FEED THE FUTURE

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

Innovation Lab for Collaborative Research on Peanut Productivity and Mycotoxin Control

Feed the Future Innovation Lab for Collaborative Research on Peanut Productivity and Mycotoxin Control

(Peanut & Mycotoxin Innovation Lab)

Annual Report – Fiscal Year 2016

(1 October 2015 – 30 September 2016)

PMIL Management Entity
The University of Georgia, Athens, Georgia
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FROM THE AMERICAN PEOPLE

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Note from the Director

On behalf of the entire Peanut & Mycotoxin Innovation Lab team, it is my pleasure to present the Feed the Future Innovation Lab for Collaborative Research on Peanut Productivity and Mycotoxin Control Annual Report for Fiscal Year 2016 (FY2016). During our fourth year, we made significant progress in reaching the objectives in each of the projects. Our findings have been captured in this report and disseminated via refereed publications, guides and infographics, presentations in scientific conferences, discussions with other development-oriented stakeholders, and most importantly, with farmers and consumers.

We also were pleased to see several PMIL-funded graduate students complete their studies and receive their graduate degrees during the year. Most of the students have either continued their studies, or have started to apply their new knowledge in their work.

A highlight of the year was the Annual Research and Planning Meeting conducted in Ghana. During the opening days of the meeting in Tamale, more than 100 PMIL scientists and other stakeholders had the opportunity to discuss the progress made thus far and plans for the last year of the project. It was exciting to see the impacts of our efforts during visits to local villages and partner institutions in Tamale, Kumasi and Accra.

As many of the projects are reaching the end of the data-collection phase, results are now being analyzed and already providing insights on what interventions make significant impact on both peanut production and aflatoxin reduction in farmers' fields. The results from studies to determine the economic incentives for farmers to adopt such practices are proving to be equally important. What makes sense scientifically does not always fit how farmers view such interventions in their own systems. Our effort to support breeding programs in our target countries is already demonstrating that regional networks are feasible and will enable breeders in several countries to share germplasm and even employ modern genomics in their respective programs. Clearly, this approach is something we want to continue to build on in the future.

As we move into our last year of the program, we are focused on completing all objectives and documenting the results in appropriate media. While many research projects will have a natural end, many efforts will need to continue, e.g., breeding programs that must maintain an active pipeline approach or agronomic studies that will continue evaluating rotations. Hopefully, through our efforts to build capacity in our partner institutions, these programs will be more sustainable.

We have appreciated all the feedback we received this past year from stakeholders and look forward to your continued input into the program. Finally, just a reminder to please make sure you register to receive our electronic newsletter, visit our website for more information, and follow us on social media.

Dave Hoisington, Director, PMIL

Acronyms

AFB	Aflatoxin B_1
APRES	American Peanut Research and Education Society
AOR	Agreement Officer's Representative
APHIS	Animal and Plant Health Inspection Service, USA
ASU	Albany State University, Albany, GA
CAES	College of Agricultural and Environmental Sciences
CERAAS	Centre d'Etude Régional pour l'Amélioration de l'Adaptation á la Sécheresse, Senegal
CNRA	Centre National de Recherches Agronomiques, Senegal
Co-PI	co-Principal Investigator
COMESA	Common Market for Eastern and Southern Africa
CRI	Crops Research Institute, Ghana
CRP	CGIAR Research Program
CRSP	Collaborative Research Support Program
CSB+	Corn Soy Blend
CSIR	Counsel for Scientific and Industrial Research, Ghana
DBS	Dried Blood Sample
EAP	External Advisory Panel
EMMP	Environmental Mitigation and Management Plan
FY2013	Fiscal Year 2013
FY2014	Fiscal Year 2014
FY2015	Fiscal Year 2015
FY2016	Fiscal Year 2016
GRD	Groundnut Rosette Disease
GWAS	Genome-Wide Association Study
HACCP	Hazard Analysis and Critical Control Points
HIV	Human Immunodeficiency Virus
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IFA	Iron and folid acide
IIAM	Instituto de Investigação Agrária de Moçambique, Mozambique
IITA	International Institute for Tropical Agriculture, Nigeria
ISRA	Institut Sénégalais de Reserches Agricoles, Senegal
KNUST	Kwame Nkrumah University of Science and Technology, Ghana
LUANAR	Lilongwe University of Agriculture and Natural Resources, Malawi
ME	Management Entity
MoFA	Ministry of Food and Agriculture, Ghana
MSc	Master of Science Degree
MSU	Mississippi State University, MS
MUAC	Mid-Upper Arm Circumference
NaCRRI	National Crops Resources Research Institute, Uganda
NARO	National Agricultural Research Organization, Uganda
NaSARRI	National Semi-Arid Resources Research Institute, Uganda
NASFAM	National Smallholder Farmers Association of Malawi, Malawi
NBCRI	Norman Borlaug Commemorative Research Initiative
NCSU	North Carolina State University, NC
NGO	Non-Governmental Organization
NMSU	New Mexico State University
NPRL	National Peanut Research Lab, Dawson, GA
PCR	Polymerase Chain Reaction
PhD	Doctor of Philosophy Degree
PI	Principal Investigator
PIIM	Peanut Industry Incubator Model
PMIL	Peanut & Mycotoxin Innovation Lab
RDA	Recommended Daily Allowance
RNAi	RNA interference
RSS	Rich Site Summary
RUSF	Ready-to-Use Supplemental Food
RUTF	Ready-to-Use Therapeutic Food
SARI	Savanna Agricultural Research Institute, Ghana
SNP	Single Nucleotide Polymorphism
SPAD	Soil Plant Analysis Development
SSR	Simple Sequence Repeat
STN-PCR	Single Tube Nested Polymerase Chain Reaction
TNAU	Tamil Nadu Agricultural University, India
UDS	University for Development Studies, Ghana
UFL	University of Florida, FL
UGA	University of Georgia, GA
UHPLC	Ultra-High Performance Liquid Chromatography
UNIMMAP	United Nations International Multiple Micronutrient Supplement
UNZA	University of Zambia, Zambia
USAID	United States Agency for International Development, USA
USDA	United States Department of Agriculture
USDA-ARS	United States Department of Agriculture – Agricultural Research Service
WUSTL	Washington University, St Louis, MO
ZARI	Zambian Agricultural Research Institute, Zambia

Executive Summary

As the Peanut & Mycotoxin Innovation Lab entered its fourth year of a five-year program at the start of FY2016, many of the projects were approaching important phases of the overall timeline – when objectives are reached and significant research findings collected and analyzed.

During the year, some of the first graduate students completed their thesis research and received their degrees. Many were also given the opportunity to present their results to diverse academic and professional groups beyond their university, and defend their findings and answer questions. Most all students are either continuing toward advanced degrees or have found employment based on their new skills and knowledge.

Improved peanut varieties remain a critical initial component in improving farmers' productivity. Excellent progress has been made to develop new varieties with better tolerance to water stress and resistance to leaf spots, rust and rosette. Efforts are focused on farmer and market traits that are important for best acceptance of the new varieties. Initial crosses are underway to introgress quality traits such as high oleic acid content into local and improved varieties.

Breeders are working together across southern Africa, evidence that a regional network is feasible and can accelerate breeding efforts in many countries.

Critical to long-term sustainability are linkages with the private sector, especially those involved in seed production and dissemination (e.g., ExAgris in Malawi and Acceso in Haiti) and processing (e.g., Meds & Food for Kids in Haiti). The partnerships have resulted in the ability to conduct research on company sites, providing opportunities for scaled, well-managed research plots and the more rapid adoption of the results by the companies.

While sampling for aflatoxin remains the biggest challenge in accurately testing for contamination, efforts to develop and deploy detection devices such as the Mobile Assay mReader and the "Aflabox" are making headway to reduce the expense and complexity of testing. Nearly 30 tablets have been purchased and provided to partners in all PMIL countries, along with training in proper sampling strategies and the extraction and detection protocols using the Neogen lateral flow test strips. A mini-review of the Aflagoggles project (which developed into the Aflabox) in the beginning of the year, indicated that the latest device does have great promise as an essentially free-of-cost aflatoxin test, and provided recommendations on the remaining areas for research and testing.

The application of modern genomics made major strides forward with the development of the first SNP chip for peanut. The chip, containing over 55,000 markers, will help democratize plant breeding by allowing breeders across the world to have their materials genotyped rapidly. Efforts are now focused on linking the molecular markers to important traits in order to make genetic gains in breeding.

As on-station and on-farm research produces results, we have better data on the importance of various pre- and post-harvest interventions in improving peanut production and reducing aflatoxin contamination. We are also learning that some of the simplest ways to reduce aflatoxin, e.g., tarps for drying, might be more complicated to incentivize than initially thought, considering cultural and economic practices of using the peanut crop as savings by many smallholder farmers.

Our efforts to create and disseminate instructional materials, like production guides and infographics, and have these translated into several local languages, have been very successful. Scientists and other stakeholders can now discuss with farmers and consumers about the importance of growing and consuming peanuts, and straightforward methods to reduce aflatoxin contamination. We are planning to produce more materials to convey results across the value chain in the coming year.

Program Countries

PMIL primary target countries are Ghana, Haiti, Malawi, Mozambique and Zambia. In addition to the primary countries and the USA, PMIL has research partnerships in Burkina Faso, Ethiopia, India, Kenya, Mali, Niger, Nigeria, Senegal and Uganda.

Program Partners

PMIL works with universities and other institutions located in 15 US states (Alabama, California, Connecticut, District of Columbia, Florida, Georgia, Louisiana, Maine, Missouri, Mississippi, North Carolina, New Mexico, New York, Texas and Virginia) and 14 foreign countries (see above list). Details on the specific institutions in each US state and foreign country are provided in Appendix A.

Program Highlights

Partnerships forged between public or philanthropic organizations and private industry are improving farmers' access to markets (through Acceso in Haiti), making improved varieties of seed more available in the market (Exagris in Malawi) and providing students access to research plots (MFK in Haiti and Exagris in Malawi).

In Haiti, the program performed variety tests and scale-up of seed systems with Premier Steppe Farms, Inc. and iF Foundation; provided technical expertise, as well as production guides, field visits and aflatoxin training for depot managers of Acceso Peanut Enterprise, a private supply chain business working with smallholders; provided guidance and expertise to MFK agronomists; continued support of the aflatoxin detection facility at iF Foundation; and established a Research/Teaching mycotoxin lab at Faculté d'Agronomie et de Médecine Vétérinaire (FAMV), Université d'État d'Haïti in Damien.

Ongoing plant breeding activities are making continuous improvement toward high-yielding, disease-resistant varieties and building local capacity to scale up seed production, including:

- Proposals were submitted for release of two LS-resistant peanut accessions as new varieties in Burkina Faso and for a high-oleic Valencia peanut in Texas. In Zambia, two varieties with resistance to Groundnut Rosette Disease and Early Leaf Spot were submitted for pre-release testing.
- In Haiti, a sub-contract was executed with Université de Quisqueya, home institution of Dr. Raphael Colbert, the breeder identified to lead the peanut breeding effort in Haiti.
- In Malawi, field days at harvesting showcased performance of newly released groundnut varieties (designated CG 8 to CG 14) and a workshop updated research technicians and extension staff on groundnut trial management.

In the area of nutrition, a study of 1873 moderately malnourished pregnant women showed the impact of feeding two types of corn-soy meal plus fortification or supplements, and peanut-based Ready to Use Supplemental Food (RUSF) on mothers and babies. After 14 days' prenatal treatment of the mother, 1524 infants were measured at birth, 94% within 24 hours. Women who received the peanut-based

RUSF were most likely to recover from malnutrition compared to women who received one of the corn-soy blends (37%, compared to 35% and 32%) as determined by their upper arm circumference. Their babies were also less likely to be underweight (24%, compared to 25% and 31%).

As part of interventions to improve production and reduce contamination:

- We trained 1,005 farmers in 40 villages in the northern part of Ghana on aflatoxin risks and post-harvest techniques for aflatoxin reduction.
- The program provided training and farmer field demonstrations in north and central plateau of Haiti.
- Six extension officers (three females and three males) and 76 farmers (24 females and 52 males) in Zambia were trained on groundnut production, detecting leaf-miner damage and Participatory Varietal Selection; 2000 copies of groundnut production guides in Chewa (local language) and 150 copies in English were distributed during farmer field days.
- Infographics promoting the nutrition and health value of peanuts, and on controlling aflatoxin, were designed and translated into 15 local languages. Two-page production guides were produced in Ghana and Zambia, translated into local languages and distributed to extension agents and farmers.

Farmer surveys to collect production and agronomic data at the village level continue to assess the value of interventions to smallholder farmers, with particular attention to gender differences. Since women constitute half or more of the farmers and processors of groundnuts, questionnaires and interventions are designed specifically to address gender differences. Modules are built on gender, individual assets and joint asset ownership at baseline to capture the gender dynamic around reasons why/why not individuals or households adopt control measures.

Key Accomplishments

Genetic markers array completed – The genomics project identified more than 55,000 genetic markers to use in mapping the peanut genome. Created a single-nucleotide polymorphism (SNP) array that will assist plant breeders around the world in marker-assisted selection.

Aflatoxin risk model created: Empirical risk management decision aids nearly complete in Zambia will allow producers to assess the risk of aflatoxin contamination based on environmental considerations and plan accordingly. These models, built through algorithms and refined annually through field trials, will help farmers prioritize the use of limited inputs and labor.

Testing system deployed – Following validation of the accuracy of the Mobile Assay mReader for detection of aflatoxin in peanut and peanut products, the project provided supplies and training, as well as deploying more than 30 testing systems to research partners in Haiti, Ghana, Zambia, Malawi and Mozambique. The equipment is allowing research to proceed more quickly and at lower cost than if samples were sent to offsite laboratories for testing.

Non-destructive test demonstrated: A prototype machine was created that can perform a non-destructive, no-cost test for the presence of aflatoxin by scanning with a certain spectrum of light. Called "aflabox" by the team, the device uses an electronic tablet and special box to capture the fluorescence of maize kernels contaminated with aflatoxin. The proof-of-concept will allow further research to refine the device and evaluate adapting the technology for peanuts.

RNAi technique proven in seed: Research demonstrated for the first time in peanut seeds the proof-of-concept on the effectiveness of plant-RNAi-mediated control of aflatoxin accumulation. The team created a collection that now has 2000 *Aspergillus* isolates from peanuts and soil, with samples from Ethiopia, Malawi, Tanzania, Uganda, Zambia and the USA.

Partnership forged for seed increase: In Malawi, a seed multiplication field under irrigation was established jointly with Exagris. Four newly released groundnut varieties were planted and harvested in November 2016. Availability of quality seed is a challenge facing farmers in Malawi; the seed will go a long way to meet their needs.

Processors certified after training: One Malawian peanut butter processor gained certification from the Bureau of Standards, and two more are pending certification, after they participated in a four-day training session based on interventions developed by a PMIL student-researcher during an assessment of products on the local market.

Solar dryer put into use: Simple solar dryer made of easily-sourced materials was tested for effectiveness in the U.S. and Ghana. After consulting with local smallholders about their needs, a large version of the device was built and installed in a village near Kumasi, Ghana. Follow up will determine how the machine could be adapted to meet the needs of the community further.

Blood-testing method validated: Follow-up tests of the DBS method for detection of aflatoxin B_1-Lysine (AFB-Lys) adducts in humans suggested that the previously developed HPLC-florescence method is valid in detecting the AFB-Lys adducts, and the method is now in standardization for application in large scale of epidemiological studies in Nepal supported by the Feed the Future Nutrition Innovation Lab.

Students research completed: Two dozen program-supported graduate students wrapped up research in agronomy or food-science projects and presented to mentors and teachers in the U.S. and at home.

A partnership with Exagris in Malawi has facilitated seed multiplication, given students like Lydia Mkandawire (seen in lower photo with PMIL PI Rick Brandenburg) research plots and exposed the private sector to PMIL research. (Photos by Allison Floyd)

Research Program Overview and Structure

PMIL aims to increase the productivity and profitability of peanut production for smallholder farmers and to reduce the negative impacts of mycotoxin contamination along the value chain of peanut and other crops in five Feed the Future countries – Haiti, Ghana, Malawi, Mozambique and Zambia. The research program is organized into three main areas: (a) peanut germplasm development, (b) mycotoxin detection and peanut nutritional studies, and (c) peanut value chain interventions to increase quantity, decrease mycotoxin contamination and enhance economic returns to smallholder farmers. The FY2016 program supported 11 of the following 12 projects. Each is coordinated by a Principal Investigator located at a US university or USDA-ARS research station. The B3 project, "Aflatoxin in Peanut and Peanut Products: Comparative Study on Analytical Methods for Detection of Aflatoxin," ended in FY2015.

