FEED THE 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 2020

October 1, 2019 – September 30, 2020

USAID
FROM THE AMERICAN PEOPLE

FEED THE FUTURE INNOVATION LAB
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 2020

This annual performance report for FY 2020 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:
Women involving in participatory evaluation in Maradi, Niger

Photo credit: Ndjido Kane

This publication may be cited as:
Feed the Future Innovation Lab for Collaborative Research on Sorghum and Millet. October 2020. Feed the Future Innovation Lab for Collaborative Research on Sorghum and Millet Annual Performance Report FY 2020. Sorghum and Millet Innovation Lab, Kansas State University, Manhattan, KS, pp. 46.

Management entity information

During FY 2020, the management entity team welcomed Christine Daskais as the new Program Administrator replacing Kira Everhart-Valentin. The rest of the team remains the same as follows:

- Timothy J. Dalton – *Director*
- Nathanael Bascom – *Assistant Director*
- Christine Daskais – *Program Administrator*
- Kimberly Suther – *Fiscal Analyst*

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. All original five members elected to continue their service into Phase 2, 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) Tim Lust - *Chief Executive Officer of the National Sorghum Producers*
4) Dr. Peter Matlon - *Adjunct Professor at Cornell University*
5) Prof. Barbara Stoecker - *Regents Professor and Marilynn Thomas Chair at Oklahoma State University*

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.

Our face to face annual meeting was moved to an online version due to the COVID-19 pandemic. The External Advisory Board (EAB) provided valuable input to each project's representatives. The EAB found the format to be effective way to discuss each project as we reviewed them one at a time. It also allowed for more in-depth discussion and reflections.

Focus countries

The Lab continues to work primarily in its focus countries – Ethiopia, Senegal, and Niger – and secondarily in Burkina Faso, Haiti and Togo.

Figure 1: Sorghum and Millet Innovation Lab map of program activities and partners

List of program partners

United States

Cornell University
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

Ethiopia

Amhara Agricultural Research Institute
Amhara Bureau of Agriculture and Natural Resources
Ethiopian Institute of Agricultural Research (EIAR)
Haramaya University
Hawassa University
Holleta Biotechnology Center
Oromia Agricultural Research Institute
Tigray Agricultural Research Institute

Senegal

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

Niger

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

Burkina Faso

Institut de l'Environnement et de Recherches Agricoles (INERA)

Togo

Institut Togolais de Recherche Agronomique (ITRA)

Haiti

CHIBAS
Quisqueya University

Germany

University of Hohenheim

France

Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD)

Acronyms

ARS	Agricultural Research Service
BMR	Brown Midrib
CERAAS	Centre d'Etude Régional pour l'Amélioration de l'Adaptation à la Sécheresse
CGIAR	Consultative Group on International Agricultural Research
CHIBAS	Centre de Recherche sur les Biocarburants et l'Agriculture Durable
CIRAD	Centre de Coopération Internationale en Recherche Agronomique pour le Développement
CNRA	Centre National de Recherche Agronomique
EAB	External Advisory Board
EIAR	Ethiopian Institute of Agricultural Research
EMMP	Environmental Mitigation and Monitoring Planning
EMS	Ethyl Methanesulfonate
DNA	Deoxyribonucleic Acid
GBS	Genotyping-by-sequencing
HX	Heterowaxy
HPD	High Protein Digestibility
ICRISAT	International Crops Research Institute for the Semiarid Tropics
IDIN	International Disease and Insect Nursery
IDLT	International Drought Line Test
INERA	Institut de l'Environnement et de Recherches Agricoles
INRAN	Institut National de Recherches Agronomiques du Niger
IPM	Integrated Pest Management
ISRA	l'Institut Sénégalais de Recherches Agricole
ITA	Institut de Téchnologie Alimentaire
KSU	Kansas State University
KDA	Kansas Department of Agriculture
ME	Management Entity
MHM	Millet Head Miner
MLT	Midge Line Test
MSB	Millet Stem Borer
NAM	Nested Association Mapping
NARI	National Agricultural Research Institutes
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
SNP	Single Nucleotide Polymorphism
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

Glossary

Agglomerate: Process of creating food product balls, such as couscous
Anthracnose: A group of fungal diseases
Forage: Plant material consumed by livestock
Fortificant: Food additive to increase nutritional quality
Genomic-enabled: Plant breeding selection process focusing on genetic markers
Genotyping: The process of determining genetic differences
Landrace: Traditional or local unimproved plant or animal
Lysimeter: A device that can measure evapotranspiration
Pathotype: A disease-causing variant of a microorganism
Phenotyping: Assessment of expressed traits in plants
Phylogeny: The evolutionary development and diversification of a species
Pleiotropic: Producing multiple effects from a gene
Smut: Fungal disease
Stover: Leaves and stalks of a plant
Striga: Genus of a parasitic plant

Table of contents

Executive summary

The Feed the Future Innovation Lab for Collaborative Research on Sorghum and Millet completed its seventh year during the 2020 fiscal year. This is the second year of the second phase with a revised portfolio of projects that included modifications of the first phase and new research projects on pearl millet breeding and another on sorghum pathology.

In the second phase of the program, projects were encouraged to focus on the continued development and refinement of products for downstream application for producers, processors and consumers by harvesting advancements in knowledge, technologies and delivery science generated during the first phase. At the same time, projects will continue to develop global public goods for the scientific community.

This year several technological advances were made including the release of a new disease resistant sorghum variety in Ethiopia ("Marara"), widespread demonstration of a hybrid sorghum variety released in Ethiopia last year, and the testing of new hybrids varieties for improved food products. In West Africa there is continued emphasis on the value chain. Fortified flour blends are being scaled up by entrepreneurs in Niger, targeting malnutrition at-risk children. In Senegal, a sensory lab—the first in West Africa—is near completion at the Institute for Food Technology (ITA). The program continues to emphasize sorghum and Pearl millet varietal development in Niger, Senegal and associated countries of Burkina Faso and Togo. To this end, new forage varieties have entered a demonstration stage, improved food quality varieties are being tested for commercial use and genomics-enabled breeding has led to greater resiliency against *Striga*, heat and drought stress. We continue to scale-up the seedball technology for millet by expanding into new regions of Niger and supporting investigations on its use with sorghum seeds.

This annual report focuses on a year disrupted before the cropping season due to COVID-19. While this forced the cancellation of our proposal annual review meeting in Ethiopia and difficulties with project implementation, it also provided an opportunity to examine activities, data and our general process of conducting research for development. The annual report reflects a decrease in face-to-face activities with downstream clients due to national policies aimed at reducing the risk of COVID-19 transmission.

Focus Country Key accomplishments

a) ETHIOPIA

Investment in genetic enhancement of sorghum has yielded important new varieties for Ethiopian farmers on three separate fronts. Initial investment in the Ethiopian Core Collection in phase I has led to the release of "Marara" a variety that contributes to production resilience because of its host-plant resistance against diseases prevalent in western Ethiopia. ESH5, a hybrid variety released last year has been planted at 124 demonstration plots in Tigray, Amhara and Oromia. Varieties that are highly digestible and have advantageous processing characteristics have entered pre-release testing while continuing to be evaluated for food product utilization.

There are six male students from Ethiopia who are currently pursuing a Ph.D. under the long-term training program. One female was admitted to a Ph.D. program but her entry has been delayed due to COVID-19.

b) NIGER

The program in Niger continues to develop improved food products for consumers and fortified blends of millet and sorghum flour for consumption by children at risk of undernourishment. Blends of these flours challenge imported soy and maize blends and are manufactured using locally available grains and micronutrient dense fortificants. This program is being led by the national program coordinator who completed his Ph.D. training in early 2020. Additionally, the sorghum breeding program is being reinforced with new Ph.D. trained scientists to lead research on the development of highly digestible forage sorghum varieties for the livestock sector. This has led to the development of a targeted forage improvement program at the Kollo research station near Niamey. A second scientist returned to Niger with a doctorate to lead efforts on molecular breeding and the identification of traits to improve the resiliency of sorghum against Striga and drought stressors. New inbred lines with resistance against Striga are being evaluated in filed conditions. A large-scale survey of the prevalence and severity of sorghum diseases was completed with 21 different diseases identified. This has led to breeding strategies that incorporate identified disease resistant cultivars with high productivity lines to increase host plant resistance and resiliency against disease outbreaks. Production resiliency of Pearl millet has been enhanced with widespread testing of new treatments of the seedball technology in two regions of Niger and initiation of evaluation of the seedball for sorghum.

The Lab facilitated the short-term training of 1305 individuals across 8 different training events. The types of short-term trainings conducted varied, and included farmer trainings, professional workshops, on-the-job capacity-building exercises, and academic courses.

Two male students from Niger are currently pursuing a Masters' degree program under the long term training program.

c) SENEGAL

The food product development program made significant advances in the development of an "economic" couscous that uses a non-mechanical approach to agglomerate sorghum and millet flour. This will reduce the cost of production of the product making it more affordable for many classes of consumers. The Institut de Technologie Alimentaire in Dakar nearly completed the development of their sensory laboratory that will develop into the region's first center for product evaluation with trained expertise to facilitate entrepreneurial activity in the agri-foods sector. An important complementary element of this program was the development of the food quality assessment laboratory at CERAAS and its staffing with a new Ph.D. level trained scientist specialized in this area. Together the linkage of these two programs will streamline the pathway from grain to "good" and ensure that a pipeline of new varieties will improve the quality of end products. In addition, a new scientist with expertise in genomics-enabled breeding recently completed doctoral studies and will continue in the development of sorghum varieties with greater resilience against heat and drought stress. This resilience research is complemented with a geographical study on the prevalence and severity of sorghum diseases which has identified three cultivars that are resistance to local strains of anthracnose but susceptible to grain mold.

The Lab facilitated a one to one mentoring meeting for a returning graduate student in his workplace with the national agricultural research system.

Seven students from Senegal are currently following a long-term training program. Among those 7 trainees, 4 male and 1 female are seeking a Masters' degree; and 2 females are seeking a Ph.D. One female was admitted to a Ph.D. program in the United States, but her entry has been delayed due to COVID-19.

Research program overview and structure

The Sorghum and Millet Innovation Lab's research program continues its established course with a few changes that are responsive to program evolution. The program currently has nine projects and funding commitments to 15 institutions. Projects are led by several institutions including Purdue University (four projects), Kansas State University (one project), Texas A&M (two projects), the Senegalese Institute for Agricultural Research (ISRA – one project) and the University of Hohenheim (one project). The pearl millet improvement project is being led by the Senegalese national agriculture research program (ISRA) and integrates researchers from Burkina Faso, 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. There are activities in Haiti under an Associate Award that are led by Cornell University that is coming to an end.

The program is organized around three areas of inquiry: 1) Genetic enhancement, 2) Production systems management, and 3) Market development and added-value products. Since the program is commodity focused, sixty-seven percent of our projects focus on sorghum and pearl millet crop improvement, eight percent in production systems management and twenty-four percent in added-value products. Geographically, slightly more than 35% of Lab financial resources for research are focused on Ethiopia and the remainder in West Africa.

