</td>
<td>Yes – works for BAKO Research Center at Oromia Research Institute</td>
<td>Ethiopia</td>
</tr>
<tr>
<td>Cheikh Dieng</td>
<td>Male</td>
<td>Ecole National Superieure d’Agriculture (ENSA)</td>
<td>Master’s</td>
<td>Production Végétales</td>
<td>January 2016</td>
<td>Yes – currently farming but awaiting near-term appointment from national research program</td>
<td>Senegal</td>
</tr>
<tr>
<td>Mouhamadou Diome</td>
<td>Male</td>
<td>ENSA Thies</td>
<td>Master’s</td>
<td>Socio-economy</td>
<td>December 2017</td>
<td>No</td>
<td>Senegal</td>
</tr>
<tr>
<td>Aminata Diouf</td>
<td>Female</td>
<td>ITA</td>
<td>Master’s</td>
<td>Agricultural Economics</td>
<td>May 2016</td>
<td>Yes</td>
<td>Senegal</td>
</tr>
<tr>
<td>Nadre Gbedié</td>
<td>Male</td>
<td>CERAAS</td>
<td>Master’s</td>
<td>Breeding</td>
<td>April 2016</td>
<td>Yes – currently applying to DADD fellowship program for Ph.D.</td>
<td>Côte d’Ivoire</td>
</tr>
<tr>
<td>Michael Guerci</td>
<td>Male</td>
<td>Virginia Tech</td>
<td>Master’s</td>
<td>Agricultural Economics</td>
<td>May 2016</td>
<td>Yes – works (volunteers) for U.S. Peace Corps in the Philippines</td>
<td>United States</td>
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<tr>
<td>Hamidou Idrissa</td>
<td>Male</td>
<td>Université Abdou Moumouni de Niamey</td>
<td>Master’s</td>
<td>Entomology</td>
<td>January 2018</td>
<td>No</td>
<td>Niger</td>
</tr>
<tr>
<td>Abdou Illiassou</td>
<td>Male</td>
<td>Université Dan Dicko Dankoulodo</td>
<td>Master’s</td>
<td>Agronomy</td>
<td>December 2017</td>
<td>No</td>
<td>Niger</td>
</tr>
<tr>
<td>El Hadj Malick Kane</td>
<td>Male</td>
<td>CERAAS</td>
<td>Master’s</td>
<td>Microbial and vegetal biotechnology</td>
<td>September 2017</td>
<td>No</td>
<td>Senegal</td>
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<tr>
<td>Name</td>
<td>Gender</td>
<td>Institution</td>
<td>Degree</td>
<td>Field</td>
<td>Month Year</td>
<td>Status</td>
<td>Country</td>
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<tr>
<td>Mengistu Kassie</td>
<td>Male</td>
<td>Kansas State University</td>
<td>Master's</td>
<td>Agricultural Economics</td>
<td>May 2018</td>
<td>Yes – on an internship with AGRA; looking for Ph.D. funding</td>
<td>Ethiopia</td>
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<tr>
<td>Omar Kandji</td>
<td>Male</td>
<td>University Cheikh Anta Diop</td>
<td>Master's</td>
<td>Pest Management</td>
<td>May 2017</td>
<td></td>
<td>Senegal</td>
</tr>
<tr>
<td>Said Laminou</td>
<td>Male</td>
<td>Université Abdou Moumouni de Niamey</td>
<td>Master's</td>
<td>Entomology</td>
<td>January 2018</td>
<td>No</td>
<td>Niger</td>
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<tr>
<td>Marietou Ly</td>
<td>Female</td>
<td>ENSA/University of Thies</td>
<td>Master's</td>
<td>Sustainable development and society/agriculture</td>
<td>August 2017</td>
<td>Yes – searching for Ph.D. funding</td>
<td>Senegal</td>
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<tr>
<td>Mahamadou Maazou</td>
<td>Male</td>
<td>University of Tahoua</td>
<td>Master's</td>
<td>Socio-economy</td>
<td>December 2017</td>
<td>Yes</td>
<td>Niger</td>
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<tr>
<td>Loza Mengistu</td>
<td>Female</td>
<td>Hawassa University</td>
<td>Master's</td>
<td>Food Processing and Preservation</td>
<td>March 2017</td>
<td>Yes – now employed at a private company</td>
<td>Ethiopia</td>
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<tr>
<td>Oumou Moumouni</td>
<td>Female</td>
<td>Abdou Moumouni University of Niamey with Short Training at Virginia Tech</td>
<td>Master's</td>
<td>Agricultural Economics</td>
<td>January 2018</td>
<td>No</td>
<td>Niger</td>
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<tr>
<td>Benoit Ouedraogo</td>
<td>Male</td>
<td>University of Ouagadougou</td>
<td>Master's</td>
<td>Breeding and conservation of seed</td>
<td>April 2017</td>
<td>No</td>
<td>Burkina Faso</td>
</tr>
<tr>
<td>Charles Rigaud</td>
<td>Male</td>
<td>CHIBAS</td>
<td>Master's</td>
<td>Genetics</td>
<td>November 2017</td>
<td>No</td>
<td>Haiti</td>
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<tr>
<td>Gnilane Sene</td>
<td>Female</td>
<td>University Cheikh Anta Diop</td>
<td>Master's</td>
<td>Pest management</td>
<td>December 2015</td>
<td>Yes – recruited by agricultural entreprise</td>
<td>Senegal</td>
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<tr>
<td>Baye Thiam</td>
<td>Male</td>
<td>University of Thies</td>
<td>Master's</td>
<td>Agricultural engineering</td>
<td>April 2017</td>
<td>No</td>
<td>Senegal</td>
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<tr>
<td>Zongo Rachelle Yvonne</td>
<td>Female</td>
<td>INERA</td>
<td>Master's</td>