Research Project Title	Principal Investigator	Lead Institution
A. Peanut Germplasm Development		
A1. Translational Genomics to Reduce Pre-harvest Aflatoxin Contamination of Peanut	Peggy Ozias-Akins	University of Georgia
A2. Silencing of Aflatoxin Synthesis through RNA Interference (RNAi) in Peanut Plants	Renee Arias	USDA-ARS National Peanut Research Laboratory
A3. An Integrated Global Breeding and Genomics Approach to Intensifying Peanut Production and Quality	Mike Deom	University of Georgia
B. Mycotoxin Detection and Peanut Nutritional Studies		
B1. AflaGoggles for Screening Aflatoxin Contamination in Maize	Haibo Yao	Mississippi State University
B2. Development and Validation of Methods for Detection of Mycotoxins Exposure in Dried Spotted Blood Samples	Jia-Sheng Wang	University of Georgia
B3. Aflatoxin in Peanut and Peanut Products: Comparative Study on Analytical Methods for Detection of Aflatoxin ***- COMPLETED***	Kumar Mallikarjunan	Virginia Polytechnic Institute and State University
B4. Randomized Controlled Trial of the Impact of Treating Moderately Malnourished Women in Pregnancy	Mark Manary	Washington University in St. Louis
C. Peanut Value Chain Interventions		
C1. Production to Consumption – Technologies to Improve Peanut Production, Processing and Utilization in Haiti	Greg MacDonald	University of Florida
C2. Using Applied Research and Technology Transfer to Minimize Aflatoxin Contamination and Increase Production, Quality and Marketing of Peanut in Ghana	David Jordan	North Carolina State University
C3. Producer and Consumer Interventions to Decrease Peanut Mycotoxin Risk in Ghana	Nicholas Magnan	University of Georgia
C4. Aflatoxin Management Interventions, Education and Analysis at Various Steps Along the Peanut Value Chain in Malawi, Mozambique and Zambia	Rick Brandenburg	North Carolina State University
C5. Productivity and Profitability Growth in Peanut Production: A Farm Level Analysis in Malawi, Mozambique and Zambia	Boris Bravo-Ureta	University of Connecticut

A. Peanut Germplasm Development

Project A1. Translational Genomics to Reduce Pre-harvest Aflatoxin Contamination of Peanut

The goal of the project is to associate molecular variation with resistance to pre-harvest aflatoxin contamination and other traits on a genome-wide scale and to begin to utilize this information in breeding programs. To achieve the goal, both genotyping and highly replicated phenotyping of genetic resources and populations for aflatoxin contamination are being pursued. Genotyping with genome-wide SNP (single-nucleotide polymorphism) markers is being enabled by peanut genome sequence information, both from cultivated tetraploid genotypes as well as diploid progenitors of the tetraploid. Genetic populations are being developed in India, Senegal and the USA. Phenotyping is being done under controlled field conditions in Niger, Senegal and the USA.

Collaborators

The project team remains the same as the previous year.

Name	Institution	Country	Role
Peggy Ozias-Akins	University of Georgia	USA	PI
David Bertioli	University of Brasilia/University of Georgia	Brazil/USA	Co-PI
Rajeev Varshney	ICRISAT	India	Co-PI
Haile Desmae	ICRISAT	Mali	Co-PI
Issa Faye	ISRA	Senegal	Co-PI
Daniel Fonceka	ISRA	Senegal	Co-PI
Corley Holbrook	USDA-ARS	USA	Co-PI
Scott Jackson	University of Georgia	USA	Co-PI
Hari Upadhyaya	ICRISAT	India	Partner
Pasupuleti Janila	ICRISAT	India	Partner
Pawan Khera	ICRISAT	India	Partner

Achievements

A 60K SNP array, constructed through a collaborative effort with ICRISAT and with SNP discovery (see Clevenger, J. and P. Ozias-Akins, 2015) led by graduate student, Josh Clevenger, has been used for genotyping materials related to this project (see Clevenger *et al*., Mol Plant, under revision). Validation of SNPs on the array was done by genotyping 384 tetraploid and diploid accessions including 109 from the USDA mini core collection to represent the scope of diversity among tetraploids, the 21 tetraploid accessions from which sequence data were used for SNP discovery, lines harboring traits of interest related to aflatoxin contamination, drought tolerance, and disease resistance, 11 diploid *Arachis* species and three induced allotetraploid interspecific hybrids, among others. This set of 384 accessions resulted in 54,564 markers that produced high quality polymorphic clusters between diploid species, 47,116 polymorphic markers between cultivated and interspecific hybrids, and 15,287 polymorphic markers within *A. hypogaea* germplasm. SNPs on this array have been catalogued as part of the pending publication. Subsequent genotyping of the aflatoxin "core" related to the PMIL project (82 accessions) plus seven additional parental lines yielded 12,348 polymorphic markers. Three populations related to the PMIL project, biparental Tifrunner x C76-16 and Florida-07 x C76-16, part of a larger nested association mapping population, plus an interspecific chromosome segment substitution line population (CSSL), also were genotyped. C76-16 is a breeding line from Dr. Corley Holbrook that has been identified to have reduced aflatoxin contamination and increased drought tolerance. These biparental population parents are less divergent yielding 1,269 and 979 polymorphic markers for each pairwise comparison, respectively. The CSSL data are just beginning to be analyzed.

Even though 94% of the SNPs called with SWEEP were validated on a diverse set of tetraploid and diploid accessions, only 33% of those called with the whole genome resequencing data were validated among the tetraploid accessions genotyped. Using true- *versus* false-positive SNP array data, we have further improved the SNP calling pipeline using machine learning (graduate students Walid Korani and Josh Clevenger) to achieve greater than 80% true calls. If the larger peanut community perceives a need for and is willing to support construction of a more robust SNP array for genotyping tetraploids, we will proceed with development of a second generation Affymetrix array. A survey of US and African breeders recently was conducted in an attempt to gauge interest in SNP genotyping (Table A1-1). Responses indicate sufficient interest, in terms of sample numbers breeders might process as well as use of the data in breeding (see applications), for support of an improved array. A proposal to fund a portion of the US component has been submitted to the Peanut Foundation.

Table A1-1. Breeder survey results

Traits	US (5)	Africa (3)	Relative priority
Drought tolerance	XXX	XX	XXXXX
High SPAD	X		X
Heat tolerance		X	X
High oleic	XXXXX	X	XXXXXX
Yield	XXXX		XXXX
Leaf spot resistance	XXXX	X	XXXXX
Sclerotinia blight resistance	XX		XX
Grade	XX		XX
Early maturity	X	X	XX
Pod rot resistance	X		X
Nematode resistance	XX		XX
Tomato spotted wilt virus resistance	XX		XX
White mold tolerance	XX		XX
Groundnut rosette disease tolerance	X	XX	XXX
Stay green		X	X
Oil content		X	X
Flavor		X	X
Applications			
Catalog genetic diversity among breeding materials	3,2,2,3,3	3,1,1	2.2[a]
Identify genomic regions under positive or negative selection or alleles fixed in your program	3,1,1,3,3	1,1,1	1.8
Genome-wide background selection	4,2,3,5,3	2,3,1	2.9
Identify a subset of polymorphisms to be developed for single-marker analysis for specific traits	1,1,2,1,1	1,1	1.1
Genetic maps of populations	2,2,4,2,1	1, 1.5,1	1.8

[a]1-5=highest-lowest priority

Phenotyping. Phenotyping for resistance to pre-harvest aflatoxin contamination continued in the US, Senegal and Niger. All entries have a minimum of three and a maximum of five reps for each, grown under late-season drought stress that is either naturally occurring (Africa) or simulated (US). All entries in the US also were visually scored for drought stress response in addition to aflatoxin contamination. Analysis of 2014 and 2015 data indicate that there is a small, but significant, correlation between drought stress and aflatoxin contamination among lines of the aflatoxin core. Two of the ICG/ICGV lines (ICGV 93305 and ICG 4750) were consistently drought intolerant and had higher aflatoxin contamination than most lines in the population. This correlation did not hold for all lines. One of the reportedly resistant lines from ICRISAT, ICG 1471 (aka 55-437), was characterized in the US for aflatoxin contamination after *in vitro* seed inoculation and found to be highly resistant although it was not in the top 15% of lines with resistance response in the field (US) nor in the top 50% of drought tolerant lines (US), yet it was low in aflatoxin contamination when used as a check in the CSSL testing in Senegal. Two US breeding lines (C321-2-2, C321-2-3) were consistently among the most aflatoxin contamination resistant and drought tolerant lines. These lines have not been tested *in vitro*. Florida-07, a high oleic line, was tested *in vitro* and showed high levels of aflatoxin contamination, although field contamination was low to moderate. The seed inoculation results may be more relevant to postharvest contamination but additional data on both traits will be collected.

A second-year's phenotyping test of the chromosome segment substitution lines in Senegal was completed. The susceptible check, Fleur 11, was consistently contaminated. Lines 12CS_084, 12CS_037 and 12CS_106 showed consistently very low (equal to or less than 5 ppb) aflatoxin contamination. Lines 12CS_020, 12CS_034, 12CS_041, 12CS_052, 12CS_079 and 12CS_109 showed consistently low (equal or less than 20 ppb) aflatoxin contamination. Seeds were increased in the US in 2016 and aflatoxin testing in a simulated drought environment in the US is planned for the next field season.

MAGIC Population. Over 7,300 F_4 plants from five eight-way crosses have been advanced in rainy and post-rainy seasons to develop a MAGIC population (Multi-Parent Advanced Generation Inter-Cross). Two additional cycles will be achieved prior to the end of the project and genotyping of these lines at the F_6 is planned. The eight parental lines include two reportedly aflatoxin contamination resistant lines, 55-437 (aka ICG 1471) and ICGV 88145, with our *in vitro* data supporting strong resistance in 55-437, although field data indicate an intermediate contamination ranking for both.

Capacity Building

The aflatoxin "core" was provided to Dr. James Asibuo at the Crops Research Institute in Kumasi, Ghana. Dr. Asibuo served on the graduate committee of BHEARD student, Afia Karikari, who will be returning to Ghana in December to complete her research. A PhD student from Kenya, Davis Gimode, matriculated at UGA in August 2015, completed most of his coursework by summer 2016, and has been conducting research in Tifton since August 2016. His research is focused on the chromosome segment substitution lines derived from interspecific hybridization and generated/studied by the co-PIs in Senegal, Daniel Fonceka and Issa Faye. Both Senegalese collaborators also have visited our breeding/genomics facilities in Georgia. Daniel Fonceka presented in a symposium, "Translating Genome Sequence to Peanut Improvement," at the APRES meeting in July 2016, organized by Peggy Ozias-Akins. Fonceka's talk was on "Accelerating Introgression of Favorable Alleles from Wild Species Using Genomic Tools," a topic highly relevant to the PMIL project.

Lessons Learned

The use of GBS (genotyping by sequencing) in cultivated peanut germplasm is not cost-effective given the low level of SNP polymorphisms detected even with an improved SNP calling pipeline.

Phenotyping for aflatoxin contamination is highly susceptible to Type-II errors and identifying a line as resistant because it escaped contamination. Although we apply pressure (inoculation, drought, heat) to minimize escapes, contamination remains highly variable, making genotypic associations difficult without numerous years of phenotyping data.

Some peanut breeders are eager to embrace new genomic technologies, but there is a gap between the generation of genome-wide data specific to each breeding program and application of genotyping data to selection for improved cultivars. The best way to address this gap, which exists for US as well as developing country breeders, needs to be discussed.

Presentations and Publications

Clevenger, J. and P. Ozias-Akins. 2015. SWEEP: A tool for filtering high-quality SNPs in polyploid crops. G3 5: 1797-1803

Clevenger, J., Y. Chu, C. Chavarro, G. Agarwal, D.J. Bertioli, S.C.M. Leal-Bertioli, M.K. Pandey, J. Vaughn, B. Abernathy, N.A. Barkley, R. Hovav, M. Burow, S.N. Nayak, A. Chitikineni, T.G. Isleib, C.C. Holbrook, S.A. Jackson, R.K. Varshney, and P. Ozias-Akins. Genome-wide SNP Genotyping Resolves Signatures of Selection and Tetrasomic Recombination in Peanut. Molecular Plant (under revision)

Clevenger, J., K. Marasigan, B. Liakos, V. Sobolev, G. Vellidis, C. Holbrook, and P. Ozias-Akins. RNA sequencing of contaminated seeds reveals the state of the seed permissive for pre-harvest aflatoxin contamination and points to a potential susceptibility factor. Toxins (under revision)

Relevant presentations made by PhD student, Josh Clevenger:

SWEEPing Up SNPs: A practical workshop for SNP identification in peanut. Workshop offered at the annual APRES meeting, Clearwater, FL, July 2016

A 60K Arachis SNP array uncovers signatures of selection in the history of US peanut breeding. Paper presented at the annual APRES meeting, Clearwater, FL, July 2016

RNA Sequencing of Contaminated Seeds Reveals the Permissive State for Pre-harvest Aflatoxin Contamination and Points to a Potential Susceptibility Factor. Paper presented at the annual APRES meeting, Clearwater, FL, July 2016

Best practices for SNP calling using Next Generation Sequencing (NGS) data. Workshop offered at the annual Institute of Plant Breeding, Genetics, & Genomics retreat, Athens, GA – 40 participants, May 2016

Identification of SNPs for the development of a 60 K SNP array in groundnut. Paper presented at the 8th Advances in Arachis Genomics and Biotechnology international meeting, Brisbane, Australia, Nov. 2015

Relevant presentations by PhD student Walid Korani:

Estimation of aflatoxin contamination tolerance and the progress of fungal infection among different peanut genotypes using an Aspergillus flavus GFP-engineered strain, Poster presented at IPBGG retreat, Athens, GA, May 2016

Variability Among Genotypes for *Aspergillus flavus* Seed Infection Monitored with a GFP-Engineered Strain. Paper presented at the annual American Peanut Research and Education Society Meeting, Clearwater, FL, July 2016

Relevant presentations by PhD student Afia Karikari:

Drought Stress in Peanuts: What Role Do Root Architecture and Leaf Traits Play? Poster presented at IPBGG retreat, Athens, GA, May 2016

Relevant presentations made by PhD student Carolina Chavarro:

SNP Genotyping As a Tool for Peanut Breeding. (2016, Jul) Paper presented at the annual APRES meeting, Clearwater, FL, July 2016

Relevant presentations by Peggy Ozias-Akins:

The Georgia Peanut Breeding Team. Georgia Peanut Tour, Tifton, GA, Sept. 2016

Peanut SNP Markers. APRES Seed Summit, Clearwater, FL, July 2016

Gene expression profiling in cultivated peanut: putative gene functions and candidate gene discovery. Paper presented at the 8th Advances in Arachis Genomics and Biotechnology international meeting, Brisbane, Australia, Nov. 2015

Project A2. Silencing of Aflatoxin Synthesis through RNA Interference (RNAi) in Peanut Plants

The overall goal of this project is to use RNA interference (RNAi) to reduce aflatoxin contamination of peanut seeds. The research has two main objectives, 1) develop RNA interference (RNAi) technology to reduce/eliminate aflatoxin accumulation in peanut (mainly funded by Feed the Future-NBCRI); and 2) analyze the genetic diversity of aflatoxigenic *Aspergillus* species in sub-Saharan African countries (Ethiopia, Kenya, Malawi, Tanzania, Uganda and Zambia) and the USA, that will allow adapting the RNAi technology to each geographic area (mainly funded by PMIL). The first objective is the most challenging: first, because it had never been demonstrated that RNAi produced in a plant, could silence aflatoxin-synthesis genes in the fungus *Aspergillus*; and second, because the technology to prove this concept, including how to test its effectiveness without performing extensive and multi-year field trials, had to be developed within this project. The second objective, though apparently straightforward, required developing the adequate molecular tools for it. These tools had to be effective, doable at a reasonable cost, and required logistics, permits and research agreements for a work that extended through many countries. Once the proof of concept in the use of RNAi against aflatoxin is demonstrated, and the predominant genotypes of aflatoxigenic *Aspergillus* are identified in each geographic area, the technology will be transferred to and adapted for each region.

Collaborators

Name	Institution	Country	Role
Renée Arias	USDA-ARS National Peanut Research Lab	USA	PI
Steven Runo	Kenyatta University	Kenya	Co-PI
Samuel Njoroge	ICRISAT	Malawi	Co-PI
Phat Dang	USDA-ARS National Peanut Research Lab	USA	Co-PI
Victor Sobolev	USDA-ARS National Peanut Research Lab	USA	Co-PI
Julius Serumaga	National Crops Resources Research Institute	Uganda	Partner
Charles Chen	Auburn University	USA	Partner

Achievements

- Demonstrated for the first time in peanut seeds, the proof-of-concept on the effectiveness of plant-RNAi-mediated control of aflatoxin accumulation; the method developed for the analysis, and the results were published in 2016 in a peer-reviewed journal both as text and video formatting.
- Created a collection that now has 2000 *Aspergillus* isolates from peanut and soil, with samples from Ethiopia, Malawi, Tanzania, Uganda, Zambia and the USA; the collection will be curated at the NPRL.
- Generated whole genome sequencing for 34 *Aspergillus* isolates (10 from USA, 19 from Ethiopia and five from Malawi); 10 of these genomes have been published in 2016 and are now available to the public in NCBI-GenBank.

- Reported for the first time the presence of aflatoxin in peanut cake in Ethiopia and the data were published in a peer-reviewed journal in 2016; making this information public is an important step towards minimizing this health threat.

Lessons Learned

- There is a great need for the transfer of skills, from simple technologies to help farmers in Sub-Saharan countries to current laboratory tools to build the next generation of scientists in those countries.
- Investing, even for a short time, in providing training to foreign students can have a significant impact in their careers and their countries, e.g., the Ph.D. student Abdi Mohammed was invited by Haramaya University, Ethiopia, to form part of the Regional Universities Forum for Capacity Building in Agriculture project and focus on aflatoxin and fumonisin contamination.