Theory of change and impact pathways

All research projects contribute towards *Objective I* of our theory of change, *Build a coalition of science and industry around sorghum and millet.* In addition, this project also supports *Objective II: Incubate and nurture a new wave of feed and food products to stimulate demand for sorghum and millet thereby extending economic benefits beyond the farmgate into the broader population* and *Objective III: Create an economically rationalized business and research investment plan to leverage USAID core financing and attract associate awards and broader donor support.*

The theory of change for the Sorghum and Millet Innovation Lab continues to be based on the development of technological innovations targeted at the sorghum and millet value chains in response to national needs assessments. It is centered on the development of new varieties, crop management practices, and food processing and marketing techniques. As a commodity-based Innovation Lab, the emphasis of much of its work is in the area of technological innovation, facilitating diffusion of technology packages and disruptive system change in order to increase productivity and profitability at several entry points along the value chain. The following diagram illustrates our theory of change:

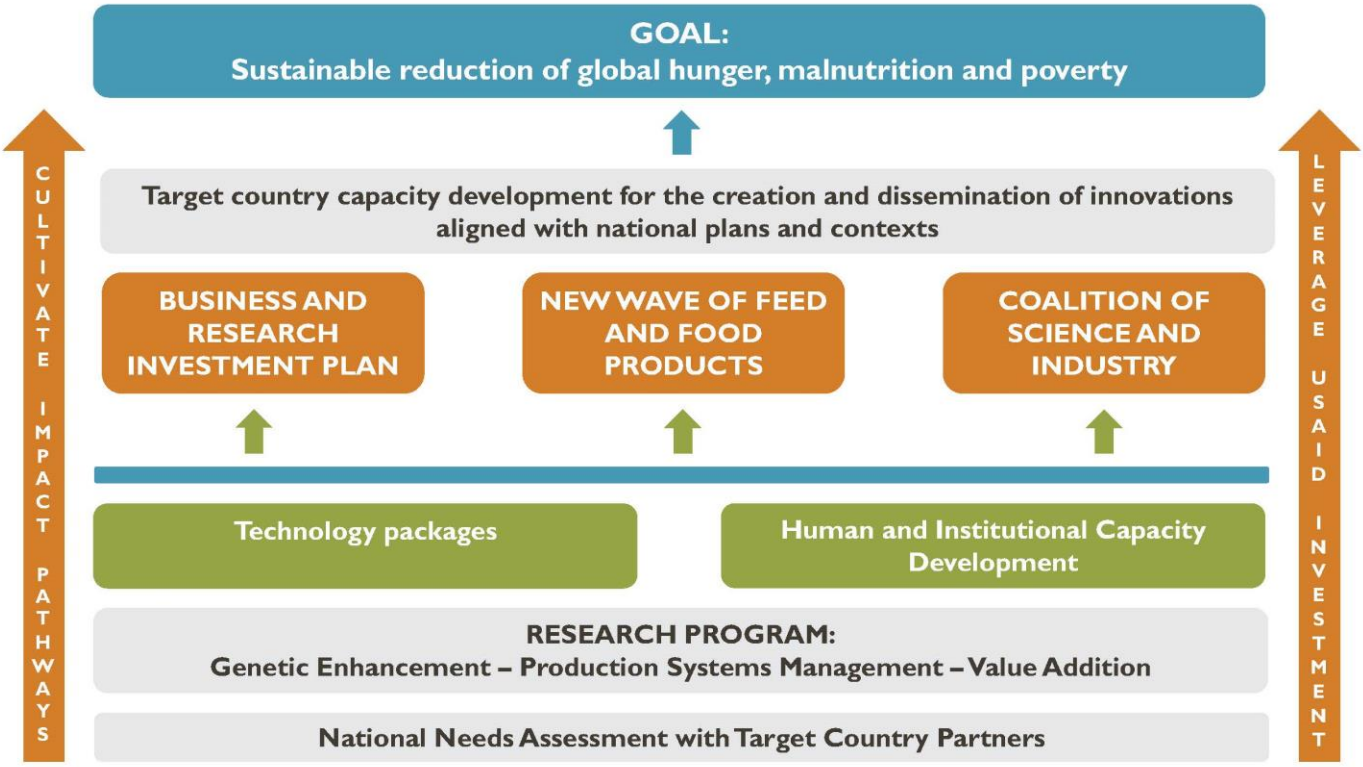


Figure 2: Sorghum and Millet Innovation Lab Theory of Change

The theory of change embedded in the Sorghum and Millet Innovation Lab's activities is based on a "bottom up" approach of identification of needs and priorities derived from stakeholders along the sorghum and millet value chains. A competitive call for proposals is used to identify the innovative research projects to address these national identified needs.

Specific technology packages are key outputs of each research proposal and the management entity will cultivate pathways to support uptake and scaling of technology packages that are at a Phase III, ready for scaling level. The technology catalog https://www.k-state.edu/smil/techcatalog/index.html features on our website technology packages at the Phase III level. Using a scaling tool, a scaling scan per technology package can be used to better assess the potential for scaling. This includes an assessment of areas such as technology practice, awareness/demand, business case, value chain integration,

finance, knowledge/skills, collaboration networks, evidence/learning level, leadership/management, and public sector governance.

Through strategic partnerships, the Lab management entity is leveraging multi-sectoral networks and collaborations as well as USAID investments to accelerate further scaling. This demand-driven approach ensures research relevance based on national needs which supports USAID's overarching aim to sustainably reduce global hunger, malnutrition, and poverty.

Human and institutional capacity development is an essential cross cutting component of the SMIL's theory of change. The Lab is building on the primary inputs into the innovation systems to include human capital in the form of stakeholders in product outcomes, trained and equipped research scientists, students, technicians, extensionists, technology transfer specialists; physical capital in the form of innovation centers, laboratories, farm and research station fields, other durable capital used to irrigate and cultivate fields, disposable supplies such as biochemical inputs, fuel and laboratory supplies, electricity, internet access and telephone. In addition, critical social capital found in producer groups and cooperative organizations contribute to familiarization, facilitation and adoption of technologies.

Performance Monitoring Plan and the Theory of Change

The Lab performance monitoring plan continues to provide overarching strategies for implementing the theory of change. In summary, the Lab is contributing towards the overall goal of sustainably reducing global hunger, malnutrition and poverty through the generation of innovative technologies that will be scaled along the sorghum and millet value chains as well as long-term human and institutional capacity development in agricultural research.

The management entity is playing an enabling role to develop and capacitate global research teams that implement projects that are fully integrated into the national-level research priorities. In addition to the long-term human and institutional capacity development outputs, technology packages are being generated which will become ready for uptake and scaling. The management entity is leveraging multi-sector collaborations and USAID investment to further scale these technologies.

Three key objectives of the program stated in the performance monitoring plan play a pivotal role to our theory of change:

I. *Build a coalition of science and industry around sorghum and millet where structure and opportunity can create entrepreneurial advances to reduce poverty and hunger.*

II. *Incubate and nurture a new wave of feed and food products to stimulate demand for sorghum and millet thereby extending economic benefits beyond the farmgate into the broader population.*

III. *Create an economically rationalized business and research investment plan to leverage USAID core financing and attract associate awards and broader donor support.*

The Lab's research program includes the areas of inquiry of genetic enhancement, production systems management, and value addition. Technology packages and human and institutional capacity are key outputs across these areas of inquiry.

All research projects support the key *Objective I*: *Build a coalition of science and industry around sorghum and millet where structure and opportunity can create entrepreneurial advances to reduce poverty and hunger,* which in turn is contributing to the program goal of *sustainably developing the capacity to create and disseminate innovations aligned to national plans and context.* Research projects are also contributing towards *objectives II and III* depending on their specific area of inquiry and integration of economic research.

Research project reports

Genetic improvement of sorghum for resistance to fungal pathogens

Led by
Dr. Tesfaye Mengiste
Purdue University - USA

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

Description
The overarching goal of this project is to improve the livelihood of sorghum farmers in the plant disease prone regions of Ethiopia by providing disease resistant and adapted varieties that also integrate other desirable traits. This project will build on scientific discoveries, disease resistant germplasm, and networks of collaborators established in the first phase, to deliver genotypes that integrate critical traits including wide adaptation, disease resistance and high yield potential. Resistant genotypes identified through multi-year and multi-location field trials in the first phase of this project are already incorporated into the breeding pipeline of the national and regional research institutes. Introgression of disease resistance genes into widely adapted elite materials that are deficient in diseases resistance genes is also underway. These parallel efforts will be accelerated to complete the development and release of regionally or nationally adapted varieties that integrate important traits. To support sorghum improvement in the project target region and beyond, strategic research that focuses on gene discovery and scientific advances will be conducted through genetic and genomics studies of unique resistant materials and populations we developed. Genetic resources such as adapted landraces, breeding lines and recombinant inbred populations harboring resistance to foliar and grain disease were identified and characterized. Genes underlying these traits will be identified to develop molecular marker to support improvement of the crop in Ethiopia and other countries with similar challenges. A collection of Ethiopian sorghum landrace population was partially characterized, and genotype information generated. Deep phenotyping and sequencing of a core representative set of landraces, defined on the bases of genomic data, will be conducted to serve as the main source of traits for future breeding and strategic research, and lay the foundation for genomics enabled breeding platform. Finally, the project will incorporate graduate education, short term training and knowledge enhancing workshops to strengthen the human and institutional capacity of local research institutions.

Theory of change and impact pathways
All research projects contribute towards *Objective I* of our theory of change, *Build a coalition of science and industry around sorghum and millet*. In addition, this project also supports *Objective II: Incubate and nurture a new wave of feed and food products to stimulate demand for sorghum and millet thereby extending economic benefits beyond the farmgate into the broader population*.

Collaborators

U.S. collaborating institution(s):	Purdue University, Kansas State University
Intl. collaborating institution(s):	*Ethiopia* - EIAR (Asosa Research Center, Bako Research Center), Oromia Agricultural Research Institute, Haramaya University

Achievements

An improved sorghum variety 'Marara' was released this year. This variety is a result of selection from the SMIL Ethiopian core collection and officially released in 2020. Demonstration and scaling up of the variety will be carried out in the coming cropping season. A representative core subset was developed that will facilitate access to and efficient utilization of germplasm. We found that genetic uniformity arising from recycling of parental sources in breeding programs is a bottleneck that can be overcome by genomic characterization of germplasm. A linkage disequilibrium decay pattern (r2 = 0.2) within 9 kb across the large sorghum landrace collection improves GWAS efficiency. Genome-environment association analyses revealed candidate genes associated with adaptive traits. A core subset of about 400 landrace lines were defined to capture the diversity of the Ethiopian collection based on genomic and phenotypic data. This collection was planted at Bako, Assosa, Jimma, Melkassa and Meiso research centers. A comprehensive data capture on various agronomic, disease and pest response traits will be conducted. Diseases resistant genotypes were selected based on multi-year and multi-location nurseries. These lines have become sources of disease resistance traits for the regional and national research institutions. Six of these lines with disease resistant traits, especially those with resistance to grain mold and other leaf diseases, were crossed to a polymorphic genotype to generate recombinant inbred populations. These populations will be advanced to the F6 generations. Anthracnose Resistance Genes (ARG2) and grain mold resistance loci completed. ARG2 encodes a CC-NBS-LRR resistance protein. We also identified seed proteins that contribute to grain mold resistance.

Capacity building

Individuals trained under this project include:

12	Haramaya University	Ph.D.	Plant pathology
39	Purdue University	Ph.D.	Plant pathology
80	EIAR, Assosa Research Center	Ph.D.	Plant pathology

Lessons learned

The need for back up plans when unexpected challenges emerge. The number of local staff at the regional research centers is limited to one or two people. In their absence due to attrition or study leave, programs suffer, and the transfer of research data, and research continuity becomes challenging.

Presentations and publications

Bayable, D. (January 2020). Sorghum ANTHRACNOSE RESISTANCE 2 Encodes an NBS-LRR Immune Receptor that Confers Race-specific Resistance. Presentation at PAG 2020, San Diego, California

Mengiste, T. (March 2020). Genetic Improvement of Sorghum for Resistance to Fungal Pathogens. Presentation at SMIL Administrative virtual meeting, Virtual

Tessema, G. G., Nida, H., Tirfessa, A., Lule, D., Bejiga, T. E, Seymoun, A., Mekonen M., Nega, A., Birhanu, C., Bekele, A., Gebreyohannes, A., Ayana, G., Tesso, T., Ejeta, G., Mengiste, T. (September 2020). A Comprehensive Phenotypic and Genomic Characterization of Ethiopian Sorghum Germplasm Defines Core Collection and Reveals Rich Genetic Potential in Adaptive Traits. Tesfaye Purdue. doi:DOI:10.1002/tpg2.20055

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

Led by
Dr. Gebisa Ejeta
Purdue University - USA

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

Description
Ethiopian sorghums have been a great source of novel genes and valuable traits for improving the sorghum crop worldwide. Modern sorghum breeders have heavily relied on the natural diversity in sorghum landraces in search of useful traits in advancing sorghum as a feed crop in major economies, particularly in the Americas and Australia. Unfortunately, sorghum improvement in Africa lags far behind the successes that the crop has enjoyed in these other geographies. It is possible that modern research advances made on sorghum improvement in these advanced economies may benefit current and future sorghum research efforts in Africa.

This project proposes to employ tools of biotechnology, breeding, and agronomy to unleash the potential of the crop for needy farmers. They will work as members of a team in developing a core-set of sorghum germplasm population to characterize the inherent variability through genotyping by sequencing. The team will couple that with phenotyping of valuable traits under target environments and treating data with appropriate bioinformatics and statistical procedures to identify useful allelic variations for drought and Striga resistance. They will develop local capacity and restore rigor and discipline to the Ethiopian sorghum breeding program to produce superior sorghum cultivars on a regular basis.

The project aims to develop a functional sorghum breeding program in Ethiopia focused on the development of adapted, high yielding sorghum hybrid cultivars for broad societal impact. They will promote the use of hybrid cultivars to strengthen the seed supply value chain and catalyze the development of a commercial sorghum seed enterprise system in the country. Building a commercial value chain system for sorghum in Africa is among the most badly needed investments in Africa.

