



# FEED <sup>THE</sup> FUTURE

The U.S. Government's Global Hunger & Food Security Initiative

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

### Annual Performance Report FY 2016



*October 1, 2015 – September 30, 2016*



**USAID**  
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Collaborative Research  
on Sorghum and Millet

**KANSAS STATE**  
UNIVERSITY

## Feed the Future Innovation Lab for Collaborative Research on Sorghum and Millet Annual Performance Report FY 2016

This annual performance report for FY 2016 is made possible by the generous support of the American people through the United States Agency of International Development (USAID). The contents are the responsibility of Kansas State University and do not necessarily reflect the views of USAID or the United States Government.

Program activities are funded by the United States Agency for International Development (USAID) under Cooperative Agreement No. AID-OAA-A-13-00047.

### **Cover photo:**

*A woman threshes millet in a village near Koure, Niger in November 2015.*

Photo credit: Nat Bascom

### **This publication may be cited as:**

Feed the Future Innovation Lab for Collaborative Research on Sorghum and Millet. October 2016. Feed the Future Innovation Lab for Collaborative Research on Sorghum and Millet Annual Performance Report FY 2016. Sorghum and Millet Innovation Lab, Kansas State University, Manhattan, KS, 66 pp.

## Executive summary

The Feed the Future Innovation Lab for Collaborative Research on Sorghum and Millet completed its third year of programmatic activities in late July 2016. At that point in time, the third year of field-based research activities was firmly in the ground in Ethiopia, Senegal, Niger, Mali, Burkina Faso, the United States and South Africa after capitalizing upon off-season nurseries in many of the same locations. Harvest will begin in the 2017 fiscal year. Being at the mid-point of the program, research activities can be characterized as being in a “young adult” stage with many activities building upon foundations of initial trials (with attendant “growing pains”) in a search for additional data to build evidentiary bases for field phenotyping, genetic, agronomic and integrated pest management innovations. This field data has been complimented by off-season nurseries and more continuous, and less-seasonal, research and development of value-added food products and attendant food technology and science innovation.

New, targeted research projects have been initiated that will contribute to genetic enhancement of sorghum and pearl millet. Near the end of the fiscal year, a new project designed to harness the potential of genomics-assisted sorghum breeding was approved after several months of project development, and will focus on application to a small country context with new collaborations between Haiti, Kansas State University and Cornell University. The pearl millet improvement program is also advancing after the hiring of a pearl millet breeder by Kansas State University in late FY 2015. This program revived the Kansas breeding program and initiated greenhouse studies during the winter. This has led to seasonal field trials, intellectual and materials exchange with the West African breeding team and a field monitoring tour of West African materials in September.

Building these research projects has required investment in long-term capacity building through students and post-doctoral researchers. The Lab surpassed its original planning goals for long-term training with the cohort of students starting in the 2016-2017 academic year and this leads us to anticipate even higher numbers by the end of the program. Currently, thirty-eight students are enrolled in degree-seeking post-graduate coursework. In addition to the students that were originally identified in project proposals, intermediate research findings have generated new questions and opportunities. Through judicious use of available and leveraged funding, additional students were mobilized to contribute to the program's goals. At the same time, food product and IPM technologies are ready for broader uptake. To meet information dissemination needs on these technologies and products, over 2,000 people were contacted through short-term trainings to bridge knowledge differences and adoption impediments.

The Management Entity (ME) continues to contribute to human and institutional capacity development in our target countries through environmental management and mitigation support and training, facilitating private-public sector linkages in Ethiopia with the Kansas Department of Agriculture and building cross-cutting research activities on gender, mechanization and livestock. Leveraged university resources are being invested in applied economics research in West Africa and Ethiopia with supervision supplied by the director. The ME is working outside of target countries to build a stronger research and development community by participating in local agricultural field days and STEM outreach activities to emphasize the domestic and international linkages in sorghum and pearl millet science. The director has assumed leadership of the Innovation Lab Council, which is the umbrella group facilitating interaction between USAID and the Innovation Lab directors and staff.

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## Management entity information

The core management entity that was established in the Lab's first year has seen some change in FY 2016 with the mid-cycle resignation and replacement of the previous half-time business financial specialist, Kristen Sanborn. The current program management team is as follows:

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

Kimberly's transition onto the team was relatively seamless, as Kristen remained at the institution and provided regular guidance and training to Kimberly as she learned the Lab's systems and processes. 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, Maria Ramirez Lopez was hired as a temporary student worker to assist in the Lab's activities associated with the organization of the 2016 SICNA conference, as well as researching the economic impact of U.S. investment in international agricultural development. Maria will graduate and leave the Lab in December 2016.

The management entity's in-country coordination team has also seen some transition, with the current team as follows:

- 1) Senegal - Ndiaga Cisse
- 2) Soumana Souley – Niger (replacing previous coordinator, Moustapha Moussa)
- 3) Getachew Ayana – Ethiopia (replaced previous coordinator, Habte Nida, in FY 2015)

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.

Dr. Desalegn Serba, a Kansas State University pearl millet breeder hired during FY 2015, continues to make strong progress in his first year of 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 research in future years.

## 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 Marilyn Thomas Chair at Oklahoma State University*

In FYI 2016, 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 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. Plans are currently in development for a similar approach in FY 2017.

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 has continued to work primarily in its focus countries – Ethiopia, Senegal and Niger – as well as Burkina Faso and Mali, which were included in FY 2015 with the addition of a regional dual-purpose pearl millet breeding research project. A new project was developed for Haiti during FY 2016 that will be initiated in FY 2017.

### Ethiopia

Ethiopia continues to be the site of a large-scale sorghum phenotyping activity involving more than 2,000 accessions and multiple trial sites that represent a large variety of growing conditions and environmental stresses. In addition, research into the performance of sorghum in doughs and baked goods – particularly rolls as well as injera – continues to show promising results with the incorporation of improved high digestibility sorghum varieties.

A public-private partnership between Kansas State University and Chromatin is currently under development with the intent that Chromatin seed be sent to Ethiopia for testing there. Import/export regulations led to a delay in the shipment, but it should continue to move forward in FY 2017. Additionally, the Kansas Department of Agriculture has shown heightened interest in Ethiopia for potential trade opportunities, and a trade mission was organized in August 2016 to explore some of these opportunities.

Additional activities, including a multi-regional study on gender and sorghum production, have been hampered by the growing unrest during the second half of FY 2016. Those activities will resume as stability in the country resumes.

### Senegal

Senegal remains a central player in the Lab's regional focus on genomics and high-throughput phenotyping efforts in the regional breeding platforms. The Innovation and Plant Breeding in West Africa (IAPWA) initiative was launched during FY 2016, and is currently operating under the leadership of Daniel Fonceka of Senegal's CERAAS.

Agronomic efforts in the area of the biological control of the millet head miner and the optimization of the pearl millet seed balls continue in Senegal as well as Niger. In addition, food product development activities continue in partnership with the national food science institute, ITA. As a side development to these efforts, an extruder was presented by USAID to the Groupe d'Intérêt Economique Touba Daara Salaam in March 2016 in support of the community group's efforts to produce and sell high-quality extruded foods.

### Niger

Aligned regionally with Senegal as well as Burkina Faso and Mali in the program's genetic enhancement efforts in both pearl millet and sorghum, Niger has continued to be a key player in the FY 2016 developments. It has also been the location of a heavy short-term training push under both the biological control of the millet head miner and the food product development projects. More than 1,000 individuals (primarily producers) participated in short-term trainings in Niger during FY 2016.

In support of the strong food product development efforts in Niger, the Lab management entity supported a research study into the economics and market potential of such food products in Niger. The data was collected in late FY 2016 and analysis of that data will become available during FY 2017.

## Mali and Burkina Faso

Efforts and activities in Mali and Burkina Faso have been primarily focused on a regional approach to the development of dual-purpose pearl millet varieties under the leadership of Roger Zangré.

## List of program partners

### United States

Integrated Pest Management Innovation Lab  
Kansas State University  
Kansas State University – Western Kansas Agricultural Research Center, Hays  
Purdue University  
Texas A&M AgriLife Research  
Texas A&M University  
USDA-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  
Hollela Biotechnology Center  
Oromia Regional Program  
Tigray Agricultural Research Institute  
Tigray Regional Program

### Senegal

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

### Niger

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

University of Maradi

## **Mali**

Institut d'Economie Rurale

## **Burkina Faso**

Institut de l'Environnement et de Recherches Agricoles

## **Germany**

University of Hohenheim

## **France**

Centre de Coopération Internationale en Recherche Agronomique pour le Développement

## **Republic of South Africa**

University of Pretoria

## Acronyms

AGP	Agricultural Growth Program
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, Haiti.
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
HX	Heterowaxy
HPD	High Protein Digestibility
ICRISAT	International Crops Research Institute for the Semiarid 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 Agricoles
ITA	Institut de Technologie 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 Feed the Future Innovation Lab for Collaborative Research on Sorghum and Millet completed its third year of activities in FY 2016. Field activities in West Africa and Ethiopia are still in production and will not be harvested until the final quarter of FY 2017. As a result, most of the results presented in this report draw upon fieldwork completed in 2015 and off-season nurseries that were planted in early 2016.

Research in the area of genetic enhancement in Ethiopia continues to center around phenotyping of the Ethiopia core collection of 2,200 varieties, hybrids and lines at six sites around the country. In FY 2015, many sites were affected by the El Nino drought pattern and comprehensive data was affected. So far during the FY 2016 growing season, all sites report good conditions and strong data collection efforts despite political unrest in the nation. A post-doctoral fellow was hired to conduct genetic analysis of the collection. A specific subset of the population was identified as being resistant to anthracnose and grain mold both in field and in laboratory experiments. In addition to field assessment, efforts to characterize the nutritional qualities of the population have started with the characterization of protein digestibility, zinc and iron content completed for 700 lines already. Food processing research with Hawassa University developed standardized sorghum-based injera-making protocols so that systematic evaluation of food product attributes could be rigorously addressed. High-digestible protein lines demonstrate a functional advantage over existing commercial varieties when integrated with wheat in hard rolls and pan breads. Eleven students from Ethiopia are pursuing Ph.D. or Masters degrees under these projects.