Presentations and Publications

Manuscripts Published:

Arias RS, Dang PM, Sobolev VS (2015) RNAi-mediated control of aflatoxins in peanut: Method to analyze Mycotoxin production and transgene expression in the peanut/*Aspergillus* pathosystem. Journal of Visualized Experiments, Issue 106, e53398, doi:10.3791/53398

Faustinelli PC, Wang XM, Palencia ER, Arias RS (2016) Genome sequences of eight *Aspergillus flavus* spp. and one *A. parasiticus* sp., isolated from peanut seeds in Georgia. Genome Announcements 4(2):e00278-16. doi:10.1128/genomeA.00278-16

Mohammed A, Chala A, Dejene M, Hoisington DA, Sobolev VS, Arias RS (2016) Survey of *Aspergillus* in groundnut cake in eastern Ethiopia. Food additives and Contaminants http://dx.doi.org/10.1080/19393210.2016.1216468

Manuscripts Submitted:

Faustinelli, Paola, Xingye Wang, Edwin Palencia, Jaime M.-Castillo and Renee Arias. Workflow to study genetic biodiversity of aflatoxigenic *Aspergillus* spp. in Georgia, USA. Mycologia, 2016

Power, Imana, Victor Sobolev, Phat Dang, Marshall Lamb and Renee Arias. Characterizing small RNA populations in non-transgenic and aflatoxin-reducing-transgenic peanut lines. Plant Science, 2016

Presentations:

RNAi-mediated control of aflatoxins and Genetic Diversity of *Aspergillus*. Renee Arias, Peanut Mycotoxin Innovation Laboratory Annual Meeting, Tamale, Ghana, Aug. 2016

Characterizing small RNA populations in non-transgenic and aflatoxin-reducing-transgenic peanut lines. Imana Power; Renée Arias; Victor Sobolev; Phat Dang; Marshall Lamb. APRES meeting, Clearwater, FL, July 2016

Workflow to study genetic biodiversity of aflatoxigenic *Aspergillus* spp. in Georgia, USA. Paola Faustinelli, Xingye Wang, Edwin Palencia, Jaime M-Castillo and Renee Arias. APRES meeting, Clearwater, FL, July 2016

Working with aflatoxins and *Aspergillus*, health risks and how to prevent them. Renee Arias, Tifton, GA, June 2016

Project update presentation at the ICRISAT regional planning meeting. Samuel Njoroge, Zimbabwe, April 2016

RNAi-mediated control of aflatoxins: Method to assess effectiveness in peanut; Workflow to study genetic diversity of aflatoxigenic *Aspergillus*. Renee Arias, International Conference on Advances in *Arachis* through Genomics and Biotechnology (AAGB), Brisbane, Australia, Nov. 2015

Genomics of peanut leaf-spot pathogens; and RNA-interference-mediated control of aflatoxins. Plant Pathology Department Seminar Series, University of Georgia. Athens, GA, USA, Oct. 2015

Project A3. An Integrated Global Breeding and Genomics Approach to Intensifying Peanut Production and Quality

Seed-scaling projects, like this one in Malawi, is helping to make new varieties more available to smallholders. (Photo by Allison Floyd)

The overall goal of this project is to use conventional and molecular breeding to enhance the productivity, quality and marketability of peanut in PMIL target countries. The proposed research focuses on intensifying the biotic resistance, abiotic tolerance and quality aspects of peanut varieties through partnerships with US and developing country breeding programs. Biotic stresses include resistance to economically important pathogens and pests, while the primary abiotic stress addressed is drought tolerance and avoidance, a trait that factors into mitigating aflatoxin contamination. The breeding programs also focus on value-added traits, including high oleic content (nutrition and shelf-life), increased micronutrient density (iron and zinc), high oil content (cooking oil and butter) and large seeds (edible market). Outreach programs are used to stress technology transfer and the value of new cultivars and system considerations for utilizing appropriate crop-management strategies. Considerable resources are directed to host countries for capacity building, including student training, scientist training and infrastructure improvements. As advanced varieties become available, they are distributed to PMIL target country collaborators and PMIL value chain projects for evaluation as well as other developing countries that request the material.

The outcomes of the research include increased yields and increased quality. Subsequent benefits result in improved peanut value chains, increased food security, better nutritional and dietary traits and increased income throughout PMIL target countries as well as other developing countries. Capacity building results in in-country knowledge, expertise and improved infrastructure, which build a foundation to continue improving peanut yields and quality.

Collaborators

Name	Institution	Country	Role
Mike Deom	University of Georgia	USA	PI
Phillippe Sankara	Université de Ouagadougou	Burkina Faso	Co-PI
Nicholas Denwar	SARI	Ghana	Co-PI
Patrick Okori	ICRISAT	Malawi	Co-PI
Amade Muitia	IIAM	Mozambique	Co-PI
Gayi Dennis	NaSARRI	Uganda	Co-PI
David Okello	NaSARRI	Uganda	Co-PI
Boris Bravo-Ureta	University of Connecticut	USA	Co-PI
Mark Burow	Texas A&M University	USA	Co-PI
Rangaswamy Muniappan	Virginia Tech	USA	Co-PI
Greg MacDonald	University of Florida	USA	Co-PI
Naveen Puppala	New Mexico State University	USA	Co-PI
Charles Simpson	Texas A&M University	USA	Co-PI
Barry Tillman	University of Florida	USA	Co-PI

Achievements

While the project is organized around trait objectives, the achievements are presented on a country/region basis, with the US partner indicated.

Ghana and Burkina Faso (with Texas A&M)

- Submitted proposal for release of two leaf spot-resistant peanut accessions as new varieties in Burkina Faso
- Identified two high-oleic leaf spot-resistant release candidates in Ghana based on yields up to 3.7 t/ha
- An F_3 high-oleic population with resistance to leaf spot was increased in Texas to send to Ghana and Burkina Faso
- Several ICRISAT and US COC accessions out-yielded checks under drought in Burkina Faso and Ghana
- Submitted release documents for a high-oleic Valencia peanut in Texas
- Produced 122 F_2 seed from B genome cross *A. gregory* x *A. magna* for mapping SNPs
- Synthesized primers for 192 SNPs
- Initiated genotyping for leaf spot resistance using Kompetitive Allele Specific PCR markers

Haiti (with the University of Florida)

- From 55 breeding lines and identified several lines with low rust and leaf spot ratings. Crosses among four such lines were made to develop breeding populations for future selection.
- Developed a sub-contract with Quisqueya University, home institution of Dr. Raphael Colbert, the breeder identified to lead the peanut breeding effort in Haiti.
- Trials of several Valencia lines, including local and US commercial checks have been compared to elite breeding lines from NMSU in multiple locations and over multiple seasons, with evidence of some improved disease resistance, but little yield improvement over the local.

Malawi

- Trials run on seven high-yielding, short to medium duration materials with groundnut rosette disease and early leaf spot resistance

- Six newly developed Valencia lines from NMSU and eight high oleic lines evaluated for the second season for yield, disease resistance and maturity
- 182 lines from the mapping population evaluated for disease resistance and yield
- Maintenance of groundnut germplasm lines in the breeder's working collection and breeder seed multiplication of all the released groundnut varieties
- Field days conducted at harvesting showcasing performance of newly released groundnut varieties (designated CG 8 to CG 14)
- Refresher workshop conducted for research technicians and extension staff on groundnut trial management

Mozambique (with New Mexico State University)

- Evaluated advanced breeding materials of Valencia for high yield, high oleic acid content and leaf spot resistance in Haiti, Malawi, Mozambique, Zambia and USA
- Initiated release procedure for high oleic and partial resistant to *Sclerotinia* blight of Valencia in US
- Evaluated high oleic breeding population with 180 recombinant inbred lines in Malawi, Mozambique, Zambia and US
- NuMex-01 high oleic Valencia, NMSU breeding lines with groundnut rosette disease resistance crossed to incorporate GRD resistance. Spanish crosses with leaf spot resistance were crossed with high oleic Valencia variety NuMex-01.

Uganda (with University of Georgia and University of Connecticut)

- First Valencia National Performance Trials since 1969 ongoing
- Improved Serenut 1 and Serenut 3R in National Performance Trials
- Gwerinut, Erudurudu and Acholiwhite landraces improved for groundnut rosette disease and late leaf spot resistances
- Initiated introgression of high oleic trait into groundnut rosette disease and leaf spot resistant cultivars Serenut 5R and Serenut 6T
- 30 new F_1 populations generated from various crosses
- 17 confectionery groundnut types developed and undergoing final yield trials on-station
- 11 Zambian lines undergoing groundnut rosette disease improvement
- Three leaf miner resistant lines undergoing national performance trial
- Two extra early drought tolerant lines (dok1Tan and dok1Red) identified
- Survey of technology adoption and impact completed and publications being written

Zambia

- Six on-farm trials planted in different agriculture zones across three districts
- 180 mapping population lines acquired from NMSU for screening
- Two varieties with resistance to groundnut rosette disease and early leaf spot submitted to the Seed Control and Certification Institute for pre-release testing
- Six extension officers (three females and three males) and 76 farmers (24 females and 52 males) were trained on groundnut production, detecting leaf miner damage and participatory varietal selection
- 2000 copies of groundnut production guides in Chewa (local language) and 150 copies in English distributed during farmer`s field days
- Infographics on importance of groundnuts and aflatoxin management translated into local language (Chewa)
- The aphid rearing and screen house constructed and functional
- Screening for GRD resistance in landraces and some elite lines completed

- 500 brochures distributed to farmers and extension workers during field days
- Sent 10 landraces to Uganda to cross for improved GRD resistance

ICRISAT-Malawi & Kenya

- Groundnut mapping populations for leaf spot, GRD and rust disease were evaluated
- Early Leaf Spot (ELS) F_8 mapping population was genotyped using 394 SSR primers, 82 of which were polymorphic across the parental lines. A major QTL for ELS on linkage group 2 identified.

Lessons Learned

Ghana & Burkina Faso

- A joint regional meeting of the breeding co-PIs is beneficial for exchanging ideas and materials, and enhancing collaborations. The PMIL project gives opportunities for student training.

Haiti

- Breeding peanut for the highly variable local Haitian conditions will require in-country efforts.
- Future budgets and work plans need to reflect a small breeding effort in Haiti with direct ties to the University of Florida peanut-breeding program.

Malawi

- Access to information by farmers of released technologies is very important in the adoption process. Demonstration fields and field days are crucial in promoting released technologies.
- It was realized in the field days that many farmers do not know about the newly released varieties and other varieties already available.

Mozambique

- There is a lot of potential for Valencia peanuts.
- The biggest requirement is to incorporate the groundnut rosette disease resistance in Valencia or to grow peanuts in areas where GRD pressure is lower and Valencia varieties perform better, places such as Namapa and Mapupulo.

Uganda

- Need to measure genetic gains on-station and reduce yield gaps between on-station and on-farm. Varieties developed under stressed environment should still demonstrate superior performance even in absence of stress for it to be adopted. Improved varieties can significantly increase yields in farmers' fields.
- Media involvement in dissemination of research outputs is important to achieve results.
- Early bulking of seeds of pre-releases is a good practice to avert seed crisis post-release.
- Need for a cold storage facility to enhance germplasm conservation.
- Need for irrigation facility on-station for sustainable drought screening and seed multiplication.
- Participatory varietal selection (PVS) that involves both growers and traders ensures that varieties are tailored to meet requirements for both household food security and for markets.

Zambia

- There is a growing demand for improved varieties by farmers, but seed of improved varieties is not available. There is need to multiply seed of improved varieties and also engage seed businesses in seed production. Community seed banks are proving to be an effective tool in making seeds available and more seed should be put in to ensure accelerated adoption and access.
- There is need to use the media to disseminate information about improved varieties and productions guidelines. The field days/PVS have proved to be a good tool for dissemination of information on available technologies.
- There is need for a pickup truck to be used for fieldwork.

- The publication of production guides was a good tool. There is need to print more next season as there are many stakeholders interested in the production guides.
- Collaboration among National Agricultural Research System and ZARI and NARO is vital and can help in the accelerated release of varieties and improvement of breeding programs through knowledge sharing. David Okello has mentored the groundnut program in Zambia with guidance and germplasm.

ICRISAT-Malawi & Kenya

- A very high percentage of groundnut seeds harvested as successful crosses were actually false positives. It will be important that all seeds selected at F1 and advanced to F2 be verified and any likely off-types removed in order to obtain more accurate populations.

Project Presentations and Publications

Presentations

Bravo-Ureta, B.E. "UConn Update: An Integrated Global Breeding and Genomics Approach to Intensifying Peanut Production and Quality (Uganda)." Selected Presentation for the 2016 PMIL Annual Meetings, Tamale, Ghana. Aug. 2016

Burow, M. D., Selvaraj, M.G., Chagoya, J., Ayers, J.L., Belamkar, V., Chopra, R., Sankara, P., Zagré M'bi Bertin, B.,and Holbroo, C.C.. Use of genomics for breeding for tolerance to water deficit stress in peanut. Eighth International Conference of the Peanut Research Community. Advances in Arachis through Genomics & Biotechnology, Brisbane, Australia. Nov. 2015

Burow, M.D., Chopra, R., Kulkarni, R., Tengey, T., Chagoya, J., Wilson, J., Baring, M.R., Hillhouse, A., and Simpson, C.E. Use of SNP technology for marker-assisted breeding using peanut interspecific introgression lines. Eighth International Conference of the Peanut Research Community. Advances in Arachis through Genomics & Biotechnology, Brisbane, Australia. Nov. 2015

Burow, M.D., Selvaraj, M.G., Chagoya, J., Ayers, J.L., Belamkar, V., Chopra, R., Sankara, P., Zagré M'bi Bertin, B., Burow, G., Payton, P., and Puppala, N. Association mapping of the U.S. peanut minicore collection for tolerance to water deficit stress. ASA, CSSA and SSSA International Annual Meeting. Nov. 2015

Burow, M.D., Selvaraj, M.G., Chagoya, J., Belamkar, V., Chopra, R., Ayers, J.L., Sankara, P., Zagré M'bi Bertin, B., Burow, G., Payton, P., and Puppala, N. Phenotypic Screening and Association Mapping of a Peanut Germplasm Collection for Tolerance to Water Deficit Stress. Plant and Animal Genome. Jan. 2016

Chagoya, J., Selvaraj, M.G., Ayers, J.L., Kulkarni, R., Belamkar, V., Chopra, RT., Baring, M.R., Payton, P., Holbrook, C.C., and Burow,M.D. Use of Genomics for Breeding Drought-Tolerant Peanut. APRES meeting. July 2016

Dura, S., P. Lujan, S. Sanogo and N. Puppala. 2016. Screening of U.S mini cores for resistance against Sclerotinia Blight in peanut. Western Society of Crop Science, Albuquerque, NM, July 12-13, 2016

Jelliffe, J.L., Bravo-Ureta, B.E., Deom, C.M., and Okello, D.K. "The Sustainability Of Farmer-Led Multiplication and Dissemination of High-Yielding and Disease Resistant Groundnut Varieties" Poster Selected for the 2016 PMIL Annual Meetings, Tamale, Ghana. Aug. 2016

Jelliffe, J.L., Bravo-Ureta, B.E., Deom, C.M., and Okello, D.K. (2016). The sustainability of project outcome from Farmers-led dissemination of high yielding rosette resistant groundnut varieties. In the African Association of Agricultural Economists (AAAE) Annual Conference proceedings, "Transforming

Smallholder Agriculture in Africa: The Role of Policy and Governance", Addis Ababa, Ethiopia. 23-26 Sept. 2016

Kaur, G., Layland, N.N., Chopra, R., Chagoya, J., Burow, M.D., Payton, P.., and Puppala, N. Validation of SNP markers for high oleic acid trait in valencia mapping population in peanut. Western Society of Crop Science, Albuquerque, NM. 12-13 July 2016

Kaur, G., Layland, N.N., Chopra, R., Chagoya, J., Burow, M.D., Payton, P., and Puppala, N. High Oleic Acid Trait in Valencia Peanut Mapping Population: Validation with SNP Markers By KASP Assay. ASA-CSSA-SSSA International Annual Meetings. Phoenix, Ariz. 6-9 Nov. 2016

Lujan, P., Szaloy, J., Sanogo, S., and Puppala, N. Effect of valencia peanut seed treatments on germination, vigor, and soilborne diseases. Western Society of Crop Science, Albuquerque, NM. 12-13 July 2016

Okello**,** D.K., Deom, C.M., and Okori, P. (2016). Uganda groundnut improvement program at a glance. Plant and Animal Genome XXIV Conference Abstract Poster P1036 under Genome Mapping, Tagging & Characterization: Legumes, Soybeans, Common Beans section. Town & Country Hotel, San Diego, California. 9-13 Jan. 2016

Puppala, N., Mura, J.D., Vadez, V., Upadhyaya, H.D., Pandey, M., and Varshney, R. Variation in transpiration efficiency and its related traits in valencia mapping population. APRES meeting, Clearwater, FL, 12-14 July 2016

Tillman, B.L. 2016. Peanut Breeding. 2016 PMIL-Haiti training event for Haitian peanut specialists. June 20, 2016. Meds and Food for Kids, Cap Haitian, Haiti

Publications

Asekenye, C., Bravo-Ureta, B.E., Deom, C.M., Kidula, N., Okello, D.K., Okoko, N., and Puppala, N. (2016). Productivity gaps among groundnut farmers in Kenya and Uganda: A stochastic production frontier analysis. *African Journal of Agricultural and Resource Economics* 11(2): 85-100

Dwivedi, S.L., Puppala, N., and Ortiz, R. (2016). Microbiome, prebiotics, and human health. Reference Module in Food Science, Elsevier 1-9. http://dx.doi.org/10.1016/B978-0-08-100596-5.03154-1

Jelliffe, J.L., Bravo-Ureta, B.E., Deom, C.M., and Okello, D.K. "The Sustainability of Farmer-Led Multiplication and Dissemination of High-Yield and Disease Resistant Groundnut Varieties. The Zwick Center for Food and Resource Policy, University of Connecticut, Research Report No. 4 (2016). Web: http://zwickcenter.uconn.edu/outreach_reports_24_1166833251.pdf

Lujan, P., Sanogo, S., Puppala, N., and Randall, J. (2016). Factors affecting mycelium pigmentation and pathogenicity of Sclerotinia sclerotiorum on valencia peanut. *Canadian Journal of Plant Pathology*, 96(3:)461-473

Mugisa, I.O., Karungi, J., Akello, B., Ochwo-Ssemakula, M.K.N., Biruma, M., Okello, D.K., Otim, G. (2016). Determinants of groundnut rosette virus disease occurrence in Uganda. *Crop Protection* 79: 117-123. http://dx.doi.org/10.1016/j.cropro.2015.10.019

Nalugo, R.G., W. Wilber, J.M. Ssebuliba, D.K. Okello, and N. Puppala. 2016. Heritability for resistance to rosette disease in exotic valencia groundnuts. *African Crop Science Journal*, 24(2) 203-211.