Theory of change and impact pathways
All research projects contribute towards *Objective I* of our theory of change, *Build a coalition of science and industry around sorghum and millet*. In addition, this project also supports *Objective II: Incubate and nurture a new wave of feed and food products to stimulate demand for sorghum and millet thereby extending economic benefits beyond the farmgate into the broader population.*

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
Following the release of ESH5 sorghum hybrid in phase I, on-farm demonstrations and seed productions have been initiated in phase II. During this reporting period, ESH5 was demonstrated to farmers on a total of 124 demo plots in the three project regions (36 in Tigray, 38 in Amhara and 50 in Oromia). Since ESH5 is white seeded (which is preferred for good injera making) and has tall plant height compared to a previously released hybrid, farmers showed interest for this hybrid. Six quintals of seed of the hybrid was multiplied at Melkassa which has been distributed to the three regions (2 qt to Tigray, 1 qt to Oromia and 1.5 qt to Amhara) and a private sector (0.5 qt) which has been planted on 5 ha of land. Seeds

of the parental lines were also produced during the reporting period, which includes 123 kg of P9511A, 116 kg of P9511B. The R parent is being multiplied on an area of 0.25 ha at Melkassa while ESH5 hybrid seed is under multiplication in Tigray and Amhara regions. Engagement of a private company in production of ESH5 (currently as grain on 5 ha of land), farmers increased interest for the hybrid because of higher grain quality and preferred plant stature are some factors going to push this hybrid into potentially a wider adoption and appears to be one of the key achievements of the project. Additional hybrids are in development. Among the F1 hybrids, 50 hybrids of Ethiopian landrace B-lines (i.e 25 landrace B-lines crossed to the 2 testers) have been planted for evaluation along with their landrace parents and check cultivars at two locations (Melkassa and Mieso). This activity will generate the first level of evidence of heterotic values of the B landrace cross combinations with the tester lines.

A set of 200 landraces have been evaluated for resistance against the parasitic weed Striga at three locations in North-Western Ethiopia (Humera, Shiraro and Maiayni). The locations represent the most Striga prone environments in the country. Striga resistance data has been collected. A graduate student is enrolled at a local university to prepare a thesis entitled "Genetic analysis of a core collection of Ethiopian sorghum accessions and advanced backcross lines for Striga resistance in Northern Ethiopia." This activity will generate Striga resistant lines based on local germplasms (landraces). QTLs associated with resistance will be identified.

Capacity building

Individuals trained under this project include:

68	Purdue University	Post-doctoral	Plant genetics
44	Purdue University	Ph.D.	Plant breeding and pathology

Lessons learned

Presentations and publications

Ejeta, G. (March 2020). Genetic Enhancement of Sorghum to Promote Commercial Seed Supply and Grain Market Development. Presentation at SMIL Administrative virtual meeting, Virtual

Improving Sorghum Adaptation in West Africa with a Genomics-Enabled Breeding Network (SAWAGEN)

Led by
Dr. Geoffrey Morris
Kansas State University - USA

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

Description
Despite some important successes in sorghum breeding in West Africa, the overall impact of sorghum improvement has not yet met stakeholder expectations on varietal adoption, increased farm income, or improved nutritional status. SAWAGEN brings existing R&D capacity together into a network to regularly deliver sorghum varieties that are adapted to West African environments, adopted by smallholder farmers, and appreciated by value-chain actors.

The SAWAGEN network brings together NARS breeders, NARS researchers, international collaborators, and farmer organizations. To align missions and leverage expertise among diverse scientists and stakeholders, we use a goal-directed hypothesis-driven (GoHy) method for program planning and adaptive management. At the core of the network are four early-career NARS breeders in Senegal (ISRA), Burkina Faso (INERA), Togo (ITRA), and Niger (INRAN), who were trained in genomics-enabled breeding during phase-I (SMIL and/or WACCI).

SAWAGEN's top priority is to develop new versions of locally preferred varieties that carry stress-resilience traits by the project's end in 2023. Each NARS breeder has identified 2–3 product concepts that will be delivered to smallholders within a 5–10-year time frame. The varieties will be under testing in farmers' fields - in partnership with farmer organizations - by 2023. SAWAGEN's other major product is the R&D network itself, with four platforms designed to scale beyond the current participants and beyond the end of the project.

Varietal development will be carried out in the Local Adaptation Breeding Platform with marker-assisted backcross of known stress tolerance alleles into locally preferred varieties and participatory evaluation. The foundation for delivery of future products will be laid with the Broad Adaptation Breeding Platform (gender-responsiveness training, germplasm exchange, recurrent population development, multi-environment trials); the Genetic Mapping Research Platform (genome-wide marker discovery, genetic mapping, marker development); and the Physiological Mapping Research (trait discovery, trait validation, ideotype definition).

Theory of change and impact pathways
All research projects contribute towards *Objective I* of our theory of change, *Build a coalition of science and industry around sorghum and millet.* In addition this project also supports *Objective II: Incubate and nurture a new wave of feed and food products to stimulate demand for sorghum and millet thereby extending economic benefits beyond the farmgate into the broader population* as well as *Objective III: Create an economically rationalized business and research investment plan to leverage USAID core financing and attract associate awards and broader donor support.*

Collaborators

U.S. collaborating institution(s):	Kansas State University
Intl. collaborating institution(s):	*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)
Burkina Faso - Institut de l'Environnement et de Recherches Agricole (INERA)
Togo - Institut Togolais de Recherche Agronomique (ITRA)
France - Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD)

Achievements

True F1 genotypes from crosses between Nganda x B35, Faourou x B35, and Darou x B35 have been confirmed based on SSR genotyping at CERAAS. One and two KASP markers at Stg3a and Stg3B were confirmed to differentiate B35 allele from ISRA elite parental lines, respectively. A second set of 10 KASP markers at Stg3a and Stg3b loci were selected from ~1300 markers from the Generation Challenge Program (GCP) have been analyzed to test if markers differentiate the B35 donor allele from recurrent allele at Stg3a and Stg3b loci, using the same test plate that was sent to Intertek. Most of these 10 KASP markers were able to differentiate B35 allele from ISRA allele; therefore potential markers to use for marker-assisted selection. BC1F1 populations have been developed by ISRA breeding program and planted in the field. Marker selection will be applied by the end of September to select genotype with donor alleles. F1 genotypes from the crosse between Kapelga x B35 for post-flowering drought tolerance improvement in INERA program have been sent to CERAAS for verification/genotyping of true F1s. Analysis from the lysimeter experiment showed 12% to 30 % of phenotypic variances explained by botanical types in well water and water stress treatments in the subset of WASAP. GWAS was conducted. We observed water transpiration variability among the botanical types under water-stress treatment. The ongoing second experiment at ICRISAT Sadore is to test our hypothesis under which the lysimeter environment reflects the environment of the TPE in Niger. A set of 24 genotypes are being tested in the lysimeter and on station. Ten KASP markers were tested for the Striga backcross population at KSU and inbred genotypes from Niger. The markers selected were for Striga, sugarcane aphid, tannin, stay green genes. Data are now being analyzed. Each of the inbred parents in Niger will be selfed to keep track of seed purity and desirable trait in the genotypes.

Capacity building

Individuals trained under this project include:

70	Universite Abdou Moumouni Niamey	Master's	Crop Physiology
71	Universite Abdou Moumouni Niamey	Master's	Crop Physiology

Lessons learned

We found that drought response QTLs were explained by between 11 to 27% of phenotypic variance. Positive pleiotropic QTLs were found to exist among the identified QTLs. All four-known stay-green trait loci co-localized with drought response QTLs. We also found that the favorable allele of the lead SNP at each Stg locus is associated with high grain weight per plant under rain fed conditions. We need to establish a more broad and systemic review of GoHy for implementation and to garner feedback from end-users. Maturity6 was found to be the major gene controlling photoperiodic flowering in West African sorghum.

Presentations and publications

Falalou, H., Abdou, H., Inoussa, S., Ouba, M., Fanna, H., & Morris, G. (February 2020). Does Lysimeter Phenotyping Reflect Field Phenotyping in Niger? Poster presentation during regional Planning meeting at ICRISAT Bamako.

Morris, G. (March 2020). SAWAGEN: Improving Sorghum Adaptation in West Africa with a Genomics-Enabled Breeding Network. Presentation at SMIL Administrative virtual meeting, Virtual

Maina Assane Mamadou, F. (2020). Genomics-enabled breeding for sorghum in West Africa. Doctoral dissertation, Kansas State University. https://hdl.handle.net/2097/40866

Faye, J.M. (2020). Genomics-enabled breeding for sorghum improvement in sub-saharan Africa. Doctoral dissertation, Kansas State University. https://hdl.handle.net/2097/40870

Sorghum Trait Deployment Pipeline for Improved Food and Feed Value

Led by
Dr. Mitchell Tuinstra
Purdue University – USA

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

Description
This proposed project expands the team's sorghum crop improvement efforts through targeted research and technology transfer to promote and enhance sorghum production and nutritional value. Researchers have already identified allelic variation in genes that influence grain and forage quality; specifically, grain protein digestibility, modified starches that produce new functional food and nutritional attributes, and improved forage quality.

The Protein Digestibility Lab established in Senegal will serve as a hub of activity in West Africa for efforts to develop sorghum cultivars with improved post-cooking protein digestibility. As new varieties are developed, ISRA will engage with sorghum farmers and end-users to evaluate the bread-making and couscous-making qualities of grain produced using these varieties as well as their feed value in poultry rations.

A Forage Sorghum Breeding Program will be established at the INRAN Kollo Research Station. The bmr6 and bmr12 alleles will be used to develop new forage varieties in the El Mota and SEPON82 backgrounds. Hybrid forage varieties will be developed using locally adapted seed and pollinator parents. AN223 and selected A-lines from the breeding program will be crossed with elite forage and Sudangrass pollinators being developed at Purdue.

The crop development activities described in this proposal will produce new and unique sorghum varieties and hybrids with enhanced food- and feed-quality traits. Farmer participation during evaluation and selection of the best new varieties will promote acceptance and production of new cultivars. Researchers will also work with seed system specialists to encourage and enable seed production and distribution. Increased production and availability of high-quality seeds and grains will stimulate and support the development of new markets.

Theory of change and impact pathways
All research projects contribute towards *Objective I* of our theory of change, *Build a coalition of science and industry around sorghum and millet*. In addition this project also supports *Objective II: Incubate and nurture a new wave of feed and food products to stimulate demand for sorghum and millet thereby extending economic benefits beyond the farmgate into the broader population* as well as *Objective III: Create an economically rationalized business and research investment plan to leverage USAID core financing and attract associate awards and broader donor support.*

Collaborators

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

Achievements
Dr. Diatta is making great progress in advancing breeding populations selecting for the hl locus and other EMS mutations for highly digestible protein from SbEMS1613 and SbEMS33234. These mutations are being backcrossed into ISRA 621A, ISRA 621B, ISRA 622A, ISRA 622B as well as important seed and pollinator parent lines for hybrid variety development.

At Purdue, more than 200 new backcross progenies from these populations are being screened for protein digestibility. Forage quality is another key consideration in sorghum improvement for West Africa. Dr. Diakite is making great progress in establishing a laboratory for managing the sorghum breeding program in Niger. The breeding program is developing three different types of cultivars: improved sorghum varieties, dual-purpose varieties, and forage hybrids. Plant breeding activities are focused on crossing and backcrossing bmr6 and bmr12 into the well-adapted genotypes to improve forage digestibility characteristics. In 2020, the forage nursery and preliminary testing program was established in Kollo. Sorghum variety trials were established in Kollo, Konni, and Maradi with experiments testing more than 100 bmr6 and bmr12 entries. Hybrid varieties are also being developed with efforts including seed parent and pollinator parent development in nurseries planted at the INRAN facility in Niamey. These efforts are being backstopped by the forage breeding program at Purdue with development of new grain and Sudan pollinators as well as new seed parents for hybrid variety development.

Capacity building

Individuals trained under this project include:

73	University Cheikh Anta Diop	Master's	Plant and microbial biotechnology
79	University Cheikh Anta Diop	Master's	Plant and microbial biotechnology

Lessons learned

Efforts to enhance protein digestibility are progressing nicely. Four promising lines with good adaptation, food-grade quality, and highly digestible protein have been identified in multi-location trials. These lines were advanced to multi-location trials in year 2. Collaboration with ITA and industries (SEDIMA, NMA and Mamelles Jaboot) were initiated. One important lesson learned in 2019-20 was that fodder is as important as grain for farmers! Maintenance of the research equipment in the protein digestibility laboratory has been challenging. The forage breeding program in NIGER is making great progress developing OPVs and parent lines for hybrid seed production. Local farmers and animal producers have expressed great interest in the program because of persistent shortages in stover availability throughout the region.

Presentations and publications

Griebel, S., Westerman, R., Adeyanju, A., Addo-Quaye, C., Craig, B, Weil, C.F., Cunningham, S.M., Patel, B., Campanella, O.H., Tuinstra, M.R. (October 2019). Mutations in sorghum SBEIIb and SSIIa affect alkali spreading value, starch composition, thermal properties and flour viscosity (pp.3357–3374). Theoretical and Applied Genetics, 132, Switzerland. doi: https://doi.org/10.1007/s00122-019-03430-0

Tuintra, M. (March 2020). Sorghum Trait Deployment Pipeline for Improved Food and Feed Value. Presentation at SMIL Administrative virtual meeting, Virtual

Seedballs - Enhancing the yield effect in pearl millet and sorghum and disseminating the technology in West Africa

Led by
Dr. Ludger Herrmann
University of Hohenheim – Germany

Location (department level)
Niger - Aguie

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

The project builds on the previous activities in phase I to pursue 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 team continues to refine develop and dissemination of the seedball technology in Niger. The research component addresses application to sorghum and combination with other yield enhancing innovations (e.g. fertilizer-micro-dosing). The development aspect is focused on mechanization of the seedball construction process. Dissemination is based on collaboration with farmer federations (Fuma Gaskiya, Mooriben) in Niger. The latter is accompanied by a research component that surveys adoption pre-requisites and constraints.