We continue to focus on upstream genomics and genetics in collaboration with national and regional partners in West Africa through two lines of study. The Morris project is focusing on the development of a genomics-enabled breeding program through genotyping of 2,000 sorghum lines from Niger, Senegal, Mali, Togo and Nigeria and production of a nested associational mapping population. Tuinstra's project is focusing on the identification of desirable traits, including protein digestibility, heat and drought resistance, in a population of mutants of BTx623. This has proved successful and it serves as an intuitive platform for student training. This approach is balanced against a screening and evaluation of international nurseries with resistance against diseases and insects led by Pendleton combined with the screening of botanicals to reduce post-harvest losses. These sorghum breeding programs are complemented by research on food product development and in particular, the development of agglomerated foods from extruded flour fortified with local available nutrient-dense additives, such as baobab, Moringa and hibiscus. Thirteen students are pursuing Ph.D. or Masters degrees under these projects.

The dual-purpose pearl millet project is in the process of completing its second year of field evaluation of grain and forage yield in four West African nations. This project has been complemented with research activities led by Dr. Desalegn Serba who is based at the Western Kansas Agricultural Research Center in Hays, Kansas, and who is focusing on forage quality and grain. The combined team conducted a four-nation monitoring tour of millet field trials in September 2016. This project is also being complemented by agronomic studies to improve seed germination and reduce damage from the pearl millet head miner. The IPM project is being refined for scaling and a new line of study to identify and rear head miner egg parasites has started. Additionally, the study on seed balls is being implemented again to study efficacy. Thirteen students are pursuing Ph.D. or Masters degrees, with one bachelors' degree, under these projects.

Outside of the research activities, the Lab undertook several activities to improve the functioning of programs in all countries. In Ethiopia, the management entity continues to work with the management at EIAR on the implementation of the program and in creating new opportunities through linking research and the private sector to U.S. leaders in forage sorghum and food product development. In West Africa, we are contributing to capacity development in environmental compliance by linking stronger partners with weaker ones to build transnational capacity.



## Key accomplishments

Key accomplishment in the Lab build upon previous investments and exceed expected targets in several categories. As this is a mid-program report, we are building greater momentum in project outputs as sufficient time has elapsed for cropping trials and new technology and product development.

### Program highlights

- Crossing of stress-resistant lines identified in the 2015 phenotyping with local susceptible landraces and released varieties has begun in Ethiopia.
- Another planting of the entire core germplasm population ( $\approx 2,200$  lines) occurred at six locations in selected agroecologies across Ethiopia for field phenotyping and characterization for nutritional quality profiles.
- A post-doctoral fellow was recruited to conduct genetic analysis of the Ethiopian core collection.
- Three West Africa Ph.D. students have characterized the genomes of almost 2,000 West Africa landraces and breeding lines to lay the foundation for genomics-assisted breeding.
- Extruder and processing technology was transferred to Senegal and Niger and extruded instant flours were developed, refined and underwent sensory testing.
- The general formula for pearl millet seedballs in the Sahelian context was established.
- Regional, multi-locational on-state trials were conducted to evaluate over 100 pearl millet accessions across West Africa for forage and grain quality
- A panel of open pollinated varieties, inbred lines and experimental hybrids were assembled and planted in Niger and Senegal.
- New developments around the host acceptability of the *Coryra cephalonica* of a parasitoid wasp that targets both the millet head miner and the millet stem borer creates the exciting prospect of controlling two major pearl millet pests present in the Sahel.
- The host acceptability of the *Coryra cephalonica* by the parasitoid wasp was identified and is significant progress toward mass rearing of the egg parasitoids for the millet head miner biological control program.
- A practical sorghum injera-making protocol was developed in Ethiopia in collaboration with women injera entrepreneurs, priming the project to move into pilot testing phase of improved highly digestible sorghums by the end of the project phase.
- Physio-chemical traits relevant to food processing and quality of improved high-digestibility sorghum were assessed in Ethiopia and associated adaptation of the varieties were completed in Ethiopia.
- It has been demonstrated that improved high digestible sorghum lines can be blended with wheat to create bakery products.
- Short- and long-term trainings both exceeded targets for FY 2016.

### Feed the Future indicator performance

The Lab again surpassed target values for FY 2016 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 2016 also saw the advancement of 20 technologies and management practices – a significant increase from last year. In the area of policy, discussions continue around the AGP-II in Ethiopia and sorghum has been officially listed in the document as a priority crop.

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

The long-term training initiated in FY 2016 surpassed target values as 38 individuals took part in long term training at either a bachelor's, Master's, Ph.D. or postdoc level. Of those students, 12 are female and 26 are male. Increasing the overall number of female trainees continues to be a goal for the Lab, but numerous challenges are faced at national and institutional levels. Fourteen of these students have received training at a

U.S. institution, while the remaining are located in home country or 3<sup>rd</sup> country institutions and/or sandwich programs. In-country and 3<sup>rd</sup> country programs create more opportunities for projects to support long-term trainings as the cost per student is considerably less in some cases than for students training in the U.S.

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

The Lab again exceeded target numbers for FY 2016 in the area of short-term training. There were a total of 25 reported trainings that took place in Burkina Faso, Ethiopia, Ghana, Mali, Niger, Senegal, South Africa and the United States and reached more than 2,000 reported trainees. Of these trainees, approximately 33 percent were female and 67 percent were male. Additionally, approximately 78 percent of those trained were producers, 5 percent were government affiliates, 4 percent were from the private sector, 12 percent were from civil society and 1 percent was unknown. Large-scale trainings in relation to field testing of the parasitoid for the millet head miner under Malick Ba's project accounted for a large percentage of the trainings, as did food product development trainings under Joseph Awika and Bruce Hamaker's projects.

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

The Lab saw the advancement or continuation of twenty technologies and management practices in FY 2016 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 and rural incubation centers. Eleven of the technologies were in Phase 1 (Under Research) or while nine were in Phase 2 (Under Field Testing).

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

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). However, it remains in the new FTFMS Stage 3 category of *Presented for legislation/degree*, though it is anticipated that it will advance to the fourth stage of passage during the FY 2017 year.

## Research program overview and structure

The research program of the Sorghum and Millet Innovation Lab continues on its charted course with a few changes that are responsive to program evolution. The program allocated part of its strategic funding reserve to the pearl millet improvement program with a small start-up grant for activities of Dr. Desalegn Serba, assistant professor of pearl millet breeding, and a strategic monitoring tour of the four west African breeders, Dr. Serba and Nat Bascom to evaluate the regional dual-purpose germplasm evaluation trials and to strategize on the most cost effective way to evaluate forage quality. In addition, Dr. Serba has initiated trials to revive the pearl millet improvement program at the Western Kansas Agricultural Research Institute and has backstopped research design, data analysis and presentation.

The program currently has twelve projects (with the addition of Dr. Serba's project), 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 proposed a new associate award project to develop a genomics assisted breeding program in Haiti that will draw in two new institutions - CHIBAS, in Haiti, and Cornell University - in addition to collaborators at Kansas State University. This project was approved at the end of FY 2016 and is scheduled to be initiated in FY 2017.

The program is at mid-stage of its five-year time horizon and is producing intermediate research outputs and products that exceed our expected technology and management practice targets by 53%. This has created new partnership opportunities with organizations and the private sector that are interested in scaling innovations such as the millet head miner IPM package and new food products. Our long-term training goals have been met and exceeded by 10%. Our short-term trainees exceed 2,000 persons which is dramatically greater than what we expected. This is due, in part, to the number of technologies that have moved into stage 3.

## 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 (Melkassa Research Center, Sirinka Research Center, Pawe Research Center), Tigray Agricultural Research Institute, Haramaya University

#### *Achievements*

The core germplasm collection was replanted for a third year in six locations to collect reliable phenotype information. An affiliated activity developed new breeding populations that advanced lines to F4 families and those with high nutritional qualities will be evaluated in multilocal trials in 2017. In addition, efforts were initiated to characterize the population for nutritional quality.

### *Capacity building*

Two students are currently being trained: Alemnesh Bekele (Master's at Haramaya University) and Yemane Belayneh (Ph.D. student at Kansas State University).

A search to hire a post-doctoral trainee has started.

### *Lessons learned*

There is wide variation in protein availability in Ethiopia sorghum varieties that can be exploited in future breeding activities.



## 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

The groundwork to initiate the sequencing of the Ethiopian core collection has been established and materials and supplies for this activity have been delivered to Melkassa after clearing importation hurdles. The post-doc recruited to conduct this analysis has been selected. A subset of varieties from the Purdue collection obtained from the Ejeta lab have been identified as possessing dual resistance to anthracnose and grain mold and these materials have been crossed with locally preferred, but susceptible, varieties. Within the Ethiopian core collection, about 8% of 225 lines exhibited resistance to anthracnose at Assosa and this may represent additional mechanisms of plant resistance. Recombinant lines of resistant and susceptible lines have helped to identify specific regulators and mechanisms of function that is designated as Anthracnose Resistance Gene I (ARGI).

### Capacity building

Three students are currently being trained: Demeke Bayable (Ph.D. at Purdue University), Habte Nida (Ph.D. at Purdue University) and Chemed Berhanu (Master's at Haramaya University)

One student completed training in FY 2016: Kebede Dessalgn (Master's at Haramaya University)

### Lessons learned

There are limited lines of resistance to anthracnose in the Ethiopian core collection.

### Presentations and publications

Desalegn, K. (2016). Evaluation and characterization of Ethiopian sorghum landraces for anthracnose resistance. (Master's, Oromia Agri Research Institute, Bako Agricultural Research Center).

Fu, F., Adeyanju, A., Ejeta, G., & Mengiste, T. (2016). Identification of broad spectrum anthracnose resistance QTL in sorghum by whole genome. *Poster Presentation at Plant and Animal Genome Conference, San Diego, USA.*

Nida, H. (2016). Overview of 2015 and review of external fund activities. *Presentation at SMIL Annual Program Review Meetings, Saly, Senegal.*

Nida, H. (2016). Overview of current sorghum research activities. *Presentation at HOPE II Inception Workshop, Ethiopia.*

## 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

Building upon funding from the Bill and Melinda Gates Foundation, and the development a *Striga* lab at Holetta, the project trained technicians and graduate students from several Ethiopian institutions on DNA analyses, lab phenotyping in order to generate useful information on breeding for *Striga* resistance. In addition, the project continues to phenotype the Ethiopian core collection for *Striga* resistance at multiple sites and will link this to genetic information once the collection is mapped.

