Semi-Annual Report

Feed the Future Innovation Lab
for the Reduction of Post-Harvest Loss

October 2015 – March 2016

Submitted by:

Kansas State University (co-lead)
University of Illinois (co-lead)
Oklahoma State University
University of Kentucky
University of Nebraska – Lincoln
South Carolina State University
Ft. Valley State University
USDA-ARS Center for Grain and Animal Health Research

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<u>Revised, Final version</u>

Members of the Internal Steering and Evaluation Committee (ISEC):

- Dr. John Leslie – Kansas State University, Interim Director, Feed the Future Reduction of Post-Harvest Loss Innovation Lab (Afghanistan project leader).
- Dr. Prasanta Kalita – UIUC, ADM Institute Director (co-PI; Bangladesh project co-leader)
- Dr. Subramanyam Bhadriraju – Kansas State University (Ethiopia project co-leader; Research/ Environmental Issues Coordinator)
- Dr. Andreia Bianchini-Huebner– University of Nebraska (Guatemala project co-leader; mycotoxin contamination prevention)
- Dr. Carlos Campabadal – Kansas State University (Guatemala project co-leader; grain drying, storage facilities and equipment)
- Dr. Floyd Dowell – USDA-ARS Center for Grain & Animal Health Research, Engineering Research Unit Leader
- Dr. Nina Lilja – Kansas State University (Gender co-Coordinator)
- Dr. Rizana Mahroof – South Carolina State University (Ethiopia project co-leader; stored product pest management)
- Dr. George Mbata – Ft. Valley State University (Ghana project; monitoring of pest populations), Dr. Sam McNeill – University of Kentucky (Ghana project co-leader; grain drying, storage facilities and equipment)
- Dr. George Opit – Oklahoma State University (Ghana project co-leader; stored product insects and pests)
- Dr. Gordon Smith – Kansas State University (Bangladesh project co-leader; technology transfer)
- Dr. Shannon Washburn – Kansas State University (Engagement Coordinator)

The Feed the Future Innovation Lab for the Reduction of Post-Harvest Loss had active projects in five countries from October 1, 2015 to March 31, 2016

Afghanistan

Team Leaders: John F. Leslie (Kansas State University); Debra Frey (Kansas State University); Dr. Andreia Bianchini-Huebner (University of Nebraska-Lincoln)

Bangladesh

Team Leaders: Dr. Prasanta Kalita (University of Illinois); Dr. Gordon Smith (Kansas State University)

Ethiopia

Team Leaders: Dr. Subramanyam Bhadriraju (Kansas State University); Dr. Rizana Mahroof (South Carolina State University)

Ghana

Team Leaders: Dr. George Opit (Oklahoma State University), Dr. Samuel McNeill (University of Kentucky)

Guatemala

Team Leaders: Dr. Carlos Campabadal Teran (Kansas State University), Dr. Andreia Bianchini-Huebner (University of Nebraska-Lincoln)

Program Partners

Companies
Archer Daniels Midland Company (ADM) (Illinois, USA)
Agri Commercial Service Ltd. (Ghana)
GrainPro (Massachusetts, USA)
Hiwot Agricultural Mechanization P.L.C. (Ethiopia)
John Deere (USA)
Pens Food Bank Enterprise (Ghana)
Romer Labs (Austria)
Vestergaard Frandsen (Switzerland)
Woods End Labs (USA)

International Agencies
Ghana Agriculture Technology Transfer (ATT) (Part of IFDC)
ADVANCE (Ghana)
SPRING (USAID)
Africa RISING

Universities
Bahir Dar University (Ethiopia)
Bangladesh Agriculture University (Bangladesh)
Fort Valley State University (USA)
Hawassa University (Ethiopia)
Kansas State University (USA)
Kwame Nkrumah University of Science and Technology (KNUST) (Ghana)
Mekelle University (Ethiopia)
Oklahoma State University (USA)
South Carolina State University (USA)
Universidad del Valle (Guatemala)
University of Kentucky (USA)
University of Nebraska – Lincoln (USA)

Government Agencies
Ministry of Agriculture, Irrigation and Livestock (Afghanistan)
Savanna Agricultural Research Institute/Council for Scientific Research (Ghana)
US Agency for International Development (USAID)
USDA-ARS Center for Grain and Animal Health Research (USA)

Non-Profits
ADM Institute for the Prevention of Postharvest Loss at the University of Illinois (USA)
Compatible Technologies International (USA)
Partners in Food Solutions (USA)
Practical Action (Bangladesh)
SHARE Guatemala (Guatemala)

Acronyms

ADVANCE - Agricultural Development and Value Chain Enhancement
Africa RISING - Research in Sustainable Intensification for the Next Generation
ATT – IFDC – Agriculture Technology Transfer – International Fertilizer Development Council
BARC - Bangladesh Agricultural Research Council BARC
BARI - Bangladesh Agricultural Research Institute
BAU - Bangladesh Agricultural University
BD - Bangladesh
BRRI - Bangladesh Rice Research Institute
DAE - Directorate of Agricultural Extension
EIAR – Ethiopian Institute of Agricultural Research
FGD - Focused Group Discussions
FtF – Feed the Future
GRAMAUS - Grameen Manobic Unnayan Sangstha
KNUST - Kwame Nkrumah University of Science and Technology KNUST
KSU – Kansas State University
MAIL – Ministry of Agriculture, Irrigation and Livestock
ME – Management Entity
MoFA – Ministry of Food and Agriculture
OSU – Oklahoma State University
PHL – Post-harvest loss
PHLIL – Feed the Future Reduction of Post-Harvest Loss Innovation Lab
PICS – Purdue Improved Crop Storage
SAWBO – Scientific Animations Without Borders Organization
SBD – Solar Bubble Dryer
SPRING – Strengthening Partnership, Results, and Innovations in Nutrition Globally
STR – a low cost dryer made locally in Asia
UIUC – University of Illinois, Urbana, Champaign
USAID – U.S. Agency for International Development
USDA-ARS – United States Department of Agriculture –Agriculture Research Service
wb/w.b. – wet basis
WEAI – Women Empowerment in Agriculture index
RH – Relative Humidity

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Feed the Future Innovation Lab
for the Reduction of Post-Harvest Loss

I. Executive Summary

The Feed the Future Innovation Lab for the Reduction of Post-Harvest Loss (PHLIL) is a strategic, applied, research and education program aimed at improving food security by reducing post-harvest loss and food waste of seeds and durable staple crops, *e.g.*, grains, oilseeds, and legumes. The Lab's efforts are focused in four Feed the Future countries (Bangladesh, Ethiopia, Ghana, and Guatemala) and Afghanistan. Major goals/activities include:

- Increased understanding of current post-harvest task division in rural communities and households, and the development of technologies usable by all household members.
- Improve drying, handling, and storage technologies to reduce insect and fungal contaminants.
- Pilot test drying and storage technologies with low acquisition costs and limited operational footprints that are sustainably accessible to poor farmers.
- Develop creative animation tools that help non-literate farmers understand, value and implement technologies developed as part of the project.
- Develop a standard operational protocol for conducting baseline surveys of mycotoxin contamination in targeted agricultural products in multiple countries.
- Increase the quantity and quality of stored food staples to increase food safety and security for poor farmers.
- Develop strong partnerships with local NGOs to effectively spread information on the technologies developed to farmers throughout the targeted regions.

II. Program Activities and Highlights

- Developed and finalized the Environmental Mitigation and Monitoring Plan (EMMP) checklist and a comprehensive EMMP plan for all projects in the Lab. An EMMP module in Piestar (data depository website for PHLIL) is being developed. Standard Operation Procedures (SOP) for decontaminating and disposing of materials used during mycotoxin analysis also were developed. These documents and the Travel and Management Activity Calendars are now available on the public and Piestar websites associated with the Lab.
- Rumela Bhadra replaced Interim Program Coordinator Anne Huss.

Afghanistan

Established and staffed a functional mycotoxin detection laboratory and detected all of the mycotoxins being screened (aflatoxin, deoxynivalenol, ochratoxin, and T-2 toxin) in at least one of the tested foods (raisins, tree nuts and wheat). Identified ergot alkaloids in approximately one third of the wheat samples. Held a conference in Delhi, India, March 14-16.

Bangladesh

Significant findings were gathered on moisture levels in patty rice, further underscoring the need for better drying technologies. Available drying and storage technologies have been adapted and tested, with an adapted local dryer (STR – a low cost local dryer) found suitable and effective to control moisture in rice, especially in the monsoon season. Field testing of STR dryers, and demonstrations, are being carried out in two districts, by two in-country NGOs from Jessore and Mymensingh. PICS bags were found to be best for storage, in trials comparing storage technologies (including prevalent local ones). Mycotoxins were found to contaminate rice, with local capacity for testing enhanced/established at the national university lab through this exercise. Gender study findings were disseminated, and will be integrated into a gender curriculum moving forward.

Overall, human and institutional capacity building is being cultivated through these activities, which are being primarily driven by the in-country university partners. Three presentations were delivered at the 1st International Congress on Postharvest Loss Prevention in Rome, Italy (Oct 4-7, 2015). To disseminate findings, workshops and Focus Group Discussions (FGDs) were held in four districts (264 farmer participants, 52% female) on drying, storage bag usage, and mycotoxins.