Nalugo, R.G., Wambi, W., Sebbuliba, J.M., Okello, D.K., and Puppala, N. (2016). Gene effects for resistance to groundnut rosette disease in exotic valencia groundnuts. *African Crop Science Journal*, 24(1): 89 – 95.

Okello, D.K., Deom, C.M., Puppala, N., Monyo, E., and Bravo-Ureta, B. (2016). Registration of 'Serenut 5R' groundnut. *Journal of Plant Registrations* 10: 115-118.Wambi, W., Tukamuhabwa, P., Tirumalaraju, S.V., Okello**,** D.K., Deom, C.M., and Bravo-Ureta, B.E. (2015). Genetic variability studies of Valencia groundnut varieties for late leaf spot (*Phaeoisariopsis personata*) resistance. *African Journal of Plant Sciences*, 9(8), pp. 327-333. DOI: 10.5897/AJPS2015.1299

Wilson, J. N., Chopra, R., Baring, M.R., Gomez Selvaraj, M., Simpson, C.E., Chagoya, J., and Burow, M.D. (in press). Identification of quantitative trait Loci (QTLs) and genes associated with oil concentration and oil quality in peanut (*Arachis hypogaea* L.). *Tropical Plant Biology*.

B. Mycotoxin Detection and Peanut Nutritional Studies

Project B1. AflaGoggles for Screening Aflatoxin Contamination in Maize

Aflatoxin contamination in maize and peanut is a major food safety issue worldwide. The problem is of special importance in African countries because these crops, among others, are staple foods. A primary limitation to controlling ingestion of contaminated food in these countries is the lack of affordable and feasible methods for farmers on small village farms to screen for aflatoxin contamination. Due to the high cost associated with any existing aflatoxin detection methods and the need for sample processing and detection, there is an urgent need to develop portable, rapid, and non-destructive technology for aflatoxin detection in maize and peanut for these farmers. Therefore, the goal of the project is to develop portable, fluorescence spectral-based technology for rapid and non-destructive aflatoxin detection in maize (and peanut). A detection device for this purpose will be developed in the project.

Collaborators

Name	Institution	Country	Role
Haibo Yao	Mississippi State University	USA	PI
Alpha Kamara	International Institute for Tropical Agriculture	Nigeria	Co-PI
Robert Brown	USDA-ARS	USA	Co-PI

Achievements

The project team completed Objective 6: Implement trials to test AflaGoggles for feasibility in real world situations and also for continuous improvement of the screening procedures. During the past year, the team finalized the initial development of the prototype demonstration detection box. Maize samples from a 2015 field were used for prototype testing. The test experiments were designed to sort out contaminated maize kernels from bulk samples. Two experiments were conducted. One was a controlled experiment which involved sorting pre-mixed contaminated kernels. One hundred 50-gram samples demonstrated a mean aflatoxin reduction from 6,947 ppb to 14 ppb. The second experiment processed 15 silk-inoculated ears (close to natural fungal infection). The mean aflatoxin reduction was from 5,214 ppb to 560 ppb. With additional silk inoculations in 2016, the team plans to run more tests to further evaluate the performance of the prototype. The team is also in the process of upgrading the prototype for easier portability and lower cost. In addition, contaminated peanut samples were studied during this period based on the suggestion of the evaluation team.

As this project was close to the end of its initial proof-of-concept phase, three external experts (Drs. Kitty Cardwell, Jonathan Colton and Jack Davis) and the PMIL Director and Assistant Director reviewed the project in February 2016. The team determined that there is great potential for such a low-cost screening device and encouraged the PI and his team to continue to develop the device. Recommendations were made regarding the need to determine the quantitative nature of the system and the potential to use it for screening peanuts.

The aflatoxin detection prototype dubbed "aflabox" uses UV light to show the fluorescing of maize kernels contaminated with aflatoxin, which are visible in red.

Lessons Learned

While addressing the need of high performance UVLED for maize sample fluorescence excitation, it was noted the prototype uses a high power UVLED array that needs constant cooling, which shortens operation time. To correct this, one option is to use high power custom-made UVLED array with low heat dissipation, which is battery powered. This will improve the portability of the device.

Presentations and Publications

Hruska, Z., Yao, H., Kincaid, R., Zhu, F., Brown, R. L., & Bhatnagar, D. (2016). Evaluating the BGY Fluorescence Signal in Maize Kernels Inoculated with Various Aflatoxin-producing Fungi Using Fluorescence Hyperspectral Imaging. 9th Conference of the World Mycotoxin Forum and the XIVth IUPAC International Symposium on Mycotoxins. Winnipeg, Canada.

Yao, H. (2015). Rapid Aflatoxin Contamination Detection in Maize. IITA Abuja Station, Abuja, Nigeria.

Yao, H. (2016). Rapid Detection of Aspergillus Flavus Infected and Aflatoxin Contaminated Corn Using Spectral Imaging. Corn Utilization & Technology Conference. St. Louis, Mo.

Yao, H., Hruska, Z., Kincaid, R., Brown, R., Bhatnagar, D., & Cleveland, T. (2015). Sorting Aflatoxin Contaminated Maize Kernels with Fluorescence Spectra. Book of abstracts from the 17th International Conference on Near Infrared Spectroscopy. Foz do Iguacu, Brazil. 170.

Zhu, F., Yao, H., Hruska, Z., Kincaid, R., Brown, R. L., Bhatnagar, D., & Cleveland, T. E. (2016). Integration of Fluorescence and Reflectance Visible Near-Infrared (VNIR) Hyperspectral Images for Detection of Aflatoxins in Corn Kernels. Transactions of the ASABE. 59(3), 785-794.

Project B2. Development and Validation of Methods for Detection of Mycotoxins Exposure in Dried Spotted Blood Samples

The goal of this project is to establish and validate methods for measuring major mycotoxin biomarkers, especially for aflatoxin-lysine adduct, in human dried blood spot (DBS) samples for supporting urgent needs of nutrition impact and intervention studies conducted in Asia and Africa countries by PMIL, as well as the Feed the Future Nutrition Innovation Lab at Tufts University. The methods will be validated and applied to assess susceptibility factors in determination of human aflatoxicosis, to evaluate the linkage between aflatoxin exposure and human nutrition deficiency and growth retardation and developmental inhibition in children.

Collaborators

Name	Institution	Country	Role
JS Wang	University of Georgia	USA	PI
L Tang	University of Georgia	USA	Co-PI
Jeffrey Griffiths	Tufts University	USA	Co-PI
Patrick Webb	Tufts University	USA	Co-PI
Barnabas Natamba	Gulu University	Uganda	Co-PI

Achievements

In this funding year, we focused on proposed phase 2 and phase 3 objectives, i.e., validation of DBS method for detection of aflatoxin B_1-Lysine (AFB-Lys) adducts in humans. We validated the analytical protocol and examined the correlation between AFB_1 exposure and levels of AFB-Lys adducts in DBS samples in small scale human samples and compared with the matched serum samples from same study participant. DBS cards prepared from human whole blood were spiked with known levels of AFB-Lys adduct and human serum samples from Kenya and Uganda were used for the validation study. Further, 172 DBS samples collected from a high-risk area of children growth stunting in Nepal were used to validate the methods for measurement of AFB-Lys adducts. Each of these DBS samples was processed and analyzed using previously developed laboratory protocols. The detection rate was 98% (168/172) and the median level of AFB-Lys adducts was 3.71 (range: 0.5-27.63) pg/mg albumin. The geometric mean was 3.37 (95% confidence interval; 3.01-3.78) pg/mg albumin. The results of DBS samples were further compared with those of corresponding serum samples collected at the same time from same study participant. The overall Pearson's correlation coefficient was 0.69 (p= 0.0006) between DBS and serum samples. The Bland-Altman Plot analysis also showed a good agreement with over 95% samples within the mean difference ±1.96 standard deviation. Results of this study suggested that our previously developed HPLC-florescence method is valid in detecting the AFB-Lys adducts in the field-collected DBS samples, and the method is now in standardization for application in large scale of epidemiological studies in Nepal supported by the Feed the Future Nutrition Innovation Lab.

During FY16, the project also:

- Provided validation and technical support for the use of the Mobile Assay mReader for detection of aflatoxins in peanut and peanut products.
- Assisted PMIL PI Kumar Mallikarjunan at Virginia Tech to make comparisons among different available aflatoxin detection methods.
- Analyzed AFB-Lys adduct in blood samples from 45 participants in the Malawi intervention study conducted by PMIL PI Mark Manary at Washington University, and found that aflatoxin exposure in Malawi is predominant, as demonstrated by the detection rate of 98% (44/45) and median AFB-Lys adduct level of 5.19 (range: 0.51-568.87) pg/mg albumin.

Lessons Learned

Although the DBS method for measurement of AFB-Lys adduct was developed, funding limitations mean only Nutrition Innovation Lab studies in Uganda and Nepal have adopted the method. Efforts will be devoted to the collaborations within PMIL targeted countries.

Presentations and Publications

Presentations were given to different audiences in this funding year. Two with published abstracts were presented at the Society of Toxicology Annual Meeting held in New Orleans, Louisiana, 9-14 March 2016. Another presentation was given at the International Symposium on Food Safety in April 6-8, 2016, titled "Detection of Mycotoxin Exposure in Susceptible Young Populations Using DBS Method" in Nanchang, China. In addition, a manuscript, titled "Aflatoxin B_1-Lysine Adduct in Dried Blood Spot Samples of Animals and Humans" was submitted to Journal Food and Chemical Toxicology for review for publication.

Seawright, A. G., Tang, L. and Wang, J.S. (2016). Current Status of Aflatoxin B_1 Contamination in Grains and Peanuts Grown in the State of Georgia, USA. Toxicologist 150 (1):2274.

Xue, K., Tang, L. and Wang, J.S. (2016). Validation of Dried Blood Spot Method for Detection of Aflatoxin B_1-Lysine Adduct in Animals and Humans. Toxicologist 150 (1):1134.

Project B3. Aflatoxin in Peanut and Peanut Products: Comparative Study on Analytical Methods for Detection of Aflatoxin

This project was completed in FY2015.

Project B4. Randomized Controlled Trial of the Impact of Treating Moderately Malnourished Women in Pregnancy

The objective of this project is to determine the benefits of treating moderately malnourished pregnant women with a peanut butter-based nutritional supplement. The trial is a randomized, investigator-blinded controlled clinical effectiveness trial in pregnant women with moderate malnutrition, with and without HIV-infection, in southern Malawi. The trial is using three different nutritional supplements for comparison: (1) a peanut-based Ready-to-Use Supplementary Food formulated to deliver about 200% of the RDA of most micronutrients in pregnancy (RUSF); (2) fortified corn soy blend (also known as CSB+ or super-cereal) with a multiple micronutrient tablet chosen to deliver about 200% of the RDA of most micronutrients (CSB-UNI, or UNIMMAP; United Nations International Multiple Micronutrient Supplement); or (3) the Malawi standard of care which is a fortified corn soy blend, vegetable oil and sugar with supplementary iron and folic acid tablets (CSB-IFA), delivering between 0-350% of the RDA. The primary outcomes for this study are both maternal; recovery and Mid-Upper Arm Circumference (MUAC) change, as well as infant outcomes in mean birth weight, mean birth length, and percentage of premature delivery. The aim of the study is to provide significant evidence that using a peanut-based supplementary food will reduce maternal mortality and improve infant growth and development. This will provide national and international agencies with evidence to recommend and promote the use of peanut-based products for maternal health, as well as purchase some for use in their nutrition programs.

Collaborators

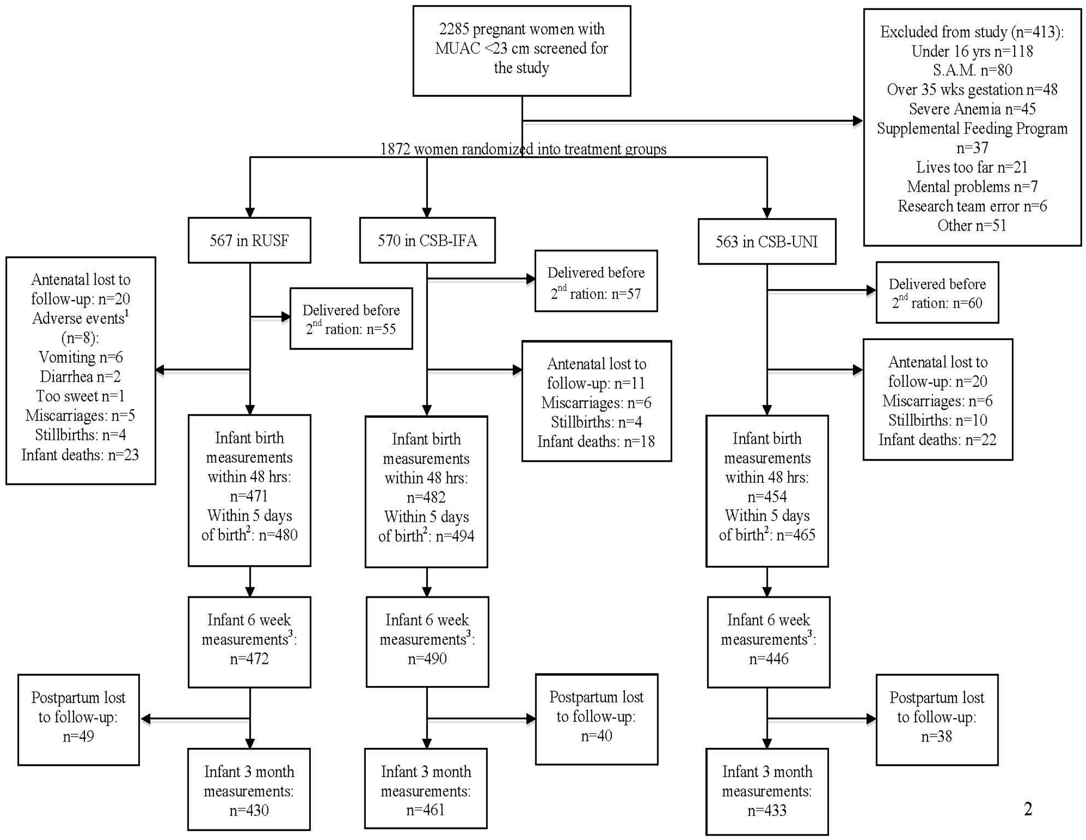
Name	Institution	Country	Role
Mark Manary	Washington University	USA	PI
Ken Maleta	University of Malawi	Malawi	Co-PI
Chrissie Thakwalakwa	University of Malawi	Malawi	Co-PI
Peggy Papathakis	California Polytechnic State University	USA	Co-PI

Achievements

During the study period, 2285 pregnant women with a MUAC <23 cm were screened for the study participation. A total of 413 were excluded from the study and 1873 were randomized into treatment groups. There were 1524 infants measured at birth, with 1429 (94%) measured within 24 hours, 60 within 48 hours and for 35 measurements were taken within five days of birth (Figure B4.1). All follow up data entry and data analysis has been completed for the study. The results, overall, were remarkably similar when moderately malnourished pregnant women received a supplemental feeding. Recovery from malnutrition was highest in the RUSF and IFA groups compared to the UNIMMAP group (36.7%, 35.3%, 32.1%, respectively, p=0.026). Mothers in the RUSF and IFA groups had the highest mean gestational weight gain (3.44 kg, 3.26 kg, 3.06 kg in RUSF, IFA, UNIMMAP, respectively, p=0.0349) (Table B4.1). There were no differences across treatment groups in any infant outcomes except for the rate of low birth weight, with the RUSF and IFA groups having the lowest rate (24.5% and 25.05%, respectively, compared with 31.2% in the UNIMMAP group; p=0.044) (Table B4.2). Using regression modeling, the duration of treatment was shown to be a determinant of infant length, suggesting that food supplementation is more effective when started earlier in pregnancy and given longer. Almost 28% of all infants measured were born with a low birth weight, defined as weighing ≤2.5 kg, with the RUSF and IFA groups having the lowest rate of low birth weight (24.5% and 25.05%, respectively, compared with 31.2% in the UNIMMAP group; p=0.044). On average, at birth, infants weighed around 2.7 kg, with length of around 47.0 cm, head circumference of 34.2 cm, and MUAC of 9.5 cm. Infants in this study born to pregnant women with moderate malnutrition receiving nutritional supplementation were small with mean z-scores for length and weight near -1.3, and weight for length of -0.5. Although linear growth was generally compromised with maternal under-nutrition, head circumference was spared, with a mean z-score of 0.012 (Tables B4.3 and B4.4).