### Capacity building

One individual is currently being trained: Adedayo Adeyanju (post-doc at Purdue University)

One individual completed training during FY 2016: Patrick Ongom (Ph.D. at Purdue University)

### *Lessons learned*

Complementary investment by other donors has created opportunities to train graduate students on applied issues such as identifying the genetic sources of *Striga* resistance.

### *Presentations and publications*

No presentations or publications have been reported during the FY 2016.

## **Improving sorghum adaptation in West Africa with genomics-enabled breeding**

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



### **Location (department level)**

Niger – Aguié, Bkonni, Kollo, Niamey, Tillabéri, 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

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

### **Achievements**

Three West African Ph.D. students have characterized the genomes of almost 2000 West African landraces and breeding lines to lay the foundation for genomics-enabled breeding. Preliminary analysis of the Senegal mini-NAM (F4 generation) has been completed at CERAAS using KASP marker system. This information will be combined with



phenotyping information. Three seasons are completed with the fourth to be planted at the end of 2016. Phenotyping for *Striga* resistance in Konni has been successful but phenotyping for drought has been mixed.

### Capacity building

Three students are currently being trained: Eyanawa Akata Atchozou (Ph.D. at CERAAS), Jacques Faye (Ph.D. at Kansas State University), and Fanna Maina (Ph.D. at Kansas State University)

One student completed training in FY 2016: Nadre Gbedié (Master's at CERAAS)

### Lessons learned

Managing drought to phenotype for drought resistance requires sophisticated farm management skills. Preliminary findings suggest that West African breeding programs may not have sufficient kinship for standard genomic selection models to be successful.

### Presentations and publications

Falalou, H., Aissata, M., Falké, A., Abdou, H., Oumarou, H., Morris, G. P., et al. (2016). *Poster on phenotypic evaluation of sorghum land-races for early and terminal drought tolerance under lysimetric conditions*. Unpublished manuscript.

Faye, J. M., Cisse, N., Sine, B., Foncéka, D., Rami, J., & Morris, G. P. (2016). Genome-wide association studies of yield components under water limitation for a West Africa sorghum association panel. *Poster Presentation at the 2016 Sorghum Improvement Conference of North America*, Manhattan, KS.

Maina, F., Mamadou, A., Abdou, M., Hamidou, F., Saïdou, A. A., Bouchet, S., et al. (2016). Genetic structure and diversity of nigerien sorghum breeding program accessions. *Paper Presented at the 2016 Sorghum Improvement Conference of North America*, Manhattan, KS.

## ***Trait development pipeline for food and feed value in sorghum***

(Led by Dr. Mitchell Tuinstra – Purdue University)



### ***Location (department level)***

Niger - Aguié, Bkonni, Kollo, Niamey, Tillabéri, 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***

A forward genetic screen of additional unsequenced sorghum EMS mutants was used to identify an additional mutant with highly digestible protein in the kernels. Three EMS mutants with highly-digestible protein have been identified to date. A specific mutant (P721Q) is a high lysine sorghum mutant that exhibits 3- to 4-fold increase in protein digestibility after cooking as compared to other sorghum cultivars. Mutations that influence starch quality were identified. An additional mutant with high protein digestibility in sorghum forage was validated in 2016 in addition to the three mutants that were previously identified in 2015 (and subsequently crossed with TX623). Thirty-four elite parent lines and 127 breeding lines derived from crosses with West African germplasm were sent to INRAN from Purdue.

### ***Capacity building***

Two students are currently being trained: Elizabeth Diatta (Ph.D. at WACCI) and Ousmane Seyni (Ph.D. at WACCI)

### *Lessons learned*

The development of laboratory facilities for protein digestibility at CERAAS is ongoing so breeding populations will be maintained at Purdue University until completed.

### *Presentations and publications*

Kane, K. (2017). Programation 2017. *Presentation to the Senegalese Institute of Agricultural Research*, Dakar, Senegal.

Massafaro, M., Thompson, A., Tuinstra, M. R., & Weil, C. F. (2016). Mapping the increased protein digestibility trait in the high lysine sorghum mutant P721Q. *Crop Science*, 56, 2647-2647-2651.

Massafaro, M. (2015). Mapping and identification of increased protein digestibility in sorghum. (Master's, Purdue University).

## **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, Niore 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**

A second year of pearl millet trials were put into place in 2016 following multi-locational field trials in each of the four participating countries in 2015. Nearly 100 Pearl millet varieties were evaluated based upon grain and fodder yield, and some new varieties were introduced. The second year of performance data will be available in December 2016. Each location found significant grain and fodder yield differences emphasizing the importance of environmental interactions. Students at the University of Ouagadougou characterized the population structure of the materials and found that there were strong similarities between the Mali and Burkina Faso lines which were more closely related to the Niger materials. By contrast, the lines from Senegal were very different from those from the three other countries. A

monitoring visit was conducted in September 2016. The four principal investigators plus Dr. Serba and Nat Bascom visited trial sites in each of the four countries to facilitate a common appreciation of evaluation and performance across environments and this yielded several new insights.

### *Capacity building*

One student is currently under training: Benoit Ouedraogo (Master's at University of Ouagadougou and INERA)

One student completed training in FY 2016: Yvonne Zongo (Bachelor's at University of Ouagadougou and INERA – completed)

### *Lessons learned*

Despite the interaction of environmental conditions with plant genotypes, several lines emerged with high grain and fodder yield and the regional environmental differences may be a source of diversity to exploit.

### *Presentations and publications*

Zongo, R. Y. (2016). Evaluation agromorphologique de germoplasmes ouest africain de mil (*pennisetum glaucum* (L.) R. br) (Bachelor's, Université de Ouagadougou).



## **NEW PROJECT: 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 - Aguié, 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 pearl millet nursery, consisting of historical lines from the Western Kansas Agricultural Research Center and new materials from collaborators was established in Hays. These materials were planted under a greenhouse in the winter and under field conditions during the summer growing season. Dr. Serba attended the Lab annual meeting in Senegal in March and then took part in a field monitoring tour with the West African pearl millet breeders in September to help identify program priority areas and backstop quantitative analysis of the 2015 results.

### *Capacity building*

No students at this time.

### *Lessons learned*

Preferences for plant types differ dramatically between nations.

### *Presentations and publications*

Due to the fact that this project was just awarded in FY 2016, there were no publications or presentations produced during the fiscal year.

## 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 - Aguié, Bkonni, Kollo, Tillabéri  
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*

Using international disease and insect, as well as drought line nurseries, the project was able to identify nine international varieties with high degrees of host plant resistance to stresses. These lines were reevaluated in 2016 and continued resistance (or tolerance) will be used to confer better host plant protection in locally adapted sorghum varieties. The midge line tolerance nursery was evaluated in Texas because tolerance to midge is universally conferred. The resistance of 10 sorghum genotypes and mechanisms of resistance to two storage pests found in Senegal and Niger

was investigated. In addition, the effectiveness of botanicals to control the maize weevil and the red flour beetle in stored sorghum was investigated. Recommendations were transferred to farmers and grain merchants.

### Capacity building

Four students are currently being trained: Hame Kadi Kadi (Ph.D. at West Texas A&M University), Gnilane Sene (Master's at University Cheikh Anta Diop), Adja Thiam (Ph.D. at University of Thies) and Fatou Welle (Ph.D. at University Cheikh Anta Diop)

### Lessons learned

The collection of botanicals in sufficient quantities for replicated trials to evaluate the effectiveness against storage pests has been difficult. Few commercial sources are available.

### Presentations and publications

Kadi Kadi, H. A. (2014). Developpement des variétés de sorgho résistantes aux contraintes biotiques au Niger  
*Presentation to the SMIL/INRAN Program Launch Workshop, Niamey, Niger.*

Kadi Kadi, H. A., & Pendleton, B. (2016). Assessing the efficacy of botanicals for control of maize weevils in stored sorghum. *Presentation at 25th International Congress of Entomology, Orlando, FL.* pp. 358.

Kadi Kadi, H. A., & Pendleton, B. (2016). Boosting sorghum production by using sorghum resistant varieties in Niger. *Presentation at 64th Annual Meeting of the Southwestern Branch of the Entomological Society of America and the Annual Meetings of the Society of Southwestern Entomologists, Tyler, TX.* pp. 16.

Kadi Kadi, H. A., Pendleton, B., & Aboubacar, K. (2016). Farmers' application of post-harvest management strategies in Tahoua and Maradi regions of Niger (West Africa). *Presentation at 64th Annual Meeting of the Southwestern Branch of the Entomological Society of America and the Annual Meeting of the Society of Southwestern Entomologists, Tyler, TX.* pp. 32.

Kadi Kadi, H. A., Pendleton, B., & Aboubacar, K. (2016). Farmers' application of post-harvest management strategies in Tahoua and Maradi regions of Niger (West Africa). *Presentation at the West Texas A&M University 22nd Annual Student Research Conference, Canyon, TX.* pp. 22.

Kadi Kadi, H. A., Pendleton, B., & Aboubacar, K. (2016). Farmers' application of post-harvest management strategies in Tahoua and Maradi regions of Niger (West Africa). *Presentation at the 2016 Sorghum Improvement Conference of North America, Manhattan, KS.*

Kadi Kadi, H. A., Pendleton, B., & Aboubacar, K. (2016). Farmers' application of post-harvest management strategies in Tahoua and Maradi regions of Niger (West Africa). *Presentation at the International Congress of Entomology, Orlando, FL.* pp. 332.

Mbulwe, L., Peterson, G. C., Armstrong, J. S., & Rooney, W. (2015). Registration of sorghum germplasm Tx3408 and Tx3409 with tolerance to sugarcane aphid [*melanaphis sacchari* (zehltner)]. [ ] *Journal of Plant Registrations*, 10, 51-51-56.