Theory of change and impact pathways
All research projects contribute towards *Objective I* of our theory of change, *Build a coalition of science and industry around sorghum and millet*. In addition, this project also supports *Objective III: Create an economically rationalized business and research investment plan to leverage USAID core financing and attract associate awards and broader donor support.*

Collaborators
Intl. collaborating institution(s): *Niger* - INRAN, Fuma Gaskiya (farmer organization), FUGPN Mooriben (farmer organization)

Achievements
The reporting year was dominated by the novel Corona virus pandemic. Nevertheless, the project continued its activities in most work packages as planned. This is a great achievement mainly based on the performance of the national counterparts in Niger, namely INRAN, Fuma Gaskiya and Mooriben. The difficult meteorological conditions at the beginning of the 2020 season added to the problem. Nevertheless, progress was made on the distribution of the seedball technology. With respect to sorghum, on-farm testing started, though at a small scale. The mechanization of the seedball production could be raised to a level where a sufficient outcome could be achieved per time unit, sufficient seeds are present per ball, and germination rates, too, are sufficient. This was achieved by a semi-continuous process. Progress was made with respect to seedball technology application at the Mooriben site Falwel (Dosso region). Farmers reported some problems with the technology due to overdosing of the fertilizer (NPK) component. Also thinning appeared to be a problem, since it was conducted during dry phases. Hence further training is still mandatory. In particular, progress was made in human resource development and publications. One Ph.D. Student joined the University of Hohenheim for two months, received training on participatory research, and developed skills with respect to scientific writing. Two master theses started; one was already finalized. Two publications were submitted, one is already under revision. Pending is the seedball website.

Capacity building

Individuals trained under this project include:

54	University of Hohenheim	Post-Doctoral studies	Soil science/Agronomy
74	University of Hohenheim	Master's	Agritropics
81	University of Hohenheim	Master's	Agricultural Engineering

Lessons learned

The major lesson learned is that our local partners in Niger were able to perform the intended activities without major personal support from outside. Most of the planned activities could be conducted under difficult seasonal (lacking rain) and external (COVID-19 pandemic) conditions. This underlines the state of human resource development if long-term collaboration is enabled. Sorghum seedballs have shown their principle functioning but this needs to be verified on-farm. Collaboration with Mooriben in the Falwel region has better functioned in the 2020 season due to a better support from Dr. Oumarou. Seedball production mechanization is feasible. However, to produce the same quality of seedballs with respect to germination rates, a lot of care has to be invested into the production process. If that is achievable on-site, still needs to be validated.

Presentations and publications

Herrmann, L. (March 2020). Seedballs - Enhancing the yield effect in pearl millet and sorghum and disseminating the technology in West Africa. Presentation at SMIL Administrative virtual meeting, Virtual

Advancing improved functionality and protein quality sorghum hybrids for food applications in Ethiopia

Led by
Dr. Joseph Awika
Texas A&M University - USA

Location (department level)
Ethiopia – Sidama

Description
New sorghum hybrids under development combine high protein digestibility (HPD) mutation with waxy and heterowaxy (WX/HX) starch traits in hard endosperm show a lot of promise for various food applications due to superior functionality and improved protein nutritional quality. This project aims to advance the use of these new sorghums for food and nutrition security in Ethiopia. Based on the key findings from phase I, the research team proposes to: 1) Develop commercially viable technologies to successfully incorporate the improved sorghums in various food processes and products in Ethiopia; and 2) Establish improved HPD sorghum hybrid seed and grain production in Ethiopia. Based on phase I findings, researchers expect that the improved sorghum hybrids can be successfully incorporated in mainstream food processing value chain to produce commercially competitive products that meet quality expectations of a broad consumer base in Ethiopia. They also expect to demonstrate that the improved sorghum hybrids will compete favorably with local hybrids in both high input and low input environments in Ethiopia. This will likely lead to a more rapid incorporation of these hybrids into local sorghum breeding and seed production systems targeting specific market applications. Addressing these objectives will lead to development of commercially viable, superior quality sorghum-based food products that will open new markets and enhance sorghum value-chain. This will benefit small-scale farmers who dominate sorghum production, and small and medium scale food enterprises (SMEs) a large portion of which are female owned. Additionally, increased utilization of HPD-sorghums in local products would significantly contribute to reduced malnutrition in children from regions that rely on sorghum as a staple.

Theory of change and impact pathways
All research projects contribute towards *Objective I* of our theory of change, *Build a coalition of science and industry around sorghum and millet.* In addition, this project also supports *Objective II: Incubate and nurture a new wave of feed and food products to stimulate demand for sorghum and millet thereby extending economic benefits beyond the farmgate into the broader population.*

Collaborators
U.S. collaborating institution(s): Texas A&M University
Intl. collaborating institution(s): *Ethiopia* - Hawassa University, Ethiopian Institute of Agricultural Research (EIAR)

Achievements

Bulk grain (approx. 800 kg) of improved HD/Waxy sorghums (4 varieties) grown in Texas in 2019 was shipped to Hawassa University from Texas A&M University to be used in establishing standardized milling and processing methods. The Hawassa team characterized the quality attributes of these grains relative to local varieties that will be used for process comparisons. TAMU also completed pilot milling of these same samples and will ship the flour to Ethiopia for food processing. Pilot scale millers in Ethiopia with different types of mill (hammer, disk, and pin mill) were engaged, and will partner with us to evaluate the effect of milling method on the processing quality of improved sorghums once COVID-related restrictions in Ethiopia are eased. A total of 30 sorghum hybrids from TAMU grown in Ethiopia to check agronomic performance were harvested in November 2019 by EIAR and characterized for quality at Hawassa. The overall competitive performance of the TAMU lines relative to local hybrid checks was confirmed in Kobo and Miesso, Ethiopia. The best performing lines had yields on 4,100 – 5,850 kg/ha. The data confirms the improved HD hybrids are commercially viable in Ethiopia. Evaluation of the TAMU parental lines for hybrid seed production in Ethiopia was successfully initiated. Three hybrids were developed from A-lines crossed with R-lines in Melkassa, Ethiopia. In addition TAMU shipped a larger set (12 kg) of 3 HD hybrid parental lines (A,B,R) to EIAR in late summer of 2020. This was delayed due to COVID, and prolonged internet outage in Ethiopia due to social unrest. Consequently, the seed could not be planted this season. However, EIAR may plant the seed set using irrigation in the dry season of 2021.

Capacity building

One MS student has been recruited at Hawassa University; start of research was delayed due to COVID shutdown of the University. Another graduate student is undergoing training through project activities at EIAR. One Graduate student recruited at TAMU, initiated studies in the fall of 2020.

Lessons learned

The persistent global COVID pandemic has disrupted research activities and overall productivity beyond what we had imagined initially. Much of our work requires coordinated hands-on activities to execute, and remote engagements cannot compensate. However, we learnt to conserve resources and used the downtime to have infrastructure and facilities in place, ready to execute delayed tasks as soon as situation allows. We anticipate the next year will present a more positive outlook for both fieldwork and processing activities.

Presentations and publications

Olalekan J. Adebowale, John R.N. Taylor, Henriëtta L. de Kock, Stabilization of wholegrain sorghum flour and consequent potential improvement of food product sensory quality by microwave treatment of the kernels, LWT, Volume 132, 2020,109827, ISSN 0023-6438, https://doi.org/10.1016/j.lwt.2020.109827

Awika, J. (March 2020). Advancing improved functionality and protein quality sorghum hybrids for food applications in Ethiopia**.** Presentation at SMIL Administrative virtual meeting, Virtual

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

Led by
Dr. Bruce Hamaker
Purdue University – USA

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

Description
In Phase 2, the focus of this project will be on resilience of the Hub Food Innovation Centers as convergence points for product innovation and drivers of economic and nutritional impacts for Niger and Senegal. Hub Food Innovation Centers will be strengthened to better engage with entrepreneurs, improve their effectiveness as product development centers, and bolster their sustainability. Process and product innovation of millet and sorghum foods will be enhanced by expansion of "next level" product development tools including sensory science capacity, packaging, and shelf-life assessment. These tools will enhance their support for entrepreneurs and solidify INRAN and ITA as regional R&D centers. Activities will strengthen sensory science capacity at ITA Senegal to "raise the bar" of their product development capacity and establishing their potential as a regional center of development, will complete and optimize food processes and products begun in Phase I in Niamey and Dakar to include: 1) varietal optimization in traditional and new product concepts, 2) expanded product/process optimization to include packaging and shelf-life assessment, 3) training of candidate youth from local universities, 4) facilitate youth and existing women entrepreneur processors by allowing them to use the Hub processing facilities on a fee-basis, and market products. A study will be conducted to test the hypothesis that nutritional status improvement can be achieved in rural communities in Niger through introduction of low-cost fortified millet-based foods designed with local ingredients and aligned with documented preferences of local consumers. The Hub-and-Spoke Food Innovation System will test formulations developed from Phase I activities as well as develop new high quality, safe, and nutrient-enhanced millet products using local nutrient-dense plant ingredients for food-to-food fortification, and show if these locally produced products will gain a market and additionally be preferred to imported food-aid blends facilitating improved adoption by rural children in Niger.

Theory of change and impact pathways
All research projects contribute towards *Objective I* of our theory of change, *Build a coalition of science and industry around sorghum and millet.* In addition, this project also supports *Objective II: Incubate and nurture a new wave of feed and food products to stimulate demand for sorghum and millet thereby extending economic benefits beyond the farmgate into the broader population* and *Objective III: Create an economically rationalized business and research investment plan to leverage USAID core financing and attract associate awards and broader donor support.*

Collaborators

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

Achievements
The achievement of note in this period was the finding that the Niger rural Spoke Food Innovation Centers are now (2019) processing more of the nutrient-fortified millet-based flour blends than other millet products they make. The fortified flour blends, using simple roasting and milling technologies, were formulated and introduced in 2017 and training took place that year. They were also shown in a preference test with mothers to be preferred to food aid corn-soy+ and locally-made Misola millet-soy+ blends. Through working with local Health Centers and through rural radio broadcasts, the fortified blends have become the most popular millet products - selling a total volume in all 4 rural Centers in 2019 of

~6 metric tons at ~3,200,000 CFA (~5,300 USD). At the site in Falwel, a food-aid organization has contracted the group to process 3,000,000 CFA of fortified product in 2020. This is a part of our Hub-and-Spoke model of disseminating food and nutrition technologies to rural and urban entrepreneurs and is a joint project at the rural level between SMIL and the McKnight Foundation. Because the fortified products have been designed for local preferences, we postulate that there can be nutritional status improvement of young people in rural areas through this market-led nutrition approach. Other achievements in the period include the near completion in construction of the sensory laboratory at ITA/Dakar that, with certification training in sensory science scheduled for 2020, will position them to be a regional leader in this important activity in moving food processing technologies and products to the private sector and consumers. Progress was made in developing processes for new consumer-desired millet-based products in Niger and Senegal. In Senegal, Lactobacillus spp. have been identified for culturing for "economic" couscous. A market-study of extruded millet products in Niamey was completed showing consumer interest.

Capacity building

Individuals trained under this project include:

51	INRAN	Ph.D.	Food Science
58	Cheikh Anta Diop University/ITA	Ph.D.	Microbiology
75	University of Tillaberi	Master's	Nutrition
76	Cheikh Anta Diop University	Master's	Food Science and Technology
77	Cheikh Anta Diop University	Master's	Food Science and Technology
79	Cheikh Anta Diop University	Master's	Food Science and Nutrition

Lessons learned

The Hub-and-Spoke food innovation system is a promising model to get nutrition to rural children through making fortified foods that they really want to eat. At the same time, it drives entrepreneurism and empowers women, and we think also can be used to empower youth. This has been done with simple and cheap food processing technologies and has the potential to be scalable. In urban areas of Niamey and Dakar, extrusion processes and products have been developed, though this depends on cost effectiveness and feasibility to markets; in this regard an initial cost analysis was done, though this needs to be expanded to include a better idea of product pricing to understand their true market potential. This will be incorporated into our near-term work plan.