Ethiopia

A first of its kind survey across four commodities, in four regions of the country resulted in baseline information revealing both the scope of PHL issues, and the effectiveness of different interventions. Pests and mycotoxins have both been identified as critical issues. For example, sesame (so valued it is called "white gold") was found to have significant contamination by several mycotoxins, and not insects. Further, tested interventions for insect management showed hermetic bags to be promising in reducing insect numbers and damage within the range of storage technologies tested, especially in heavily infested commodities such as maize, wheat, and chickpea. The team is continuing to adapt drying and storage interventions through research, and in parallel both:

- build national capacity to conduct this research (e.g., a first in the country postharvest graduate program is being established, and laboratory capacities of two national universities has been enhanced)
- and communicate research findings with stakeholders, including through training of potential end-users of the promising technologies.

To help ensure that the pathway to impact for envisioned development outcomes is mapped out, strategic partner engagement and surveys of gender have been ongoing. A concept note for nutrition projects is also under development. For gender, women were found to have a disproportionate role in postharvest activities, and be less empowered than men in several areas; this enables us to adapt our training and interventions with the aim of better empowering women in this part of the value chain, where they play a large role.

Reciprocal researcher exchanges continued, ensuring continued intensive engagement between in-country and US-based partners. This included visits by a KSU team to both universities, to review research progress, with a major focus on nutritional aspects and drying experiments. In February, this KSU team conducted a training workshop and to evaluate and monitor insect storage, mycotoxin and drying experiments for all four crops. A workshop on reducing Postharvest Grain Losses in Ethiopia was successfully completed on 25th February 2016 at Harmony Hotel in Addis Ababa with 44 dynamic participants. Protocols for all experiments were reviewed and adapted as necessary during these trips.

Ghana

Earlier work by Pens Food Bank Ent. established that postharvest yield losses were disproportionally caused by postharvest molds and insect pests: in the major and minor seasons, 23% and 12% postharvest losses by molds and insects during storage, representing 77% and 63% of the total postharvest loss, respectively. To reduce these critical losses, the PHLIL team has identified and is now working with a USAID-funded NGO (ATT), a USDA-funded NGO (AMPLIFIES Ghana) and industry partners to adapt a set of four critical cost-effective interventions: an adapted **dryer** (for drying and disinfesting maize of insects), a low-cost **moisture meter** to monitor drying progress and the condition of stored grain, ZeroFly Storage bag, and adapted **storage** containers (7 MT). Each of these four areas involves collaborations with in-country partners (universities, NGOs and/or private industry), to involve potential technology end users in the testing and adaptation phase, and in parallel build national capacity to address evolving postharvest losses in the future. A PHLIL-adapted Solar Biomass Hybrid Dryer (SBHD) has been validated. It can use local agricultural and industrial waste as biomass to dry grains, vegetables, roots and tubers, fruit and even heat-sensitive produce such as mushrooms. USDA-PHLIL low-cost, easy to fabricate moisture meters were previously validated. Arrangements are in progress for a local USAID-funded NGO (ATT) to purchase an adapted SBHD and moisture meters for use in their work to improve and preserve the quality of agricultural seeds in Ghana. For a locally-appropriate storage solution, PHLIL is collaborating to validate efficacy of an adapted, Ghanaian-made plastic water storage container, adapted by a local industry partner – Pens Food Bank Ent. Through these achievements, PHLIL has a complementary set of PHL interventions moving from research into adoption, where they will soon be reducing PHL with target beneficiaries in the near term.

Collection of baseline information continues for moisture content, aflatoxin contamination, and insect infestation levels; as does assessment of insect traps for monitoring stored-product insect pest populations in warehouses. Two M.Phil. students at KNUST are summarizing and analyzing data collected to date, and have begun writing manuscripts for submission to peer-reviewed scientific journals.

Guatemala

PHLIL continued iterative testing and adaptation of various drying and storage technologies, considering the significant challenge posed by high altitude and low solar radiation (due to usual cloudy conditions). Improvements to dryer performance were noted, however the local environment may require alternative drying approaches. The team will continue testing and adapting other furnace-driven dryers, and work to further lower dryer cost with use of less expensive materials.

Storage container testing continued. It has been concluded that there are appropriate storage technologies available off the shelf, that can reduce postharvest loss in these communities. Key considerations for further investigation include cost, efficacy of locally produced bags, and necessary sensitization of farmers on the benefits of improved storage technologies.

It was determined that maize from the highlands has aflatoxin and fumonisin at levels below international guidelines, but remains a food safety concern because of the large amount of maize consumed by highland residents. [1] Grain from the lowlands is "imported" to the highlands as the year progresses since most farmers in the highlands do not grow enough maize on their own to be self-sustaining for an entire year. In some cases farmers in the highlands purchase grain for household consumption for up to nine months of the year. *[1] Agricultural Cooperative Development International Volunteers Oversees Cooperative Assistance.*

III. Key Accomplishments

- Studies identified a lack of solar radiation and flat terrain as constraints to effective use, and by extension, adoption of the solar bubble dryer technology with the target users Alternative hybrid solar dryers, e.g., biomass assisted hybrid solar dryers in Ghana and a shallow bed mechanized dryer in Guatemala are now being tested in-country, and are expected to perform better than the commercially available solar bubble dryer.

Afghanistan

Conducted a Food Safety Workshop in Delhi, India with participants from three Afghan ministries, USAID-Washington and Kabul, FAO, IITA, KSU, CNR-Italy, several NGOs and the private sector. Results from the mycotoxin survey were presented and nominal group discussions were held to focus on needed activities from research through the development of government regulations and their implementation.

Bangladesh

Progress across all areas is resolving technology and training-based interventions to address key issues in PHL, making tangible progress towards development outcomes including establishment of national capacity to conduct research to adapt PHL interventions, and effectively engage a range of stakeholders to help ensure uptake by scaling agents and other stakeholders.

The mycotoxin testing lab established through this program is the first lab in the country, to the best of our knowledge. This lab is first to do baseline mycotoxin on rice varieties, which represents 28% of their GDP. Transitioning from subjective or observational tests to evaluate damaged rice, now the capacity to scientifically determine mycotoxin in the rice is possible.

Effective drying and storage technologies have now been validated. A relatively low cost, PHLIL-adapted local dryer was found to be highly effective and is being further tested in the field.

Ethiopia

The contributions of the program are becoming recognized at the upper levels of partner universities and within the Government:

- The Presidents of Mekelle and Bahir Dar Universities have committed to supporting the development of a postharvest curriculum, and have invested their own university funds to expand PHL activities, including sending their scientists for training at KSU.
- The Ministry of Agriculture has shared their extension materials, which PHLIL team members are reviewing and adapting, and we have been invited to apply for Ministry funding to expand our engagement in this area. According to the PHL survey, approximately 80% of farmers desire training on addressing PHL mitigation issues.

- Validation and adaptation of drying and storage technologies, including moisture meters, continued. PICS bags were found to be highly effective, and work towards deploying effective interventions to reduce PHL for targeting beneficiaries continues.
- PHLIL's work here over the past two years has brought renewed focus to an area that was neglected in Ethiopia. PHL findings were shared at a workshop in Addis Ababa with private producers, development agents and researchers. Thirteen presentations were given, and participants from Sasakawa Global 2000 and GTZ expressed interest in collaborating with Mekelle and Bahir Dar Universities in expanding our PHL reduction activities among farmers.
- Human and institutional capacity building continued to accelerate, with frequent visits and researcher exchange featuring prominently in these efforts. Laboratory capacity continued to be enhanced at both Ethiopian universities, through both expansion of available equipment and Standard Operating Procedures, as well as continued training of Ethiopian faculty members and graduate students.

Ghana

- A local drying technology (SBHD) has now been adapted and validated.
- A low-cost, easy to fabricate moisture meter has been validated in the field here.
- Arrangements are underway for uptake of both of these two technologies (above) by the first two local partners (ATT, USAID-funded NGO; and AMPLIFIES, USDA-funded NGO) for their work to reduce PHL for target beneficiaries.
- The Project team has signed MOUs and activity agreements with Africa RISING (October, 2015), IFDC-ATT (September, 2015), and SPRING (October, 2015).
- Collaboration with a local industry partner (Pens Food Bank Ent.) has begun, wherein PHLIL is assisting in the ongoing validation in their adaptation of a Ghanaian-made plastic water storage container for grain storage.

Guatemala

A range of drying and storage technologies have been tested and adapted. Appropriate storage technologies have been identified, with considerations regarding adoption models for the most effective to be investigated moving forward. Dryer tests have produced information that can be fed back to US manufacturers of drying technologies (eg, for the Solar Bubble Dryer); this could enable them to adapt their product to better suit markets with these challenges.

Mycotoxin surveys revealed that while levels were typically below the maximum allowable limit (US FDA), exposure levels were significantly higher than those typically recommended due to the high consumption of corn as a staple. Linkage with the public health community and policymakers is necessary, to improve our collective understanding on how chronic exposure to "low" levels of mycotoxins, at levels well above US exposure limits, can have on stunting of these populations. Maize from lowland regions in Guatemala (not Feed the Future regions) was tested for mycotoxins, with analysis underway.