In conclusion, the RUSF treatment improved gestational weight gain with greater recovery rates from moderate malnutrition than CSB with UNIMMAP. Infant weights, lengths and head circumferences were similar regardless of type of supplementary feeding, but low-birth-weight infants were less frequent in those consuming RUSF.

Figure B4.1. Study flow diagram indicating numbers in each class.



[1]Mothers in the RUSF treatment group experiencing adverse events were switched to non-study.
[2]Infant birth measurements do not include 84 infants that were measured between 6 and 14 days after birth.
[3]Infant six-week measurements include infants who were not included in birth measurements but came back for six-week follow-up measurements.
CSB-IFA = corn soy blend with iron and folic acid, CSB-UNI = corn soy blend with multiple micronutrients, RUSF = ready-to-use supplementary food, MUAC = mid-upper arm circumference

Table B4.1. Maternal outcomes for mothers treated ≥14 days

Characteristic	Ready-to-Use Supplementary Food n = 567	Corn Soy Blend with Iron & Folic Acid n = 570	Corn Soy Blend with UNIMMAP n = 563	*P* Value
Number Who Achieved MUAC >23 cm	208 (36.7%)	201 (35.3%)	181 (32.1%)	0.26
Weeks Receiving Supplementary Food	9.7 ± 5.5	9.9 ± 5.4	9.8 ± 5.4	0.92
Gestational Weight Gain (kg)	3.4 ± 2.5^{A}	3.3 ± 2.4^{AB}	3.1 ± 2.2^{B}	0.03
Weight Gain <480g/week	0.3 ± 0.2	0.3 ± 0.2	0.3 ± 0.2	0.32
MUAC at Delivery (cm)	438 (83.1%)	435 (82.5%)	439 (84.1%)	0.79
Change in MUAC during Supplementary Feeding (cm)	22.2 ± 1.0	22.2 ± 0.9	22.2 ± 1.0	0.16
Hemoglobin after 10 Weeks of Feeding (g/dL)	-0.04 ± 0.9	-0.07 ± 0.8	-0.16 ± 0.8	0.08
Anemic after 10 Weeks of Feeding (g/dL)[1]	11.1 ± 1.7^{B}	11.3 ± 1.6^{AB}	11.4 ± 1.7^{A}	0.01
Anemic after 10 Weeks of Feeding (<11g/dL)	226 (44.2%)^{A}	196 (37.6%)^{B}	181 (36.0%)^{B}	0.02

MUAC = Mid-Upper Arm Circumference, UNIMMAP = Multiple Micronutrient Supplement
Cells contain Mean ± SD or n (%). ANOVA or Chi-square tests were conducted. Wilcoxon / Kruskal-Wallis test or Fisher's Exact test was conducted if corresponding model requirements were not met. Connecting Letters Plot created using Tukey-Kramer HSD. N = 1700 women.
[1]Hemoglobin was measured at 3 months; Anemic variable corresponds to this measurement.

Table B4.2. Infant outcomes for mothers treated ≥14 days

Characteristic	Ready-to-Use Supplementary Food n = 476	Corn Soy Blend with Iron & Folic Acid n = 491	Corn Soy Blend with UNIMMAP n = 463	*P* Value
Birth Length (cm)	47.0 ± 2.4	47.1 ± 2.3	47.0 ± 2.4	0.95
Birth Weight (kg)[1]	2.7 ± 0.42	2.7 ± 0.4	2.7 ± 0.4	0.50
Number with Low Birth Weight (≤ 2.5 kg)	114 (24.5%)[B]	121 (25.1%)[B]	143 (31.2%)[A]	0.04
Birth Head Circumference (cm)	34.2 ± 1.7	34.2 ± 1.7	34.1 ± 1.6	0.27
Birth Mid-Upper Arm Circumference (cm)	158 (37.5%)	151 (33.5%)	161 (37.8%)	0.33
Number of Multiple Birth Pregnancies	7 (1.2%)	8 (1.4%)	4 (0.7%)	0.52
Final Fundal Height 14 Days before Delivery (cm)	31.3 ± 2.7	31.5 ± 2.2	31.2 ± 2.6	0.18
Number with Final Fundal Height 14 Days before Delivery <28cm[2]	31 (7.7%)[A]	15 (3.6%)[B]	31 (7.2%)[A]	0.03

UNIMMAP = Multiple Micronutrient Supplement
Cells contain Mean ± SD or n (%). ANOVA or Chi-square tests were conducted. Wilcoxon / Kruskal-Wallis test or Fisher's Exact test was conducted if corresponding model requirements were not met. Connecting Letters Plot created using Tukey-Kramer HSD or Odds Ratios. N = 1430 women, 17 live twin pairs and 1 live triplet (1-out-of-3).
[1]1429 infants were measured within 24 hours after birth; 60 more infants were measured within 48 hours after birth; 35 infant weights within 5 days after birth were adjusted to an estimated birth weight.
[2]Used as a proxy indicator for premature delivery.

Table B4.3. Infant Outcomes

Characteristic	Ready-to-Use Supplementary Food n = 622	Corn Soy Blend with Iron & Folic Acid n = 627	Corn Soy Blend with UNIMMAP n = 623	*P* Value
Birth Length (cm)	47.0 ± 2.4	47.1 ± 2.3	47.0 ± 2.4	0.79
Birth Weight (kg)[1]	2.7 ± 0.4	2.7 ± 0.4	2.7 ± 0.4	0.41
Number with Low Birth Weight (≤2.5 kg)	129 (25.4%)[A]	140 (26.7%)[A]	165 (32.7%)[B]	0.02
Birth Head Circumference (cm)	34.2 ± 1.7	34.2 ± 1.6	34.1 ± 1.6	0.15
Birth Mid-Upper Arm Circumference (cm)	9.5 ± 0.9	9.5 ± 0.8	9.5 ± 0.9	0.54
Number of Multiple Birth Pregnancies	8 (1.3%)	8 (1.3%)	4 (0.6%)	0.45[3]
Final Fundal Height 14 Days before Delivery (cm)	31.2 ± 2.0	31.4 ± 2.3	31.1 ± 2.6	0.10
Number with Final Fundal Height 14 Days before Delivery <28cm[2]	34 (7.8%)[A]	20 (4.4%)[B]	40 (8.4%)[A]	0.04

UNIMMAP = Multiple Micronutrient Supplement
Cells contain: Mean ± SD or n (%). ANOVA or Chi-square tests were used to determine *P* values. Wilcoxon Rank Sum test was conducted if data not normally distributed. Connecting Letters Plot were created using Tukey-Kramer HSD or Odds Ratios. N = 1540 Infants; includes 17 live twin pairs and 1 live triplet (1-out-of-3).
[1]1429 infants were measured within 24 hours after birth; 60 more infants were measured within 48 hours after birth; 35 infant weights within 5 days after birth were adjusted to an estimated birth weight.
[2]Used as a proxy indicator for premature delivery.
[3]Determined using Fisher's Exact Test

Table B4.4. Newborn Z-scores

Characteristic	Ready-to-Use Supplementary Food n = 622	Corn Soy Blend with Iron & Folic Acid n = 627	Corn Soy Blend with UNIMMAP n = 623	*P* value
Weight-for-Age (WFA) z-score	-1.3 ± 1.2	-1.3 ± 1.0	-1.4 ± 1.1	0.36
Length-for-Age (LFA) z-score	-1.3 ± 1.3	-1.3 ± 1.2	-1.4 ± 1.2	0.70
Weight-for-Length (WFL) z-score	-0.5 ± 1.0	-0.5 ± 1.0	-0.5 ± 1.1	0.41
Head Circumference-for-Age (HCFA) z-score	0.0 ± 1.4	0.1 ± 1.3	-0.1 ± 1.3	0.12
Number Underweight (WFA < -2)	103 (20.5%)	99 (19.1%)	122 (24.6%)	0.09
Number Stunted (LFA < -2)	116 (23.8%)	114 (22.8%)	126 (26.6%)	0.37
Number Wasted (WFL < -2)	22 (5.3%)	25 (5.8%)	26 (6.5%)	0.76
Number with Small Head Circumference (HCFA < -2)	32 (6.8%)	24 (4.9%)	22 (4.7%)	0.31

UNIMMAP = Multiple Micronutrient Supplement
Cells contain: Mean ± SD or n (%). ANOVA or Chi-square tests were used to determine *P* values. Wilcoxon Rank Sum test was conducted if data not normally distributed. N = 1520 Infants. 16 live twin pairs, 1 live twin (1-out-of-2), and 1 live triplet (1-out-of-3).
[1]1429 infants were measured within 24 hours after birth; 60 more infants were measured within 48 hours after birth; 35 infant weights within 5 days after birth were adjusted to an estimated birth weight.
[2]Used as a proxy indicator for premature delivery.
[3]Determined using Fisher's Exact Test

Lessons Learned

The study has experienced a larger percentage of women than originally anticipated in the "loss to follow up" group, mainly due to delivering before they could receive a full 14 days of treatment. More than 80% of all participants had low weekly gestational weight gain; this was not different across treatment groups (p=0.32). The average MUAC at delivery was 22.2 cm, and was not different by treatment group (p=0.16). Anemia were reduced after 10 weeks of treatment in all groups, from 70%, but still remained high, 36-44%, depending on the treatment group. After 10 weeks of treatment, hemoglobin concentration was higher across all groups by an average of 1.23 g/dL, but was lower in the RUSF group and anemia rate higher compared to either the IFA or UNIMMAP groups (p=0.0073, 0.017, respectively).

Almost half of women who had recovered from malnutrition relapsed (MUAC dropped to ≤23 cm) before delivery when study food was no longer provided; this was not different by treatment group (p=0.203). Two-thirds of those who relapsed recovered from low MUAC before delivery when provided their study food again; this was not different by treatment group (p=0.3183).

The study was limited in that no true control group was included; all women received some supplementary feeding in order to meet national guidelines in Malawi, however, these guidelines are rarely seen in practice. The data regarding gestational age could have been strengthened if ultrasound technology had been employed to assess the subjects.

Presentations and Publications

Papathakis PC, Singh LN, Manary MJ. How maternal malnutrition affects linear growth and development in the offspring. Mol Cell Endocrinol, Nov 2016; 435; 40-7

Papathakis PC, From SLO to Malawi: a quest to improve the nutrition of pregnant women and their babies. Cal Poly Distinguished Scholarship Colloquium, San Luis Obispo, 28 Sep 2016.

C. Peanut Value Chain Interventions

Project C1. Production to Consumption – Technologies to Improve Peanut Production, Processing and Utilization in Haiti

The overall goal of this project is to address and mitigate key constraints to peanut production and utilization in Haiti. Peanuts have been and continue to be an important part of Haitian diet and culture. In addition, peanuts provide an important source of cash income. To combat malnutrition in the country, certain NGOs have developed facilities to produce peanut-based Ready-to-Use Therapeutic Food or RUTF. To date, however, there has been limited utilization of locally grown peanut due to issues with productivity, quality and aflatoxin contamination.

In this project, we are developing a comprehensive production, processing and utilization strategy for peanuts in Haiti. All phases of peanut production are being evaluated, including varieties specific to the region and market influences. We are instituting a seed-increase program and developing facilities to maintain genetic resources through curation of important peanut germplasm. Capacity building through the introduction of labor-saving devices and harvesting equipment and procedures is underway, along with evaluating the infrastructure to improve peanut handling, drying and long-term storage. Once these improvements have been evaluated, we take the best management practices and strategies to the grower level at several villages and communities in the region, particularly through the depot network partnership with the Acceso Peanut Enterprise Corporation. We are providing training and infrastructure support to realize these improvements and ensure long-term capacity building. Aflatoxin and the role of women in the peanut value chain is being measured/surveyed throughout the duration and in all phases of the project. We are also establishing aflatoxin-testing facilities and re-training Haitians in how to measure and the importance of avoiding aflatoxin in their diet. Another important capacity-building measure is the creation of alternative products/markets for high aflatoxin contaminated peanuts.

Collaborators

Name	Institution	Country	Role
Greg MacDonald	University of Florida	USA	PI
Timothy Brenneman	University of Georgia	USA	Co-PI
Dan Brown	Cornell University	USA	Co-PI
Robert Kemerait	University of Georgia	USA	Co-PI
Genti Kostandini	University of Georgia	USA	Co-PI
Robert Johnson	Acceso Peanut Enterprise Corporation	Haiti	Partner
Alex Carroll	Meds & Food for Kids	Haiti	Partner
Francois Laroche	Premier Steppe Ferme	Haiti	Partner
Raphael Colbert	Quisqueya University	Haiti	Partner
Gael Pressoir	Quisqueya University	Haiti	Partner
Rick Brandenburg	North Carolina State University	USA	Partner
David Jordan	North Carolina State University	USA	Partner
Frank Nolin	Frank's Design for Peanuts	USA	Partner
Barry Tillman	University of Florida	USA	Partner
Patricia Wolff	Meds & Food for Kids	USA	Partner

Achievements

- Conducted trials on fertility, disease management with fungicides and variety evaluations at two locations (Quartier Morin in the North Department and Coup Gorge in the Central Plateau Department)
- Conducted additional trials at Quartier Morin on inoculant and phosphorus fertilizers
- Performed additional research trials with Premier Steppe Ferme, Inc. and iF Foundation – variety tests and scale-up of seed multiplication
- Provided training and farmer field demonstrations in north and central plateau
- Provided technical training, materials and support to Acceso Peanut Enterprise Corporation that included production guides, field visits, aflatoxin training for depot managers, technical expertise in planting, harvesting, storage and aflatoxin detection
- Provided guidance and expertise to MFK agronomists
- Continued support of the aflatoxin detection facility at iF Foundation – additional training of staff; established a research/teaching mycotoxin lab at Faculté d'Agronomie et de Médecine Vétérinaire (FAMV), Université d'État d'Haïti in Damien

Lessons Learned

- Oversight is critical with field operations, especially research field locations.
- High pH soils (often >8.0) are common in Haiti and create difficulties in soil fertility and inoculant recommendations to increase peanut yields.
- Research and recommendations must be regionally targeted to either Runner (North) or Valencia (Central Plateau) varieties, due to seasonal rainfall limitations and market preference.
- Multi-year, multi-location trials using multiple varieties support limited fungicide applications (two or three times per season) as cost effective in increasing yields.
- Continued oversight and training of technologies and aflatoxin lab facilities is required for quality data.
- More frequent visitation and collaboration is needed with Drs. Pressoir and Colbert as they build their peanut breeding program.

Presentations and Publications

- Provided training presentations to growers in the north and central plateau regions on peanut agronomy, disease management and harvesting technologies
- Provided research updates and applicable training to students, depot managers and growers – this based on our research work
- Continued work on updates for production guides and for aflatoxin mitigation and utilization of aflatoxin contaminated peanuts
- Poster presentation at the annual APRES meeting
- Several refereed publications on aflatoxin detection and monitoring and PhD dissertation – Jeremy Schwartzbord at Cornell University

Fulmer A, Brenneman T, Kemerait K, Faroutine G, Carroll DA, Sheard W, Rhoads J, MacDonald G, Puppala N. Evaluation of improved Valencia cultivars with and without fungicide for peanut production in Haiti. Poster Session. APRES. Clearwater, FL, July 2016.

Fulmer A, Brenneman T, Kemerait K, Faroutine G, Carroll DA, Sheard W, Rhoads J, MacDonald G.

Effect of fungicide timing and frequency on reducing foliar diseases and yield loss on runner and Valencia type peanuts in Haiti. Poster Session. APRES. Clearwater, FL, July 2016

Rhoads J, Kostandini G, MacDonald G, Johnson R, Carroll E. Gender differences in peanut productivity and post-harvest practices: Evidence from Haiti. Presentation. APRES. Clearwater, FL, July 2016.

Project C2. Applied Research and Technology Transfer to Minimize Aflatoxin Contamination and Increase Production, Quality and Marketing of Peanut in Ghana

Smallholder farmers work with PMIL to explore which interventions work to increase yield and reduce aflatoxin. (Photo by Dave Hoisington)

A wide range of abiotic and biotic stresses negatively impact peanut production in the field and generally contributes to the reduced quality of marketed peanut in Ghana and West Africa. Aflatoxin contamination can occur and increase at all steps of the peanut supply chain including production in the field, storage in fields and villages, and in processed products. Interventions at each step of the supply chain can minimize aflatoxin contamination. Improved production in the field including pest resistant cultivars, adequate soil fertility and plant nutrition, and synchronization of peanut pod growth phase with adequate soil moisture can increase peanut yield and quality and minimize aflatoxin contamination. Adequate and timely drying of farmer stock peanut minimizes additional production of aflatoxin during storage in villages prior to marketing. Effective processing of farmer stock and shelled stock peanut can also reduce aflatoxin prior to purchase and consumption. Determining current practices by farmers, conducting research to mitigate aflatoxin and improve peanut quality, and transferring appropriate technology to farmers are needed to improve productivity, profits, and quality of peanut and to increase safety of peanut products consumed by humans and livestock.

The primary platform being used to research aflatoxin contamination of peanut in the supply chain in Ghana is taking place in nine villages in the northern and central parts of the country. Interventions at each step of the supply chain are being implemented and aflatoxin contamination determined. Research is conducted at two CSIR institutes, the Savanna Agricultural Research Institute (SARI) and the Crops Research Institute (CRI), to develop appropriate production and pest management strategies and to evaluate new germplasm suitable for the region. Results from efforts at villages and research stations are presented to farmers using the Farmer Field School approach and appropriate posters, bulletins, and manuals. Graduate student training is closely linked to activities in villages and research stations.