Presentations and publications

Debelo, H., Ndiaye, C., Kruger, J., Hamaker, B. R., & Ferruzzi, M. (November 2019). African Adansonia digitata fruit pulp (baobab) modifies provitamin A carotenoid bioaccessibility from composite pearl millet porridges(pp.1382-1392). Journal of Food Science and Technology, 57(4), New York, New York. doi:doi.org/10.1007/s13197-019-04173-y

Dieme, E., N'Diaye, C., Traore, D., & Seydi, M. (December 2019). Managing aflatoxin contents in cereals and their byproducts in Senegal. Presentation at Doctorials in Cheikh Anta Diop University, Diamniado

Hayes, A., Swackhamer, C., Mennah-Govela, Y., Martinez, M., Diatta, A., Bornhorst, G., & Hamaker, B. R. (January 2020). Pearl millet (Pennisetum glaucum) couscous breaks down faster than wheat couscous in the Human Gastric Simulator, though has slower starch hydrolysis(pp.111-122). Food & Function, 11, Cambridge, England. doi:DOI: 10.1039/c9fo01461f

Hamaker, B. (March 2020). Expanding markets for sorghum and millet farmers in West Africa through strengthening of women and youth processors and nutrition-based promotion of products. Presentation at SMIL Administrative virtual meeting, Virtual

Debelo, H., Corbin, S., Chegeni, M., Valacchi, G., & Ferruzzi, M. (June 2020). Repeated Exposure of Native African Adansonia Digitata (Baobab) and Moringa Oleifera (Moringa) Modifies Caco-2 Cell Differentiation but Not Carotenoid Absorption. Nutrition 2019, Baltimore, MD

Genetic Enhancement of Pearl Millet for Yield, Biotic and Abiotic Stress Tolerance in West Africa (GENMIL)

Led by
Dr. Ndjido Kane
Institut Sénégalais de Recherches Agricoles (ISRA)/CERAAS - Senegal

Location (department level)
Niger – Niamey
Senegal – Thies, Bambey

Description
Drought, diseases and insects are key constraints for millet production in West Africa. There is a recognized need for rapid advancement in the development of varieties addressing these constraints and taking into consideration farmer's practices and market acceptability. This project aims to accelerate the development of a combination of pearl millet (PM) innovations to put into farmers hands that at finite will result in sustainable productivity enhancement of PM for food security and income generation. Specific objectives are: i) modernizing INRAN and ISRA breeding program to deliver high-yielding PM cultivars that tolerate drought, Striga and downy mildew in Niger and Senegal; ii) assisting production with adapted and resilient farmer's practices and crop management strategies; iii) co-developing and up-scaling selected options of integrated genetic, natural resource management context to improve PM production; and iv) empowering human and institutional capacities.

The five-year research project (2019-2023) is compartmentalized to meet these 4 specific objectives, relying on series of activities and strategic criteria. A first criterion is dialogue between scientists and farmers and back-and-forth with end-users for a high rate of adoption of PM innovations. The activities around will consist of promoting adoption and advocating the uses and benefits of new PM technologies, within an innovative platform gathering actors of the value chain (stakeholders, private sector, farmer's organizations, extension services, scientists). Sharing material and knowledge will bring on germplasm originating from West Africa, from Niger and Senegal. Genetic materials either available or being developed will be shared between teams and research programs. Breeding Management System (BMS) will be used as standardize unique management and sharing resources (plant materials and data) system. Germplasm will be evaluated in both Senegal and Niger. Inter population improvement approach of reciprocal recurrent selection (RRS) method will be applied using selected populations to make use of both general and specific combining ability. Recent phenotyping and genotyping approaches will be conducted to evaluate the germplasm and identify/validate major quantitative traits loci (QTLs) for tolerance to drought, resistance to major biotic stresses in Senegal and Niger (complementary and co-working). Farming practices coping with diseases or ecologically intensifying production will be added into the breeding product profile (co-conceptualization). All identified elite cultivars will be integrated into local breeding programs (co-breeding) and evaluated on-farm for performance and farmer/market acceptability (scaling-up). Mentoring of early career research and continuous empowering of young trainees (PhD an MSc), farmers and seed producers will contribute to human and institutional capacity building needed to modernize sustainable PM breeding programs across the NARIs.

Theory of change and impact pathways
All research projects contribute towards *Objective I* of our theory of change, *Build a coalition of science and industry around sorghum and millet.* In addition this project also supports *Objective II: Incubate and nurture a new wave of feed and food products to stimulate demand for sorghum and millet thereby extending economic benefits beyond the farmgate into the broader population.*

Collaborators
U.S. collaborating institution(s): Kansas State University
Intl. collaborating institution(s): *Senegal* - Institut Sénégalais de Recherches Agricoles (ISRA), Centre d'Etudes Régional pour l'Amélioration de l'Adaptation à la Sécheresse (CERAAS)

Niger - International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Institut National de la Recherche Agronomique du Niger (INRAN)

Achievements

The project management team has taken into account new challenges during the implementation of the project, with the Covid-19 pandemic. Not knowing how this situation will evolve, priority has been given in implementing research activities where and when possible, in respect of local health and sanitary authorities' decisions. Whilst the in-person gatherings (focus groups, innovation platform workshops, and surveys) were canceled, reduced in size, or postponed, field and lab activities were carried out as planned. Monthly meetings are held monthly with ECR and team members as well as external partners in accordance with the schedule.

Capacity building

Individuals trained under this project include:

72	Kansas State University	Ph.D.	Plant breeding and genetics

Lessons learned

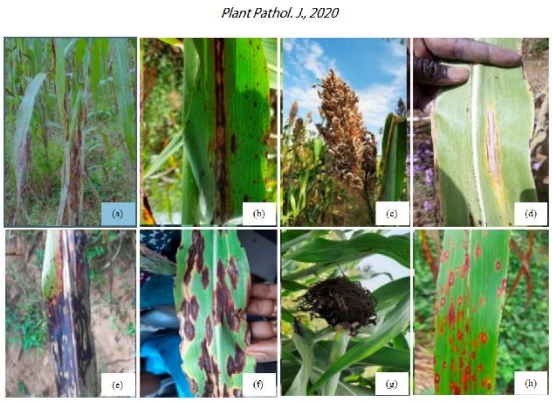
Pearl millet (PM) breeding programs are being empowered in TTMs and institutional capacities needed to conduct high quality research and training are being developed. PM product profiles are set and a minimum viable product has been identified (high yielding under dry environment). Consumer's preference for PM (new) products is gaining in popularity Farmers are using varieties/hybrids from INRAN, ISRA or ICRISAT. Stakeholders and the private sector ask for high yielding, micronutrients-rich varieties

Risk management actions and prioritizing lab work and field activities in the research station of ISRA have allowed continuity during the pandemic situation. This organization has proven its efficiency in this particular situation and is an asset.

Presentations and publications

Serba D.D. et al. (2020) Genomic Designing of Pearl Millet: A Resilient Crop for Arid and Semi-arid Environments. In: Kole C. (eds) Genomic Designing of Climate-Smart Cereal Crops. Springer, Cham. https://doi.org/10.1007/978-3-319-93381-8_6

Kane, N. (March 2020). Genetic Enhancement of Pearl Millet for Yield, Biotic and Abiotic Stress Tolerance in West Africa (GENMIL). Presentation at SMIL Administrative virtual meeting, Virtual



Enabling Marker Assisted Selection for Sorghum Disease Resistance in Senegal and Niger

Led by
Dr. Clint Magill
Texas A&M University - USA

Location (department level)
Niger – Niamey
Senegal – Thies, Bambey

Description
Research collaboration between Texas A&M, INRAN, and ISRA extended to include researchers at nearby Universities in Niger and Senegal will result in the identification or creation of disease resistant, locally adapted, sorghum cultivars that maintain properties preferred by farmers and consumers alike. Target diseases are anthracnose and long smut in Niger and anthracnose and grain mold in Senegal. The cultivar creation aspect will be derived from the ability to track resistance genes or quantitative trait loci (QTLs) with DNA-based tags that can be economically scored, in-country, through the development of allele-specific PCR primers at TAMU. Marker tagging will use Genome Wide Association studies to identify Single Nucleotide Polymorphisms (SNPs) derived from sources of genetic resistance identified in each country. F2 or later generation DNA samples from resistant and susceptible progeny of segregating crosses will identify markers associated with disease response. This technology will enable breeders to take advantage of marker assisted selection to greatly speed the development of cultivars with resistance to new races of the pathogens that are certain to occur over time. Publications in scientific journals will inform other scientists interested in sorghum pathology and genomics while demonstrations and interactions with local farmers unions, including sorghum growers, will showcase the value of growing disease resistant cultivars.

Theory of change and impact pathways
All research projects contribute towards *Objective I* of our theory of change, *Build a coalition of science and industry around sorghum and millet*. In addition this project also supports *Objective II: Incubate and nurture a new wave of feed and food products to stimulate demand for sorghum and millet thereby extending economic benefits beyond the farmgate into the broader population*.

Collaborators

U.S. collaborating institution(s):	Texas A&M University, USDA-ARS
Intl. collaborating institution(s):	*Senegal* - Institut Sénégalais de Recherches Agricoles (ISRA), Centre d'Etudes Régional pour l'Amélioration de l'Adaptation à la Sécheresse (CERAAS) *Niger* - Institut National de la Recherche Agronomique du Niger (INRAN), University of Tillaberi

Achievements
Disease surveys conducted by Dr. Louis Prom and in-country colleagues were conducted in 120 farmers' fields across the primary growing areas in Niger and 206 fields across Senegal. In Niger, 21 different diseases were found and 15 were identified in Senegal, but the survey was made before grain mold scoring was possible. GPS coordinates were taken for each field surveyed and 'hot spots' for many of the diseases were identified in both countries. An important observation in Senegal was that many local cultivars appeared to be resistant to anthracnose, but that leaf blight was present at high levels in all areas. Seeds from potential resistant cultivars have been collected for use in further tests, and leaf samples for isolation of pure samples of the pathogens were collected. In Senegal about 160 isolates of Colletotrichum sublineolum, the anthracnose pathogen, have been purified for use in race identification on host differential and for phylogeny analysis based on DNA sequencing to be conducted in the US. In Niger, the standard host differentials for anthracnose were tested for resistance or susceptibility to other diseases. Cultivar SC748-5 that has single gene resistance to all common

pathotypes in the US was found to be susceptible to 3 common diseases. In the US, a subset of the Senegalese cultivars in the USDA Sorghum collection were tested under optimal greenhouse conditions for response to a mix of spores the pathotypes that are prevalent in Texas.

Crosses between anthracnose resistant and susceptible cultivars have been advance to the F2 generation in Niger and have been made in Senegal. Pure cultures of pathogens are being prepared that can be shipped in fixative (95% ETOH) to the US for DNA extraction, identification via ITS sequencing and for diversity analysis. Seeds from selected lines from each country have been or are being sent to Dr. Prom so he can evaluate their response to Texas isolates. Attempts to identify races of Colletotrichum sublineola based on standard host differentials led to mixed success.

Capacity building

Individuals trained under this project include:

69	University of Tillaberi	Master's	Plant Pathology/Plant Breeding

Lessons learned

There are many foliar diseases affecting production of sorghum in Niger and Senegal. It is difficult to assess crop losses due to each disease, although anthracnose for the most part seems to be the most destructive. However, leaf blight is very wide spread and needs to be considered as we go forward. Grain mold assessments will need more mature plants, so perhaps the next survey should be done later. It took a lot longer to get graduate students recruited and accepted in the US and Africa to work on the project than was anticipated. Travel approvals for, and reimbursement to Dr. Prom, a USDA scientist traveling with their permission were especially difficult, in part because of TAMU system rules for paying travel for a non-employee.

The global epidemic of a virus has greatly impacted our project. Not only did it prevent the annual gathering in Ethiopia, it also prevented Coumba Fall, a student accepted by the Plant Pathology program at Texas A&M to begin her Ph.D. program. For some time, the travel lockdown prevented travel even to field sites or gatherings of farmers for educational purposes. On the positive side, we have learned to communicate using ZOOM technology which provides a more personally satisfying platform than just using e-mail.

Presentations and publications

Prom, L., Haougui, A., Adamou, I., Abdoulaye, A. A., Karimou, I., Bibati, A. O., & Magill, C. (February 2020). Survey of the Prevalence and Incidence of Foliar and Panicle Diseases of Sorghum Across Production Fields in Niger(pp.106-113). Plant Pathology Journal, 2020(19), online, open access. doi:DOI: 10.3923/ppj.2020.

Prom, L., Haougui, A., Adamou, I., Abdoulaye, A. A., Karimou, I., ALI, O. B., & Magill, C. (March 2020). Response of the Set of Anthracnose Differentials to other Foliar and Panicle Diseases in Niger(pp.1-4). Journal of Agriculture and Crops, 6(1), Science Web Publishing, Online Open Access. doi: https://doi.org/10.32861/jac.61.1.4

Magill, C. (March 2020). Enabling Marker Assisted Selection for Sorghum Disease Resistance in Senegal and Niger. Presentation at SMIL Administrative virtual meeting, Virtual

Associate award project reports

FTFIL for Genomics-Assisted Sorghum Breeding

Award number: AID-OAA-LA-16-00003

(Led by Dr. Geoffrey Morris – Kansas State University, Dr. Gael Pressoir – CHIBAS, and Dr. Ed Buckler – Cornell University)

Description

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

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

Theory of change and impact pathways

All research projects contribute towards *Objective I* of our theory of change, *Build a coalition of science and industry around sorghum and millet*. In addition this project also supports *Objective III: Create an economically rationalized business and research investment plan to leverage USAID core financing and attract associate awards and broader donor support.*

Collaborators

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

Achievements

We ran two cycles of genomic selection (GS), including one that happened in the middle of the COVID-19 pandemic. We established a consistent genotyping method for future GS cycles, and published a paper using data generated from this project in March of this year. The results of this study were presented at the international Plant and Animal Genome conference in January 2020, during a session holding up to 600 attendees.