IV. Research Program Overview and Structure

PHLIL manages parallel projects in four core Feed the Future countries, *i.e*., Bangladesh, Ethiopia, Ghana, and Guatemala. Afghanistan was added as a mission buy-in for a baseline mycotoxin analysis of dried fruits, tree nuts and wheat. Each country project is led by U.S. scientists representing the lead project organizations and an in-country counterpart from the primary subcontractor and collaborator.

Initial PHL Assessment – Surveys were conducted to understand the practical details and social context within each country. Baselines for storage, contamination and mycotoxin profiles have or soon will be established. The surveys identified multiple participants in the value-chain and that 80% of the household level processing is done by women.

Promising in-country, "on-the-shelf" and "in the field elsewhere" technologies/best practices are being evaluated through on-farm research with stakeholder participation. These technologies include**: storage** (Purdue Improved Crop Storage (PICS) bags, GrainPro® Superbags/cocoons, hermetic metal drums/bins); **drying (**GrainPro® or Hohenheim solar bubble dryer); moisture measurement (USDA-ARS and John Deere moisture meters); **mycotoxin assessment** (Romer Lab® test strips); **insect pest control** (diatomaceous earth dusts, silica nanoparticles, approved insecticides, insecticide impregnated bags, and pheromone sticky traps); and **market access** (USAID Warehouse Receipt Systems). Projects focus on gaps identified in the initial PHL assessment, previous in-country experience, and input from USAID missions. In each country, there are three common research themes – mycotoxin contamination, storage, and drying. Projects in each country are led by Country Team Co-Leaders and overseen by a U.S. PI and the Lab's Director, with input from local and international academic, private sector, and governmental and non-governmental organizations.

Project Implementation – Projects in each country initially were confined to a select group of smallholder farms, universities, or storage facilities to generate proof of concept and potential acceptability. Beginning in year 3, the shift is to outreach and to testing available technologies in villages and other non-research locations with NGO, public and private partners, selected based on input from in-country collaborators and USAID missions.

Our 'engagement strategy' moves results from pilot projects out for testing in broader geographic areas within the target country by targeting potential bottlenecks to wider adoption of new technologies. For example, education and training at the local village level was essential in West Africa for the success of the Purdue Improved Crop Storage (PICS) bags. This technology was adopted rapidly because it was readily available, inexpensive ($2 to $3 for 100 kg of grain capacity) and successfully reduced the Bruchid infestation of cowpeas. The private sector in Ghana has helped to design and scale-up grain drying strategies in Ghana to ensure local acceptability and utilization. Training local entrepreneurs to use and distribute handheld moisture meters and mycotoxin test strips should increase the adoption of these technologies. Minimizing grain moisture content as soon after harvest as possible is the most effective way to reduce insect infestation and prevent mycotoxin synthesis during storage.

Inclusion of In-Country Private Sector and Other Organizations – Numerous, diverse organizations are assisting in scale up and outreach. Assistance provided to PHLIL includes the time of academic faculty and staff to assist in project development, implementation and analysis, access to commercial and research facilities where pilot projects can be conducted, insights on cultural practices and preferences, contacts with in-country networks that enable on-farm experimentation and product/process training, evaluation, implementation, demonstration and adoption. PIs and country project team leaders are exploring, with USAID Mission staff scale-up/expansion and funding of additional projects of local interest to identify funding to encourage distribution and integration of the technology (ies) developed.

<u>Cross-cutting Analyses</u> – These analyses are part of each project:

Gender – Men and women participate differentially in post-harvest activities at the different locations. All four core countries have a local gender specialist who assesses and documents relative roles by gender in the villages where new technologies are to be piloted. Dr. Cheryl O'Brien (San Diego State University) monitors and assists in country gender specialists and provides input to PIs and the lab director on critical gender specific practices that must be considered as part of the provision of new technologies.

Nutrition – Chronic malnutrition rates are high in all five host countries. We view improved nutritional outcomes from both food quantity and food quality perspectives. Better post-harvest management will increase the quantity and quality of grain available for consumption and/or sale, and improve nutrition by providing more calories for consumption or enabling the purchase of more diverse foods and reducing the acute and sub-acute mycotoxin toxicities and related diseases. These toxins may stunt development in children under age 5, reduce immune system activity, and increase susceptibility to other diseases.

Environment – Research programs and activities adhere to USAID's Environmental Compliance Procedures in Title 22 of the Code of Federal Regulations, Part 216 (22 CFR 216). Most projects do not have a significant effect on the environment as they fall outside the 11 classes of action identified in Part 216.2 (d)(1). Portions of projects in Ethiopia and Ghana include the use of pesticides on commodities and in warehouses that must comply with procedures in Part 216.3. Wherever possible, all projects utilize renewable energy sources, *e.g.*, solar drying, and engage local artisans, business people and laborers to create and develop locally-produced tools and technologies.

Dissemination of technologies to small-scale farmers – Train-the-trainer programs will be established with US and host country PIs developing and training leadership teams, comprised of local stakeholders, in best technologies and practices. These groups will help develop the training programs for the larger groups. National symposia modeled on the 2012 Ghana Grains Council Pre-Harvest Networking event also will be developed. Subsequent village level training workshops will be reinforced by educational videos developed by UIUC's Scientific Animations Without Borders Organization (SAWBO).

V. Research Project Report

This section is organized on the basis of the country in which the work was done, and the three objectives common to all four countries – drying, storage, and mycotoxins. Collaborations, gender activities, and publications and presentations are summarized by country to avoid repetition, and then the activities for each objective within the countries are addressed. Capacity building is summarized in section VI.

<u>Afghanistan</u>

Collaborators:
Ministry of Agriculture Irrigation and Livestock (MAIL)
Gender: Nothing to report.

Bangladesh

Collaborators:

Bangladesh Agricultural University (BAU), Jagorani Chakra Foundation in Jessore, Grameen Manobic Unnayan Sangstha (GRAMAUS) in Mymensingh.

Gender: Shahana Begum, a freelance consultant, conducted a gender equality assessment in eight villages during year 2. The findings of the report were disseminated and implications discussed with farmers and NGOs through workshop/training sessions in Mymensingh on November 22, 2015 and in Manirampur on January 7, 2016. These sessions sensitized the participants to women's unrecognized roles in agriculture and problems women encounter during post-harvest activities.

Presentations:

- Alam, M.M., Ali, M.A., Awal, M.A., Saha, C.K., Ali, M.R. & Momin, M.A. 2015. USAID Post Harvest Loss Reduction Innovation Lab (PHLIL): Bangladesh component. *Proc. 1st Intl. Cong. on Postharvest Loss Prevention (October 4-7, 2015, Rome, Italy)*, p. 41.
- Awal, M.A., Hossain, M.A., Ali, M.R. & Alam, M.M. 2015. Effective rice storage technologies for smallholding farmers of Bangladesh. *Proc. 1st Intl. Cong. on Postharvest Loss Prevention (October 4-7, 2015, Rome, Italy)*, p. 94.
- Saha, C.K., Alam, A., Momin, M.A. & Alam, M.M. 2015. Paddy drying technologies for small farmers and traders in Bangladesh. *Proc. 1st Intl. Cong. on Postharvest Loss Prevention (October 4-7, 2015, Rome, Italy)*, p. 122.
- Alam, M.M. 2015. USAID Post Harvest Loss Reduction Innovation Lab (PHLIL): Bangladesh component. Bangladesh Agricultural University Research System Annual Workshop, Mymensingh, October 11, 2015.
- Saha, C.K., Momin, M.A. & Alam, M.A. 2015. Appropriate paddy drying technologies for farmers and small traders. Bangladesh Agricultural University Research System Annual Workshop, Mymensingh, October 11, 2015.
- Awal, M.A., Ali, M.R. & Hossain, M.A. 2015. Appropriate paddy storage technologies for farm households. Bangladesh Agricultural University Research System Annual Workshop, Mymensingh, October 11, 2015.
- Ali, M.A., Zahan, A., & Alam, M.M. 2015. Baseline survey on mycotoxins in paddy during postharvest operations. Bangladesh Agricultural University Research System Annual Workshop, Mymensingh, October 11, 2015.

Publications/Theses:

- Khan, A.U. 2015. *Evaluation of different paddy storage structures at farm households*. MS thesis, Dept. Farm Power & Machinery, Bangladesh Agricultural University, Mymensingh.
- Hassan, Z. 2015. *Invasion of mycotoxins molds in boro paddy samples of Bangladesh*. MS thesis, Dept. of Plant Pathol., Bangladesh Agricultural University, Mymensingh.
- Saha. C.K. 2015. Paddy drying in Bangladesh: Learning better practices to prevent drying losses. Prevent PHL blog campaign, ADM Inst. for the Prevention of Post-Harvest Loss, Univ. Illinois. December 22, 2015. Available at http://publish.illinois.edu/phlinstitute/2015/12/22/paddy-drying-saha/

Ethiopia

Collaborators:

Bahir Dar University, Mekelle University, EIAR, Sesame Research Center at Humera.

Gender: The WEAI framework was used to assess gender equality issues within the cultural context of post-harvest activities. Men had higher empowerment and adequacy status than women. Average empowerment scores for men exceeded 90%, while women's scores ranged from 72-77%. The main contributors to the differences in the scores are leadership, lack of autonomy in decision making, time allocation/heavy workloads, and access to and control of resources.