Results from the project are providing farmers in Ghana with information on documented interventions that reduce aflatoxin contamination throughout the supply chain. Improved productivity and quality, coupled with acceptable levels of aflatoxin in peanut products, improve access to local, regional, national and international markets, enhancing economic viability of farmers and their communities.

Collaborators

Name	Institution	Country	Role
David Jordan	North Carolina State University	USA	PI
Mumuni Abudulai	CSIR-Savanna Agricultural Research Institute	Ghana	Co-PI
Richard Akromah	KNUST	Ghana	Co-PI
Grace Bolfrey-Arku	CSIR-Crops Research Institute	Ghana	Co-PI
William Ellis	KNUST	Ghana	Co-PI
Moses Mochiah	CSIR-Crops Research Institute	Ghana	Co-PI
George Mahama	CSIR-Crops Research Institute	Ghana	Co-PI
Maria Balota	Virginia Polytechnic Institute and State University	USA	Co-PI
Rick Brandenburg	North Carolina State University	USA	Co-PI
Boris Bravo-Ureta	University of Connecticut	USA	Co-PI
Kenneth Boote	University of Florida	USA	Co-PI
Jinru Chen	University of Georgia	USA	Co-PI
Greg MacDonald	University of Florida	USA	Co-PI
Kumar Mallikarjunan	Virginia Polytechnic Institute and State University	USA	Co-PI
R. Dixon Phillips	University of Georgia	USA	Co-PI
James Asibuo	CSIR-Crops Research Institute	Ghana	Partner
Agnes Budu	University of Ghana	Ghana	Partner
Awere Dankyi	CSIR-Crops Research Institute	Ghana	Partner
Tim Brenneman	University of Georgia	USA	Partner
Manjeet Chinnan	University of Georgia	USA	Partner
Koushik Adhikari	University of Georgia	USA	Partner

Achievements

Objective 1. Evaluate the effect of on-farm interventions at production, drying, storage and processing steps on aflatoxin contamination in the peanut

Recent surveys of farmers in Ghana during September 2015 demonstrate the level of knowledge relative to aflatoxin. Eighty-three percent of farmers experienced problems with aflatoxin contamination over the past five years. The most common resources for aflatoxin information exchange are among farmer group members, neighbors and relatives. Based on the information exchange, the farmers were most likely to change cultivar choice.

Most farmers did not know the cause of aflatoxin, but among those who did the most important causes reported include: poor drying, too much rain, pests and disease, and poor storage. Visibly moldy and rotten peanuts were removed before eating by 80% of farmers in Ghana while removal before storage was done by 76% of farmers in these respective countries. Visibly moldy or rotten peanuts were most commonly disposed of or used as other peanuts would be, presumably consumed.

Interactions to control aflatoxin contamination at the village level

Preliminary results from the Ghana value chain research project in a rural village in central Ghana (Drobonso) are presented from 2015. In the project peanuts in the field were subjected to improved pest management and fertility compared with the traditional farmer practice. Although the improved practices resulted in increased peanut yield, quality and economic return (774 versus 978 USD/ha, $p = 0.0002$), only a minor difference in aflatoxin concentration was noted when sampling occurred immediately after harvest but prior to drying (1.0 versus 0.5 µg/kg, $p = 0.0015$). Aflatoxin levels subsequently increased during drying.

The impact of minor differences at harvest was manifested after drying but approaches to drying affected aflatoxin concentration more than management prior to harvest. Drying on plastic tarps was much more effective at limiting aflatoxin contamination than drying on the ground (29-80 µg/kg compared to 153-226 µg/kg) regardless of the level of aflatoxin coming out of the field at harvest.

The practices most closely resembling on-farm conditions – relatively low input in the field, drying on the ground, and storage in readily available poly sacks with limited protection from elements – resulted in an aflatoxin concentration of 1407 µg/kg. Use of the most effective approaches in field production, drying with tarps and storage in hermetically-sealed bags resulted in the lowest aflatoxin concentration (53 µg/kg). Adopting a single improved practice or two of the three possible improved practices resulted in aflatoxin concentrations between 100 and 600 µg/kg.

As buyers become more discriminating in their purchases, they might reject some of the peanut crop with compromised quality. After shelling, variation in categories of good kernels, shriveled kernels, kernels with visible mold, and discolored kernels were observed based on practices in the field and following drying and storing (Table C2.1). When correlated with aflatoxin concentration in peanut after storing, coefficients were highly significant ($p \leq 0.0001$) for good kernels ($R = -0.84$), shriveled kernels ($R = 0.59$), kernels with visible mold ($R = 0.64$), and discolored kernels ($R = 0.83$). These results were not surprising given the strong correlation between damaged kernels and aflatoxin contamination. When improved practices were included in the field and during drying and storing, 79% of the 500 g sample was considered good and would be of high value in the market and safe for consumption. In contrast, the current practices used by many farmers resulted in less than half of the kernels (49%) in the good category.

The lower yield of farmer stock peanut under current farmer practices in the field would be compounded by the lower percentage of high quality peanut available for the market after storage. This would be the case even if aflatoxin contamination were not a deciding factor for peanut sales. Removal of good peanut kernels for household consumption or removal for seed used for sowing during the next season would further reduce income.

Table C2.1. Aflatoxin concentration in farmer stock peanut after storage following various practices in the field, during drying, and in storage.

Management Practices				Peanut Response[a]				
				Aflatoxin after storage	Kernel status after storage for 4 months			
Field	Drying	Storage			Good	Shriveled	Moldy	Discolored
				µg/kg	*g/500 g sample*			
Farmer	Ground	Poly bag		1407 a	223 f	124ab	20 a	134 a
Farmer	Ground	Sealed bag		297 bc	264 e	129 a	2 c	106 bc
Farmer	Tarp	Poly bag		298 bcd	306cd	110abc	1 c	82 c
Farmer	Tarp	Sealed bag		100 e	339bc	103 c	0 c	59 d
Improved[b]	Ground	Poly bag		548 b	263 e	118abc	8 b	111 ab
Improved	Ground	Sealed bag		177 cde	299 d	106bc	0 c	95 bc
Improved	Tarp	Poly bag		149 de	366ab	80 d	0 c	57 d
Improved	Tarp	Sealed bag		53 f	393 a	80 d	0 c	27 e

[a]Means followed by the same letter are not significantly different according to Fisher's Protected LSD test at $p \leq 0.0001$. Actual data are presented with mean separation performed on log transformed data. Data are pooled over 12 farmers in a village cluster.
[b]Improved practice included one additional weeding, application of local soaps to suppress pests, and calcium applied at flowering.

Objective 2. Evaluate pre- and post-harvest technologies to reduce aflatoxin contamination on-station at SARI and CRI

Research projects associated with graduate students composed a major part of this research objective. Projects include drying and storing peanut using different methods, planting and harvest dates, management strategies to control weeds and disease, and calcium and other fertilizers in increasing yield and reducing risk of aflatoxin contamination.

In addition to work in Ghana, MSc student Esther Akoto completed her research at the University of Georgia on the impact of composting on aflatoxin content of contaminated peanut meal, showing significant reduction in levels regardless of added biological starters. She will complete her degree in FY17. Visiting researcher Maxwell Lamptey evaluated the potential of a solar dryer developed in collaboration with UGA faculty. They found promise in not only the ease of drying, since the dryer provides protection from rainfall, but also the potential increase in quality of the peanut due to reduced peak temperatures that may cause oxidation. This may also lead to an improvement in germination for drying seed. One dryer has been built at CRI and is in use by the breeder and a second dryer is being evaluated by one of the participating villages. Researchers are considering complications in scaling, such as cost effectiveness, whether the dryer could have uses other than peanut-drying and what alternative materials might be used.

Objective 3. Evaluate new peanut germplasm from ICRISAT, US and African breeders
Thirty breeding lines and varieties were compared on research stations near Kumasi, Tamale and Wa. Seven varieties and promising lines were selected from this pool of varieties and planted in all villages represented in Objective 1. In addition, SARI and CRI groundnut breeders are working with the local USAID Mission-funded scaling-up seed production project in Northern Ghana with ICRISAT.

Objective 4. Disseminate best practices to farmers and other stakeholders
Farmer Field Schools (FFSs) were conducted at CRI-Kumasi (10), SARI-Tamale (3) and SARI-Wa (2). A guide to production and effective harvesting was developed for farmers in Ghana and was translated into two languages representing regions in the Tamale area and Kumasi area.

Objective 5. Analyze the economics of each aflatoxin reduction intervention
A survey was conducted during fall 2015 of 600 groundnut producers from 50 villages across five districts in central Ghana. Obtaining a clean data set has proven to be a challenge, which still continues. We anticipated that the final dataset would be ready by the end of October 2016. Information was received for field-experiment trials of best management practices in Northern (Mumuni Abdulai) and Central (Moses Mochiah) regions. Partial processing has been done and the work continues.

Objective 6. Survey level of aflatoxin contamination in peanuts and peanut products and develop recommendations for reducing aflatoxin contamination in the peanut processing value chain
Surveys of 30 processors and traders in Accra, Kumasi and Tamale were conducted during 2014 and 2015. The demographics showed that all the 30 processors were females and with a median age of 40. More than 80% of the participants have been in the peanut processing business for more than 10 years. Results indicate that aflatoxin contamination is prevalent in all three regions in finished products (Accra region, Northern Tamale Region and Ashanti Kumasi Region) and above the allowable limit of 15 ppb. The aflatoxin level in raw peanuts is highest in the Northern Region (>500 ppb), followed by Ashanti (>300 ppb) and then Accra Region (<10 ppb). Regardless of the contamination levels in raw peanuts, the finished products (peanut paste, peanut cake, kulikuli and peanut oil) had similar level of contamination

across the regions. These results demonstrate the requirement of interventions at the processor level to manage and mitigate the toxin in finished products.

Lessons Learned

Initial results from the field trials indicate increased yield associated with selected management practices, which include early planting, weeding, and the application of yara legume fertilizer, oyster shells, and alata soap.

The results in central Ghana are still preliminary, but do show the importance of each step in the value chain in terms of the concentration of aflatoxin in the final product. After storage, peanuts will be consumed directly by individuals in the household or will enter the market in some form. The yield and economic return captured immediately after harvest could rise or fall during storage, depending on quality and seasonal price dynamics, especially if buyers consider aflatoxin contamination in their decision making. The final price farmers receive could change depending on whether they process peanuts prior to marketing or to accept the price offered by the buyer.

The impact of aflatoxin contamination on human health is the key issue, although market pressures often dictate whether people accept the risk of aflatoxin. While pre-storage segregation to remove damaged or moldy peanuts is effective in reducing the risk of aflatoxin contamination, the decision by the farmer to remove damaged farmer stock prior to selling or saving higher quality farmer stock for seed for the following season's planting can impact the farming household. Failure to save high quality seed for planting will most likely affect stand establishment, seedling vigor and yield the next season.

Poor quality peanuts that are removed from the marketed product might be consumed by the household or livestock, increasing exposure to aflatoxin.

From the buyer's perspective, the cost of processing farmer stock will impact the price he or she can offer to the farmer. If prices are segregated based on the quality of pods and kernels, individuals purchasing lower quality peanuts might risk exposure to high levels of aflatoxin. Efficiencies in the market are important at each step in the value chain, and finding a use for each product in processing, whether the initial focus or byproducts of processing, is essential in competitive markets. Minimizing aflatoxin contamination at earlier steps, going all the way back to the field level, can make the value chain more efficient and profitable with less risk of exposure to aflatoxin.

Presenting incentives at each step in the value chain to deliver a high quality and safe peanut is critical if effective and sustainable value chains are to exist. Developing incentives for farmers to adopt greater management and inputs in the field and invest more during drying and in storage increases the likelihood that the entire value chain delivers higher quality peanuts with less risk of aflatoxin to the consumer. While on the surface the difference in aflatoxin immediately after harvest was low, small differences in aflatoxin contamination were translated into larger differences after drying and even larger after storage.

The investment in improved practices in the field are more likely to be adopted by many farmers because higher yield from those inputs more than offsets the cost associated with them. Certainly the limited availability of fertilizer and other inputs, increased time and financial cost of pest management and fertilizer application, and limited available cash or credit to purchase inputs can negatively impact adoption. However, in this case increased economic return would justify the improved field practices and would continue to decrease aflatoxin contamination during drying and storage. Use of tarps in the drying step compared with ground drying may be limited because of the expense of the tarp relative to overall budget. Whether or not the farmer would adopt tarps could also be determined by availability, especially in rural villages, and what other uses the farmer may have for the tarp once harvest begins.

We have done several surveys and every time we face different challenges. In this case, the primary lesson learned, once again, is the importance of having as close a supervision of the field work, by the leading researchers, as time and resources allow.

Presentations and Publications

Bravo-Ureta, B. "UConn Update: Using Applied Research and Technology Transfer to Minimize Aflatoxin Contamination and Increase Production, Quality and Marketing of Peanut in Ghana" Selected Presentation for the 2016 PMIL Annual Meetings, Tamale, Ghana, August 2016

Jelliffe, J., Bravo-Ureta, B., Mochiah, M., Dankyi, A., Jordan, D., Muitia, A., Salegua, V., and Urban, E. "Diagnostic Survey of Groundnut Farmers in Ghana and Mozambique: Preliminary Findings and Next Steps." Poster Selected for the 2016 PMIL Annual Meetings, Tamale, Ghana, August 2016.

The following are abstracts of papers presented at APRES. They are considered in press:

Comparative Study of Sorting Raw and Blanched Peanuts as Pre-Storage Treatment in Reducing Aflatoxin Along the Peanut Value Chain. C. Darko*, P. Kumar Mallikarjunan, Biological Systems Engineering Department, Virginia Tech, Blacksburg, VA; K. Dizisi, Agricultural Engineering Department, Kwame Nkrumah University of Science & Technology, Kumasi, Ghana; M. Abudulai, CSIR-Savanna Agricultural Research Institute, Tamale, Ghana; M.B. Mochiah, CSIR-CRI, Kumasi, Ghana, and D.L. Jordan, North Carolina State University, Raleigh, NC

Overview of the PMIL Ghana Value Chain. D.L. Jordan* and R.L. Brandenburg, North Carolina State University, Raleigh, NC; M. Abudulai, CSRI-SARI, Tamale, Ghana; I.K. Dzomeku, University for Developmental Studies/CSIR-SARI, Tamale, Ghana; J. Naab, S. Buah and G. Mahama, CSIR-SARI, Wa, Ghana; M.B. Mochiah, G. Bolfrey-Arku, A. Dankyi, J. Asibuo, M. Owusu-Akayaw, A. Ibrahim, B. Amoabeng, J. Lamptey, and M. Lamptey, CSIR-CRI, Kumasi, Ghana; R. Akromah, W. Ellis, and W.O. Appaw, KNUST, Kumasi, Ghana; A. Budu, University of Ghana, Legon, Accra, Ghana; G. MacDonald, K. Boote, and J. Erickson, University of Florida, Gainesville, FL; J. Chen, D. Phillips, M. Chinnan, K. Adhikari, T. Brenneman, University of Georgia, Griffin, GA; K. Mallikarjunan and M. Balota, Virginia Tech, Blacksburg, VA; and B. Bravo-Ureta, University of Connecticut, Stores, CT

Comparison of Drying Methods for Peanut in Ghana. I.K. Addo*, K.A. Dzisi, R. Akromah, W. Ellis, and W.O. Appaw, KNUST, Kumasi, Ghana.

A Fact Sheet on Managing and Harvesting Peanut in Ghana. D.L. Jordan* and R.L. Brandenburg, North Carolina State University, Raleigh, NC; M. Abudulai, CSRI-SARI, Tamale, Ghana; I.K. Dzomeku, University for Developmental Studies/CSIR-SARI, Tamale, Ghana, G. Mahama, CSIR-SARI, Wa, Ghana; M.B. Mochiah and M. Owusu-Akayaw, CSIR-CRI, Kumasi, Ghana; G. MacDonald and K. Boote, University of Florida, Gainesville, FL; K. Mallikarjunan and M. Balota, Virginia Tech, Blacksburg, VA; B. Bravo-Ureta, University of Connecticut, Stores, CT; and J. Rhoads, D. Hosington, and A. Floyd, University of Georgia, Athens, GA

Influence of Herbicides and Fungicides on Peanut Production and Quality in Ghana. S. Arthur*, G. Bolfrey-Arku, and M. B. Mochiah, CSIR-Crops Research Institute, Kumasi, Ghana; J. Sarkodie-Addo and W.O. Appaw, KNUST, Kumasi, Ghana; and D.L. Jordan and R.L. Brandenburg, North Carolina State University, Box 7620, Raleigh, NC

Traditional Processing of Peanut Oil in Ghana: Implications for Food Safety. S. Baah-Tuahene*, A. Simpson Budu and K. Firibu Saalia, University of Ghana, Legon, Ghana; K. Mallikarjunan, Virginia Tech University, Blacksburg, VA; and K. Adhikari, University of Georgia, Griffin, GA

Aflatoxin Control: Evaluation of Pre and Postharvest Practices on Toxic Levels in Peanut. W.O. Appaw*, W.O. Ellis, I. Oduro, R. Aggeledbe, and R. Akromah, KNUST, Kumasi, Ghana; M.B. Mochiah, CSIR-CRI, Kumasi, Ghana; and D.L. Jordan, North Carolina State University, Raleigh, NC

Evaluation of Peanut Butter in Northern Ghana. Y. Abubakari*, R. Akromah, W. Ellis, and W. Appaw, KNUST, Kumasi, Ghana; M. Abudulai, CSIR-Savanna Agricultural Research Institute, Tamale, Ghana; A. BUDU, University of Ghana, Legon, Accra, Ghana; M. Chinnan and K. Adhikari, University of Georgia, Griffin, GA; K. Mallikarjunan, Virginia Tech., Blacksburg, VA, and D.L. Jordan, North Carolina State University, Raleigh, NC

Project C3. Producer and Consumer Interventions to Decrease Peanut Mycotoxin Risk in Ghana

The goal of this project is to investigate the relative and combined impact of technological and market aflatoxin mitigation interventions for groundnuts in northern Ghana. The technological intervention will facilitate the adoption of simple and low-cost aflatoxin prevention technologies. Essentially, we are giving a randomly selected subset of study farmers the materials and information necessary to adopt. We worked with local experts to identify the preventative measures with the best potential to provide long-term and affordable solutions. The market intervention ensures a premium for a different and partially overlapping randomly selected subset of study farmers. To do this, we work with local groundnut buyers to offer a premium for groundnuts tested by the project that pass a safety criterion. Producers selected to receive the market intervention are made aware of the potential customers for safe groundnuts, and what the standards are to qualify for the price premium.