<td>Seed selection and conservation (SELCOSE)</td>
<td>December 2015</td>
<td>Bachelor’s granted, now working on Master’s</td>
<td>Burkina Faso</td>
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<tr>
<td>Name</td>
<td>Gender</td>
<td>University/Institution</td>
<td>Degree</td>
<td>Field</td>
<td>Date</td>
<td>Country</td>
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<tr>
<td>Laouali Amadou</td>
<td>Male</td>
<td>University of Maradi</td>
<td>Ph.D.</td>
<td>Entomology</td>
<td>January 2019</td>
<td>Niger</td>
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<tr>
<td>Eyanawa Akata Atchozou</td>
<td>Male</td>
<td>CERAAS</td>
<td>Ph.D.</td>
<td>Agronomy (Breeding &amp; Genetics)</td>
<td>January 2018</td>
<td>Togo</td>
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<tr>
<td>Demek Bayable</td>
<td>Male</td>
<td>Purdue University</td>
<td>Ph.D.</td>
<td>Plant pathology</td>
<td>August 2019</td>
<td>Ethiopia</td>
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<tr>
<td>Yemane Belayneh</td>
<td>Male</td>
<td>Kansas State University</td>
<td>Ph.D.</td>
<td>Plant breeding and genetics</td>
<td>December 2019</td>
<td>Ethiopia</td>
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<tr>
<td>Diriba Hika Chere</td>
<td>Male</td>
<td>Kansas State University</td>
<td>Ph.D.</td>
<td>Plant pathology/breeding</td>
<td>December 2020</td>
<td>Ethiopia</td>
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<tr>
<td>Hawi Debelo</td>
<td>Female</td>
<td>Purdue University</td>
<td>Ph.D.</td>
<td>Food science</td>
<td>August 2018</td>
<td>Ethiopia</td>
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<tr>
<td>Cyril Diatta</td>
<td>Male</td>
<td>CERAAS</td>
<td>Ph.D.</td>
<td>Plant breeding and genetics</td>
<td>December 2019</td>
<td>Senegal</td>
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<tr>
<td>Elizabeth Diatta</td>
<td>Female</td>
<td>West African Center for Crop Improvement</td>
<td>Ph.D.</td>
<td>Plant Breeding</td>
<td>December 2018</td>
<td>Senegal</td>
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<tr>
<td>Eliasse Dieme</td>
<td>Male</td>
<td>Cheikh Anta Diop University/ITA</td>
<td>Ph.D.</td>
<td>Microbiology</td>
<td>July 2018</td>
<td>Senegal</td>
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<tr>
<td>Abdourahmane Diop</td>
<td>Male</td>
<td>Universite de Thies</td>
<td>Master's</td>
<td>Agricultural Economics</td>
<td>2017</td>
<td>Senegal</td>
<td></td>
</tr>
<tr>
<td>Maty Diop</td>
<td>Female</td>
<td>Cheikh Anta Diop University</td>
<td>Ph.D.</td>
<td>Food Science and Nutrition</td>
<td>July 2018</td>
<td>Senegal</td>
<td></td>
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<tr>
<td>Jacques Faye</td>
<td>Male</td>
<td>Kansas State University</td>
<td>Ph.D.</td>
<td>Agronomy (Plant Breeding &amp; Genetics)</td>
<td>December 2018</td>
<td>Senegal</td>
<td></td>
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<tr>
<td>Name</td>
<td>Gender</td>
<td>University</td>
<td>Degree</td>
<td>Field</td>
<td>Date</td>
<td>Work Location</td>
<td>Country</td>
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<tr>
<td>Mame Fatoumata Goudiaby</td>
<td>Female</td>
<td>University Cheikh Anta Diop</td>
<td>Ph.D.</td>
<td>Entomology</td>
<td>December 2017</td>
<td>No</td>
<td>Senegal</td>
</tr>
<tr>
<td>Stephanie Griebel</td>
<td>Female</td>
<td>Purdue University</td>
<td>Ph.D.</td>
<td>Agronomy</td>
<td>December 2018</td>
<td>No</td>
<td>Germany</td>
</tr>
<tr>
<td>Anna Hayes</td>
<td>Female</td>
<td>Purdue University</td>
<td>Ph.D.</td>
<td>Food Science and Nutrition</td>
<td>August 2019</td>
<td>No</td>
<td>USA</td>
</tr>
<tr>
<td>Sarah Jensen</td>
<td>Female</td>
<td>Cornell University</td>
<td>Ph.D.</td>
<td>Plant breeding and genetics</td>
<td>August 2021</td>
<td>No</td>
<td>USA</td>
</tr>
<tr>
<td>Hame Abdou Kadi Kadi</td>
<td>Male</td>
<td>West Texas A&amp;M University</td>
<td>Ph.D.</td>
<td>Plant, Soil and Environmental Science - Insect Pest Management</td>
<td>July 2018</td>
<td>No</td>
<td>Niger</td>
</tr>
<tr>
<td>Laouali Karimoune</td>
<td>Male</td>
<td>ICRISAT – Niger</td>
<td>Ph.D.</td>
<td>Entomology</td>
<td>December 2019</td>
<td>No</td>
<td>Niger</td>
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<td>Female</td>
<td>Kansas State University</td>
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<td>No</td>
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<td>December 2018</td>
<td>No</td>
<td>Niger</td>
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Institutional development continues to carry a high priority in the Lab, and is evidenced by the Lab’s efforts in establishing strong linkages with and between regional initiatives and collaborators.