Presentations and publications:
Workshop on *Innovation Lab for the Reduction of Post-Harvest Loss: Goals and Progress-to-date,* Feb 25, 2016, Harmony Hotel, Addis Ababa. Presentations included:

- Powell, T. K. USAID/Ethiopia's Feed the Future investments in Ethiopian agriculture and opportunities for reduction of postharvest loss.
- Mahroof, R. M. Innovation Lab for the Reduction of Postharvest Loss: Goals and progress-to-date.
- Kalsa, K. Summary of insect research at Bahar Dar University.
- Berhe, M. Summary of insect research at Mekelle University.
- Fanta, A. Summary of mycotoxin research at Bahar Dar University.
- Alamayehu, S. Summary of mycotoxin research at Mekelle University.
- Asemu, A. M. Summary of drying research at Bahar Dar University.
- Gebreyesus, M. Summary of drying research at Mekelle University.
- Demissie, G. Postharvest insect pest management research in Ethiopia.
- Tsehay, A. Postharvest loss reduction efforts by Sasakawa Global 2000.
- Fanta, F. Postharvest loss reduction efforts by HiTec Trading House.
- Petros, S. Role of gender in postharvest loss reduction.
- Kulkarni, U. Postharvest loss reduction and nutrition.

- Subramanyam, Bh. 2016. Postharvest loss prevention: experiences in Ethiopia. International Development Class, April 29, 2016, Kansas State University, Manhattan, Kansas.

Ghana

Collaborators:

Middle Belt – Ghana Grains Council, Pens Food Bank, Yedent Agro Group, Sahel Grains, Kwame Nkrumah University of Science and Technology (KNUST), local farmers and grain processors.

Northern Belt – The nine members of the Northern Ghana EAT Antika Co. Ltd., Masara N'Arziki Farmers' Association, Upper West MoFA Office, Northern Region MoFA Office, SPRING, Takhilla Farms Ltd.

Gender: Dr. Irene S. Egyir has been hired by the project as a gender consultant. Quarterly interactions with PIs/Co-PIs and farmer groups have begun, as has a review of methodology and training curricula to ensure gender sensitivity. In-country gender sensitization training for the Ghana co-PIs is scheduled for April 2016. Students at KNUST included more than 50% female farmers and traders in their insect and moisture monitoring research.

Presentations and publications:

- Abena Ocran, George P. Opit, Kandara Shakya, and Sandipa G. Gautam. 2016. Effects of 43% relative humidity on survival of stored-product psocids (Psocoptera: Liposcelididea). Poster: 64th Annual Meeting of the Southwestern Branch of the Entomological Society of America. Tyler, TX. February 22–25, 2016.
- Sulochana Paudyal, George P. Opit, Sandipa G. Gautam, and Kandara Shakya. 2015. Effectiveness of the ZeroFly® Storage Bag Fabric as a Barrier to Stored-Product Insect Pests. Poster: 63rd Annual Meeting of the Entomological Society of America. Minneapolis, MN. November 15–18, 2015.

- McNeill, S., P. Armstrong, G. Opit, E. Osekre, N. Manu, J. Danso, I. Addo, A. Sanghi, K. Adu-Gyamfi, E. Nsiah, J. Campbell and F. Arthug. 2015. Assessment of grain moisture measurement and solar dryers in Ghana. *Poster presentation: 88th National FFA Convention.* Louisville, KY. Oct. 29.
- McNeill, S., P. Armstrong, G. Opit, E. Osekre, N. Manu, J. Danso, I. Addo, A. Sanghi, K. Adu-Gyamfi, E. Nsiah, J. Campbell and F. Arthug. 2015. Assessment of grain moisture measurement and solar dryers in Ghana. *Abstract and poster presentation: 1st Intercultural Awareness Day. UK College of Agriculture, Food and Environment.* Lexington, KY. Oct. 14.
- McNeill, S., P. Armstrong, G. Opit, E. Osekre, N. Manu, J. Danso, I. Addo, A. Sanghi, K. Adu-Gyamfi, E. Nsiah, J. Campbell and F. Arthug. 2015. Assessment of grain moisture measurement and solar dryers in Ghana. *Poster presentation: 1st Intl. Congress on Postharvest Loss Prevention.* Rome, Italy. Oct. 4-7.
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Guatemala

Collaborators:
SHARE (local NGO), Universidad del Valle.

Gender: Workshops organized by the gender consultant were conducted in Chiantla and Todos los Santos to assess items in the Women's Empowerment in Agriculture Index (WEAI).

Presentation and publications:

- Campabadal, C. A. Bianchini, A., Maier, D., Reddy, V., Ellis, J., and Sabillon, L. 2014. Improving Food Security and Food Safety of Smallholders Farmers in the Western Highlands of Guatemala through Reduction on Post-Harvest Losses of Corn. *International Working Conference in Stored Product Protection (November 26).* Chiang Mai, Thailand.
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Drying Technology and Implementation

Bangladesh – Focus crop: Rice

Achievements: Based on results from the 2015 Boro rice season, both a low cost dryer (STR) and the solar bubble dryer (SBD) were modified and tested with rice harvested in the 2015 Aman season. The STR dryer was modified by replacing bamboo mats with a wire mesh to construct the drying bins and using a diesel generator to power the blower rather than electricity from the commercial power grid. Mixing in the SBD dryer was increased by adding a roller stirring mechanism in addition to the recommended rake stirring. Milling recovery and seed quality were evaluated for short, medium and long grain rice. Temperature and moisture were uniformly distributed across the contents of the dryers, but were different for the STR and SBD dryers. A STR drier could adequately dry 500 kg of rice in no more than six hours (variety dependent). SBD and traditional sun-drying methods required 3-5 days due to foggy, cloudy, cold weather, and short day length, and the grain moisture content was 14% or more. More than 90% of the grain dried in the STR

drier was unbroken, while the proportion of unbroken grains from both SBD and traditional drying methods was significantly lower. In an economic analysis, the per kg cost for STR and SBD driers were similar. The payback period for a STR dryer was less than one year, and more than three years for a SBD dryer.
Lessons learned: The conclusion that the STR dryer is preferable to the SBD dryer, both technically and economically, needs to be tested on farm in the next growing season (Boro, late April to early June).

Ethiopia – Focus crops: Maize, Wheat, Chickpea, and Sesame

Achievements: During the 2015-16 dry season, the SBD was tested with 400 kg of sesame or 400 kg of chickpea in three modes – solar drying with natural convection, solar drying with forced (fan) convection, and loaded SBD with forced convection. The goal was to measure variation in solar radiation, wind speed, temperature, relative humidity, and initial moisture content, and to identify the variable(s) that affect the efficiency of the SBD. The best drying time was between 10 am and 4 pm on both sunny and cloudy days. Two moisture meters were used, Moisture Check Plus and a Rod/Probe type Moisture Meter, and gave somewhat different results. For sesame, the temperature was 20°C, the relative humidity 49%, and the grain moisture 7.4% wb when measured with the Moisture Check Plus and 8.3% wb when measured with the Rod/Probe type Moisture Meter. This sesame sample might not have needed to be dried. For chickpea, temperature and relative humidity were the same as for the sesame, but the grain moisture was 10.7% wb when measured with the Moisture Check Plus and 8.5% wb when measured with the Rod/Probe type Moisture Meter. This sample was moist enough to require some drying.

Maize was dried in the SBD and in local cabinet dryers with 20 kg load capacity in which grain was distributed in thin layers. The grain was exposed to temperatures that ranged from 25-48ºC and solar radiation 850-155,100 lux for consecutive days until the moisture content was less than 14%. When loaded with 200 kg of maize, it took 13 hours of drying time for the SBD to reduce the sample moisture from 34.4% to 12% (wb), and when loaded with 1000 kg of ma the drying time increased from 13 to 40 hours. The cabinet dryer required 26 hours of drying time to reduce the moisture content from 24% to 11.8% (wb). The efficiency of the SBD was 13.75% when loaded with 200 kg of grain, while the efficiency of the cabinet dryer was only 4.0% when loaded with 18.65 kg of maize.

Further drying tests for wheat and maize are planned for the rest of the project year.

Lessons learned: Cloudy days and delays due to rain remain a concern for the SBD due to slower drying and for the condensation that occurs during this time, especially when the dryer is loaded with the maximum load (1000 kg). Modifications to the SBD design, such as size, could make this a more suitable technology in these environmental conditions, and for these types of farmers who have limited access to land and credit; related discussions are ongoing.