In Ghana, women constitute over 48% of the agricultural labor force. Furthermore, mainly women purchase groundnuts, then use them to make paste and extract oil. Hence, when designing the questionnaires and intervention, we considered gender differences. We built in modules on gender, individual assets and joint asset ownership at baseline. In this way, we have attempted to capture the gender dynamic around reasons why/why not individuals or households adopt control measures.

Collaborators

Name	Institution	Country	Role
Nicholas Magnan	University of Georgia	USA	PI
Vivian Hoffmann	International Food Policy Research Institute	USA	Co-PI
Gissele Gajate-Garrido	Abt Associates	USA	Co-PI
Nelson Opoku	University for Development Studies	Ghana	Partner

Achievements

As part of our interventions, we trained 1,005 farmers in 40 villages in Northern and Upper East Regions on aflatoxin risks and post-harvest techniques for aflatoxin reduction. The interventions were very effective at improving post-harvest practices in a number of dimensions.

Lessons Learned

Aflatoxin levels vary greatly across years and across farmers

The average aflatoxin level in groundnuts sampled in 2015 was 63.1 ppb. The average aflatoxin level in groundnuts sampled in 2016 from the same 1,005 farmers was 3.3 ppb. We find no statistically significant effects of our intervention done before the 2016 harvest despite seeing large changes in behavior, but should not expect to, given the very low levels of aflatoxin among control farmers. Aflatoxin levels vary greatly from farmer to farmer due to unobserved factors. We tested for correlations between farmer behavior and aflatoxin levels at baseline (using the 2015 data, when aflatoxin levels were higher) and found it very hard to predict aflatoxin levels using observed post-harvest practices.

The fact that much of the variation between farmers and between years appears to be idiosyncratic makes it very difficult to precisely estimate the impact of interventions targeting farmer practices on aflatoxin levels. We therefore recommend testing the impacts of such interventions on practices that have been proven in more controlled experimental settings (e.g., extension test plots).

Farmer demand for drying tarps is low and highly price sensitive

When given tarps, all farmers took them and over two-thirds used them to dry their groundnuts as instructed. When offered tarps at a discounted price of $2.50, only 10% bought tarps, even after given multiple opportunities to purchase them. Considering the benefits of tarp drying, we anticipated higher demand.

Farmers sell groundnuts in small quantities on a need basis

Very few farmers (less than 5%) offered a premium for groundnuts with aflatoxin levels below 15 ppb agreed to sell to our buyer. This purchase offer was made 2-3 months after harvest. Discussions with farmers indicate three reasons for the refusal to sell:

- Farmers had already sold their nuts
- Farmers were waiting for market prices to go up (above the premium price we were offering)
- Farmers sell small quantities of groundnuts when they need money throughout the year, and did not need money when our buyer came

The fact that farmers keep groundnuts in storage to speculate on prices and/or sell small quantities of nuts on a need basis will make it very difficult to integrate them into high value markets. Much more research is needed on farmer marketing decisions and interventions that could be used to get farmers to sell their groundnuts early on (before sitting in poor storage conditions) and in large quantities.

Presentations and Publications

Gajate-Garrido, G., V. Hoffmann, N. Magnan, and N. Opoku. "Technological and Market Interventions for Aflatoxin Control in Ghana" presented at University of Georgia Department of Foods and Nutrition, Athens, GA, 27 April 2016

Gajate-Garrido, G., V. Hoffmann, N. Magnan, and N. Opoku. "Technological and Market Interventions for Aflatoxin Control in Ghana" presented at Agricultural and Applied Economics Association annual meetings, Boston, MA, 31 July 2016

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Project C4. Aflatoxin Management Interventions, Education and Analysis at Various Steps Along the Peanut Value Chain in Malawi, Mozambique and Zambia

This project addresses a wide range of production, post-harvest handling, and processing issues relative to peanuts in Malawi, Zambia and Mozambique that can impact aflatoxin contamination levels, yield, and profitability. The strength of this project is that interventions are being evaluated throughout the value chain and the cumulative effect of these efforts is being measured against traditional production and marketing practices. Through linkages with various partners, farmer education will be emphasized and extended linkages with various industries and marketing groups will help accelerate aflatoxin mitigation and market development.

Malawi has a strong history of research on peanut through ICRISAT, the Department of Agriculture Research at Chitedze Research Station, and LUANAR, but the ability of farmers to produce high yielding, high quality peanuts with consistently low aflatoxin levels is still quite limited. Additional agencies such as NASFAM (National Smallholder Farmers' Association of Malawi), the Ministry of Agriculture, Exagris, Afri-Nut, TWIN of the U.K., the Clinton Development Initiative and others all are engaged in further evaluation of production, processing, and marketing strategies as well as farmer education. Improved cultivars are available, but the lack of an effective seed program limits availability. Limited marketing due to high aflatoxin contamination levels exacerbates the problem by reducing farmers' incentive to implement current production recommendations and limits commercial processing and marketing.

Our project, with its multidisciplinary team, takes a comprehensive approach to problem-solving research and effective technology transfer through key partnerships with in-country research counterparts and NGOs. The higher level of peanut research in Malawi will be expanded and emphasis placed on implementation and additional research efforts will be rapidly phased in to Zambia and Mozambique creating a regional project providing research data with even wider scale application. Key components include taking advantage of improved germplasm already available, in-country aflatoxin testing equipment and technicians already in place, key production, processing, marketing and technology transfer partners. Our project is addressing the challenges from production to processing including information transfer and creating aflatoxin awareness along the whole value chain.

Collaborators

Name	Institution	Country	Role
Rick Brandenburg	North Carolina State University	USA	PI
Justus Chintu	Chitedze Agriculture Research Station	Malawi	Co-PI
Agnes Mwangwela	LUANAR	Malawi	Co-PI
Samuel Njoroge	ICRISAT	Malawi	Co-PI
Amade Muitia	Instituto de Investigação Agrária de Moçambique	Mozambique	Co-PI
Alice Mweetwa	University of Zambia	Zambia	Co-PI
John Shindano	University of Zambia	Zambia	Co-PI
Koushik Adhikari	University of Georgia	USA	Co-PI
Manjeet Chinnan	University of Georgia	USA	Co-PI
David Jordan	North Carolina State University	USA	Co-PI
Kumar Mallikarjunan	Virginia Polytechnic Institute and State University	USA	Co-PI
Jim Goodman	Exagris Africa Ltd.	Malawi	Partner

Achievements

Pre-harvest Interventions

Malawi

- One trial on the effects of planting and harvest dates was successfully implemented at Chitedze and Baka research stations. Yield and yield components data was collected, however, aflatoxin analysis is still being done.
- A seed multiplication field under irrigation was established jointly with Exagris. The field is at Exagris farm in Salima district. There are four newly released groundnut varieties, which were planted and the crop was scheduled for harvest in November 2016. Availability of quality seed is a big challenge farmers face in Malawi and the seed being multiplied will go a long way towards meeting farmers' needs.
- Planting date experiment was implemented on farm to demonstrate how yield is affected due to delayed planting. The planting date trial was put in three districts of Mangochi, Blantyre and Karonga.
- A long-term crop rotation study in collaboration with LUANAR and ICRISAT has completed the first phase with a master's student project and is scheduled for continuation beyond four years.

Zambia

- Biochar and calcium experiments have been conducted by the BSc. and MSc. students. Data being analyzed.
- Preliminary data on soil organic matter, calcium and moisture management has been generated. Additional data from remote sites has also been collected on planting time and soil organic matter management. Development of an index still underway.

Mozambique

- A planting date/cultivar/harvest date study was completed at multiple locations in collaboration with a master's student at IIAM and UEM.

USA (NCSU)

- New updated version of peanut risk decision program was made available on line: http://www.peanut.ncsu.edu/riskmgmt/

Post-harvest Interventions

Zambia

- MSc Student in Agricultural Engineering (John Yawe) has submitted his MSc dissertation on "Assessing Existing Drying and Storage Systems of Raw Groundnuts Along the Value Chain and Identifying Areas of Improvement." The main outputs in the dissertation included: (a) Identifying the current existing drying and storage practices, (b) Evaluating six current drying practices for drying parameters and effect on aflatoxin contents, and (c) Making recommendations on the evaluated drying practices. A research paper from the MSc student work on drying research has been submitted to an Asian Journal of Agricultural Engineering and we are waiting for the review.

USA (University of Georgia)

- Raw shelled peanut samples have been packaged in either nylon mesh bags or high density clear polyethylene bags, and stored at room temperature (~23°C) and 40°C. Two replicates were done. Descriptive analysis and instrumental analysis (peroxide value and GC-MS aroma profile) are being done at eight time points (0, 6, 12, 18, 24, 32 and 48 weeks). The objective is to determine if lightly roasted peanuts have a better shelf life than raw peanuts. This study can help the retail points in Southern Africa increase the shelf stability of peanuts. The lightly roasted peanuts can be screened easily for discolored kernels, which are associated with higher aflatoxin content.

Processing Interventions

Malawi

- One peanut butter processor in Malawi certified by the Bureau of Standards and two others pre-certified by Malawi Bureau of Standards
    - Ms. Mauluka, Blantyre, Certified, Brand name: Linotha
    - Mr. Kananza; Blantyre Pre-certification; Brand name: LIAM Peanut Butter
    - Mrs. Mandala, Brand name: JESCAL Peanut; Lilongwe
- Training in USA for Mr. Vincent Mlotha (LUANAR) at the University of Georgia and Virginia Tech
    - Sensory Evaluation and Techniques; Partnership with industry
    - Aflatoxin testing methods in Virginia Tech
    - Data Analysis using SAS
    - Drafting a manuscript

Processors including Enid Mauluka (right) are getting certified by the Bureau of Standards after a PMIL-sponsored training in best practices for processors. (Submitted photo)

Zambia

- We have conducted a market survey for the occurrence of aflatoxin in three peanut products: raw peanuts, powdered peanuts and roasted peanuts sold in open markets of 14 districts of Zambia. Sampling has been completed and analysis for moisture content, water activity and aflatoxin content is being conducted in the laboratory.
- A MSc student in nutrition was recruited for the peanut-processing research. The student completed his academic year coursework, and is now working on the research proposal. To expedite the peanut-processing component of the work, we are in the process of recruiting two undergraduate students to assist with certain components of the work.

Lessons Learned

Empirical risk management decision aids can be developed for Africa focusing on in-field aflatoxin contamination risk using algorithms and refined annually through field trials.

Collaboration with Exagris has yielded improvements in research trial scale and quality and added multiple locations. It also improves the likelihood of research uptake by the private sector and their grower network, including the use of improved varieties produced during the dry season under irrigation.

Presentations and Publications

Chalwe H., Mweetwa, A.M., Lungu O.I., Phiri E., Njoroge S. and Brandenburg, R. L. Reducing pre-harvest aflatoxin content in groundnuts through soil water management. Fifth African Higher Education Week and RUFORUM Biennial Conference, 14-21 October, 2016 (submitted)

Moyo, T.T., Mwangwela, A.M., Adhikari, K., Chinnan, M. and Mallikarjunan, K. (2016). Quality characterisation and improvement of peanut butter on the Malawian Retail Market. Poster presented at the IFT 16, Chicago, IL; USA. 16 -19 July 2016

Mwangwela Agnes M., P. Kumar Mallikarjunan and Manjeet S. Chinnan. (2016). Food processing priorities to reduce food losses in Malawi. Oral Presentation made at IFT 16, Chicago, IL; USA. 16 -19 July 2016

Phan, Uyen T.X., Shangci Wang, Koushik Adhikari, Manjeet Chinnan, Kumar Mallikarjunan. Quality changes in peanuts as affected by blanching, storage temperature, packaging materials and storage time. Oral Presentation at SPISE International Sensory Analysis Symposium, Ho Chi Minh City Vietnam, 29-31 July 2016

Wang, Shangci. Koushik Adhikari, Manjeet Chinnan. Storage quality evaluation of lightly roasted blanched peanuts when compared to raw shelled peanuts. Poster Presentation at IFT Annual Meeting at Chicago, 16-20 July 2016

Project C5. Productivity and Profitability Growth in Peanut Production: A Farm Level Analysis in Malawi, Mozambique and Zambia

The overarching objective of this project is to generate and transfer economic knowledge needed to intensify groundnut production, and its subsequent use, so as to significantly increase productivity and farm profits, while reducing the risk of aflatoxin contamination in the harvested crop. The end goal is to boost productivity growth in groundnut farming systems as a way to increase food safety, food security, and farm income in Malawi, Mozambique, and Zambia. This work will be done in close collaboration with the Southern Africa Value Chain and Integrated Breeding Projects.

A fundamental underpinning of the project proposed here is that a major constraint to a healthy groundnut value chain in much of Africa is low farm productivity and profits. Productivity and profits can be improved in various ways, including increasing the yield of marketable peanuts. Thus, the primary focus of this project is to analyze the farm-level costs and benefits of alternative treatments designed to reduce the aflatoxin levels with the goal of increasing peanut quality and prices received by farmers.

A second area of work is to utilize data from the World Bank Living Standard Measurement Studies-Integrated Surveys on Agriculture (LSMS-ISA) and variety data generated by the Integrated Breeding Project to evaluate the farm benefits of improved seed varieties, particularly in Uganda and Malawi.

A third area of work will be to undertake human capacity building through workshops in various topics including production economics, farm management principles and/or impact evaluation techniques.

Collaborators

Name	Institution	Country	Role
Boris Bravo-Ureta	University of Connecticut	USA	PI
Jeremy Jelliffe	University of Connecticut	USA	Res. Tech.
Rick Brandenburg	North Carolina State University	USA	Partner
Amade Muitia	IIAM	Mozambique	Partner
Justus Chintu	DARS	Malawi	Partner
David Okello	NARO	Uganda	Partner

Achievements

- Visited the three target countries and completed the elaboration of the research objectives based on actual production and agronomic work completed to date and planned for the future.
- Designed protocols to collect production and agronomic data from other collaborating projects.
- In cooperation with the in-country collaborators, prepared plans for in-country workshop in 2017.
- Completed productivity analysis of the LSMS-ISA Malawi data, and a manuscript for submission is under preparation.
- Completed adoption analysis of the Ugandan LSMS-ISA data.
- Developed an economic engineering model to undertake the work under Objective 1.

Lessons Learned

The results of the estimations, using LSMS-ISA data, show positive and significant effects of improved seed varieties on farm-level productivity. Furthermore, the results from Malawi indicate that even under unfavorable climatic conditions, improved seeds are observed to increase farm-level yields.

Presentations and Publications

Amponsah, K. and Paliwal, N. "Technology And Managerial Gaps In The Adoption Of Improved Groundnut Varieties In Malawi and Uganda." Selected Paper presented at the 2015 Agricultural & Applied Economics Association and Western Agricultural Economics Association Annual Meeting, San Francisco, Calif., July 26-28 2016.

Bravo-Ureta, B. "UConn Update: Productivity and Profitability Growth in Peanut Production: A Farm Level Analysis in Malawi, Mozambique and Zambia (MalMoZam)" Selected Presentation for the 2016 PMIL Annual Meetings, Tamale, Ghana, August 2016.

Jelliffe, J., Bravo-Ureta, B., Mochiah, M., Dankyi, A., Jordan, D., Muitia, A., Salegua, V., and Urban, E. "Diagnostic Survey of Groundnut Farmers in Ghana and Mozambique: Preliminary Findings and Next Steps." Poster Selected for the 2016 PMIL Annual Meetings, Tamale, Ghana, August 2016.

Associate Award Research Project Reports

No Associate Awards have been received to date.