Annual program review meetings
As in FY 2016, the Lab again chose to pull together its entire research teams together for program-wide annual meetings in March 2017. The meetings were held in Senegal (the location was initially planned for Ethiopia, but political unrest led the team to decide to change location) and all Lab researchers and students were invited to take part. Additionally, relevant local collaborators, including representatives from IAVAO and the Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD) as well as L’Agence Nationale de Conseil Agricole et Rural (ANCAR) and Réseau des Organisations Paysannes et Pastorales du Sénégal (RESOPP) also took part in meeting discussions. The meeting structure was set up in such a way to maximize researcher interaction and sharing, including regular poster presentation sessions, project-level question and answer periods and significant blocks of project work periods. This format highly encouraged researcher networking and cross-fertilization between countries and regions.

IAVAO (West Africa)
The Lab continued to support the Innovation and Plant Breeding in West Africa (IAVAO) initiative, which was launched in FY 2016 in an effort to “implement innovative plant breeding programmes to address the complexity of afro-ecological systems in West Africa,” and incorporates researchers from across West Africa and France, including Burkina Faso, Mali, Niger and Senegal around collaboration and partnership in research, teaching and training. The Lab supports and partners with the initiative where appropriate and will continue to do so in the future. Activities in IAVAO are highly complementary to Lab activities and both programs work well at maximizing the joint benefit of both programs.

Private industry partnerships – Kansas Department of Agriculture
In August 2016, the Lab management entity supported the Kansas Department of Agriculture (KDA) trade mission to Ethiopia. A site visit was organized to EthioGreen, a gluten-free teff and sorghum food processing company selling to the domestic and international market in Addis Ababa. The KDA then provided support for a reverse trade mission in January 2017 for Rahel Mogos the owner of EthioGreen, to visit multiple institutions in Kansas including the Sorghum and Millet Innovation Lab, KDA, American Baking Institute (AIB), a Kansas State Legislator and NuLife Markets. The Lab supported this mission and assisted in the facilitation of Rahel’s visit and...
associated discussions. This was another key step in strengthening the capacity of this small- to medium-sized company in producing agricultural value addition products.

**Gender in sorghum production research study debrief workshop**

As will be discussed further under “Other Topics,” the Lab commissioned a woreda-based gender study in Ethiopia on the role of gender in sorghum production and utilization. As a part of the data collection, research teams were formed for each woreda and included both male and female researchers that represented scientific expertise ranging from breeding and genetics to agronomy to social science (all from the national agricultural research system). The teams worked together to collect the data and gathered at a post-data collection debrief workshop to report on their results and share their observations. This format proved to be an important capacity-building exercise as hard scientists learned the role and importance of social science in the identification and development of new technologies to address production and utilization issues, while social scientists gained knowledge in the technical aspects of sorghum production. In addition, all teams reported back that the exercise solidified the necessity of successful gender integration in research projects as they saw first-hand the impact that gender has on many production and utilization issues. Several committed to integrating gender into the overall national program priorities.
Innovation transfer and scaling partnerships

In the development of innovations and technologies to address important needs and challenges along the sorghum and millet value chains within the developing world, the Lab keeps the smallholders and other end users at the forefront. The ultimate goal to all innovations and other advancements is to improve the livelihoods of those that will use and benefit from them; therefore, the Lab consistently works to integrate their needs and feedback as much as possible from the earliest stages of the research projects.

Due to the more upstream nature of a fair amount of the research occurring under the Lab’s portfolio, many of the technologies and innovations currently under development remain in the early stages of research and field testing in preparation for larger scale dissemination in future years and phases. However, even in these initial stages, research teams are expected to engage end users whenever possible and incorporate their feedback, needs and opinions into all stages of technology development.

Phase 1 technologies – Under Research

1. **Technology: Sorghum germplasm/variety development for food quality**

   **Category:** Biological

   **Area of inquiry:** Genetic enhancement

   **Description and steps taken:** Large number of populations, families and advanced breeding lines are being evaluated to select the most promising materials with enhanced agronomic adaptation and nutritional quality for use by smallholder sorghum grower community in Ethiopia. More population will be developed based on genetic and genomic information being generated. Altogether, these will advance sorghum research for enhanced protein nutrition and along with other nutritional programs will contribute to improved health and productivity of communities who rely on sorghum as primary source of energy and protein.

   **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:** Completing field phenotyping and laboratory work on PD and factors surrounding protein availability in sorghum.

   **Target country:** Ethiopia

2. **Technology: Development of parental materials for disease resistance**

   **Category:** Biological

   **Area of inquiry:** Genetic enhancement

   **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. Some of the very promising disease resistance lines are being crossed into the locally adapted material with the goal of generating segregating population that will be further selected for disease resistance as well as other agronomic traits.

Target country: Ethiopia

3. Technology: Experimental hybrids for commercial sorghum seed industry

Category: Biological

Area of inquiry: Genetic enhancement

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

Target country: Ethiopia

4. Technology: Genomics-enabled breeding platform

Category: Management Practices

Area of inquiry: Genetic enhancement

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: The team anticipates establishing partnerships 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 the team 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. They will identify and test new genetic markers for drought-related and locally-preferred genetic backgrounds.