Capacity building

Individuals trained under this project include:

67	Cornell University	Ph.D.	Plant breeding and genetics

Lessons learned

During the last (fifth) cycle of genomic selection (June 2020), a series of tests were developed to check the quality of the plant samples, the DNA profiling data, and the data analysis. After such tests, we identified a source of contamination which would have otherwise been detrimental to the accuracy of our predictions. The "checklist" we developed will be useful in future selection cycles to avoid losses in accuracy.

Presentations and publications

Jensen, S.E., Charles, J.R., Kebede, M., Bradbury, P.J., Casstevens, T., Deshpande, S.P., Gore, M.A. *et al.* (2020) A sorghum practical haplotype graph facilitates genome-wide imputation and cost-effective genomic prediction(pp.20009). The Plant Genome, 2, Madison, WI, USA. doi:https://doi.org/10.1002/tpg2.20009

Other publications from Phase I Projects

Karimoune, L., Ba, M.N., Baoua, I.B. *et al.* Field performance of the parasitoid wasp, *Trichogrammatoidea armigera* (Hymenoptera: Trichogrammatidae) following releases against the millet head miner, *Heliocheilus albipunctella* (Lepidoptera: Noctuidae) in the Sahel. *BioControl* **65,** 389–399 (2020). https://doi.org/10.1007/s10526-020-10015-0

Duressa, D, Bean, S, Amand, PS, Tesso, T. Identification of variant α-kafirin alleles associated with protein digestibility in grain sorghum. *Crop Science*. 2020; 60: 2467– 2478. https://doi.org/10.1002/csc2.20198

Serba, D.D., Muleta, K.T., St. Amand, P., Bernardo, A., Bai, G., Perumal, R. and Bashir, E. (November 2019), Genetic Diversity, Population Structure, and Linkage Disequilibrium of Pearl Millet. The Plant Genome, 12: 1-12 180091. doi:10.3835/plantgenome2018.11.0091

Human and Institutional Capacity Development

Human and institutional capacity development continues to be prioritized in the Sorghum and Millet Innovation Lab as it enters the third year of its second phase of research activities. Most long-term trainees from the first phase have completed their degrees and are contributing to research community as they establish their own research for development programs. New long-term trainees are being added to the ranks with the continuation of research projects, while short-term trainings continue despite the challenges because of COVID-19. The Lab maintains its focus on the development of institutions and capacity – particularly among NARS – to set their own priorities and drive solutions.

Short-term training

FY 2020 was a difficult year due to COVID-19 pandemic, so the numbers of short-term trainings were lower than targeted. In FY 2020, the Lab facilitated the short-term training of 1390 individuals across 12 different training events. The types of short-term trainings conducted varied, and included farmer trainings, professional workshops, on-the-job capacity-building exercises and academic courses.

Of the 1390 trainees, producers made up the largest group with 1297 trained, followed by 47 people in government, 33 people in private sector firms and 13 civil society members (predominantly researchers and students). Of the total trainees, 558 were female and 832 were male, demonstrating a concerted effort to target women in the training process and achieve better gender equity.

Table 1. Short-term trainees supported by the Sorghum and Millet Innovation Lab – FY 2020

Country of Training	Purpose of Training	Who was trained	Number trained		
			M	F	Total
Burkina Faso	This training was about the implication of gender in breeding activities	Producers: 36	22	14	36
Burkina Faso	Statistical analysis: Initiation of Sorghum Team to R software	Government: 18	15	3	18
Niger	Project review and co-PI mentoring: The goal of this meeting was to provide mentoring about technical sorghum breeding issues and brainstorming of new research ideas.	Civil Society: 1	1	0	1
Niger	The objective was to make technicians and animators familiar with the seedball technology. Participants were orally introduced into the technology followed by a hands-on training. Per site a one-day training took place.	Producers: 1150	700	450	1150
Niger	Meeting of the SMIL Sorghum Pathology team and INRAN: The objective was to take stock of the execution of project activities.	Government: 6	5	1	6

Niger	Sensitization and training of producers and their extension workers involved in the project	Producers: 6 Government: 10	15	1	16
Niger	Workshop on participatory breeding and seed ball technology	Producers: 60 Government: 2 Private Sector: 2 Civil Society: 10	49	25	74
Niger	Training of Niamey women processors, members of the INRAN Hub processor association, on nutritional foods and fortification; and members of the rural Spoke Food Innovation Centers in Niger on data analysis, organization, and presentation	Government: 5 Private Sector: 25	2	28	30
Niger	Capacity building training on digital application for data collection on market and nutrition components using smartphones	Producers: 12 Government: 3	2	13	15
Niger	Determination of production cost factors for millet and sorghum extruded products	Producers: 3 Government: 3 Private Sector: 6 Civil Society: 1	4	9	13
Senegal	Project review and co-PI mentoring: The goal of this meeting was to provide mentoring about technical sorghum breeding issues and brainstorming of new research ideas.	Civil Society: 1	0	1	1
Uganda	The main objective of this training is to examine the gendered trait preferences for new striga resistant sorghum genotypes development that will be easily adopted by the farming community	Producers: 30	18	12	30

Long-term training

In FY 2020, the Sorghum and Millet Innovation Lab saw several long-term training programs initiated in Phase I come to an end. A total of 81 long-term trainees will be completed in Phase I and early Phase II combined. A handful number of trainees from Phase I will complete their program in December 2020 and May 2021.

Among those 81 trainees, 57 are male and 24 are female. The group also represents a variety of degree levels with 2 agricultural engineers, 5 bachelor's degrees, 40 master's degrees, 32 Ph.Ds. and 2 post-doc.

Table 2. Long term trainees supported by the Sorghum and Millet Innovation Lab – FY 2020 (Phase II)

Trainee number	Sex	University	Degree	Major	Graduation date	Degree granted?	Home Country
1	Male	Universite Prive de Segou Agri SUP	Bachelor's	Agronomy	Dec-18	Yes	Mali
2	Male	INRAN	Bachelor's	Agronomy	Nov-17	Yes	Niger
3	Female	CERAAS	Bachelor's	Agronomy	Jan-17	Yes	Niger
4	Male	ICRISAT – Niger	Bachelor's	Ecophysiology	Dec-18	Yes	Niger
5	Female	CERAAS	Bachelor's	Agronomy	Jan-17	Yes – Pursuing Master's degree at University Cheikh Anta Diop	Senegal
6	Male	ISFAR/University of Thies	Engineer	Agricultural Engineering	Jul-17	Yes – on an internship with an agricultural entreprise	Senegal
7	Female	ISFAR/University of Thies	Engineer	Agricultural Engineering	Jul-16	Yes – has been recruited by agricultural firm, SODAGRI	Senegal
8	Male	University of Ouagadougou	Master's	Breeding and conservation of seed	Apr-17	Yes	Burkina Faso
9	Female	INERA	Master's	Seed selection and conservation (SELCOSE)	Dec-15	Bachelor's granted, now working on Master's	Burkina Faso
10	Male	Hawassa University	Master's	Food science and postharvest technology	Dec-18	Yes	Ethiopia
11	Female	Haramaya University	Master's	Plant pathology/breeding	May-18	Yes	Ethiopia
13	Male	Kansas State University	Master's	Agricultural Economics	May-18	Yes - now pursuing Ph.D. at Kansas State University	Ethiopia
14	Male	CHIBAS	Master's	Genetics	Nov-17	Yes	Haiti
15	Male	INRAN	Master's	Socio-economy	Jan-18	Yes	Niger
16	Male	Université Abdou Moumouni de Niamey	Master's	Entomology	Jan-18	Yes	Niger
17	Male	Universite Dan Dicko Dankoulodo	Master's	Agronomy	Dec-17	Yes	Niger
18	Male	Université Abdou Moumouni de Niamey	Master's	Entomology	Jan-18	Yes	Niger
19	Male	University of Tahoua	Master's	Socio-economy	Dec-17	Yes	Niger
20	Male	Ecole National Superieure d'Agriculture (ENSA)	Master's	Production Végétales	Jan-16	Yes – currently farming but awaiting near-term appointment from national research program	Senegal
21	Male	ENSA Thies	Master's	Socio-economy	Dec-17	Yes	Senegal
22	Female	ITA	Master's	Agricultural Economics	May-16	Yes	Senegal

23	Male	CERAAS	Master's	Microbial and vegetal biotechnology	Sep-17	Yes	Senegal
24	Male	University Cheikh Anta Diop	Master's	Pest Management	May-17	Yes – on an internship with AGRA; looking for Ph.D. funding	Senegal
25	Female	ENSA/University of Thies	Master's	Sustainable development and society/agriculture	Aug-17	Yes – searching for Ph.D. funding	Senegal
26	Male	University of Thies	Master's	Agricultural engineering	Apr-17	Yes	Senegal
27	Male	Universite de Thies	Master's	Agricultural Economics	2017	Yes – works as consultant to NGO Terre des Hommes and on East African Media Lab project	Senegal
28	Male	CERAAS	Master's	Breeding	Apr-16	Yes – currently applying to DADD fellowship program for Ph.D.	Côte d'Ivoire
29	Male	Haramaya University	Master's	Plant pathology/breeding	Dec-15	Yes – works for BAKO Research Center at Oromia Research Institute	Ethiopia
30	Female	Hawassa University	Master's	Food Processing and Preservation	Mar-17	Yes – now employed at a private company	Ethiopia
31	Male	Haramaya University	Master's	Agronomy	Jul-16	Yes - now working for Oromia Agricultural Research Institute, Fedis Research Center	Ethiopia
32	Female	Abdou Moumouni University of Niamey with Short Training at Virginia Tech	Master's	Agricultural Economics	Jan-18	Yes	Niger
33	Female	University Cheikh Anta Diop	Master's	Pest management	Dec-15	Yes – recruited by agricultural enterprise	Senegal
34	Male	ISRA	Master's	Agroforestry ecology and adaptation	Nov-18	Yes	Senegal
35	Female	ISRA	Master's	Analytical Chemistry	Jul-18	Yes - under consideration for a Ph.D., in training at biochemistry lab at CERAAS	Senegal
36	Male	Virginia Tech	Master's	Agricultural Economics	May-16	Yes – works (volunteers) for U.S. Peace Corps in the Philippines	United States
69	Male	University of Tillaberi	Master's	Plant Pathology/Plant Breeding	May-21	No	Niger
70	Male	Universite Abdou Moumouni Niamey	Master's	Crop Physiology	April-20	Yes – Continuing PhD studies at University of Niamey	Niger
71	Male	Universite Abdou Moumouni Niamey	Master's	Crop Physiology	Dec-19	Yes – Continuing PhD studies at University of Niamey	Niger
73	Female	University Cheikh Anta Diop	Master's	Plant and microbial biotechnology	Oct-20	No	Senegal
74	Male	University of Hohenheim	Master's	Agritropics	Jul-20	Yes	United States
75	Male	University of Tillaberi Cheikh Anta Diop	Master's	Nutrition	Jun-21	No	Niger
76	Male	University of Tillaberi Cheikh Anta Diop	Master's	Food Science and Technology	Dec-21	No	Senegal
77	Male	University of Tillaberi Cheikh Anta Diop	Master's	Food Science and Technology	Jul-21	No	Senegal