Pendleton, B. (2016). African agriculture and adventures. *Presentation to Canyon Rotary Club, Canyon, TX.*

Pendleton, B. (2016). Collaborative agricultural research in African countries. *Presentation to the West Texas A&M University Africa Student Association, Canyon, TX.*

- Pendleton, B., Pendleton, M., & Peterson, G. C. (2015). Variable-pressure scanning electron microscopy images of sorghum predict resistance to storage insect pests. *Presentation at the ASA, CSSA, SSSA and ESA 2015 Meeting*, Minneapolis, Minnesota.
- Pendleton, B., Pendleton, M., & Peterson, G. C. (2016). Variable-pressure scanning electron microscopy images of sorghum predict resistance to storage insect pests. *Poster Presentation at the 64th Annual Meeting of the Southwestern Branch of the Entomological Society of America and the Annual Meeting of the Society of Southwestern Entomologists*, Tyler, TX. pp. 38.
- Pendleton, B., Pendleton, M., & Peterson, G. C. (2016). Variable-pressure scanning electron microscopy images of sorghum predict resistance to storage insect pests. *Poster Presentation at the 2016 Sorghum Improvement Conference of North America*, Manhattan, KS.
- Pendleton, B., Peterson, G. C., Kadi Kadi, H. A., Cisse, N., Mamadou, A., Sarr, I., et al. (2016). Development of biotic stress-resistant sorghum cultivars for Niger and Senegal. *Presentation to the 2016 SMIL Annual Project Review Meetings*, Saly, Senegal.
- Peterson, G. C., Mbulwe, L., & Rooney, W. (2016). Sugarcane aphid on sorghum: Developing resistant germplasm and understanding resistance. *Presentation to the 64th Annual Meeting of the Southwestern Branch of the Entomological Society of America and the Annual Meeting of the Society of Southwestern Entomologists*, Tyler, TX. pp. 15.
- Sarr, A. (2016). Évaluation des lignées de sorgho (*sorghum bicolor*) texane pour leur tolérance aux insectes ravageurs et maladies dans différentes zones du bassin arachidier. (Ph.D., Institut Supérieur de Formation Agricole et Rurale (ISFAR)).
- Sene, G. (2015). Évaluation des lignées de sorgho [*sorghum bicolor* (L) moench] pour leur tolérance aux insectes et maladies dans le bassin arachidier (Master's, Université Cheikh Anta Diop de Dakar).



## Biological control of the millet head miner in Niger and Senegal

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



### Location (department level)

Niger - Aguié, 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 *Trichogrammatoidae* 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

The project has made exciting progress on rearing a second predator to control the millet head miner (MHM) this time focusing on the egg stage. This advance will provide a two pronged approach for millet head miner control. Field collection of millet head miner eggs in Niger and Senegal confirm that *Tricogrammatoidae armigera* is present and appears as the most promising and inflicts approximately 35% mortality to the eggs of the MHM. A colony of the egg parasitoid has been established for continued research, feeding upon *Corya cephalonica*, despite the very narrow window for collecting the insect. An additional year of fine-tuning the rearing and release timing of the MHM has been conducted. It has been determined that a population of 1,600 parasitoids per five square kilometers of millet area is optimal. Community-based commercialization of parasitoids has been pilot tested at Tera in western Niger. A total of 835 parasitoid bags were sold to famers, cooperatives and NGOs.



### Capacity building

Five students are currently in training: Laouli Amadou (Ph.D. at the University of Maradi), Hamidou Iddrissa (Master's at the Université Abdou Moumouni de Niamey), Said Laminou (Master's at the Université Abdou Moumouni de Niamey), Oumou Moumouni (Master's at the Université Abdou Moumouni de Niamey with short-term training at Virginia Tech University), and Baye Thiam (Master's at the University of Thies)

One student completed training during FY 2016: Michael Guerci (Master's at the University of Virginia – completed in FY 2016),

### Lessons learned

Positive lessons were learned on the rearing of the millet head miner egg parasitoid that are contributing to generating a second line of defense against this pest.

### Presentations and publications

Amadou, L., Baoua, I. B., Ba, M. N., Muniappan, R., & Norton, G. (Unpublished). Evaluation of five different diets from a mixture of millet, sorghum, cowpea and groundnut for mass production of *habrobracon hebetor*'s host: *Corcyra cephalonica* (stainton).

Goudiaby, M. F. (2016). *Techniques d'elevage et de lacher des parasitoides bracon hebetor: Formation des producteurs dans le bassin arachidier*. Unpublished manuscript.

Guerci, M. (2016). Economic feasibility of a biological control cottage industry in Niger. (Ph.D., Virginia Tech University).

## **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 - Aguié  
 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*

Three seedball devices - low, medium and high cost - were developed for specific user groups. Manual seedball construction devices were attractive to women. Agronomic trials were reconducted in 2016 based upon findings from the previous year that indicated low germination rates.

### *Capacity building*

Three students are currently under training: Mouhamadou Diome (Master's at Ecole Nationale Supérieure d'Agriculture and ISRA), Mahamadou Maazou (Master's at University of Tahoua and INRAN), and Charles Nwankwo (Ph.D. at University of Hohenheim)

One student completed training during FY 2016: Cheikh Dieng (Master's at Ecole Nationale Supérieure d'Agriculture and ISRA),

### Lessons learned

Germination of millet in seedballs has been low and further study on the factors limiting germination are required to demonstrate technology relevance.

### Presentations and publications

Herrmann, L., Nwankwo, C. I., Mühlana, J., Butzer, D., Biegert, K., & Neumann, G. (2015). Saatkugeln als managementoption zur verbesserung des auflaufverhaltens von perlhirse (*pennisetum glaucum*) auf sandigen böden im sahel. *Presentation at Jahrestagung Der DBG, Munich, Germany.*

Herrmann, L., Nwankwo, C. I., Mühlana, J., Butzer, D., Biegert, K., & Neumann, G. (Submitted 2015). Seedball as management option to improve pearl millet (*pennisetum glaucum*) seedling development during early growth stages on sandy sahelian sites. *Agriculture, Ecosystems and Environment.*

Nwankwo C.I., Herrmann L., Rennert T., & Neumann G. (2015). Optimisation of seedball technology for pearl millet production in the sahel. *Presentation at the Tropentag 2015, Berlin, Germany.*

Nwankwo, C. I., & Herrmann, L. (2016). Seedball fabrication guide. *Poster Presentation at the 2016 SMIL Annual Program Review Meetings, Saly, Senegal.*

## 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*

Improved high digestible (IHD) sorghum varieties outperformed Ethiopian checks in most important quality traits in the first year and additional trials are required to ensure stability of performance. There is also superior functional advantage of these lines (superior volume and tenderness) when compared to locally available sorghum varieties. A micro-screening assay test for predicting performance of small quantities of sorghum on injera texture was developed to confront the problem of limited access to sufficient seed quantities of new varieties. This would be invaluable to breeding programs when limited amounts of seed area available.

When IHD is mixed at a 10 percent rate with wheat, the products had a similar acceptability rate to hard rolls and pan bread as a 100 percent wheat formulation. This may lead to an avenue to substitute inexpensive sorghum in for expensive wheat in bakery products. A standardized injera-making protocol was developed in collaboration with female injera entrepreneurs and acceptability was evaluated with a consumer-oriented sensory panel of 36 individuals. In addition, experiments on the malting qualities of improved high protein digestible/waxy sorghum lines was initiated in South Africa at the University of Pretoria.

### *Capacity building*

Three students are currently being trained: Loza Mengistu (Master's at Hawassa University), Abadi Mezgebe (Ph.D at the University of Pretoria) and Tadesse Teferra (Ph.D. at Texas A&M University)

### *Lessons learned*

There may be economically relevant opportunities for IHD sorghum to be integrated into injera and bakery products as a substitute for wheat. Based upon current progress and knowledge, and extrapolating to the end date of the project, there appears to be sufficient information to move towards pilot-scale processing to demonstrate commercial viability.

### *Presentations and publications*

Elhassan, M. S. M., Emmambux, M. N., Hays, D. B., Peterson, G. C., & Taylor, J. R. N. (September 2015). Novel biofortified sorghum lines with combined waxy (high amylopectin) starch and high protein digestibility traits: Effects on endosperm and flour properties. *Journal of Cereal Science*, 65, 132.

## 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

A small-scale extruder was installed in Senegal and Niger and training on its use was conducted. This knowledge was demonstrated to entrepreneurs who are interested in using extruded flours in food products. These instant shelf-stable flours were tested in both thick and thin porridges in sensory studies in Niamey and rural sites (supported by the McKnight Foundation). These products were found to be at least as acceptable as the checks and some that were fortified were preferred in willingness-to-pay studies in Senegal. Fortified products have not been tested in Niger yet.

An evaluation of the sensory quality of products created from ten different millet varieties found significant differences in consumer acceptance. More sensory tests are expected that investigate the interaction between millet variety and extruded product as these extrusion processes are refined during the training studies with key collaborators from Niger. There is interest in extending research on extruded flours to determine how they can be used in agglomerated products such as couscous. A complementary activity has been initiated on studying how extrusion impacts anti-



nutritional factors that limit the use of some locally-available nutrient dense fortificants, for example Moringa leaves. Moringa is high in iron but also has anti-nutritional compounds such as phytic acid and it is unknown if extrusion reduces or increases anti-nutritional properties.

### Capacity building

Four students are currently being trained: Hawi Debelo (Ph.D. at Purdue University), Maty Diop (Ph.D. at Cheikh Anta University), Anna Hayes (Ph.D. at Purdue University) and Moustapha Moussa (Ph.D. at Purdue University)

### Lessons learned

The project requires more time allocated to product marketing including identification of intrinsic traits desired by consumers and extrinsic attributes of product packaging. This will become even more important as the products become more sophisticated. To meet this need, the management entity supporting a doctoral student in agricultural economics to research these issues from funds leveraged from Kansas State University. For more on this activity, see the "Other Topics" section of the report.

### Presentations and publications

Debelo, H., Ndiaye, C., Ferruzzi, M. G., & Hamaker, B. (2016). Interactions between native African plant materials modify in vitro bioaccessibility of provitamin A carotenoids from blended cereal products. *Presentation at the Experimental Biology Conference*, San Diego, CA. pp. 9.

Dieng, C. A. T. (2016). Etude de l'effet de l'utilisation de la technologie boule de semences sur les performances du mil (*pennisetum glaucum* (L.) R. br.) (Master's, Ecole Nationale Supérieure D'Agriculture (ENSA)).

Diop, A. (2016). Analyse économique de la valorisation de la farine de mil et sorgho pour une amélioration de la nutrition des populations (an economic analysis of the valorization of millet and sorghum flours to improve the nutritional status of populations). (Master's, Université de Thiès/ENSA).

Moussa, M., & Hamaker, B. (2016). Innover pour produire et fortifier les aliments à base de mil et sorgho. *Presentation at Atelier d'apprentissage Collaboratif Et d'adaptation Programmatique: Genre Et Résilience Au Niger*, Niamey, Niger.