Target countries: Senegal and Niger

5. Technology: Locally-preferred sorghum varieties with improved adaptive traits

Category: Biological

Area of inquiry: Genetic enhancement
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: 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.

Target countries: Senegal and Niger

6. Technology: Food quality traits in sorghum

Category: Biological
Area of inquiry: Genetic enhancement

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.

Target countries: Senegal and Niger

7. Technology: Forage digestibility traits in sorghum

Category: Biological
Area of inquiry: Genetic enhancement

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.

Target country: Niger

8. Technology: Best dual-purpose genotypes selected by country

Category: Biological
Area of inquiry: Genetic enhancement
Description: Several genotypes have been selected as having the most dual productivity (grain and straw yield) in Burkina Faso (19), Mali (20), Niger (40) and Senegal (34). The main characteristics being observed in these selections include spikelet length (LOE), plant height (HTR), spikelet width (LAE) and downy mildew incidence (DM2).

Partnerships made: Research stations of Gampela, Kouaré, Katchari (Burkina Faso), N’Tarla, Cinzana (Mali), Bengou, Kolo (Niger) Nioro, Bambey (Sénégal)

Next steps: Project will continue with seed and stover/forage analysis, breeder seed production, and on-farm participatory selection. The project also plans to incorporate short- and long-training as well as gender implications in activities, including on-farm selection activities.

Target countries: Senegal, Mali, Burkina Faso and Niger

9. Technology: Food product innovation with new improved sorghum endosperm

Category: Mechanical and physical

Area of inquiry: Added-value products and markets

Description: Methods to incorporate sorghum in traditional and modern food products without negative impact on sensory quality.

Partnerships made: Pending

Next steps: Form partnerships with local food processors to test the technologies under development. Both processing quality and consumer acceptability will be evaluated.

Target countries: Senegal and Niger

10. Technology: Development of new sorghum varieties from genomic selection program (new)

Category: Biological

Area of inquiry: Genetic enhancement

Description: Development of new high-yielding sorghum varieties (for low or no-input environments)

Partnerships made: Early stage of development

Next steps: Variety development and field testing

Target countries: Haiti

11. Technology: Improved and cheaper technology for implementation of genomic selection by breeders in developing countries (new)

Category: Biological

Area of inquiry: Genetic enhancement
Description: Development of <$5 per genotype DNA extraction and genotyping, a DNA extraction and GBS pipeline requiring no lab for the breeder (just marker data). Compilation of a database with the whole genome sequence and imputed data for the entire breeding program as well as the development of a public “open source” training set and genomic-assisted breeding population for multipurpose sorghum varieties (grain and forage). Development of a population for which it would be easy to add new variation in the system (use the base system as a building block to build one’s own genomic-assisted breeding program) and an approach to breed for multiple environments (developing/improving the strategy to predict the breeding value across different environments).

Partnerships made: Kansas State University, Cornell University

Next steps: Testing

Target country: Haiti

Phase 2 technologies – Under Field Testing

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

Category: Management practices

Area of inquiry: Production systems management

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: Second field testing on-station and on-farm in 2016 in Senegal and Niger to test higher seed rates per ball in order to improve germination.

Target countries: Senegal and Niger

2. Technology: Seedball fabrication mechanization for men with mediocre investment capital

Category: Mechanical and physical

Area of inquiry: Production systems management

Description: Men will only invest in seedball technology if working time demand is relatively low. Therefore, a mechanical device was constructed that can serve interested men as well as small local seed enterprises. The device allows for a throughput of several thousand seedballs per hour at medium (in the local sense) investment costs.

Partnerships made: Fleischle GBR, Vaihingen Enz - Germany
Next steps: The mechanization option has shown to work under farmers’ conditions. However, local craftsmen were not able to copy it, which indicates that modifications need to be developed with craftsmen and farmers together.

Target countries: Senegal and Niger

3. Technology: Seedball fabrication mechanization for women with low investment capital

Category: Mechanical and physical

Area of inquiry: Production systems management

Description: The technology is based on an easy to construct frame that produces about 80 seedballs in one batch. It is designed in particular for women with low investment capital that need to sow more than a home garden surface.

Partnerships made: Fleischle GBR, Vaihingen Enz - Germany

Next steps: The mechanization option has shown to work under farmers’ conditions. However, local craftsmen were not able to copy it, which indicates that modifications need to be developed with craftsmen and farmers together.

Target countries: Senegal and Niger

4. Technology: Improved endosperm sorghum for protein quality and processing functionality

Category: Biological

Area of inquiry: Added-value products and markets

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.

Target country: Ethiopia

5. Technology: Extruded sorghum- and millet-based food products

Category: Mechanical and Physical

Area of inquiry: Added-value products and markets

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

Target countries: Senegal and Niger

6. Technology: Development of rural incubation centers

Category: Management practices

Area of inquiry: Added-value products and markets

Description: In joint work with the McKnight Foundation in Niger and Burkina Faso, the management structure and engagement approach with rural processors has been developed and the functioning is being continually refined.

Partnerships made: Partnerships have been well established with rural women processors and associations. The team is also in discussion with other donors, including the World Bank, the German government and a local Nigerien USAID project (REGIS).

Next steps: Currently in discussions on possibility of scale-up of these activities.