Ghana – Focus crop: Maize

Achievements: Drying of maize, on the cob and shelled, via open sun drying is problematic due to the availability of solar radiation and potential contamination/consumption by birds, insects, and rodents. The SBD dryer installed in Ghana was modified to increase overall efficiency and performance, especially during cloudy days. This solar dryer has a biomass back-up heating system that utilizes biomass (agricultural residues, wood waste, charcoal, *etc.*) and can be used to dry grains and other produce such as vegetables, roots and tubers, fruit, and heat sensitive produce, *e.g.*, mushrooms. Additionally, the SBD also has great potential for disinfesting stored cereal grains of stored-product insect pests. The system consists of a solar tent to enable solar heat build-up and a biomass furnace that burns biomass to supplement the solar heat when temperatures are low and/or when it is cloudy or raining. This biomass hybrid solar dryer was built in Ejura, in the middle belt of Ghana, by Pens Food Bank Ent., a local industry, in partnership with KNUST to make the existing SBD dryer more likely to be adopted and produced on a large scale.
Lessons learned: The SBD-Biomass hybrid dryer is much more promising than SBD dryer alone. The design of the SBD dryer needs improvements, such as an inner drying platform, and a smaller footprint. Gas-assisted SBD modifications also are being evaluated. The cost per unit is based on the capacity of the

unit. The 5-MT capacity unit capable drying two loads of maize per day from 22% to 12% MC is ≈ $18,000.00. However, calculations indicate this cost can be recouped in 1.5 to 3 years.

Guatemala – Focus crop: Maize

Achievements: Currently, maize is dried (unshelled) on the ground and then transferred to jute bags that are exposed to the sun or dried by smoking in the attics of the farmer's houses. In December 2015, a modified version a furnace-type dryer model (similar to the AflaStop shallow bed dryer) was developed and tested by students at UVG with both shallow and STR cylinder beds holding the maize for drying. Additional modifications were made to the dryer and it was then tested on-farm in Chiantla in January 2016. The moisture removal rate was 1% per hour for shelled maize, and 0.5% per hour for unshelled maize with a drying capacity of 250 kg in two days. This dryer has a higher capacity fan and uses more electricity to power the fan. A solar dryer with an attached furnace also was developed and tested on-farm in Chiantla. The moisture removal rate of 1% per hour was similar, but the drying capacity was only 35 kg in two days. Additional drying tests with both types of dryers will be conducted in other communities that have different temperatures and relative humidity levels.

Lessons learned: Furnace dryers require electricity to power a high capacity fan to create the airflow necessary to dry the maize in a timely matter. The cost of electricity and poor maintenance of electrical connections can limit the ability of smallholder farmers to use this type of dryer. Solar dryers in the Western Highlands in Huehuetenango are difficult to use due to extensive cloud cover. The direct solar energy available in the Western Highlands is less than in other locations in Guatemala. From here, drying and storage technologies will continue to be adapted and piloted with end-users, including a model for sustainable deployment and adoption. STR dryers will be further adapted using materials that reduce the overall price. Trials will be conducted at KSU, then tested in the field in Guatemala. Ultimately, drying centers will be established to optimize farmer access and cost. Additional work will test efficacy of providing farmers continuing to use traditional drying methods with improved storage technologies.

Low-Cost Sustainable Grain Storage Technology

Bangladesh – Focus crop: Rice

Achievements: GrainPro® bags were provided to 80 farmers in four districts in Bangladesh for them to compare with traditional rice storage methods. After 5 months of storage in a traditional Dole storage structure the grain's moisture content increased by > 2% (wb), there was a 1.8% weight loss, and insect infestation increased and the amount of damaged grain was 3.5% damaged grain. Grain stored in GrainPro® bags had only a 1.2% increase in moisture content, 0.7% damaged grain, and 1.8% weight loss. Since rice is hygroscopic, the open upper surface and porous nature of *Dole* containers, favor persistence of high oxygen levels and moisture content in the grain and enables rapid insect population increase and serious losses to insect infestations. Rice moths, rice weevils and red flour beetles were found in both on-farm and lab experiment with the *Dole* containers and GrainPro® bags. The lesser meal worm was found in higher moisture content (> 14.7%) in some on-farm storage Dole containers. GrainPro® bags were good for up to four months of storage. At five months, some GrainPro® bags began to leak due to ants, rats or insects. Similar experience is reported by ACI Ltd., Bangladesh. Farmers' perceptions of the Grainpro® hermetic bags resulted from Focus Group Discussions (FGDs) focused on safe grain drying and storage. Participants used to use moisture meters and the hermetic bags, and were very interested in the hermetic (GrainPro® and PICS) bags although concerned about the relatively high price.

Lessons Learned: GrainPro® bags were superior in terms of moisture accumulation and seed germination to *Dole*, *Motka* and plastic drum storage methods. Hermetic bags should be made in various capacities (20, 500, 1000 and 2000 kg) to meet farmers' needs. Farmers thought a reasonable price for a small bag was $0.25 and $4.00 for the larger bags. About 60% of farmers store their own harvest on farm.

Ethiopia – Focus crops: Maize, Wheat, Chickpea, and Sesame

Achievements: The most common insects in 30 maize and 30 wheat samples from farmers between March and September, 2015 (monthly), and in pitfall traps, grain probe traps, warehouses, and storage experiments are shown in the table below. Weevils were the dominant species in maize followed by flour beetles. The numbers varied during the seven month sampling period. A majority of maize by farmers was stored in traditional Gota or Gotera structure, whereas wheat was stored in polypropylene bags. Maize was treated by farmers with phosphine gas, pirimiphos-methyl dust and malathion dust, and none of the wheat samples were treated chemically. Maize was more frequently infested than wheat and had on average 10 times more live insects than wheat. Grain stored in PICS bags and GrainPro® Super bags had the smallest live insect populations and less damage than grain stored polypropylene bags, jute bags, metal silos and plastic drums.

Sesame was collected monthly (July 2015 to February 2016) from 30 farmers and 10 warehouses. The most common insect species in sesame were lesser grain borer, red flour beetle, sawtoothed grain beetle, and small-eyed flour beetle. The amount of damaged grain increased from 8% in month one to 14% in month four. Chickpea samples also were collected monthly (July to October 2015) from 30 farmers and 10 traders. The most common insect species in chickpea were Adzuki bean weevil, rice weevil and confused flour beetle. The amount of damaged grain increased from 11% in month 1 to 22% in month 4. As in the maize and wheat tests, the PICS and GrainPro® Superbags consistently had fewer insects than the polypropylene bags, jute bags and the metal drums.

Table: Insects commonly found in maize, wheat, chickpea and sesame in storage experiments and samples collected from warehouses

Crop	Most common insects	Least common insects
Maize	*Sitophilus zeamais* *Sitotroga cerealella*	*Tribolium confusum* *Rhyzopertha dominica* *Cryptolestes* spp. *Ploida interpunctella*
Wheat	*Sitophilus zeamais* *Sitotroga cerealella*	*Tribolium confusum* *Rhyzopertha dominica* *Cryptolestes* spp. *Ploida interpunctella*
Chickpea	*Tribolium confusum* *Sitophilus oryzae* *Callosobruchus chinensis*	
Sesame	*Tribolium confusum Rhyzopertha dominica* *Cryptolestes mercator* *Palorus ratzeburgii*	

Lessons learned: A KSU insect taxonomist confirmed the initial species identification. The hermetic bags were the favored technology for reducing infestations in all four of the grains tested.

Ghana – Focus crop: Maize

Achievements:

A 6-MT Kikapu bulk storage bin donated by Kepler Weber (Brazil) was installed in Ejura (middle belt), Ghana. This steel bulk storage bin was effective, but is not economically viable for widespread adoption by small-scale farmers. As an alternative to storage in the Kikapu bin, Pens Food Bank, a local industry partner, is converting plastic water storage bins to grain storage. The Kikapu bin can hold up to 6 MT of maize while two plastic silo storage bins can together hold up to 7 MT of grain. Tests of grain quality and insect infestation over six and twelve month periods began after the minor grain harvest. Four treatments are being compared: Betallic-treated polyethylene bags filled with 50 kg of grain (six); untreated 50 kg polyethylene bags filled with 50 kg of grain (six); an untreated Kikapu bin (one); and untreated plastic siloes (two). The nearly 20-MT of maize used in this study were disinfested using the SBD in Ejura.

No insect pests were introduced to the grain because the insect pressure at the test location is high, and because the location is near an important maize market. Grain quality data being collected are moisture content, mycotoxin level, number of insect damaged kernels (IDK), percentage IDK, weight of IDKs, number of discolored grains, number of insect species and their abundance (live and dead), temperature and relative humidity, and weight loss (%). Storage trials in four different warehouses begun in project Year 2 continue and include three treatments: Betallic-treated 50-kg polypropylene (PP) bags; untreated 50-kg PP bags, and deltamethrin (DM) treated 50-kg polypropylene (PP) bags (ZeroFly® Storage Bags made by Vestergaard Frandsen (VF)).

Pilot storage studies with Africa RISING and SPRING will evaluate groundnuts in: 100-kg ZeroFly® bags (100 kg); 100 kg polyethylene bags containing Ghanaian registered DE; and untreated 100-kg polyethylene bags.

Lessons learned: The lack of technical literature on insect populations in plastic storage bins means the context in which the work is being conducted remains to be well-established. Experiments in and near commercial storage sites and warehouses require significant attention to alleviate local concerns about problems that could be caused for the commercial activities.

Guatemala – Focus crop: Maize

Achievements: Storage technology trials are being conducted on farms in Chiantla and Todos los Santos with GrainPro® Super Bags, PICS bags, 1-tonne capacity metal silos, 170-liter plastic drums, and triple bagging with the locally produced "arrobera" bag (suggested by the Legume Innovation Lab). Each storage technology is tested for 90 days after harvest with maize dried following a local protocol or by a dryer developed for this project. The efficacy of the storage technologies is assessed on the quality of the maize after storage, the levels of mycotoxin(s) and insect(s) present, and the cost to use each technology.