Ndiaye, C., Sarr, F., Traore, D., Sow, S., Hamaker, B., & Ferruzzi, M. G. (2016). Impact of extrusion on fruit/vegetable-millet blends on recovery of provitamin A and product physical properties. *Presentation at Institute of Food Technologists Annual Meeting*, Chicago, IL.

## Associate award project reports

A new associate award titled “Feed the Future Innovation Lab for Genomics-Assisted Sorghum Breeding” was awarded at the end of FY 2016 and will be initiated in 2017. This project will build a consortium of researchers from Haiti, Cornell University and Kansas State University around the topic of using genomics to improve the efficiency of sorghum breeding in a small country with limited resources. The project will focus on Haiti, which is a new focus country, and some new breeding challenges - for example, the sugarcane aphid and multi-purpose usage - while expanding the program’s ability for drought and heat tolerance research. The lead investigators on this project are Dr. Gael Pressoir of Quisqueya University and CHIBAS in Port au Prince, Haiti, Dr. Geoffrey Morris of Kansas State University and Dr. Ed Buckler of Cornell University.

## 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 2016, overall training 2,065 individuals across all programs. This included 667 females and 1,395 males, with 3 individuals of unreported gender. Of the more than 2,000 trainees, producers made up the largest group with approximately 1,600 trained, followed by 251 civil society members (predominantly researchers and students), 101 people in government and 80 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 850 producers in Niger and Senegal on the rearing and deployment of parasitoid wasps to combat the millet head miner. This project has a particularly high reach with local producers and we anticipate similar activities in the future.

**Table 1. Short-term trainees supported by the Sorghum and Millet Innovation Lab**

Country of Training	Purpose of Training	Who was trained	Number trained		
			M	F	Total
Burkina Faso	Field trip and future planning of market study on consumer research on sorghum and millet foods in Niger and Burkina Faso	Primarily producers with some civil society and private sector	11	46	57
Burkina Faso	Techniques of millet seed production	Primarily producers	61	49	110
Burkina Faso	Use of international breeding platform and electronic data	Research technicians and students	9	1	10
Ethiopia	Training on grain and dough quality	Hawassa University staff	7	2	9

	analysis				
Ethiopia	Training on processing and sensory evaluation of sorghum-based products, using sorghum injera	Government and private sector, researchers	27	9	36
Ghana	Genomics workshop at WACCI	Students	15	6	21
Mali	Technician of agriculture internship	New technicians	6	1	7
Mali	Feedback and information session with Malian farmers about their preferred traits in dual-purpose millet varietal selection	Primarily producers	41	14	55
Niger	Capacity building training to reinforce private unit skills for handling and managing of parasitoid sales	Producers and government representatives	27	2	29
Niger	Training farmers on Biological control of the millet head miner	Primarily producers	731	131	862
Niger	Atelier de formation sur les insectes de stock au Niger	Actors of the cereal value chain	30	10	40
Niger	Training merchant traders how to manage pests in stored grain	Private sector – merchants	10	0	10
Niger	Training field technicians how to identify and manage insect pests in field and laboratory	Field technicians	4	2	6
Niger	Development/innovation and testing of pearl millet solar thresher in rural areas of Niger	Farmers and technicians	71	125	196
Niger	Installation, testing and hands-on training on uses of a single-screw mini-extruder	Producers, private sectors and civil society (researchers, NGOs, etc.)	18	26	44

	in Niger				
Niger	Gender and resilience in Niger – Collaborating, Learning and Adapting	Government and civil society (USAID, NGOs, etc.)	31	33	64
Niger	Training of sorghum and millet small processors in finance and marketing	Mainly processors and processing groups	11	22	33
Niger	Manual seedball production training	Millet producers	9	25	34
Niger	Advanced mechanized seedball production	Millet producers	8	82	90
Niger	Training on plastic bag method of crossing on sorghum	Technicians and students	12	6	21
Niger	Environmental compliance training	Government and private sector	25	0	25
Niger	Feedback and information session with Maradi farmers about their preferred traits in dual-purpose millet varietal selection	Primarily producers	22	8	30
Senegal	Introduction to association genetics and R statistics	Researchers/scientists	15	2	17
Senegal	Training farmers on Biological control of the millet head miner	Primarily producers	115	6	121
Senegal	Workshop on insect pests of stored cereal grain in Senegal	Farmers and technicians	20	14	34
Senegal	Formation des formateurs en gestion des revageurs post-récolte	Primarily producers	22	8	30
Senegal	English training in preparation for language preparedness exam	Student preparing for graduate level training	0	1	1

Senegal	Seedball fabrication	Millet producers	20	13	33
Senegal	2016 SMIL annual review meetings	Researchers, USAID representatives, students	18	70	88
South Africa	Malting and baking techniques training	Researchers and students	4	2	6
USA	Extrusion training at BIVAP at Kansas State University	ITA personnel - Djibril Traore	1	0	1
USA	Short-term training on scientific method of research, insect behavior and ecology	Laouali Amadou	1	0	1
USA	Impact assessment training at Virginia Tech	Moumouni Oumou	0	1	1
USA	Short training of Young Africa Entrepreneurs Leaders/Mandela/Washington Fellowship/U.S. Department of State	Young entrepreneurs from throughout Africa	10	20	30
USA	Initial training in sorghum protein digestibility	CERAAS personnel – Khalil Kane	1	0	1

### Long-term training

Through its twelve projects, the Lab saw an increase in the overall number of long-term trainees during the FY 2016. It now currently has a total of 38 long-term trainees, 12 of which are female and 26 of which are male. In addition, Ph.D. students account for 21 of those trainees, with Master's students accounting for 15 and postdocs and Bachelor's students each accounting for one. A small number of students have already completed their programs, with most continuing on in a research capacity – either as a researcher or in continuing their training at a higher degree level.

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

Name	Sex	University	Degree	Major	Graduation Date	Degree granted?	Home Country
Zongo Yvonne	Female	INERA	Bachelor's	Seed selection and conservation (SELCOSE)	December 2015	Yes – now starting Master's program	Burkina Faso
Alemnesh Bekele	Female	Haramaya University	Master's	Plant pathology/breeding	June 2017	No	Ethiopia

Chemeda Berhanu	Male	Haramaya University	Master's	Plant pathology/breeding	October 2017	No	Ethiopia
Kebede Dessalgn	Male	Haramaya University	Master's	Plant pathology/breeding	December 2015	Yes – works for BAKO Research Center at Oromia Research Institute	Ethiopia
Cheikh Dieng	Male	Ecole National Supérieure d'Agriculture (ENSA)	Master's	Production Végétales	January 2016	Yes – currently farming but awaiting near-term appointment from national research program	Senegal
Mouhamadou Diome	Male	ENSA Thies	Master's	Socio-economy	February 2017	No	Senegal
Nadre Gbedié	Male	CERAAS	Master's	Breeding	March 2016	Yes – currently applying to DADD fellowship program for Ph.D.	Côte d'Ivoire
Michael Guerçi	Male	Virginia Tech	Master's	Agricultural Economics	May 2016	Yes – works (volunteers) for U.S. Peace Corps in the Philippines	United States
Hamidou Idrissa	Male	Université Abdou Moumouni de Niamey	Master's	Entomology	March 2017	No	Niger
Said Laminou	Male	Université Abdou Moumouni de Niamey	Master's	Entomology	March 2017	No	Niger
Mahamadou Maazou	Male	University of Tahoua	Master's	Socio-economy	May 2017	No	Niger
Loza Mengistu	Female	Hawassa University	Master's	Food Processing and Preservation	March 2017	No	Ethiopia



Oumou Moumouni	Female	Abdou Moumouni University of Niamey with Short Training at Virginia Tech	Master's	Agricultural Economics	May 2017	No	Niger
Benoit Ouedraogo	Male	University of Ouagadougou	Master's	Breeding and conservation of seed	April 2017	No	Burkina Faso
Gnilane Sene	Female	University Cheikh Anta Diop	Master's	Pest management	December 2015	No	Senegal
Baye Thiam	Male	University of Thies	Master's	Agricultural engineering	April 2017	No	Senegal
Laouali Amadou	Male	University of Maradi	Ph.D.	Entomology	December 2018	No	Niger
Eyanawa Akata Atchozou	Male	CERAAS	Ph.D.	Agronomy (Breeding & Genetics)	July 2017	No	Togo
Demeke Bayable	Male	Purdue University	Ph.D.	Plant pathology	August 2019	No	Ethiopia
Yemane Belayneh	Male	Kansas State University	Ph.D.	Plant breeding and genetics	December 2019	No	Ethiopia
Hawi Debelo	Female	Purdue University	Ph.D.	Food science	September 2017	No	Ethiopia
Elizabeth Diatta	Female	West African Center for Crop Improvement	Ph.D.	Plant Breeding	December 2018	No	Senegal
Maty Diop	Female	Cheikh Anta Diop University	Ph.D.	Food Science and Nutrition	July 2018	No	Senegal
Jacques Faye	Male	Kansas State University	Ph.D.	Agronomy (Plant Breeding & Genetics)	March 2018	No	Senegal
Anna Hayes	Female	Purdue University	Ph.D.	Food Science and Nutrition	May 2018	No	USA
Hame Abdou Kadi Kadi	Male	West Texas A&M University	Ph.D.	Plant, Soil and Environmental Science - Insect Pest Management	July 2018	No	Niger

Fanna Maina	Female	Kansas State University	Ph.D.	Agronomy (Plant Breeding & Genetics)	March 2018	No	Niger
Abadi Mezgebe	Male	University of Pretoria	Ph.D.	Food Science	July 2018	No	Ethiopia
Moustapha Moussa	Male	INRAN	Ph.D.	Food Science	May 2019	No	Niger
Tebila Nakelse	Male	Kansas State University	Ph.D.	Agricultural Economics	July 2018	No	Burkina Faso
Habte Nida	Male	Purdue University	Ph.D.	Plant breeding and pathology	June 2020	No	Ethiopia
Charles Nwankwo	Male	University of Hohenheim	Ph.D.	Agriculture	June 2017	No	Nigeria
Patrick Ongom	Male	Purdue University	Ph.D.	Plant Genetics	May 2016	Yes – works at Makerere University in Uganda	United States
Ousmane Seyni	Male	West African Center for Crop Improvement	Ph.D.	Plant Breeding	December 2018	No	Niger
Tadesse Teferri	Male	Texas A&M	Ph.D.	Food Science	December 2018	No	Ethiopia
Adja Thiam	Female	University of Thies	Ph.D.	Pest management	December 2017	No	Senegal
Fatou Welle	Female	University Cheikh Anta Diop	Ph.D.	Pest management	December 2017	No	Senegal
Adedayo Adeyanju	Male	Purdue University	Post-doctoral Studies	Plant Genetics	June 2017	No	Nigeria

## Institutional development

Lab activities in FY 2016 through both management entity and research projects have continued to support partners and collaborating institutions in the development of their capacity to support current and future research programs. The management entity has also undertaken additional activities to address other holes or gaps identified among partner institutions, national programs or related stakeholders.