Target countries: Senegal and Niger

7. Technology: 120 dual-purpose pearl millet varieties selected and in farmer fields for participatory selection (new)

Category: Biological

Area of inquiry: Genetic enhancement

Description: Two years of on-station research has given the opportunity to breeders across the four West African countries (Senegal, Burkina Faso, Mali and Niger) to identify 120 dual-purpose varieties with both good grain and fodder yield as well as quality. These varieties are being planted as a part of on-farm trials to select the best varieties from farmer and breeder feedback and observations. The breeders’ seed was multiplied to produce the necessary seed for farmer trials – this provided the opportunity for farmers to learn good pearl millet cropping and seed multiplication techniques.

Partnerships made: Primarily with farmer organizations and NGOs, including Burkina Faso organizations/institutions of FEPAB (Katchari, Boulsa and Toma), the agricultural ministry (Kokologo), AGRISEM (Kaya), COPROSEL (Pobe Mengao) and FAGRI (Dedougou)

Next steps: Identify 3-5 dual-purpose varieties by farmers this season and confirm them during the 2018 rainy season. Produce breeder seed during 2017-2018 to meet farmer’s needs and produce foundation seed to meet farmer needs.

Target countries: Senegal, Mali, Burkina Faso and Niger
8. Technology: Insect-resistant sorghum cultivars

Category: Biological

Area of inquiry: Genetic enhancement

Description: Sorghum germplasm consisting of insect-resistant lines are being developed. The germplasm also should have resistance to other biotic stresses.

Partnerships made: ISRA, CNRA, CERAAS, INRAN

Next steps: Continue evaluation of germplasm for resistance to insect pests and adaptation to indigenous cropping systems.

Target countries: Senegal and Niger

Phase 3 technologies – Made available for transfer

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

Category: Management practices

Area of inquiry: Genetic enhancement

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); INRAN – Niamey, Niger

Next steps: Field testing in 2017 has shown that the technology works using materials from different locations. Now the technology needs to be described in detail and distributed to other Sahelian areas, where applicable.

Target countries: Senegal and Niger

2. Technology: Evaluation of technologies to manage insect pests of sorghum

Category: Management practices

Area of inquiry: Production systems management

Description: Developing and evaluating approaches to manage biotic and abiotic stresses in the field, storage, and laboratory without relying on pesticides.

Partnerships made: INRAN, CNRA, CERRAS, ISRA

Next steps: Identify and transfer the technologies at the farm level and storage facilities.

Target countries: Senegal and Niger
3. **Technology: Mass rearing of parasitoids for biological control**

   **Category:** Management practices  
   **Area of inquiry:** Production systems management  
   **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.  
   **Target countries:** Senegal and Niger

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

   **Category:** Management practices  
   **Area of inquiry:** Production systems management  
   **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:** Identify funding mechanism for scaling.  
   **Target countries:** Senegal and Niger
Environmental Management and Mitigation Plan (EMMP)

Strengthening the overall program environmental compliance capacity and reporting has continued. There has been ongoing utilization of the environmental monitoring and mitigation plan (EMMP) web-based module on the SMIL Resource & Reporting Hub by country coordinators, in-country environmental compliance focal persons and research teams. A verbal presentation and poster session were organized to better engage the research teams at the annual SMIL annual program meeting in Senegal around the 3R’s of Responsibility, Roles, and Resources associated with environmental compliance.

An amended Initial Environmental Examination (IEE) provides for research activities under the recent associate award titled, “Feed the Future Innovation Lab for Genomics-Assisted Sorghum Breeding,” with field activities in Haiti. The management entity met with the environmental compliance officer at the Haiti mission during a country visit there together with the principal investigator. SMIL was able to take the opportunity to present the web-based EMMP module and there was forward planning to include the program coordinator at the implementing partner Centre de Recherche sur les Biocarburants et l’Agriculture Durable (CHIBAS) in the next USAID environmental compliance training as well as a program visit by the environmental compliance officer to CHIBAS. CHIBAS has developed an initial environmental compliance plan as well as a seed treatment protocol, which are available on the SMIL Reporting Hub [https://smil.piestar.com/modules/project/1004/rp/4/emmp](https://smil.piestar.com/modules/project/1004/rp/4/emmp). During the country visit, the management entity visited multiple sorghum field sites. There were no surface water runoff concerns due to extreme slope, there were vegetative buffers around field sites and there was no pesticide usage.

Open data management plan

The Sorghum and Millet Lab maintains an open data management plan on file with USAID. The Innovation Lab currently maintains a reference library of the data collected under the program and where this data is housed. In the case of genomics data, it is held at sites that are better adapted for that purpose than the Data Development Library (DDL). Our project management system has a specific module for project investigators to enter meta data on their data sets and the location of where this data is stored. We continue to be involved in discussions with USAID on compliance with the Open Data policy and adjust our information requirements based upon policy development.
Governance and management entity activity

Innovation Lab Council leadership
Lab director Tim Dalton was elected Innovation Lab Council Chairman in FY 2016 for a one-year appointment. As a part of that role, the Lab was responsible for providing administrative support and facilitation of the 2017 regional Innovation Lab Council meetings held on February 6-8, 2017 at the King Fahd Hotel in Dakar, Senegal. The meetings saw a range of participants, including USAID personnel, Innovation Lab staff, local NGOs, government officials and other implementing partners and collaborators.

Additionally, the Lab was also responsible for leading the 2017 Innovation Lab Council meetings held September 12-13, 2017, which included a public BIFAD meeting, Innovation Lab Council Science Expo, Capitol Hill breakfast reception and Innovation Lab business meeting. The leadership for FY 2018 has transferred to the Horticulture Innovation Lab at UC Davis.