Lessons learned: Some of the storage technologies may not be useful for smallholder farmers because of the expense (PICS bags or metal silos) or limited commercial availability (GrainPro® Super Bags). The main maize storage concerns are rodents and the presence of mold. The relatively high low temperatures (14-18°C) in the Western Highlands result in relatively few insect infestations. Smallholder farmers need considerable training to understand the benefits of reducing postharvest losses that can come from investing in better storage technology.

Mycotoxins and Fungal Contamination

Afghanistan – Focus crops: Grapes/raisins, Tree nuts, Wheat

Achievements: Raisins and tree nuts are important exports from Afghanistan, with the European Union the usual target for these products, while wheat is the largest single component (500-600g/day) of most Afghan's diets. Tests were initially made at a mycotoxin laboratory established in Afghanistan and many results confirmed in the US, Italy or Austria. Aflatoxins were present at export limiting levels in 48% of the pistachio samples, 48% of the raisin samples, 32% of the walnut samples, and 19% of the almond samples. Ochratoxins were present at export limiting levels in 31% of the raisin samples, and 5% of the pistachio samples, but not in the almonds or the walnuts. In the wheat samples, 2% were contaminated with deoxynivalenol, 15% were contaminated with aflatoxin, 24% were contaminated with ochratoxin, and 34% were contaminated ergot alkaloids. The ELISA test kits for T-2 and HT-2 toxins were not reliable, but these toxins were not a problem based on HPLC and LC-MS assays in Italy and Austria. Sampling and sub-sampling of the collected samples for analysis were problematic.

Lessons learned: Contamination of raisins and tree nuts with aflatoxins and ochratoxin are significant non-tariff trade barriers for exports, especially to Europe, which has the lowest allowable levels for mycotoxin contamination of any importing agency. As acceptable contamination limits vary by country, identifying alternative markets for at least some of these products needs to be encouraged. Enabling the private sector to establish a mycotoxin lab to provide information (not certification!) on contamination will be important in properly directing exports. In wheat, the ochratoxin contamination will be the most difficult to deal with, as the ergot can be eliminated by screening grain before processing and aflatoxin contamination probably results from poor post-harvest storage practices. Implementing pre-harvest good agricultural practices also is important since much fungal contamination begins prior to harvest and storage.

Bangladesh – Focus crop: Rice

Achievements: The moisture content of rice collected from 200 households in Monirampur of Jessore and in Phulpur of Mymensingh was determined and the relationship to grain quality assessed. Grain discoloration due to molds was estimated by dry inspection. The presence of mycotototoxigenic molds was assessed with a Blotter Incubation Method. The mycotoxin lab in the Department of Plant Pathology, BAU, Mymensingh confirmed the presence and quantified the amount of aflatoxins and fumonisins in 72 grain samples from Monirampur and Phulpur.

Lessons Learned: Aflatoxins and fumonisins are present in rice grown in Bangladesh. Out of 72 samples, 9 samples had aflatoxin and 3 samples had fumonisin contamination above international tolerance limits. The grain moisture content after harvest is > 14%, which favors mold growth and mycotoxin contamination. Fumonisins were present in some samples, but did not exceed the international phytosanitary limit (2 ppm) for human food. Similarly, aflatoxins were detected in all samples but majority had contamination below the international tolerance limit (20 ppb). Moisture content did not correlate with mold incidence or concentration of aflatoxin or fumonisin.

Ethiopia – Focal crops: Maize, Wheat, Chickpea, and Sesame

Achievements: Maize (2 kg) was collected monthly (March-August 2015) from 30 farmers in Merawi and Bahir Dar from March-August 2015. Aflatoxin, fumonisin, and deoxynivalenol were measured with ELISA test kits from Romer Labs® (USA). Average monthly aflatoxin levels ranged from 3.8-16.8 ppb, all below the US FDA advisory level (20 ppb), although some individual samples exceeded this level. The proportion of samples above 20 ppb increased with storage time and exceeded 10% of all samples in July and August. Fumonisins were detected in samples collected from April-August. Nine percent of the samples contained fumonisins, but none of the samples exceed the FDA advisory level of 2 ppm. Deoxynivalenol in excess of the FDAs advisory level (1 ppm) was found in 3.3% of the samples.

Of 160 sesame samples (40 from warehouses and 120 from farmers), 80% were positive for aflatoxins (range 0-139 ppb), 91% were positive for deoxynivalenol (range 0-9.98 ppm), and 35% of 80 samples tested were positive for fumonisins. Of 160 chickpea samples (40 from traders and 120 from farmers), 34% were positive for aflatoxins (range 0-30 ppb), 33% were positive for deoxynivalenol, and 48% were positive for fumonisin. The fumonisin levels were all < 2 ppm, and the deoxynivalenol levels were all < 1 ppm. Grain in jute bags had the highest aflatoxin level (19 ppb) followed by polypropylene bags (16 ppb), PICS bags (11 ppb), and GrainPro® Superbags (9.1 ppb).

Lessons learned: Analysis of the farm samples was delayed due to a lack of test kits. These kits arrived in November 2015, and all samples had been analyzed by February 2016.

Ghana – Focus crop: Maize

Achievements: Moisture content and mycotoxin level are correlated in most Feed the Future countries. The PHLIL Ghana team is developing, testing, and comparing grain moisture content data from USDA-PHL and John Deere moisture meters to determine which is more accurate. Sufficient data for a peer-reviewed manuscript is now available. ATT and the Ghana PHLIL team are working on an agreement that

will enable ATT to purchase the low cost USDA-PHL moisture meter, however, the process is taking more time than expected. USDA AMPLIFIES (Assisting Management in the Poultry and Layer Industries by Feed Improvement and Efficiency Strategies) has also partnered with Ghana PHLIL to sponsor the construction of an additional 5 SBD in the Middle Belt to improve the quality of maize used for animal feed. AMPLIFIES will also purchase PHLIL moisture meters, ZeroFly bags, PICS bags, GrainPro Superbags, and other mitigation technologies. Collection of mycotoxin baseline data in stored maize by KNUST continues in the Middle Belt and in Northern Ghana. Bi-monthly summary reports of data collected are available. Additional mycotoxin baseline data on maize stored in a Kikapu bin and plastic silos are being collected. ATT's purchase of USDA-PHL moisture meters and a solar-biomass hybrid dryer will increase mycotoxin detection capabilities and reduce the amount of toxins being detected.
Lessons learned: Africa RISING insists that Ghana PHLIL project provide both funds and personnel to facilitate the collaboration because they are short on manpower for baseline mycotoxin tests. The Ghana PHLIL project has neither funds nor personnel for this purpose, so collaboration with Africa RISING is unlikely for mycotoxin assessment.

Guatemala – Focus crop: Maize

Achievements: An assessment of the quality of maize harvested (November 2015-January 2016) by smallholder farmers in Chiantla and Todos los Santos after 30, 60 and 90 days of storage is in process with results to be compared with a similar assessment conducted the preceding year. In the first assessment aflatoxin averaged 7.9 ppb for aflatoxins and 3.4 ppm fumonisins, which is lower than values previously reported in the literature. Given the strong effect of climate and management on mycotoxin risk, there are often discrepancies between studies conducted during different seasons – or even within the same season. Sampling and testing procedures can also lead to these differences. Several means of checking this are being considered.
Identification of stored product insects and fungi belonging to the genera *Aspergillus*, *Fusarium*, *Penicillium*, *Verticillium*, and *Cladosporium* also is in progress.
Lessons learned: Due to the low number of samples analyzed during the first assessment and the observed low levels of mold and mycotoxin contamination, a second assessment is being conducted to determine if weather or other unusual conditions affected the results. Longitudinal surveys such as this are always more reliable in determining whether mycotoxins are an issue, given their episodic occurrence and the role of climate in their accumulation.

VI. Human and Institutional Capacity Development

a. Short term Training

Country	Number (sex disaggregated)	Purpose	Home Institution/ Place of training	Training Mechanism
Bangladesh	Farmers = 88; 33 (F), 55 (M) Students =5; 1 (M) PhD, 1(M) and 1(F) MS students, 1 (M) and 1(F) undergrads Farmers = 176; 103 (F), 73(M)	Validation and gender sensitization Helped to set-up dryers, learned instrumentation and their operations. Set-up of storage experiments. Use of Hermetic bags (GrainPro® and PICS) and moisture meters	Phulpur, Mymensingh, Monirampur, and Jessore BAU, Phulpur, Mymensingh, Monirampur, and Jessore Phulpur, Mymensingh, Monirampur, and Jessore	Workshops and training Hands-on training FGDs and training
Ethiopia	Total attendees = 44; 9 (F), 35 (M) <u>Sex aggregated</u> Government Sector = 10 Private Sector = 7 Civil Society/NGOs = 6 University = 20 USAID (Govt.) = 1	Awareness of post-harvest loss in Ethiopia. Progress-to-date and future goals for FtF PHLIL. Research results on storage, mycotoxin contamination, and drying in Ethiopia were discussed.	Harmony Hotel Conference Center, Addis Ababa, Ethiopia	Workshop, Focused Group Discussion (FGD) with students and faculty members, and scientific presentations
Ghana	Farmers = 10; 3 (F), 7 (M)	Training and demonstration of usage of USDA-PHLIL moisture meter and how to incorporate good agricultural practices after harvest.	Farmers were from the Ejura municipality in the middle belt of Ghana. The training location was a Pens Food Bank Ent. (cooperating local industry) facility.	Hands-on training and demonstration.
Guatemala	Farmers = 30 (F)	To discuss and address the Women's Empowerment in Agricultural Index (WEAI)	Delivered by Ada R. Chavarria, gender consultant, in Dec 2015.	Workshop and Focus Group Discussion. Interaction based on tasks.
Afghanistan	Total Participants = 49; 9 (F), 40 (M) USAID = 8 Afghanistan govt. = 23 FAO = 2 NGOs = 2 World Bank = 1 Private sector = 8 CGIAR = 1 US Academic = 3 Italy Academic = 1	To discuss results from mycotoxin survey and to plan for future work based on these results.	Imperial Hotel, New Delhi, India	Workshop, Nominal Group Discussions, visits to relevant government and private food safety facilities.