### ***Environmental compliance***

With support of the Lab management entity, both ISRA (in Senegal) and INRAN (in Niger) have taken significant steps to reinforce their organizational environmental compliance capacity through assigning environmental compliance focal persons. The Lab was involved in coordinating with USAID for these focal persons to take part in an upcoming regional USAID environmental compliance training in Senegal. This training will also open opportunities for cross-learning between the two institutions for stronger overall programs and practices.

### ***IAVAO (West Africa)***

In an effort to “implement innovative plant breeding programmes to address the complexity of afro-ecological systems in West Africa,” the Innovation and Plant Breeding in West Africa (IAVAO) initiative was launched in FY 2016. The initiative incorporates researchers from across West Africa and France, including Burkina Faso, Mali, Niger and Senegal around collaboration and partnership in research, teaching and training. As a partner to many of the participating institutions, the Lab was invited to take part in the initial IAVAO launch meetings in Senegal in December 2015. The Lab’s director was an active contributor to that discussion and process, and the Lab will continue to support and partner with the initiative in future activities as appropriate.

### ***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. Nat Bascom, Lab assistant director, accompanied the team led by KDA’s international trade director, Suzanne Ryan-Numrich, as well as representatives of Kansas-based companies, NuLife Market, LLC, and No-Bull Enterprises. NuLife Market focuses on the milling and processing of gluten-free and non-GMO sorghum grains and roasted sunflower kernels. A site visit was organized to EthioGreen, a gluten-free teff and sorghum food processing company selling to the domestic and international market. Michael Francom, the Agricultural Counselor and USDA Liaison to the African

Union from the United States Embassy in Addis accompanied the tour and further discussions on support for capacity development opportunities of EthioGreen are under consideration.

### ***Kansas State University Innovation Lab support***

With three other Feed the Future Innovation Labs located at Kansas State University, the Sorghum and Millet Innovation Lab is part of a broader Innovation Lab team and has been a proactive player in working to identify synergies and opportunities for collaboration. The Lab has continued to be very active during FY 2016 in a supporting role to the partnering Kansas State University Labs in establishing systems and processes as they have worked through program startup and staff hiring. Additionally, the Labs have presented a single presence in variety of capacities, including at the Borlaug Dialogue, at a university-level research showcase and in broader communications. Lab director Tim Dalton has also assumed leadership of the Innovation Lab Council representing all 24 USIAD-funded Feed the Future Innovation Labs.

## 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 I 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.

#### 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. Starting next season, some of the very promising disease resistance lines will be 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.

### **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

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

*Next steps:* Continue progress in analyzing 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, including the identification and testing of new genetic markers for drought-related traits and locally-preferred genetic backgrounds.

### **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.

## **6. 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.

## **7. 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.

## **8. 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.

## **9. Technology: Best dual-purpose genotypes selected by country (new)**

*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 continued 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.

## **10. 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)

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

## **11. 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.

## **12. Technology: Food product innovation with new improved sorghum endosperm (new)**

*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.

## **Phase 2 technologies – Under Field Testing**

### **1. Technology: Evaluation of technologies to manage insect pests of sorghum (new)**

*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:* Transfer the technologies at the farm level and storage facilities.

### **2. 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.

### **3. Technology: Seedball fabrication mechanization for men with mediocre investment capital (new)**

*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:* Field testing in Niger and Senegal in 2016 on-station and on-farm. Discussion on local device construction necessary.

#### **4. Technology: Seedball fabrication mechanization for women with low investment capital (new)**

*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 technology will be tested on-farm in 2016 and adaptations made for local production.

#### **5. 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:* The technology has been tested again during the 2016 season. The experiment is now over and the next step is to make recommendation to farmers on number of parasitoid wasps that are needed per millet acreage.

#### **6. 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.

## **7. 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

## **8. Technology: Development of rural incubation centers (new)**

*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 entrepreneur processors has been developed and way of 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.

## Environmental Management and Mitigation Plan (EMMP)

The Lab has continued to strengthen its environmental compliance framework into FY 2016. In Niger, the environmental compliance focal person at INRAN, Ibrahim Biga, was further trained in the use of the EMMP module during several environmental compliance support visits to research stations by Lab assistant director Bascom as well as other INRAN researchers.

Bascom also met with Dr. Mbaye Tamsir, the environmental compliance focal person at ISRA in Senegal, for discussions to ensure further integration of the Lab's environmental compliance requirements. They explored the existing environmental compliance framework at ISRA and how the Lab's EMMP reporting tool fits within that. Tamsir and Bascom also visited USAID for meetings with the Mission-level environmental compliance team to determine further capacity development and training opportunities for INRAN and ISRA.



The EMMP module on the SMIL Resource and Reporting Hub has continued to provide a user-friendly tool for principal investigators, management entity staff, country coordinators, and environmental compliance focal persons to implement and monitor overall program environmental compliance.

## 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.

## Governance and management entity activity

In addition to its administrative oversight and support of research project activities, the management entity has also provided leadership in additional areas to contribute to institutional and human capacity as well as advises the overall research priorities established by the Lab.

### Pearl millet threshing mechanization



Off-the-grid application of solar energy has interesting potentials for powering cereal processing equipment in smallholder communities. The Lab has specifically networked with Hampshire College around this concept on their Pearl Millet High Impact Thresher (HIT) project (<https://hitmillet.com/>). Funded by the BMG Foundation, the project aims to develop an affordable and labor-saving pearl millet thresher that complements existing social and cultural dynamics of the people who use it. In Niger, the Lab teamed up with INRAN to provide on the ground support for field testing, surveys, and analysis in multiple testing sites of the AF2 prototype. The results of this field testing have been incorporated into the next prototype which will undergo additional testing in Niger.

The Lab also assisted with the networking of key contacts in Ethiopia to the Spanish-based Solar Milling company in an effort to create potential research and business partnerships for the use of their small- and medium-scale direct solar drive stone mills (<http://solarmilling.com/>). Stone mills are an existing common grinding technology and Solar Milling is optimistic about future entrepreneurial partnerships in Ethiopia to utilize direct drive stone milling technologies.

### Livestock Systems Innovation Lab support

The Associate Dean of International Agriculture Programs at Kansas State University together with other Innovation Lab staff hosted the University of Florida management team who were awarded the Livestock Systems Innovation Lab. This inter-lab exchange provided cross-learning opportunities and key discussions to assist the Livestock Lab in their startup phase. A video conference with the administrative teams of the Livestock Lab as well as the Sustainable Intensification and Sorghum and Millet Labs was later organized to provide additional support.

### Inter-Lab proposal support

In addition, the Lab supported the Sustainable Intensification Lab team in preparation for submission to the Livestock Systems Innovation Lab call for proposal by organizing a scoping visit to Ethiopia and assisting in the forming of project research teams. The Lab also provided assistance in the drafting of the research proposal, and will leverage its partnership with the EIAR sorghum research program into the proposed activities. Our commodity-based interest is in how sorghum forage might fit into these systems.

### West Africa dual-purpose pearl millet performance evaluation visits

As a part of the current pearl millet breeding efforts currently underway within two Lab projects, the management entity organized a monitoring tour across various nursery locations in four West Africa countries – Senegal, Niger, Burkina Faso and Mali. Partnering breeders from each of these locations, as well as the Kansas-based pearl millet breeder and management entity assistant director, travelled together to assess all progress in current breeding trials and the performance of the different varieties planted. The visits were extremely valuable not only in providing a comprehensive evaluation of the status of the pearl millet trials, but also in facilitating the collaboration and cross-fertilization between the breeders and institutions.

### Innovation Lab Council support

The Lab was called upon by USAID and the Innovation Lab Council to provide administrative support in the facilitation of the 2016 Innovation Lab Council meetings held September 13-14, 2016, which it provided in the organization of the



venue at the International Trade Center in Washington, D.C. The Lab will continue in that capacity as it officially took leadership of the Innovation Lab Council through the appointment of Lab director Tim Dalton as the Council chairman. The Lab will be responsible for the planning and execution of both regional and U.S. Innovation Lab Council meetings in 2017 and 2018 as well as providing leadership in addressing Feed the Future issues that impact all Innovation Labs.

### **2016 SICNA organization**

For the second year in a row, the Lab again took leadership in the organizing of the Sorghum Improvement Conference of North America (SICNA), a national-level sorghum research conference that brings together students, researchers and industry representatives around key problems in sorghum research today. The conference was held in Manhattan, KS, and saw nearly 200 attendees, including an increase in international participants. Future conferences will be organized by the National Sorghum Producers and the SICNA committee, but the Lab anticipates continued participation in the event.

### **K-State Research and Extension Sorghum Field Day**

A sorghum field day was hosted in early September 2016 by the K-State Research and Extension Research Station in Hay, KS. This field day was supported by the Lab, and was an excellent opportunity to showcase the materials currently under development by the research station team. Attendees included representatives from the National Sorghum Producers, the Kansas Grain Sorghum Commission, Kansas State University researchers and north-central Kansas producers. Additionally, by the request of the Lab, Desalegn Serba - the new pearl millet breeder that was hired as a part of the University commitment to Lab efforts – showcased the pearl millet nursey that was planted in his first year of activities under Lab funding.

### **GROW/EXCITE student programs**

The Kansas State University Office for the Advancement of Women in Science and Engineering invited the Lab management entity to participate in their on-campus GROW and EXCITE programs targeted at stimulating interest in the STEM disciplines among middle and high school girls. The Lab participated in the Feed the Future-themed workshop, including facilitating a hands-on activity around gender roles and production, and how those roles impact crop characteristic preference and food security as a whole. Nigerien graduate student Fanna Maina also helped facilitate the activities and the Lab received strong positive feedback from the students and program leaders alike.