Initiation of new associate award
The associate award titled, “Feed the Future Innovation Lab for Genomics-Assisted Sorghum Breeding,” was awarded at the end of FY 2016. This project is co-led by researchers from Haiti’s CHIBAS, Cornell University and Kansas State University using genomics to improve the efficiency of a traditional small country sorghum breeding program. The management entity organized a two-day coordination meeting in the first quarter of FY 2017 at Cornell University together with two researchers from Kansas State University and the lead researcher from the implementing partner at CHIBAS in Haiti and the Cornell University team. The project roles of each team was agreed upon, a detailed research implementation plan and timeframes developed and regular joint meetings and platform put in place.

Support for Livestock Innovation Lab-funded project in Ethiopia
Ethiopia has the largest livestock population in the continent of Africa and quality feed and fodder are key constraints. The Lab has been active in linking dual-purpose sorghum and forage research in Ethiopia to livestock systems research. The Kansas State University-led research project entitled “Linking Cattle Nutrition to Human Nutrition: A Value Chain Approach to Improving the Production, Handling, and Consumption of Animal Source Foods in Ethiopia” is funded by the Feed the Future Livestock Systems Innovation Lab. This research project is utilizing previously screened sorghum forages funded by the Sorghum and Millet Innovation Lab for research. Approximately 185 lines of long and short maturing sorghum forage varieties are being intercropped with pigeon pea at multiple seed rates to study forage production and quality levels. This is being led by a forage scientist at the Ethiopian Institute of Agricultural Research (EIAR). This forage study will then be linked to a beef cattle nutrition study at Hawassa University and eventual farmer level trials.

The Livestock Systems Innovation Lab platform meeting in Ethiopia provided the opportunity to meet Dr. Yirgalem Gebremeskel who is the USAID Ethiopia mission Livestock and Dairy Programs Specialist and Technical Advisor. During a visit to the United States Dr. Yirgalem was invited to K-State for an exchange visit with the Sorghum and Millet Innovation Lab, Kansas Department of Agriculture, School of Veterinary Medicine, and departments at Kansas State University.

Collaboration with Makerere University
Patrick Ongom, a Sorghum and Millet Innovation Lab-supported Ph.D. graduate and sorghum plant breeder in Uganda, is collaborating with Dr. Paul Gibson from Makerere University College of Agriculture and Environmental Science. The Lab management entity hosted Dr. Gibson to discuss the sorghum research base at Makerere University and potential means to strengthen collaborations.

External Advisory Board engagement
The external advisory board continued to play a key role in guiding the overall portfolio of research projects. Board members were present at the annual review meeting in Senegal with approximately 100 participants in March 2017. In addition to project presentations and Q&A sessions, a large poster presentation area within the meeting room was
organized and provided ongoing interaction between researchers, students and board members. An internal management entity and board meeting was organized at the end of the annual review meeting to discuss key board recommendations per project as well as cross cutting issues.

2018 Global Sorghum Conference
The Sorghum and Millet Innovation Lab has taken leadership in the organization of a 2018 global sorghum conference, entitled, “Sorghum in the 21st Century: Food, Feed and Fuel for a Rapidly Changing World.” The first global sorghum gathering in over 30 years, the conference will take place at the Century City Convention Centre in Cape Town, South Africa on April 9-12, 2018. The University of Pretoria and researchers John and Janet Taylor have assumed co-organization, and both an international organizing committee and local organizing committee (as well as associated sub-committees) have been established. Turners Conference of South Africa was hired to assist in conference logistics and planning, and conference promotion and planning is currently in full-force. More information about the conference can be seen at https://21centurysorghum.com/.

End of program evaluation
The Lab commenced its end-of-program external evaluation during the FY 2017. The evaluation will assess the Lab’s overall successes, challenges, opportunities and value to determine whether the Lab should be renewed for a second 5-year phase. The evaluation is still in process and an associated report is anticipated for late in the first quarter of FY 2018.
Other Topics

Ethiopia's AGP-II update and progress
Ethiopia's initial Agricultural Growth Program (AGP) Phase I was production orientated and did not include sorghum as a value chain. The second phase of the program, AGP-II (2015-2020), does include sorghum thanks to previous efforts by the Lab and Lab partners to emphasize its importance. The AGP-II also lays a foundation for a shift from a production focus towards agricultural commercialization and processing. Mirroring this change, the Agricultural Transformation Agency (ATA) has restructured away from a value chain structured departments/programs to respond to the following pillars of AGP-II or the Growth and Transformation Plan (GTP-II):

1) Increased and market oriented crop production and productivity
2) Increased livestock production and productivity
3) Reduced degradation and improved productivity of natural resources
4) Enhanced food security
5) Markets and agri-business
6) Enhancing implementation capacity

Within this framework, there exists a focus on cross cutting issues related in particular to gender equality, environment and climate change adaptation.

Gender study: Sorghum production and utilization in Ethiopia
The Lab commissioned a gender study to led by gender consultant Yeshi Chiche in Ethiopia. The purpose of the study was to assess gender roles and sorghum production/utilization by region (woreda) in Ethiopia. The FY 2017 saw village-level data collection in six different woredas using focus group interviews and rapid rural appraisal. The data from those interviews was aggregated and presented at a project debrief meeting in August 2017. The Lab program coordinator attended that meeting and worked with the teams to improve data presentation, further analysis and compilation into a full project report. The compilation of that report will occur in FY 2018 and the data will be presented at the 2018 Global Sorghum Conference in Cape Town, South Africa.