*M = Male, F= Female

b. Long term Training

Support for graduate education is an important part of PHLIL's mission to build capacity for the next generation of post-harvest experts. Graduate students are also essential in performing PHLIL's activities, including lab and on-farm research and assisting in PHL trainings. In Bangladesh, PHLIL is supporting eight graduate students at Bangladesh Agricultural University. The students are working on master's or doctoral degrees in our three key areas of drying, storage or mycotoxin analysis. There are eight graduate students involved with our programs in Ethiopia, seven at Mekelle and Bahir Dar universities and one at Kansas State University. In Ghana, two graduate students from Kwame Nkrumah University of Science and Technology (KNUST) are involved in PHLIL activities. In Guatemala one graduate student at the University of Nebraska-Lincoln is engaging in PHLIL research and training, through joint funding with USDA.

Institutional Development

Afghanistan

Partner: Ministry of Agriculture, Irrigation and Livestock
Description: Remodeled and refurbished space into a functional mycotoxin testing laboratory with separate locations for extracting samples and running tests. Provided readers and all other supplies, equipment and SOPs to conduct mycotoxin assessments. Trained local MAIL staff to sample field and storage facilities and to run Romer Co. test kits for mycotoxin contamination in tree nuts, grapes/raisins and wheat.

Bangladesh

Partner: Bangladesh Agricultural University (BAU).
Description: Installation of two types of dryers; provision of sufficient hand held moisture meters, including John Deere, probe moisture meters, Fluke data logger, six 30m k-type long thermocouples, two ACR TRH-1000 data loggers with temperature and humidity measurement capability, ACR smart button sensors were provided to conduct drying and storage trials. Gas analyzer (O_2 and CO_2), Hygrometer, hot air oven have been added in the lab of the Department of Farm Power and Machinery, Bangladesh Agricultural University. Two types of hermetic bags (GrainPro® and PICs) and 1 ton capacity silo were provided for storage experiments. Romer Lab test kits were delivered to BAU for assessing mycotoxin contamination levels. To the best of our knowledge this is the first functional mycotoxin testing lab in the country. Planning for engagement/outreach activities, including: active learning, curriculum development, assessment, use of multi-media tools, and gender inclusion strategies.

Ethiopia

Partners: Mekelle University and Bahir Dar University.
Description: Equipped mycology laboratories at Mekelle and Bahir Dar Universities with ELISA readers and test kits for mycotoxin analysis – aflatoxins, deoxynivalenol and fumonisins (at both universities), and ochratoxin (only at Mekelle). A GrainPro® Bubble dryer was delivered to and installed at each university. Nineteen HOBO data loggers with temperature and humidity measurement capability, 27 Button sensors, several USDA moisture sensors, and 3 John Deere moisture meters were provided for each university. In the last quarter of 2015, a team from K-State visited Ethiopia to develop relations with Hawassa University and Nas Foods Inc. to broaden the nutrition and gender portions of the Ethiopia program.

Ghana

Partner: Kwame Nkrumah University of Science and Technology (KNUST).
Description: MoUs between the Ghana PHLIL project and ATT (IFDC), Africa Rising, and SPRING agricultural NGOs have been completed and signed. These formalized relationships increase and strengthen

the human capacity, research goals, and mass-scale adoption portions of the program. These NGOs are now collaborating with KNUST to collect mycotoxin data and to enable widespread adoption of moisture meters. Kepler Werber Company (Brazil) donated a Kikapu steel storage silo sited in the middle belt of Ghana for experimental storage studies. USDA AMPLIFIES has also partnered with PHLIL for construction and procurement of drying and storage technologies, to improve the quality of maize used for animal feed.

Guatemala

Partners: SHARE Guatemala (a local NGO), Universidad del Valle.
Description: A mycotoxin testing laboratory at Universidad del Valle was set up by a U.S. scientist. Fungal identification workshops and seminars were presented to strengthen the background of relevant university faculty and staff in this area. Solar dryers were set up at the university, where undergraduate students are helping to design, modify and construct them as a part of their senior year project.

VII. Technology Transfer and Scaling Partnership (if applicable)

Bangladesh

Project Advisory Teams

The heads of partner institutions engaged in post-harvest loss reduction activities for rice nominated members of an Engagement Advisory team. Members have agreed to serve and will meet before project year 3 ends.

Technologies transferred and scale

One SBD solar dryer and one modified STR dryer are installed and functional at BAU. The modified STR drier will be tested on farm before the end of project year 3. Hermetic bags (80 GrainPro® and 80 PICS bags) were supplied and are being tested for use for storing rice at the on-farm household level.

Ethiopia

Project Advisory Teams

General information gathering meetings during the first and second project years enabled the project team to identify eleven key stakeholders who now serve on the Engagement Advisory Committee and who collectively represent the public and private sectors, and governmental and non-governmental organizations. The EAT first met in July, 2015 and will meet again prior to the end of the third project year.

Technologies transferred and scale

Scripts have been finalized in the local dialects for the SAWBO training videos. These training videos address best management practices for use of phosphine fumigants for insect control in stored grain and the use of solar dryers for grain drying. These videos are targeted for the general rural population in Ethiopia, including via cell phones, farmer training sessions; printed information is also key. Pilot scale solar dryers are installed and operational at both Bahir Dar and Mekelle Universities. Cabinet dryers at both locations have been rehabilitated.

Ghana

Project Advisory Teams

Engagement Advisory Teams (EATs) for both Northern Ghana and the Middle Belt have been formed. The EAT for the Middle Belt has 10 members and the EAT for Northern Ghana has 9 members. An eight member Technology Research Implementation Team for the entire project also was established. MoUs with AFRICA RISING and SPRING, who are key partners for distribution of improved technologies, have been signed with Oklahoma State University. The names of all the members from the above three regions are listed in the 2015 PHLIL Annual Report. All advisory groups will meet again before the end of project year 3.

Technologies transferred and scale

A Kipaku storage bin (steel) donated by Keplar Werber (Brazil) with six metric ton capacity was installed in Ejura, in the middle belt region of Ghana. Bulk plastic storage (7 metric ton capacity) and a Hybrid Solar-Biomass Dryer are now functional in Ghana, in addition to the SBD at KNUST. Scale-up efforts for USDA-PHLIL moisture meters and commercially available storage bags (PICS and GrainPro® are planned.

Guatemala

Project Advisory Teams

MoUs with SHARE and Universidad del Valle remain active. These agreements add to facility and capacity of the local NGO and university through the cross exchange of technologies, training, and research results. Members of an Engagement Advisory Team have been identified, and all have agreed to serve.

Technologies transferred and scale

Pilot scale solar dryers installed at Universidad del Valle were redesigned and improved by students who participate in their operation.

VIII. Environmental Management and Mitigation Plan (EMMP)

Most research activities do not have a significant effect on the environment as they fall outside the 11 classes of action identified in Part 216.2 (d) (1). However, the projects in Ethiopia and Ghana, which include the use of pesticides on commodities and in warehouses, must comply with procedures set forth in Part 216.3. Dr. Bhadriraju developed an Environmental Mitigation and Monitoring Program (EMMP) for the Lab that has been updated and approved. An EMMP checklist was developed specific to the PHLIL for use by designated individuals in each country to be completed at least quarterly that enables regular reporting and documentation of compliance with the EMMP.

Dr. Andreia Bianchini developed a standard operating procedure (SOP) for decontaminating and disposing of materials used during mycotoxin analysis, and a set of general lab safety guidelines to follow when conducting mycotoxin analyses.

All four documents are available through the reporting hub (Piestar website) and the PHLIL public website. The Piestar contractor is developing a fillable PDF of the EMPP checklist to ease reporting and will be sending quarterly e-mails to individuals responsible for completing the reports and submitting them to Piestar.

IX. Open Data Management Plan

The Management Entity (ME) will make information and data publicly accessible on the Innovation Lab's website and will develop a data sharing policy for primary investigators and research teams as a matter of priority, which will address access and timelines. The ME will abide by all the data sharing policies and procedures set by K-State, USAID, and the other partnering institutions. In addition, a web-based data collection interface (Piestar) supports internal data collection with respect to project milestones, reports, budgets and financial expenditure. The general data management plan is as follows:

A. **Data Description:** Includes Work Plans, PMPs, Annual Reports, and Repository of documents for USAID. In addition, the ME collects individual country meeting and trip reports, along with site visit reports and reports on in-country meetings held to consider strengths, weaknesses, opportunities, research priorities, and outputs. All financial data and data generated from research projects are collected and archived by the ME.