78	Male	University of Tillaberi Cheikh Anta Diop	Master's	Food Science and Technology	Dec-21	No	Senegal
79	Male	University Cheikh Anta Diop	Master's	Plant and microbial biotechnology	Oct-20	No	Senegal
81	Male	University of Hohenheim	Master's	Agricultural Engineering	Aug-20	No	Germany
12	Male	Haramaya University	Ph.D.	Plant pathology/breeding	Oct-23	No – former sponsored Master's student	Ethiopia
37	Male	Kansas State University	Ph.D.	Agricultural Economics	Jul-18	Yes - working at the FAO	Burkina Faso
38	Male	Purdue University	Ph.D.	Plant breeding and genetics	1-May-19	Yes	China
39	Male	Purdue University	Ph.D.	Plant pathology	May-20	No	Ethiopia
40	Male	Kansas State University	Ph.D.	Plant breeding and genetics	Dec-19	No	Ethiopia
41	Male	Kansas State University	Ph.D.	Plant pathology/breeding	Dec-20	No	Ethiopia
42	Female	Purdue University	Ph.D.	Food science	Aug-18	Yes - working as a post-doc at North Carolina State University	Ethiopia
43	Male	University of Pretoria	Ph.D.	Food Science	Jul-18	Yes - working at Hawassa University	Ethiopia
44	Male	Purdue University	Ph.D.	Plant breeding and pathology	May-21	No	Ethiopia
45	Male	Texas A&M	Ph.D.	Food Science	Dec-18	Yes - working at Hawassa University	Ethiopia
46	Female	Purdue University	Ph.D.	Agronomy	Dec-18	Yes	Germany
47	Male	University of Maradi	Ph.D.	Entomology	Jul-20	Yes - Scientist at INRAN-Niger	Niger
48	Male	West Texas A&M University	Ph.D.	Plant, Soil and Environmental Science - Insect Pest Management	May-19	Yes - working at INRAN	Niger
49	Male	ICRISAT – Niger	Ph.D.	Entomology	Nov-20	Yes - Senior Research technician at ICRISAT-Niger	Niger
50	Female	Kansas State University	Ph.D.	Agronomy (Plant Breeding & Genetics)	May-20	Yes – Working at INRAN	Niger
51	Male	INRAN	Ph.D.	Food Science	Dec-19	Yes	Niger
52	Male	West African Center for Crop Improvement	Ph.D.	Plant Breeding	May-19	Yes - working at INRAN	Niger
53	Female	INRAN	Ph.D.	Agronomy/Soil science	Feb-19	Yes	Niger
55	Male	Kansas State University	Ph.D.	Plant breeding and genetics	Dec-17	Yes - currently a crop genetics post-doc at the University of Illinois	Nigeria
56	Male	CERAAS	Ph.D.	Plant breeding and genetics	Dec-19	Yes - working at CERAAS	Senegal
57	Female	West African Center for Crop Improvement	Ph.D.	Plant Breeding	Jul-19	Yes - working for ISRA/CERAAS on Sorghum Trait Development Pipeline	Senegal
58	Male	Cheikh Anta Diop University/ITA	Ph.D.	Microbiology	Sept-23	No	Senegal
59	Female	Cheikh Anta Diop University	Ph.D.	Food Science and Nutrition	Jul-18	Yes	Senegal
60	Male	Kansas State University	Ph.D.	Agronomy (Plant Breeding & Genetics)	May-20	Yes – Working at CERAAS	Senegal

61	Female	University Cheikh Anta Diop	Ph.D.	Entomology	Dec-17	Yes	Senegal
62	Female	University of Thies	Ph.D.	Pest management	Dec-17	Yes	Senegal
63	Female	University Cheikh Anta Diop	Ph.D.	Pest management	Dec-17	Yes	Senegal
64	Male	CERAAS	Ph.D.	Agronomy (Breeding & Genetics)	Jan-18	Yes - working at ITRA in Togo	Togo
65	Male	Purdue University	Ph.D.	Plant Genetics	May-16	Yes – works at Makerere University in Uganda	Uganda
66	Female	Purdue University	Ph.D.	Food Science and Nutrition	Aug-19	Yes	USA
67	Female	Cornell University	Ph.D.	Plant breeding and genetics	Aug-21	No	USA
72	Female	Kansas State University	Ph.D.	Plant Breeding and Genetics	May-24	No	Senegal
80	Male	EIAR, Assosa Research center	Ph.D.	Plant Pathology	Sep-22	No	Ethiopia
54	Male	University of Hohenheim	Post-doctoral studies	Soil Science/Agronomy	Sept-22	Former PhD sponsored - working as post-doc at University of Hohenheim	Nigeria
68	Male	Purdue University	Post-doctoral Studies	Plant Genetics	Jun-17	Yes	Nigeria

Institutional development

The COVID-19 pandemic affected institutional development activities in two dimensions. In the first half of the year, the lab supported the development of all three-focus country NARS through capacity reinforcement as they evolved. In Niger, this was accelerated by the return of the country coordinator who completed Ph.D. training. In Senegal, it occurred through the support of CERRAS' agenda to develop broader funding support for their activities by leveraging phase I and phase II investment. At ITA, the development of the sensory laboratory and the training of key personnel is nearly complete. In Ethiopia, the Management Entity interacted with EIAR leadership at the Melkassa station (and again with leadership at the headquarters) to reaffirm our support of decentralized research systems as the station sees the repopulation of research capacity with Ph.D. trained scientists.

As the COVID-19 pandemic became established, we pivoted our institutional support to focus on preparing collaborators to research disruptions and offering to reorient funding to support activities and expenses to mitigate the effects of the pandemic. As a short-term response we reallocated funding towards ensuring the personal protective equipment was made available to all researchers and reiterated that national policies, aimed at reducing the transmission of the virus, were followed. Secondly each program was approached to determine whether funding could be reoriented to upgrade internet connectivity. Collectively, the program adjusted to these challenges in a constructive manner.

Programmatic activities have largely progressed, but the second important reorientation is that interactive activities between investigators on differing continents can be very fruitful without face-to-face interaction. Videoconferencing is largely productive despite intermittent outages of service. Our goal is to use this learning to institutionalize distance collaboration much in the same manner that synchronous distance learning is embraced by educational systems. We believe that this is an important finding from adapting to the challenges posed by COVID-19 and will integrates this into our long-term communication strategy.

Innovation transfer and scaling partnerships

The Sorghum and Millet Innovation Lab (SMIL) continues to support technology development, transfer and scaling of all technologies that are successfully developed through the various phases of research, field-testing and initial dissemination. The SMIL has also been invited to be formal partners with several consortiums bidding on large agricultural development proposals in West Africa in response to USAID RFAs. A successful consortium bid would further ensure a strong mechanism and platform for scaling of SMIL/USAID funded technologies.

Phase 3 technologies (Made available for transfer)

1. Technology: Mass rearing of parasitoids for biological control

Category: Management practices
Area of inquiry: Production systems management
Description: Results indicated that adding 50% cowpea floor to the millet diet enhance mass production of parasitoids. With a starting number of 25 C. cephalonica larvae kept for a three-month rearing period, the improved diet will produce 2.68 million larvae and 10 million H. hebetor adult parasitoids.
Partnerships made: None at this time
Next steps: The new formula will be shared with the farmer cooperatives for uses in the parasitoid production

Target countries: Senegal and Niger

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

Category: Management practices
Area of inquiry: Production systems management
Description: It was determined that the release of 800 parasitoids per 3km radius in the early panicle stage of the crop give a good level of control of the head miner. The 800 parasitoids correspond to 12 parasitoid bags, this will reduce the current numbers by (20%) for 3km radius. Given the current price of $3.34/bag, a saving of $10 is expected per each release. Progress was made in the identification of numbers of H. hebtor adults needed per acreage of pearl millet for controlling the millet head miner.
Partnerships made: The technology has been transferred to farmer cooperatives in Niger
Next steps: Discuss with donors and USAID value chain projects to support the dissemination

Target countries: Senegal and Niger

3. Technology: Hybrids for commercial sorghum seed industry

Category: Biological
Area of inquiry: Genetic enhancement
Description: White sorghum hybrids P9511A/PRL020817 (K9058) registered and released with 5.76 t/ha yield performance for use in lowland growing areas of Ethiopia.
Partnerships made: Collaboration with the Ethiopian Seed Enterprise (ESE), Regional Seed Enterprise (RSE), and private farms have been developed to support seed multiplication.

Next steps: Approximately five tons of hybrid seed have been distributed to dry lowland growing areas for small and large demonstrations. Regional and private seed producers were involved in the production of certified seed.

Target country: Ethiopia

4. *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); INRAN – Niamey, Niger
FY 2019 progress made: The seedball technology is physically and chemically optimized for hand production and ready for dissemination. A technical sheet was provided.
Next steps: Field testing has shown that the technology works using materials from different locations and independently from other factors like soils or gender. Now the technology needs to be tested under real world conditions, i.e. applying other yield enhancing management techniques that are usually applied by farmers and distributed to other Sahelian areas, where applicable.

Target countries: Senegal and Niger

5. *Technology: Registered germplasm with sugarcane aphid resistance for global use*

Category: Biological
Area of inquiry: Genetic enhancement
Description: Registration of RTx3410 through RTx3428 sorghum germplasm resistant to sugar cane aphid.
Partnerships made: Partnerships have been established with several US based seed companies who will introduce this germplasm in their breeding programs.
Target countries: Global

Phase 2 technologies (Under Field Testing)

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

Category: Mechanical and physical
Area of inquiry: Production systems management
Description: Men will only invest in seedball technology if working time demand is relatively low. Therefore, a mechanical device was constructed that can serve interested men as well as small local seed enterprises. The device allows for a throughput of several thousand seedballs per hour at medium (in the local sense) investment costs.
Partnerships made: Fleischle GBR, Vaihingen Enz, Germany
FY 2019 progress made: A mechanical option was developed and tested but failed to be time-efficient, i.e. the seedball product was standardized but the mechanical tool did not reduce workload.
Next steps: The mechanization option has shown to work under farmers' condition. However, local craftsmen were not able to copy it. It appears unlikely that the technology presented is worth investment. Much higher throughput per time is requested that can only be achieved by a motorized and more automated technology as used e.g. by Fleischle GBR. At the time being, independent efforts to mechanize seedball production are underway: https://seedtheglobe.com/en/platform.html.

Target country: Niger

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

Category: Mechanical and physical
Area of inquiry: Production systems management
Description: The technology is based on an easy-to-construct frame that produces about 80 seedballs in one batch. It is designed particularly for women with low investment capital that need to sow more than a home garden surface.
Partnerships made: Fleischle GBR, Vaihingen Enz, Germany
FY 2019 progress made: A mechanical option was provided but failed to be time efficient. The seedball product was standardized but workload was not significantly lower.
Next steps: The mechanization option has shown to work under farmers' condition. However, local craftsmen were not able to copy it. So modifications need to be developed with craftsmen and farmers together, also in order to increase productivity. The presented tool did not sufficiently reduce working time needed in comparison to hand-made seedballs.

Target country: Niger

3. *Pre-release of two new high yielding multipurpose Melanaphis resistant varieties for Haiti*

Category: Biological
Area of inquiry: Genetic enhancement
Description: Two new varieties are being pre-released by Chibas for participatory evaluation with selected growers before complete release (expected at the end of 2019). These 2 inbreds have been part of the extensive phenotyping and genotyping of all of Chibas's inbreds carried with support of the USAID-SMIL project. Both showed the highest breeding value with genomic prediction and broad adaptation under the 11 environments in which the varieties have been evaluated under the USAID-SMIL grant/project.
Partnerships made: Prof Patrice Dion, Département de phytologie – IBIS, Université Laval - Canada
National Seed System, Ministry of Agriculture, Natural Resources and Rural Development - Haiti
Next steps: These varieties are now moving to production of "breeders' seed" so that in the 2 seasons of 2019 (spring and autumn) they can be evaluated by participating farmers (participatory evaluation) before complete release (expected late 2019 or early 2020). Registration process is being initiated with the National Seed System (SNS) of the Ministry of Agriculture for these 2 varieties.

Target countries: Haiti

4. *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: Purdue University, Moribeen/Western Niger (Tillabery and Dosso) and Fuma Gaskiya/Eastern Niger (Maradi), McKnight Foundation, ISRA, CNRA, INRAN
Next steps: Continue testing on the products for nutrient delivery efficiency as well as product consumer feedback

Target countries: Senegal and Niger

5. *Technology: Improved sorghum variety*

Category: Biological
Area of inquiry: Genetic Enhancement
Description: An improved sorghum variety named Marara (ETSL 101371 (Acc. 212642)) has been officially released in Ethiopia with increased yield and disease resistant characteristics.
Partnerships made: Oromia Ag. Research Institute, Bako Research Center, EIAR, and the National Research and Extension System (NARES)

Target country: Ethiopia

Environmental Management and Mitigation Plan (EMMP)

The Sorghum and Millet Innovation Lab management entity has continued to ensure environmental compliance and confirm that the resources, responsibilities, and reporting (3R's) have been well defined and monitored throughout the lifetime of each research project implementation. The Lab management entity also continues to ensure that the research activities being funded comply with the environmental compliance requirements as stated in the initial environmental evaluation. Fertilizer commodity purchases were applied for and approved by USAID for research plot activities.

The associated environmental monitoring and mitigation plans (EMMPs) for each research project have been supported by an EMMP web based module, which facilitates reporting of actual environmental support visits by the environmental compliance staff and investigators of the implementing partner, as well as other relevant persons involved.

Open data management plan

During our virtual annual meeting in March 2020, the management entity organized an administrative session to go over details on various procedures. We presented to each team a data management plan with clear instructions on how to create their dataset into Dataverse or other database of their choice. Each awardee and sub-awardee will submit the link of each planned and in-progress datasets in our grant management system, PieStar. In addition to the dataset, the data package must also include metadata and other supporting documents including codebooks that document columns in the dataset, questionnaires used to collect the data, informed consent forms, reports, and any other contextual documents. Research teams were reminded that datasets should be cleaned, and all personally identifiable information should be excluded.