Research project gender integration
In FY 2017, all projects were required to build a gender integration plan into their research project operational plans in an effort to have a more effective approach to gender integration across the program. These plans included practical ways in which considerations for gender could be incorporated into existing project activities. Since that time, projects have continued to make progress in their approaches to female scientist recruitment, farmer trial and consumer feedback session structures and overall need assessment priorities. While the overall prioritization of gender varies between projects, there has generally been compliance and enthusiasm on the part of the research teams for finding ways to improve gender equity in activities and ensure that both men and women's needs are addressed in project research.
Future directions

The five-year funding period for the Feed the Future Innovation Lab for Collaborative Research on Sorghum and Millet ends on July 22, 2018. During the final nine months of the program that fall in FY 2018, the program will focus on consolidating research and development activities in preparation for termination or continuation. In several cases, technologies developed in the program are ready for transfer to implementing partners and these will naturally flow into mission-directed activities or into the private sector. Considerable investment in human and institutional capacity has created an environment where long-term breeding strategies can continue to flourish and generate new varieties and hybrids for small-scale farmers.

The Sorghum and Millet Innovation Lab is co-organizing with the University of Pretoria “Sorghum in the 21st Century” a global convening of sorghum research, development and private sector in the first meeting since the 1990’s. This conference will be held in April 2018 in Cape Town, South Africa. The Innovation Lab will use the meeting to showcase research and development findings and foster greater collaboration among the global sorghum research community. We will use the meeting as the final opportunity to convene our sorghum community. If funding permits, we will organize a small regional meeting in West Africa on pearl millet to strategize on future activities.

If funding is extended into a new five-year cycle, the Sorghum and Millet Innovation Lab will issue a new call for research proposals and develop a new portfolio of research projects by the end of 2018.
Appendices

Appendix 1 – Success stories

*Nutrition by demand: Research and technology respond to market demand for convenient, nutritious foods*

Couscous, degue, thiakry, lakhou. Sorghum and millet are the key ingredients to countless West Africa staple dishes. The dishes come in many forms and are called a variety of names, but they are all rooted in years of rich history and are key to the food security of millions of people living in some of Africa’s most challenging climates.

While these foods are an important source of nutrition for West Africans of all ages and backgrounds, they are very often prepared using traditional methods that are labor-intensive and require multiple hours of preparation each day, a responsibility that typically falls to the women of the household. With increasing urbanization and disposable income, as well as a deeper understanding and demand for nutritionally-balanced diets, these food products are seeing a market-driven revolution.

Collaborative efforts between three international organizations – the McKnight Foundation and the Feed the Future Innovation Labs for Sorghum and Millet (previously INTSORMIL) and Food Processing and Post-Harvest Handling – in partnership with numerous national research programs and local initiatives have served as the driver for a new wave of business and nutritional opportunities.

Initially launched to help build greater demand for locally-produced grains and provide more reliable income for West African smallholder farmers, the initiative concentrates on the creation of entrepreneurial opportunities and networks for local women to produce traditional food products that are packaged, easy-to-prepare and ready for purchase by local consumers.

“Focusing on local markets can help reduce transaction costs and lead to higher benefits for our target small-holder farmers,” says Bettina Haussemann, West African liaison scientist for the McKnight Foundation. “Sometimes the processing units will make contracts directly with small-holder farmers to purchase high-quality grain at a good price, which can enhance the income security of the farmer.”

Both rural and urban models of this initiative have been established, and have included food product development and testing according to local contexts, says Timothy Dalton, director of the Feed the Future Innovation Lab for Collaborative Research on Sorghum and Millet. In addition to evaluating preferences for food product type and processing method, testing has also been conducted around the fortification of grain-based products with locally available, highly nutritious ingredients such as moringa and baobab with encouraging results. Initial screenings have shown that consumers not only appreciate the flavor and texture of the fortified products, but are also willing to pay a premium for them.

“In consumer testing, we find that instant millet-based food products are rated equal, and even sometimes better, than traditional products,” says Bruce Hamaker, food scientist at Purdue University and lead researcher on the food product development initiative. “The testing has also shown that consumers are willing to pay more for the instant products, especially if they are fortified.”

It is the market-driven demand for these products that makes them so promising, both as an income-generator for local entrepreneurs and farmers, but also as a source for improved nutrition for individuals and families.
“The market appeal of these products is sustainable because they are being developed according to local food preferences and the availability of local ingredients,” says Dalton. “This interaction between supply and demand means that it does not rely upon donor funding, logistical support or external supply.”

And that, Dalton emphasizes, is key to the long-term success and impact of this initiative.

“What is needed now is continued support and empowerment to create more of these products that are in demand,” he says. “In both urban and rural areas, there are efficiency gains to be made through mechanization and the formation of more processors and cooperatives. Both strategies will increase the supply of locally-made foods to meet the rising demand.”

Women entrepreneurs process local grains such as sorghum and millet into nutritious easy-to-prepare products to meet local market demands in Niger.
Feed the Future Innovation Lab student trainee selected for prestigious BIFAD Award of Excellence, leaves mark on agricultural development in West Africa

For a millet farmer in West Africa, one of the most dreaded discoveries out in the field are the telltale signs of the millet head miner larvae twisting its way up the millet panicle. Once the larvae begin to appear, controlling the damage is extremely difficult and farmers can see up to an 85 percent loss of their year’s crop, a potentially devastating event for an already food- and income-insecure family.