## Other Topics

### Food product development market research

In an effort to gain greater understanding of the opportunities as well as constraints for sorghum and millet in the food product market in West Africa, the Lab commissioned a research study on the economics of grain-based value-added food products in Niger. Conducted by Tebila Nakelse, Ph.D. candidate in agricultural economics at Kansas State University and Lab-funded student from Burkina Faso, the study involved all identified food processors in Niger and gathered a variety of data on their production, revenue, clientele and constraints. Preliminary data has been compiled and further analyses will be available in FY 2017.

### Gender and sorghum production research

A gender consultancy was established in FY 2015 to lead a research project in gender roles and sorghum production by region in Ethiopia. The initial phase of an analysis of research currently available was completed, as was the subsequent development of a data collection tool to be administered in focus group interviews in six different sorghum-producing areas in Ethiopia. However, political unrest and the associated tensions have prevented the research team from proceeding with the data collector training session and actual village-level data collection. These activities continue to be on hold until improvement is seen in the current situation.

### Environment

Environmental compliance continues to remain a high priority for the management entity, which facilitated a training on the EMMP modules at the annual project meetings and continually maintains relationships with the USAID focal persons at the Mission level.

The Initial Environmental Examination (IEE) BFS-IEE-13-19; 8/29/2014 was amended by BFS-IEE-16-4-005; 4/29/2016 to include coverage of activities and geographies associated with the genomics-assisted breeding associate award project entitled, "Implement a genomics-assisted breeding program in a small breeding program in a developing country," which will be in partnership with the Centre de Recherche sur les Biocarburants et l'Agriculture Durable (CHIBAS) in Port-au-Prince, Haiti.

Thanks to increased efforts and attention in the area of environmental compliance by the management entity and its partners in Senegal and Niger, an opportunity for environmentally-focused short-term training provided by USAID has been made available to two individuals. Institutional representatives, Dr. Tamsir of ISRA in Senegal and Mr. Biga of INRAN in Niger will participate in the training in November 2016. This training will support further environmental compliance capacity building and planning within the Senegal and Niger national agricultural research systems.

### Presentation of extruder to economic development group in Senegal

Food product development efforts in Senegal led by principal investigator Bruce Hamaker have led to strong relationships with a variety of key players in the region, including the Institut de Technologie Alimentaire (ITA), the Institut Senegalais de Recherche Agricole (ISRA), the McKnight Foundation and many others. As a side development of these efforts, an extruder was presented by USAID to the Groupe d'Intérêt Economique Touba Daara Salaam in March 2016 in Touba, Senegal, in support of the community group's efforts to produce and sell high-quality extruded foods. The ceremony had an estimated 400-500 community members in attendance as well as representatives from USAID, ITA, the Sorghum and Millet Innovation Lab and other food product development researchers from the United States as well as Ethiopia.

## Issues

Two issues that have been of particular focus during FY 2016 have been management of project “burn rates” and the impact of security and political unrest on research progress.

### “Burn rate” management

Efficient and effective use of all funds remains a top priority for the Lab management entity. In order to proactively manage this, particularly at the project level, the Lab launched an expenditure “burn rate” graph in the online SMIL Resource and Reporting Hub. This tool, which is updated monthly by the Lab’s business financial specialist with the latest in processed expenditures and released funds, allows project principal investigators to have a current view of their overall project funding, funding-to-date and expenditures. The implementation of this tool has already assisted project leaders in having a better understanding of their spending status and facilitated better discussions and management of budgets. This issue is increasingly important as the program enters its final 20 months.

### Research and security

Security and the changing political environment in Ethiopia during the FY 2016 has affected Lab activities. The unrest and uncertainty present in the country has directly impacted the Lab’s in-country research as it has limited the ability for researchers to travel within the country as well as for outside researchers to travel in for visits and activities. The unrest and government travel restrictions has also forced the gender and sorghum production research team to postpone their data collection until tensions and unrest ease due to the potential risks to the data collectors.

Additionally, security warnings led the Lab to choose to cancel its annual program review meetings that were slated to take place in Ethiopia in early 2017. The hope for these meetings was that researchers involved in genetic enhancement activities in West Africa would have the opportunity to visit research sites and gain greater understanding of the activities taking place in Ethiopia, resulting in beneficial cross-fertilization. Unfortunately, this opportunity will be missed due to security concerns. The Lab continues to monitor the situation but is currently identifying an alternative location for team meetings.

## Future directions

Considerable progress has been made against stated project activities, objectives and goals while new opportunities for technological and food product innovation have emerged by building upon the management entity's operational strategy for adaptive management. The program has invested resources along the value chain from genomics and breeding to production systems management and in the area of added-value food products. We will continue to emphasize these areas over the remaining time of the project and do not anticipate major reorientations based upon current progress in the projects. Projects are on-track to produce the innovations that are required to build the crops of the future, including heat and drought tolerance, host plant resistance to a myriad of pests - insects, disease and weeds - and improved functionality for incorporation into consumer products. The Haiti project will provide new insights complementary to the work in West Africa. Consumer products are evolving to meet the food and nutrition needs of urbanizing populations (and wealthier rural constituents) with more nutrient dense and convenient products all through private sector growth and attendant new employment opportunities.

The program is focused on the future and the translation of cutting-edge science into the technologies and products to improve farm income, consumer benefits and the health and productivity of target populations in Africa. The management entity is contributing to the effectiveness of projects through core managerial activities and also by building new partnerships that add novel strengths to applied research, entrepreneurship and policy advocacy. These development activities are designed to build pathways for impact and the bridges between centers of scientific excellence and end-users. To this end, research projects will be required to communicate their findings and implications for development at our remaining annual meetings. The emphasis will be on translational science and will provide practice and the impetus for long-term trainees to step beyond their research and vision for future change. The second objective is to build a culture of communicating science to the public.

The management entity will channel activities towards the end goals of the program and use any remaining operational funding to enhance outcomes or position the program for the future. To achieve this end will require us to take into consideration the constraints imposed by political instability in Ethiopia and the security climate in West Africa. At this point we are in a strong position to adapt to these environments. Technologies are in the hands of farmers, cooperatives and entrepreneurs who are nimbler than the program when difficulties arise. We are exceeding our targets in short-term and long-term training and these investments will transcend the contracted project period. We are producing the global public goods that contribute to enhanced productivity of sorghum and pearl millet and its ability to adapt to the agroecological and economic climates of the future food and agricultural economy.

## Appendices

### Appendix I – Success stories

#### ***Integrated approach offers hope for natural, sustainable control of devastating millet pest in West Africa***

Pearl millet serves as a staple crop to millions of smallholder farmers and their families around the world. Due to its heat resistance and drought tolerance, it has the ability to grow and even thrive in low-quality, arid soils that can support few other crops.

But pearl millet has its weaknesses, and one of those is its susceptibility to certain insect pests. Across the African Sahel – where millet is an irreplaceable base to the diets of humans and livestock alike - the millet stem borer and millet head miner are considered the major chronic millet pests, known for wreaking havoc and causing major destruction to entire fields of production. In fact, infestation from one or both of these pests can lead to near or complete crop failure in a given year – a truly devastating prospect for a family already living on the fringes of food insecurity.

Exciting new research around the life cycles of these pests and their natural predators is pointing to a potential solution that would offer a natural, sustainable method for managing the millet head miner and stem borer and save millions of hectares of millet each year. The project, funded under the Feed the Future Innovation Lab for Collaborative Research on Sorghum and Millet, focuses on controlling the pests through the release of a naturally-occurring parasitoid wasp that targets both the head miner and stem borer eggs and kills them, effectively managing the population.

According to Malick Ba, the project's principal investigator and researcher at ICRISAT-Niger, the use of the parasitoid wasp to target the millet head miner larvae in the Sahel has been successfully achieved in the past. However, under the Innovation Lab project, researchers are identifying a new parasitoid that targets both the head miner and the stem borer eggs simultaneously, offering the exciting possibility of dual-control of the two pests by the same parasitoid wasp.

Ba and his team are continuing to dig further into mass rearing of the parasitoid wasp, identifying host acceptability among locally-occurring moths and other insects, and so far the results are promising. While focusing on this new potential biocontrol agent, the team is also working with local farmers groups and cooperatives to explore the economics and optimal business model for an entrepreneur-led cottage industry for wasp rearing that would help position the innovation towards larger-scale adoption.

Many questions still remain to be answered through continued research studies, but the possibility of controlling two of the most devastating pearl millet pests in the Sahel is an exciting prospect for Africa's farmers, and everyone that depends on them. We continue to work on this project with a consortium of partners including the McKnight Foundation.



*The millet head miner is a devastating crop pest in West Africa that can lead to complete crop failure and threaten the livelihood of millions of smallholders.*



### ***Building the future for West African agriculture – one scientist at a time***

When Fanna Maina looks ahead towards her career and the impact she hopes to have on Sahelian agriculture, she recalls a visit she made to a Nigerien farmer once as an intern in a rural village.

“I remember a farmer saying to me, ‘Our crops are not as productive today as they were decades ago. These days, we do not have enough grain,’” she says. “My question is this: how can we help those farmers to produce more and ensure that they have food security?”

It is that goal that has driven Maina to join the next generation of scientists in hopes of tackling issues of food security through breeding and genetics. Under funding from the Feed the Future Innovation Lab for Collaborative Research on Sorghum and Millet, Maina is currently working on her Ph.D. in agronomy at Kansas State University. As a member of Dr. Geoffrey Morris’s sorghum genetics lab team, her primary area of focus is on the genetic variability of sorghum in Niger and Sub-Saharan Africa by using genomics tools to understand agronomic traits useful in crop improvement.

“Growing crops in Niger where I come from is not an easy task for smallholder farmers,” she says. “With all the constraints they face, the work that breeders are doing to develop improved varieties is also very challenging. Genetics, physiology and breeding will allow me to better understand sorghum and then develop new tools that will master the challenges of agricultural production. This work can support breeders as well as the farmers in producing high and stable yielding varieties that perform under various constraints.”

Maina plans to continue to expand her knowledge in the new advances in genomics, which can provide researchers with accelerated tools for developing lines specifically adapted to local constraints – resulting in new varieties being made available to farmers much faster than through traditional breeding efforts.

After completing her Ph.D. program in 2018, Maina will return to Niger where she anticipates joining the national agricultural research system to advance their breeding program. Maina says that her program of study in the United States is giving her the needed skills and professional linkages to become an important player in the West Africa research community.

Being a part of that community, she says, is a key step to achieving her ultimate goal.