Governance and management entity activity

COVID Response and Planning

Due to the COVID pandemic the planned for in person annual review meeting in Ethiopia was cancelled and reorganized in an online Zoom meeting format. While this was unfortunate the online format actually allowed for a strong team involvement, more time per research team to present findings, achievements, challenges, and future planning and allow for lengthy questions and discussions. Both the principle investigators, co-investigators and external advisory board were very positive as regards the outcome of the online meeting format.

The management entity has worked closely with the various research teams to stay connected and current with the numerous changes and challenges of the COVID pandemic. Supplemental funding for country coordination budgets were made available to support the purchase of additional Personal Protective Equipment (PPE) for field research teams. In spite of the travel restrictions and other obstacles the field teams have done an outstanding job of maintaining the planned for implementation of activities. The field team's resilience, commitment, and ability to adapt to the COVID situation cannot be overstated.

Technology Scaling – Collaborative Networks

Scaling technology packages is a key program deliverable for the Sorghum and Millet Innovation Lab. Multiple "ingredients" that support scaling include technology practice, awareness/demand, business case, value chain integration, finance, knowledge/skills, collaboration networks, evidence/learning level, leadership/management, and public sector governance. One effort to strengthen collaboration networks has been to formally join several consortium bids for large regional USAID agricultural development call for proposals. If successful these consortiums will provide a strong platform to further, disseminate technologies that are ready for scaling into existing development programs.

Other Topics

Communications – Technology catalog

The technology catalog on the Sorghum and Millet Innovation Lab website https://www.k-state.edu/smil/techcatalog/index.html has continued to be developed and additional feature videos have been included. These 1.5-minute videos have been a great help to effectively communicate a particular technology package to a wider audience. More detailed information on the technology package as well as in-country contacts are available to enable interested parties to develop scaling partnerships.

Economic Impact Assessment

Several economic analyses were conducted to provide information for strategic resource management of the program. A doctoral candidate traveled to Niger in February 2020 to initiate research on sorghum varietal profiles through structured surveys conducted with farmers, processors, traders and plant breeders. In preparation for this research, the theoretical causes and solutions to low varietal uptake for sorghum were reviewed and reformulated for empirical assessment. Consistent with much of the structural research framework, we presented asymmetric information, bounded rationality, and weak intellectual property as key causes of seed market coordination failure. Leaning on the technology adoption under uncertainty model, we showed how market-induced uncertainty, compounded with other factors, reduces farmers' willingness to trade traditional seeds for improved ones. Furthermore, we used the matching theory, supported with a general equilibrium model, to show how consumer preference drives farm-level adoption. We argued that breeding programs can benefit from effective preference matching across the food value chain while leveraging on the growing demand-led breeding literature. This research was halted due to COVID-19 and the student was unable to conduct the field activity. The field research will be implemented at a future, yet unknown, date.

A spatial land allocation study was conducted in Niger and Nigeria to examine whether short-term weather stress is affecting crop allocations. The traditional Mendelsohn land use model was estimated, and its limitation uncovered in efficiently approximating cereal cropland allocation. We improved the appropriateness of fit of the traditional Mendelsohn model by controlling for additional factors, such as food prices, socio-demographics, and food trade factors. Overall, we found cereal acreage shares in Nigeria and Niger to be spatially heterogeneous and determined that climate affects cropping decisions but more importantly other factors such as crop prices, cropping alternatives, and consumer preferences also play an important role in planting decisions and supply response. Farmers tend to base their cropland allocation decisions upon the price of the most important staples: maize in Nigeria; millet and sorghum in Niger. This production supply response study was complemented with a consumer demand study to derive the price elasticities of demand and income elasticities of consumers in Niger.

The consumer study determined differing price elasticities of demand for wealthy versus poor consumers, and rural versus urban. Millet was determined to be a necessity while sorghum and rice were luxury goods. Urban households had a more diversified staple demand patterns than rural households. The welfare analysis revealed that an increase of millet price reduces rural welfare more than an increase in sorghum price. On the other hand, a sorghum price increase adversely affects the welfare of urban households the most. For example, a 20% increase of the millet or sorghum price reduces the average household welfare by 5.88% and 4.38%, respectively. This study highlights the importance of estimating staple food demand elasticities for both research and policymaking during a food price shocks. Findings revealed that millet price is the avenue that might foster support programs targeting the poorest households in Niger.

Third, the impact of government expenditures on agricultural productivity was evaluated. We estimated the effect of two government-spending measures: Agriculture Budget Share (ABS) and Research Share of Agricultural GDP (RSAGDP) on agriculture total factor productivity growth (TFPG). We used a panel fixed-effect estimator to control for the country-specific characteristics of twenty-eight African economies from 1991–2012. Although North African economies appear to have the highest TFPG, this does not translate into the highest agricultural and research budget share. Meanwhile, Central African economies exhibit the lowest ABS and RSAGDP, along with the lowest TFPG of the continent. The panel fixed-effect estimator revealed a marginal impact of 7% for RSAGDP on TFPG after seven years. However, the cumulative marginal impact of ABS on TFPG is estimated at 10% over the fifteen years that follow the budget increment. Additional and continuous investment in research and development is required for a significant productivity enhancement, especially in Sub-Saharan Africa.

Future directions

COVID Response and Planning

The SMIL management entity will continue to respond in close collaboration with its partners to the new and emerging challenges of COVID-19. Additional funds have been reserved to support the strengthening of each focal country phone and internet communication capacity. Going forward this will strengthen and support more regular communication.

Joint Collaboration with LSIL

The SMIL management entity has had initial discussions with the Livestock Systems Innovation Lab (LSIL) with regard to the LSIL strategic direction in their newly awarded five-year extension. Sorghum forage research in West Africa and Ethiopia is maturing and additional discussions with LSIL are planned to detail a collaboration in this area with potential joint funding.

Strengthening Engagement with USAID Missions

At SMIL management entity, we have worked to link our in-country program coordinators and research team members as key resource persons that could engage more regularly and locally with the USAID missions and their networks of partners. The ME will reinforce the linkage / collaboration with missions. One immediate goal is to work with our USAID AOR to ensure our resource persons are on existing list serves at the country level. This will assist in better engagement in the regular country level implementing partner meetings where technology package outputs could be presented.

Appendices

Appendix A – List of awards to U.S. partners – Phase II

Title: Advancing improved functionality and protein quality sorghum hybrids for food applications in Ethiopia
Award: Texas A&M - Joseph Awika
Project Dates: 04/01/19 07/21/23

FY19 Funding Released:	$129,419.00
Total Funding Released:	$129,419.00
Overall Project Budget:	$929,658.00

Title: Genetic Enhancement of Sorghum to Promote Commercial Seed Supply and Grain Market Development in Ethiopia
Award: Purdue - Gebisa Ejeta
Project Dates: 04/01/19 07/21/23

FY19 Funding Released:	$109,255.00
Total Funding Released:	$109,255.00
Overall Project Budget:	$472,500.00

Title: Expanding Markets for Sorghum and Millet Farmers in West Africa through Strengthening of Women and Youth Processors and Nutrition-based Promotion of Products
Award: Purdue - Bruce Hamaker
Project Dates: 04/01/19 07/21/23

FY19 Funding Released:	$97,125.00
Total Funding Released:	$97,125.00
Overall Project Budget:	$523,567.00

Title: Phase II - Genetic improvement of sorghum for resistance to fungal pathogens
Award: Purdue - Tesfaye Mengiste
Project Dates: 04/01/19 07/21/23

FY19 Funding Released:	$118,741.00
Total Funding Released:	$118,741.00
Overall Project Budget:	$814,897.00

Title:	Enabling Marker Assisted Selection for Sorghum Disease Resistance in Senegal and Niger	
Award:	TAMU – Clint Magill	
Project Dates:	04/01/19	07/21/23

FY19 Funding Released:	$8,910.00
Total Funding Released:	$8,910.00
Overall Project Budget:	$384,645.00

Title:	Sorghum Trait Deployment Pipeline for Improved Food and Feed Value	
Award:	Purdue - Mitch Tuinstra	
Project Dates:	04/01/19	07/21/23

FY19 Funding Released:	$23,031.00
Total Funding Released:	$23,031.00
Overall Project Budget:	$155,991.00

Title:	SAWAGEN: Improving Sorghum Adaptation in West Africa with a Genomics-Enabled Breeding Network	
Award:	KSU - Geoff Morris	
Project Dates:	04/01/19	07/21/23

FY19 Funding Released:	$86,250.00
Total Funding Released:	$86,250.00
Overall Project Budget:	$426,066.00

Title:	Genetic Enhancement of Pearl Millet for Yield, Biotic and Abiotic Stress Tolerance in West Africa (GENMIL)	
Award:	KSU-Hays - Desalegn Serba	
Project Dates:	04/01/19	07/21/23

FY19 Funding Released:	$26,758.00
Total Funding Released:	$26,758.00
Overall Project Budget:	$171,515.00

Appendix B – Success stories

Adapting to Covid-19

The management entity and all partners had to adapt to the pandemic to pursue our goals for all projects. All travel stopped mid-March when our annual meeting was scheduled, and the pandemic created a consequent challenge for all field activities.

Our annual face to face meeting was about to take place between March 23rd and March 27th in Addis Ababa in Ethiopia. Due to the pandemic growing in different part of the world, the SMIL Management Entity decided to pivot our face to face format to an online format two weeks prior the set dates. All participants adjusted to present their projects, progress, concerns and ideas of adaptation within a very short period. Regardless, all teams raised to the challenge and we were able to use the time allocated for each project efficiently. The focus on each project allowed for a deeper level of discussion and brainstorming solutions. We had very few connectivity issues and overall, the annual meeting was a successful event. The continuity of the projects was assured by all our partners, while following policies and social distancing of their respective geographical area.

After a few years in Manhattan, Kansas, two of our Ph.D. students had to postpone their return home due to the global pandemic. They counted the days until their flight and dreamt about being home. While packing after a few years in America, they reflect on their experience at Kansas State University (KSU):

"My time here at Kansas State University has been my greatest experience I have ever had. It is just like yesterday when I landed at the Manhattan regional airport. I remember when the plane was about to land, I saw the surface of the soil was completely white, but I did not know it was snow until Mr. Nat Bascom told me. I was cold and I was not wearing heavy clothing. That was my best experience in the America.

My plan is to work at Regional Center of Excellence (CERAAS) in Senegal. I believe I can contribute to my overall mission, which is to establish an efficient molecular breeding capacity in West Africa to rapidly improve crop adaptation to different environments."

"I had a wonderful and memorable experience during my Ph.D. program at Kansas State University. I am deeply grateful for the tremendous help I have received from everyone at KSU. Thank you for sharing your knowledge and experience with me!

Upon returning home, I will work at the National Institute of Agronomic Research of Niger, INRAN. My research will focus on understanding the genetic diversity of staple crops and providing genomic knowledge and tools to assist breeding programs towards delivering new adapted varieties in West Africa."

What our graduate students are up to…

Our graduate students are on a great path for success with different journeys.

Some of our students went in the workforce and are leading successful careers with the following employers in addition to private companies: Sodagri, Dakar, Senegal; Bako Research Center at Oromia Research Institute, Fedis Research Center, Addis Ababa, Ethiopia; consultant at NGO Terre des Hommes and on East African Media Lab Project, US Peace Corps in the Philippines, Food and Agriculture Organization; Hawassa University, Awasa, Ethiopia;

Istituto Nazionale di Ricerca per gli Alimenti e la Nutrizione (INRAN), Rome, Italy; CERAAS, Thies, Senegal; Senegal Institute of Agricultural Research (ISRA), Dakar, Senegal; Institut Togolais de Recherche Agronomique (ITRA), Lome, Togo; Makerere University, Kampala, Uganda.

Several of our students chose to pursue academic studies such as: Master's degree at University Cheikh Anta Diop in Senegal; PhD at Kansas State University, USA; Post-Doctorate at North Carolina State University, USA; Post-Doctorate at University of Hohenheim in Germany; Post-Doctorate at University of Illinois, USA.

A new anthracnose resistant sorghum variety

Disease pressure from fungal pathogens are major production constraints in many sorghum-growing zones of Ethiopia. One such disease known as anthracnose is a widespread disease caused by a fungus that can have devastating effects on sorghum production in Ethiopia. The most promising defense against anthracnose is the development of sorghum lines that harbor resistance to the disease.

Researchers with support from USAID through the Sorghum and Millet Innovation Lab have screened thousands of sorghum lines and successfully identified two key genes that carry anthracnose resistance in sorghum. These genes have now been successfully crossed into existing sorghum varieties in Ethiopia.

This has led to the official release by our partner the Ethiopian Institute of Agricultural Research (EIAR) of an improved red sorghum variety named "Marara" ETSL 101371 (Acc. 212642) for use by smallholder farmers. Marara provides up to a 40% yield increase over standard checks and is adapted to rainfall areas of 1,100-1,200 (mm) at altitudes of 1,500 - 1,900 (masl).