B. **Data Organization and Management:** A local data management company, Piestar, developed a web-based Monitoring, Evaluation, and Progress Reporting System (MEPRS). This system is customizable, accurate, reliable, user-friendly, and supported by secure internet connections. A major benefit derived from this system is the ability to use components already available to other USAID Feed the Future Innovation Labs based at K-State. Excel and Word files generated by the ME are stored in external hard drives at K-State available (locked with user permission) only to authorized users within the Dean of Agriculture's office.

C. **Data Access and Sharing:** The ME abides by the data sharing policies and procedures established by K-State, as well as other partner institutions. The ME bears the overall responsibility for data management over the life of the project and will monitor and supervise compliance throughout the life of the project. Data will be preserved and made available over generational shifts in technology to ensure that it remains accessible over time.

Policies: Training and regulations potentially required of or applicable to researchers participating in this project by the Research Compliance Office at K-State include:

- Human Subjects Research Institutional Review Board (IRB) - The IRB administers a comprehensive and compliant Research with Human Subjects program for researchers, students, and potential human subjects.
- Responsible Conduct of Research (RCR) - This training is an individual and an institutional requirement. All persons involved in research activities must have a working understanding of the responsible conduct of research to make the best ethical and legal choices in the face of potential conflicts involving research activities. This training develops an appreciation for the range of accepted scientific practices for conducting research, and the need to be knowledgeable about the regulations, policies, statutes, and guidelines that govern the conduct of University-sanctioned research.
- Confidential/Sensitive Research (C/SRC) - C/SRC policies govern activity (ies) proposed by K-State faculty and staff that involves information for which general access to or distribution of should be restricted, or is inadvisable, illegal, or contraindicated.
- Project staff will adhere to all federal laws and regulations for oversight of activities involving research with human subjects and will analyze, present, and communicate the results of such studies in a manner that preserves participant confidentiality and accurately portrays their views. Project staff will file the appropriate paperwork with the Institutional Review Board (IRB) at K-State. All of K-State's human subject studies, regardless of funding source, are guided by the ethical principles in *The Belmont Report: Ethical Principles and Guidelines for the Protection of Human Subjects of Research* and the *National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research*.

Status Update (Year 3, Semi-Annual): The Piestar website is fully active and serving as a depository for all reports, plans, trip summaries, EMMP checklists, and other research outcomes. The Piestar contractor is adding programs that will interface with the USAID Digital Data Library (DDL) to enable easier uploading of PHLIL data sets to the DDL. Additional data stored on K-State servers follows the University's Policies and Standards.

X. Project Management Activities

Dr. John F. Leslie has served as the Interim Director of the PHLIL since May 2015. An international search was conducted to find a permanent Director. Dr. Leslie's replacement has been identified and will begin in mid-May (Dr. Jagger Harvey). Dr. Leslie will continue as the US PI for the Afghanistan project.

Dr. Anne Huss served as the interim Program Coordinator until October 2015. Dr. Rumela Bhadra replaces Dr. Huss as the Program Coordinator in October.

Dr. Lindshield has established an operational budget and collaboration with in-country nutritionists to design surveys and research trials to assess the impact of the post-harvest loss and the reduction technologies developed by the lab.

Dr. Gordon Smith (K-State) replaced Dr. Venkat Reddy as co-PI for the Bangladesh project in collaboration with co-PI Dr. Prasanta Kalita (University of Illinois). An operations budget for Dr. Smith remains to be established.

The Ghana project has hired Dr. Irene Igyir as the in-country gender specialist.

XI. Other Topics

Nutrition: In-country partners have been identified in Bangladesh, Guatemala, Ghana, and Ethiopia to collect nutrition, economic, and grain quality data from small-scale farmers with direct relevance to FtF nutrition indicators. Discussions are in progress on the best approaches to use for collecting these data to ensure comparability across different countries. The specific status of the nutritional studies in each of the PHLIL countries are given below:

Bangladesh: The in-country PI, Dr. Monjurul Alam and Dr. Lindshield are discussing research protocols.

Ethiopia: An agreement is being finalized with the School of Public Health, College of Health Sciences, Mekelle University to conduct this research.

Ghana: Recommendations for partners were requested from a recent K-State Nutrition Ph.D. alumnus from Ghana and from PHLIL Ghana team members. Both recommended Dr. Emmanuel Ohene Afoakwa, Professor and Head of the Department of Nutrition and Food Science at the University of Ghana. An agreement is being finalize with the University of Ghana to support this research effort.

Guatemala: The NGO SHARE, the project's main in-country partner, has experience collecting this type of data for other projects. Additional funding and appropriate milestones were added to the year 3 project contract.

XII. Issues and How They Are Being Addressed

Timing of field experiments: Timing for field experiments still remains a challenge, especially for solar drying experiments. In some locations, the rainy season hindered installation and operation of the solar dryers. In some cases solar dryers have been modified to incorporate mechanisms to enable drying to continue on cloudy and rainy days.

Drs. Pittendrigh and Bello-Bravo will be leaving the University of Illinois for Michigan State University in the summer of 2016. Arrangements need to be made for continued funding of their project when the funds supporting them switch from being from ADM Institute to being from USAID in October 2016.

Projects have been slow to provide receipts for reimbursement to the ME. Improved communications between the K-State Business office and the PIs and business offices of the subcontractors have reduced this problem significantly.

Ethiopia – Supply and Equipment Availability and Capacity Building: Universities in Ethiopia have a competitive bidding process that is awkward and time consuming. Restructuring this process has been recommended to appropriate university administrators. The mycotoxin readers and test kits that were delivered last year to replace the non-functional ones are now in use.

Ethiopia – Grain Storage Pesticides: In Ethiopia, farmers use toxic pesticides available from local stores. The pesticides are sold in small vials but the chemicals present in the vials are unknown, and there are no guidelines for their safe use. Bahir Dar University has an analytical laboratory. Samples collected from farmers and warehouses will be tested for pesticide residues, and local pesticides sold to farmers for grain treatment evaluated to identify the active compounds. Previously uncharacterized compounds will be considered for laboratory trials to determine the efficacy of these products on stored-product insects.

Bangladesh – Management and Funding of the Project: With Dr. Reddy's departure in August 2015, identification of another co-PI for the Bangladesh project was essential. Dr. Gordon Smith of the Grain Science and Industry Department at K-State agreed to assume the role and traveled to Bangladesh in August 2015. There is no operational budget for the Bangladesh project in the portion of the Innovation Lab budget administered at K-State. Arrangements remain to be made with the University of Illinois to fund operations for Dr. Smith in his role as co-PI, so that his operations are not from the Lab's core budget, which is meant to benefit all of the projects supported by the Innovation Lab. It may be best to make these adjustments when funding switches from being from ADM Institute to being from USAID in October 2016.

Partnering with International Agricultural Partners Consortia in Ghana: The Ghana project has established MOUs with ATT (IDFC), Africa RISING, and SPRING to explore local production and mass adoption of solar dryers and the USDA-PHL moisture meter, and to collect additional baseline mycotoxin contamination data.

Innovation Lab Leadership: ME staff changes continue. A permanent Program Coordinator (Dr. Rumela Bhadra) has been hired and is on board.

A permanent director to replace Dr. Leslie has been identified and should begin in May 2016. Dr. Leslie will remain with Innovation Lab in an advisory role for at least the next several months and will remain the US PI for the Afghanistan project for the foreseeable future.

A new Business Manager is being recruited to replace Ms. Yasmin, who is being pulled back into the Grain Sciences Department that supports the remainder of her salary.

An External Advisory Board needs to be reconstituted.

XIII. Future Directions

- Results from Year 1 and Year 2 gender reports are assisting the development of post-harvest loss mitigation technologies, and are providing guidance for the PI and Co-PIs as the PHL moves towards the 'in-field' phase and more widespread adoption efforts. They also provide important insights into local culture-dependent norms and divisions of labor that extend beyond the management of post-harvest problems.
- Multiple options exist for suitable drying and storage solutions, and no one solution is likely to be the "right" one for all countries, or perhaps even for all of the communities within a country. Developing a portfolio of potential technologies from which the best technology for a given situation can be selected is essential for sustainable change in both storing and drying grain. Solar drying is probably an important component of the solution, but seems unlikely to be the entire solution, based on results achieved with the technologies tested to date.

- Identifying local suppliers and manufacturers of dryers and storage materials and partnering with them to ensure high quality products are put on the market remains a target in all four core countries.
- The mycotoxin component of the portfolio has developed a "blueprint" that can be used in many countries to conduct a baseline survey. Using this blueprint to solicit funding from other USAID missions would increase the number of countries in which the Lab is involved as well as providing baseline data from which decisions about needed remediation approaches, if any, could be made. The Lab is well-positioned to both lead and to partner with others in designing and implementing studies to reduce mycotoxin severity from on-farm plant production to post-harvest storage, sales, marketing and regulation.