“I dream of serving my country and Sub-Saharan Africa,” she says. “The majority of Nigeriens rely on agriculture but recent climatic conditions are not favorable to their agricultural activities. It is extremely important to develop climate resilient crops that can help those smallholder farmers produce more grain each season and achieve food security.”



*Fanna Maina's goal is to improve crop productivity in her home country of Niger through new approaches to genetics and breeding.*

## ***Opening doors: Sorghum as a food ingredient in Ethiopia's value-added market***

Few foods define Ethiopia's cuisine like injera, a large, pancake-like bread product that is a staple part of the diet throughout the entire country. Often made from a tiny grain called teff, injera is an irreplaceable part of nearly every meal.

Traditionally, injera is prepared in the home by a female household member. However, with the growth of the middle class and rise in incomes, more and more families are purchasing their injera pre-made by local vendors. This emerging market is opening new doors – and new demands – for food product development.

While teff has traditionally served as the base for injera, the usage of other grains varies by region throughout Ethiopia. Sorghum, in particular, is commonly incorporated in injera fabrication in some households – in part, due to its affordability and availability. As a drought-resistant and heat-tolerant crop, sorghum is grown widely across many regions, and is a staple crop for many smallholder farmers. However, due to its physio-chemical traits, it tends to underperform in the making of an “ideal” injera, which limits its use as a base ingredient and keeps the price of injera higher with the dependence on more expensive teff grain.

In an effort to improve the functionality of sorghum and expand the opportunities for its use in commercial grain-based food products, plant breeders and food scientists have teamed up to test new varieties developed specifically for their high digestibility characteristics. This effort, funded by the Feed the Future Innovation Lab for Collaborative Research in Sorghum and Millet, is a collaborative partnership across multiple institutions, including Texas A&M University in the United States, the University of Pretoria in South Africa and Hawassa University in Ethiopia.

Improved highly-digestible (IHD) sorghum lines have been developed at Texas A&M and have displayed improved performance in food processing over traditional varieties. Using this past research as a foundation, the Feed the Future research team is taking a two-pronged approach. Plant breeders are working together to test the IHD lines in Ethiopian environments in order to evaluate production constraints and opportunities for local farmers while simultaneously producing grain needed for food product testing. Meanwhile, food scientists are working with food product development labs and local women injera entrepreneurs to assess the performance of the IHD sorghum in injera and other grain-based products including hard rolls and pan bread.

The goal, say researchers, is have sorghum varieties that carry the characteristics to produce more voluminous, tender food products while at the same time demonstrating the sensory characteristics needed for consumer acceptability. This would give injera producers and other commercial food producers greater options for incorporating sorghum blends into their products, helping to reduce costs and provide an expanded market to the millions of smallholder sorghum producers across the country. The team is already working with local injera producers to develop a sensory profile that will be used for more consumer taste-testing in coming months.

But food product functionality has to be paired with strong performance in the field, so breeders continue to evaluate the strengths and constraints of producing the IHD lines in the Ethiopian growing environments. Those results will go right back into the breeding process as researchers modify the existing lines to maximize food product functionality while also optimizing them for strong production in the face of local stresses and constraints.

It is a complex problem, but thanks to multi-institutional collaboration and innovative approaches, solutions are on the way. Sorghum as a practical ingredient for commercial grain-based products offers the benefits of lower production costs for processors resulting in greater accessibility to larger populations, while opening new market opportunities to smallholder sorghum farmers which would result in increased incomes and, as a result, improved livelihoods.





*Ethiopian researchers have teamed up with plant breeders to develop sorghum varieties with superior functionality in grain-based food products while maximizing performance in the field.*

## Appendix 2 – List of awards to U.S. partners

**Title:** 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

**Award:** Texas A&M - Joseph Awika

**Project**

**Dates:** 04/01/14 07/22/18

FY16 Funding Released: \$170,085.00

Total Funding Released: \$497,491.00

Overall Project Budget: \$809,941.00

**Title:** Biological Control of the Millet Stem Borer and the Millet Head Miner in Niger and Senegal

**Award:** Virginia Tech-Malick Ba

**Project**

**Dates:** 04/01/14 07/22/18

FY16 Funding Released: \$61,312.00

Total Funding Released: \$183,707.00

Overall Project Budget: \$207,017.00

**Title:** Genetic Enhancement of Sorghum to Promote Commercial Seed Supply and Grain Market Development in Ethiopia

**Award:** Purdue - Gebisa Ejeta

**Project**

**Dates:** 04/01/14 07/22/18

FY16 Funding Released: \$170,688.00

Total Funding Released: \$428,634.00

Overall Project Budget: \$753,203.00

**Title:** Expanding Markets for Sorghum and Millet Farmers in West Africa through Strengthening of Entrepreneur Processors and Nutrition-based Promotion of Products

**Award:** Purdue-Bruce Hamaker

**Project**

**Dates:** 04/01/14 07/22/18

FY16 Funding Released: \$192,862.00

Total Funding Released: \$399,533.00

Overall Project Budget: \$680,888.00

**Title:** Genetic improvement of sorghum for resistance to fungal pathogens

**Award:** Purdue - Tesfaye Mengiste

**Project**

<b>Dates:</b>	04/01/14	07/22/18		
		Purdue	KSU	Total
FY16 Funding Released:		\$210,033.00	\$51,660.00	\$261,693.00
Total Funding Released:		\$386,730.00	\$117,646.00	\$504,376.00
Overall Project Budget:		\$761,755.00	\$223,486.00	\$985,241.00

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**Title:** Development of Biotic Stress-Resistant Sorghum cultivars for Niger and Senegal

**Award:** WTAMU-Bonnie Pendleton
**Project**
**Dates:** 04/01/14 07/22/18

FY16 Funding Released:	\$181,501.00
Total Funding Released:	\$396,003.00
Overall Project Budget:	\$677,563.00

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**Title:** Improved Crop Genetics and Processing Methods for Increased Productivity and Nutrition for the Smallholder Sorghum Producers in Ethiopia

**Award:** USDA-Tesfaye Tesso
**Project**
**Dates:** 04/01/14 07/22/18

	KSU	USDA	Total
FY16 Funding Released:	\$134,753.00	\$48,407.00	\$183,160.00
Total Funding Released:	\$223,153.00	\$145,221.00	\$368,374.00
Overall Project Budget:	\$482,580.00	\$147,441.00	\$630,021.00

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**Title:** Sorghum Trait Development Pipeline for Improved Food and Feed Value

**Award:** Purdue-Mitch Tuinstra
**Project**
**Dates:** 04/01/14 07/22/18

FY16 Funding Released:	\$319,051.00
Total Funding Released:	\$714,239.00
Overall Project Budget:	\$847,667.00

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**Title:** Improving sorghum adaptation in West Africa with genomics-enabled breeding

**Award:** KSU-Geoff Morris



**Project**

**Dates:** 04/01/14 07/22/18

FY16 Funding Released: \$152,254.00  
Total Funding Released: \$281,458.00  
Overall Project Budget: \$564,035.00

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**Title:** Pearl Millet Improvement for Productivity, Climate Resilience and Nutritional Quality

**Award:** KSU-Hays - Desalegn Serba

**Project**

**Dates:** 07/01/16 07/22/18

FY16 Funding Released: \$17,048.00  
Total Funding Released: \$17,048.00  
Overall Project Budget: \$23,348.00

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### Appendix 3 – Country-specific financial information

Project Title	Principal Investigator	Country Total										Project Total
		Burkina Faso	Ethiopia	Ghana	Mali	Niger	Senegal	South Africa	Germany	Int'l Student Training	U.S.	
Country Coordination (Ethiopia, Niger, Senegal)		-	133,430	-	-	209,844	55,200	-	-	-	-	398,474
Improving sorghum adaptation in West Africa with genomics-enabled breeding	Geoff Morris	-	-	-	37,197	199,640	289,221	-	-	246,941	317,094	1,090,093
Combining high digestible protein trait with waxy/ heterowaxy endosperm traits to develop superior functionality in sorghum for food applications to promote sorghum value chain in Ethiopia	Joseph Awika	-	182,718	-	-	-	-	90,000	-	141,012	396,211	809,941
Biological control of the millet head miner in Niger and Senegal	Malick Ba	-	-	-	-	311,596	120,175	-	-	140,816	66,201	638,788
Development of biotic stress-resistant sorghum cultivars for Niger and Senegal	Bonnie Pendleton	-	-	-	-	108,721	90,000	-	-	345,057	332,506	876,284
Expanding markets for sorghum and millet farmers in West Africa through strengthening of entrepreneur processors and nutrition-based promotion of products	Bruce Hamaker	-	-	-	-	134,440	134,000	-	-	249,681	295,657	813,778
Genetic improvement of sorghum for resistance to fungal pathogens	Tesfaye Mengiste	-	128,700	-	-	-	-	-	-	278,226	707,015	1,113,941
Optimization of the seed ball technology for pearl millet, and agronomic and socio-economic evaluation in the context of smallholder farmers in Senegal and Niger	Ludger Herrmann	-	-	-	-	68,334	55,770	-	61,936	-	-	186,040
Genetic Enhancement of sorghum and millets to promote commercial seed supply and grain market development in Senegal and Ethiopia	Gebisa Ejeta	-	159,500	-	-	-	-	-	-	171,513	581,690	912,703

<b>Improving crop genetics and processing methods for increased productivity and nutrition for smallholder sorghum producers in Ethiopia</b>	<b>Tesfaye Tesso</b>	-	191,400	-	-	-	-	-	-	120,000	510,021	821,421
<b>Sorghum trait development pipeline for improved food and feed value</b>	<b>Mitch Tuinsta</b>	-	-	210,000	-	149,500	149,500	-	-	201,024	379,143	1,089,167
<b>Development of dual-purpose pearl millet varieties for the benefit of farmers and agro-pastoralists in the Sahelian and Sudanian zones of West Africa</b>	<b>Roger Zangre</b>	133,650	-	-	120,450	120,450	120,450	-	-	-	-	495,000
<b>Molecular diversity study of pearl millet parental lines</b>	<b>Desalegn Serba</b>	-	-	-	-	3,336	3,220	-	-	-	23,348	29,904
<b>Total</b>		<b>133,650</b>	<b>795,748</b>	<b>210,000</b>	<b>157,647</b>	<b>1,305,861</b>	<b>1,017,536</b>	<b>90,000</b>	<b>61,936</b>	<b>1,894,270</b>	<b>3,608,886</b>	<b>9,275,534</b>