Millet is a staple crop for household consumption in many regions across West Africa, and scientists have been hard at work developing natural, effective methods to combat this serious pest. One of those scientists is Laouali Amadou, a Ph.D. candidate and student at the Université de Maradi in Niger. Amadou serves as a researcher on a project entitled, “Biological control of the Millet Head Miner in Niger and Senegal,” led by Dr. Malick Ba of ICRISAT-Niger and funded by the Feed the Future Innovation Lab for Collaborative Research in Sorghum and Millet.

In recognition of the potential for impact of the millet head miner management technologies currently under development, the Board of International Food and Agricultural Development (BIFAD) named Amadou as the 2017 graduate student recipient of the BIFAD Award for Scientific Excellence in a Feed the Future Innovation Lab. The award is presented annually to recognize significant achievements originating from research performed through the United States Agency for International Development (USAID) Feed the Future Innovation Labs.

In his research, Amadou works with scientists from Burkina Faso, Mali, Niger and Senegal on the biological control of the millet head miner, Heliocheilus albipunctella (de Joannis) (Lepidoptera: Noctuidae). This insect is a devastating regional pearl millet pest and can cause total crop loss to smallholder farmers. The focus of Amadou’s work has been to develop rearing practices for parasitoid wasps that naturally feed on the head miner. These practices are contributing to the establishment of a ‘cottage industry’ at the village level through augmentative release of this naturally occurring predator. Amadou and his colleagues have conducted a preliminary study to determine the economic viability of this approach in conjunction with a regional farmer organization in Niger, and found it to be economically profitable. Widespread adoption of this new approach has strong potential for improving millet productivity and food security for West African smallholder farmers.

Amadou is mentored at the Université de Maradi by Dr. Ibrahim Baoua and is a junior scientist at the Institut National de la Recherche Agronomique du Niger (INRAN). He recently spent six months at Virginia Tech University in a “sandwich” training program with the Feed the Future Innovation Lab for Integrated Pest Management in 2016. Upon returning to Niger following his short-term training, Amadou brought the skills and knowledge he learned to the drawing board as he and his team continue to develop the head miner management techniques.

Amadou is one of nearly 55 Masters and Ph.D students trained under the Sorghum and Millet Innovation Lab from across Africa and part of a growing network of young scientists dedicated to improving food security throughout the continent.
Laouali Amadou was recognized this year by the Board of International Food and Agricultural Development for his highly impactful work on the biological control of the millet head miner in West Africa.
**Innovation Lab helps pave the way for private industry collaboration**

Food product development and production is a rapidly growing sector in Ethiopia’s economy, particularly in large urban areas where contemporary lifestyles and middle-class incomes continue to drive the demand for convenient, quality foods. Responding to that demand is Rahel Moges, an Ethiopian entrepreneur and owner of EthioGreen, LLC, an Addis Ababa-based company that has pioneered the import of freshly baked injera from the Ethiopian capital city to Washington, D.C. in the United States as well as serving the domestic market in Addis Ababa.

Ms. Moges employs more than twenty women processors who produce the traditional Ethiopian flatbread by hand and package it for export. The EthioGreen production facility is located near the Addis Ababa Bole International Airport, which facilitates easy transport of the boxes of injera onto the daily Ethiopian Airlines flights into Washington D.C. The injera goes directly to local stores that primarily cater to African and international clientele.

As EthioGreen’s production has expanded, so has its needs in the areas of food safety, quality assurance and management. Through collaboration with the Feed the Future Innovation Lab for Collaborative Research on Sorghum and Millet, a synergistic opportunity was identified with NuLife Market, a Kansas-based food product company specializing in sorghum and allergy/gluten-free products. Also a young, growing company, NuLife’s practices and business model showed a number of applicable similarities to EthioGreen, making it a promising source of ideas and lessons learned.

The Lab facilitated engagement between the two companies, and a strong relationship of professional collaboration emerged. When the Kansas Department of Agriculture (KDA) announced its intentions to lead a trade mission to Ethiopia in August 2016, it reached out to the Lab for assistance. A natural component was clearly to strengthen the existing collaboration between NuLife Market and EthioGreen. During the visit, NuLife owner Earl Roemer and Moges discussed challenges and opportunities, and explored potential areas for future joint activities.

The trade mission’s success was such that the KDA chose to host a reverse trade mission, inviting Moges to visit Kansas institutions and companies. Her stops included Kansas State University, the Sorghum and Millet Innovation Lab, AIB International, Heartland Mill, Country Oven Bakery, Kansas Wheat Innovation Center and NuLife Market. The visits and discussions offered Moges valuable opportunity for ideas and innovation in the areas of product development, facility management, quality control and food safety as well as key professional contacts.

Moges returned to Ethiopia with an enhanced business plan in mind, including improved food safety practices, trainings for her employees as well as others in the food product industry, plans for facility expansion and ideas for a new food product line. Cooperation with the Lab and NuLife Market continues to be strong, and concrete areas of collaboration are expected to continue to strengthen her business and meet the demands of her domestic and global markets.
Mark Nightengale (left) of Heartland Mill in Marienthal, Kansas, explains his facility operations to (from left to right) Etsehiwot Gebreselassie of NuLife Market, Rahel Moges of EthioGreen and Asha Prasad of NuLife Market.
### Appendix 2 – List of awards to U.S. partners

<table>
<thead>
<tr>
<th>Title</th>
<th>Award</th>
<th>Project Dates</th>
<th>FY17 Funding Released</th>
<th>Total Funding Released</th>
<th>Overall Project Budget</th>
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<td><strong>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</strong></td>
<td>Texas A&amp;M - Joseph Awika</td>
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## Appendix 3 – Country-specific financial information

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<th>South Africa</th>
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