Human and Institutional Capacity Development

Short-Term Training (by country)

Name	Gender	Home Country	Home Institution	Dates	Research Focus	Mentor	Training Location
Fidele Neya	M	Burkina Faso	University of Ouagadougou		Training in genomics, specifically identification and use of SNP-based markers	Carl Deom	Texas A&M Agrilife Research
Maxwell Lamptey	M	Ghana	Crops Research Institute, Kumasi, Ghana	Apr-Sep 2015	Develop and evaluate a solar dryer for peanuts	Jinru Chen	University of Georgia, Griffin, GA, USA
Gary Benoit	M	Haiti	Université Roi Henri Christophe	Spring 2016	Internship and undergraduate thesis, runner fungicide timing	Greg MacDonald	Meds & Food for Kids
Rolcky Butois	M	Haiti	Université Chretienne du Nord d'Haiti	Fall 2016	Internship and undergraduate thesis, runner fungicide timing	Greg MacDonald	Meds & Food for Kids
Exan Desamours	M	Haiti	Université Roi Henri Christophe	Fall 2016	Internship and undergraduate thesis, runner fungicide timing	Greg MacDonald	Meds & Food for Kids
Laine Dorinvil	M	Haiti	Université Roi Henri Christophe	Fall 2016	Internship and undergraduate thesis, top six Valencia study at Quartier-Morin	Greg MacDonald	Meds & Food for Kids
Jean Baptiste Fontilus	M	Haiti	Université Chretienne du Nord d'Haiti	Fall 2016	Internship and undergraduate thesis, top six Valencia study at Quartier-Morin	Greg MacDonald	Meds & Food for Kids
Pierre Galet	M	Haiti	Université Chretienne du Nord d'Haiti	Fall 2016	Internship and undergraduate thesis, plant and seed spacing	Greg MacDonald	Meds & Food for Kids
John Jones Joseph	M	Haiti	Université Chretienne du Nord d'Haiti	Fall 2016	Internship and undergraduate thesis, advanced breeding lines	Greg MacDonald	Meds & Food for Kids
Judeline Joseph	F	Haiti	Université Chretienne du Nord d'Haiti	Fall 2016	Internship and undergraduate thesis, soil amendments	Greg MacDonald	Meds & Food for Kids
Galeine Queranor	F	Haiti	Université Roi Henri Christophe		Internship and undergraduate thesis, Valencia fungicide timing	Greg MacDonald	Meds & Food for Kids
Frisnel Pierre	M	Haiti	Université Roi Henri Christophe	Fall 2016	Internship and undergraduate thesis, top six Valencia study at Quartier-Morin	Greg MacDonald	Meds & Food for Kids

Name	Gender	Home Country	Home Institution	Dates	Research Focus	Mentor	Training Location
Rodemane Saint Louis	F	Haiti	Université Roi Henri Christophe	Fall 2016	Internship and undergraduate thesis, top six Valencia study	Greg MacDonald	Meds & Food for Kids
Marilene Saint-Juste	F	Haiti	Université Roi Henri Christophe	Fall 2016	Internship and undergraduate thesis, Valencia fungicide timing	Greg MacDonald	Meds & Food for Kids
Rodnie Valmy	F	Haiti	Université Roi Henri Christophe	Spring 2016	Internship and undergraduate thesis, top six Valencia study	Greg MacDonald	Meds & Food for Kids
Paul Macharia	M	Kenya	Kenyatta University	2015	Peanut-genetic transformation and molecular tools	Renee Arias	USDA-ARS National Peanut Research Lab, Dawson, GA, USA
Vincent Mlotha	M	Malawi	LUANAR, Lilongwe, Malawi		Sensory and Aflatoxin techniques	Agnes Mwangwela	University of Georgia, Virginia Tech
Amos Acur	M	Uganda	NARO, Uganda	2015	Isolation and genetic fingerprinting of *Aspergillus*	Renee Arias	USDA-ARS National Peanut Research Lab, Dawson, GA, USA
Jonothan Farr	M	USA	Georgia Southwestern University		Learn molecular tools and help with research projects	Renee Arias	USDA-ARS National Peanut Research Lab, Dawson, GA, USA
LaTanya Johnson	F	USA	Albany State University	2014-2015	DNA extraction from *Aspergillus* and from plants, PCR screenings, and DNA fingerprinting	Renee Arias	USDA-National Peanut Research Laboratory, Dawson, GA, USA
Austin Page	F	USA	Albany State University		Learn molecular tools to help with research projects	Renee Arias	USDA-National Peanut Research Laboratory, Dawson, GA, USA
Emily Urban	F	USA	University of Georgia	2016	Survey preparation and facilitation	Boris Bravo-Ureta	

Long-Term Training (by country)

Name	Gender	Home Country	Degree	Grad. Date	Discipline	Research Focus	Mentor	Training Institution
Clara Darko	F	Ghana	PhD		Post-harvest Processing	Comparison of storage systems for in-shell, shelled, and blanched peanuts	Kumar Mallikarjunan	Virginia Tech, Blacksburg, VA
Paola Faustinelli	F	Argentina	PhD		Plant Biotechnology	Genetic diversity of *A. flavus*	Renee Arias	University of Cordoba, Argentina
Fidele Neya	M	Burkina Faso	PhD	Dec 2016	Plant Pathology		Carl Deom	Université de Ouagadougou, Burkina Faso
Samson Nakone	M	Burkina Faso	MS		Plant Pathology		Carl Deom	Université de Ouagadougou, Burkina Faso
Kouha Hamidou Sogoba	F	Burkina Faso	MS		Plant Pathology		Carl Deom	Université de Ouagadougou, Burkina Faso
Fengle Zhu	F	China	PhD	Jul 2014	Biosystems Engineering	Studying fluorescence and NVIR for detection	Haibo Yao	Zhejiang University, China
Carolina Chavarro	F	Columbia	PhD	Aug 2017	Plant Breeding, Genetics and Genomics	Using genotyping for breeding	Peggy Ozias-Akins	University of Georgia, Tifton GA, USA
Alibu Abdul-Hafiz	M	Ghana	BSc	Nov 2016	Biotechnology		Nelson Opoku	University for Development Studies
Yussif Abubakari	M	Ghana	MPhil	Jul 2016	Food Science and Technology	Effects of applications of calcium to reduce aflatoxin contamination in peanut	David Jordan	KNUST, Kumasi, Ghana

Isaac Kwesi Addo	M	Ghana	MSc	Jul 2016	Food & Postharvest Engineering	Determining the utility of drying methods including fabricating a solar drier to reduce aflatoxin contamination in peanuts	David Jordan	KNUST, Kumasi, Ghana
Esther Yeboah Akota	F	Ghana	MSc	Jul 2016	Food Science	Deactivation of aflatoxin-contaminated peanut waste via composting	Jinru Chen	University of Georgia. Griffin, GA USA
Theophilus Alale	M	Ghana	MPhil	Nov 2015	Biotechnology		Nelson Opoku	University for Development Studies
Stephan Arthur	M	Ghana	MPhil	Jul 2016	Agronomy	Influence of herbicides and fungicides on pest reaction, yield, and aflatoxin contamination in peanut	David Jordan	KNUST, Kumasi, Ghana
Sylvia Baah-Tuahene	F	Ghana	MSc	Nov 2015	Food Science	Evaluating the quality (aflatoxin and microbial) of products in the local peanut processing chain	Agnes Budu, F.K. Saalia	University of Ghana, Accra, Ghana
Loretta Darkwah	F	Ghana	MSc		Food Science	Groundnut processing	Agnes Budu, F.K. Saalia	University of Ghana, Accra, Ghana
Afia Karikari	F	Ghana	PhD		Breeding	Drought stress in groundnuts	James Asibuo	Crops Research Institute
Dominic Ndela Ngagmayan	M	Ghana	BSc	Nov 2016	Biotechnology		Nelson Opoku	University for Development Studies
B.A. Charles Neequaye	M	Ghana	BSc	Nov 2016	Biotechnology		Nelson Opoku	University for Development Studies
Vincent Ninkuu	M	Ghana	MPhil	Jan 2017	Biotechnology	Leading enumerator teams, conducting laboratory testing, and doing data analysis	Nelson Opoku	University for Development Studies
William Ofori Appaw	M	Ghana	MPhil	Jul 2016	Food Science and Technology	Evaluation of interventions to reduce aflatoxin	David Jordan	KNUST, Kumasi, Ghana

Eric Owusu	M	Ghana	PhD	May 2020	Ag Economics		Boris Bravo-Ureta	University of Connecticut
Noah Saduli	M	Ghana	MPhil	Oct 2016	Biotechnology	Leading enumerator teams, conducting laboratory testing, and doing data analysis	Nelson Opoku	University for Development Studies, Tamale, Ghana
Theophilus Tengey	M	Ghana	PhD			Plant breeding and genetics	Carl Deom	Texas Tech University
Maxwell Yorke	M	Ghana	BSc	Nov 2016	Biotechnology		Nelson Opoku	University for Development Studies
Paul Karanja	M	Kenya	MSc		Plant Biotechnology			Kenyatta University, Kenya
Davis Gimode	M	Kenya	PhD	May 2019	Plant Breeding, Genetics and Genomics	Peanut genomics	Peggy Ozias-Akins	University of Georgia, Tifton, GA USA
Andrew Abraham	M	Malawi	MSc	Sep 2016	Crop Science	Effect of rotations and harvest date on pre-harvest aflatoxin contamination	W. Mhango, V. Saka	LUANAR, Lilongwe, Malawi
Kobby Amponsah		Malawi	MSc	2015	Economics	Research Technician working on the productivity effects of improved groundnut seed varieties	Boris Bravo-Ureta	
Prince Chadza	M	Malawi	BS	Jul 2017	Agriculture Engineering		Agnes Mwangwela	LUANAR, Lilongwe, Malawi
Monica Chimbaza	F	Malawi	MSc	Mar 2017	Agricultural Engineering	Drying and storage technologies for reducing aflatoxin in peanuts	Wellam Kamthunzi	LUANAR, Lilongwe, Malawi
Aggrey Gamma	M	Malawi	PhD	May 2019	Food Science	Peanut products	Koushik Adhikari	University of Georgia, Griffin, GA USA
Clara Kasukula	F	Malawi	MSc	Apr 2017	Food Science	Residual aflatoxin in oil from contaminated peanuts	Limbikani Matumba	LUANAR, Lilongwe, Malawi

Jeremy Jelliffe	M	USA	PhD	Aug 2017	Economics	Economics of interventions to reduce aflatoxin contamination in peanuts	Boris Bravo-Ureta	University of Connecticut, Storrs, CT USA
Chikondi Magombo	F	Malawi	MSc	Mar 2017	Food Science	Processing and uses of peanut flour	Agnes Mwangwela	LUANAR, Lilongwe, Malawi
Esther Mambo	F	Malawi	BS	2014	Biology		Renee Arias	University of Malawi, Chancellor College
Dickson Mbughi	M	Malawi					Renee Arias	
Lydia Mkandawire	F	Malawi	MSc	Apr 2017	Agronomy	Effect of plant density on aflatoxin development	Agnes Mwangwela	LUANAR, Lilongwe, Malawi
Tchiyiwe Moyo	F	Malawi	MSc	Feb 2016	Food Science	Baseline evaluation of peanut butter quality and processor knowledge of aflatoxin	Agnes Mwangwela	LUANAR, Lilongwe, Malawi
Chancy Sibakwe	M	Malawi	MSc	Sep 2016	Entomology	Biotic/Abiotic stress impacts on pre-harvest aflatoxin contamination	W. Mhango, V. Saka	LUANAR, Lilongwe, Malawi
Longwe Tiwonge	F	Malawi	MSc	Apr 2017	Food Science		Agnes Mwangwela	LUANAR, Lilongwe, Malawi
Emmanuel Zuza, Jr.	M	Malawi	MSc	Nov 2016		Effects planting/harvest date on aflatoxin	Rick Brandenburg	Universidade Eduardo Mondlane
Rita Valentim Manjonda	F	Mozambique	MS	Dec 2017	Agronomy		Carl Deom	Khon Kaen University, Khon Kaen, Thailand
Maria Jacinta De Carvalho Mopecane	F	Mozambique	MS	Dec 2017	Agronomy		Carl Deom	Khon Kaen University, Khon Kaen, Thailand

Imana Power	F	Suriname	PhD		Plant Pathology	RNAi for aflatoxin reduction	Renee Arias	University of Georgia, USA
Eric Simning	M	Tanzania	MSc		Economics	Research Technician working on the productivity effects of improved groundnut seed varieties	Boris Bravo-Ureta	
Neha Paliwal	F	Uganda	MSc		Economics	Research Technician working on the productivity effects of improved groundnut seed varieties	Boris Bravo-Ureta	
Jennifer Chagoya	F	USA	MS	Dec 2016			Carl Deom	Texas Tech University
Abraham Fulmer	M	USA	PhD	May 2017	Plant Pathology	Leaf spots in peanut	Bob Kemerait	University of Georgia, Tifton, GA USA
Chandler Maddox	F	USA	MS	May 2016	Plant Breeding, Genetics and Genomics		Peggy Ozias-Akins	University of Georgia, Tifton, GA USA
LaSindia Powell	F	USA	BS	Jun 2016	Forensic Science		Renee Arias	Albany State University, USA
Amanda Seawright	F	USA	MSc	2016	Environmental Health	Aflatoxin detections in peanuts and grains	Jia-Sheng Wang	University of Georgia, Athens, GA USA
Monica Wang	F	USA	BS	Jun 2015	Chemistry/ Biology		Renee Arias	Emory University, USA
Kathy Xue	F	USA	PhD	2019	Environmental Health	Aflatoxin detection in dried blood samples	Jia-Sheng Wang	University of Georgia, Athens, GA USA
Hendrix Chalwe	M	Zambia	PhD	Oct 2017	Agronomy	Modeling of pre-harvest aflatoxin contamination in peanuts	Alice Mweetwa	University of Zambia, Lusaka, Zambia
John Yawe	M	Uganda	MSc	May 2017	Post-harvest Processing	Assessment of existing drying and storage systems for peanuts	Mkandawire, Simate	University of Zambia, Lusaka, Zambia
Munsanda Ngulube	F	Zambia	MSc	Jan 2017	Agronomy	Use of biochar and gypsum to reduce aflatoxin in peanuts	Alice Mweetwa	University of Zambia, Lusaka, Zambia

Workshops and Courses

Name/Type of Event	Male	Female	Trainee(s)	Dates	Trainer/Institution	Research Focus	Mentor	Training Location
CLC-Bio-Software	5	3		May 17, 2016	Monica Wang	Training Bioinformatics	Renee Arias	Dawson, GA
Stakeholder Workshop	11	24	Extension staff, Research Technicians	Dec 14-18, 2017	Justus Chintu, Donald Siyeni/DARS, Malawi	Groundnut Trials and Demonstrations	Carl Deom	Salima, Malawi
Training of Extension staff and Technicians	19	11	Extension staff and Research Technicians	Apr 18-22, 2016	Justus Chintu, Donald Siyeni/DARS, Malawi	Trial Management, Groundnut Production	Carl Deom	Salima, Malawi
Field Days	52	98	Farmers	Apr 2016	Justus Chintu	New Groundnut Varieties, PVS, Production practices for high productivity	Carl Deom	Ntcheu, Lilongwe, and Karonga, Malawi
Plot Harvesting	12	16	Farmers	Nov 2015	Students and Women	Harvesting	Carl Deom	Gampela and POBE, Burkina Faso
Field Monitoring	12	10	Farmers	Jul 30, 2016 to harvest	M. Almissa, Students and Farmers	Plot Notes	Carl Deom	Gampela and POBE, Burkina Faso
Field Monitoring	8	20	Farmers	Aug 29, 2016	P. Sankara	Planting and Field Plot Design	Carl Deom	Gampela, Burkina Faso
Workshop, Field Day	46	24	World Vision-Mbale Butaleja cluster	Mar 2016	D.K. Okello and P. Osia,/ NASRRI	Groundnut Production System	Carl Deom	Uganda
Workshop, Field Day	33	28	World Vision Sorotu cluster	Feb 2016	D.K. Okello and P. Osia/ NASRRI	Groundnut Production System	Carl Deom	Uganda

Name/Type of Event	Male	Female	Trainee(s)	Dates	Trainer/Institution	Research Focus	Mentor	Training Location
Training Lecture, Field Visits	10	7	Technicians East and Southern Africa	May 2016	D.K. Okello/ NASRRI	Legume Breeding Systems	Carl Deom	East and Central African
Field Attachment	9	4	Students (certificate, diploma, Bachelor's)	May 2 - Jul 30, 2016	D.K. Okello/ NASRRI	Groundnut Value Chain	Carl Deom	Uganda
Workshop, Field Day	11	16	Danish Refugee Council-Amuria	May 2016	D.K. Okello, P. Anguria, and P. Osia/NASRRI	Seed Systems, Agronomy	Carl Deom	Uganda
Workshop, Field Day	32	38	ZOA Amuru	Jun 2016	P. Osia and S. Ocuga/NASRRI	Seed Systems, Agronomy, Crop Protection	Carl Deom	Uganda
Workshop, Field Day	14	18	LSB Dokolo	Jun 2016	D.K. Okello and P. Anguria/NASRRI	Seed Systems	Carl Deom	Uganda
Workshop, Field Day	73	48	Farmers	Aug 24, 2016	P. Osia and S. Ocuga/NASRRI	Seed Systems and Crop Protections	Carl Deom	Uganda
	25	7	Haitian Peanut Research Agronomists	Jun 21, 2016	MFK & PMIL	Experimental Design and best management practices	Greg MacDonald	Quartier-Morin, Haiti
Enumerator Workshop	6	3	Survey Enumerators	Jun 3-8, 2016	Boris Bravo-Ureta, Jeremy Jelliffe	Familiarize enumerators with the survey instrument	Boris Bravo-Ureta	Nampula, Mozambique
Aflatoxin Training	9	16	Farmers	Aug/Sep 2015	Abdulai Baako/MoA, Noah Saduli and Vincent Ninkuu/UDS	Train farmers on post-harvest best practices	Nick Magnan	Digbila Village, Northern Region, Ghana
Aflatoxin Training	17	8	Farmers	Aug/Sep 2015	Abdulai Baako/MoA, Noah Saduli and Vincent Ninkuu/UDS	Train farmers on post-harvest best practices	Nick Magnan	Geluwei Village, Northern Region, Ghana

Name/Type of Event	Male	Female	Trainee(s)	Dates	Trainer/Institution	Research Focus	Mentor	Training Location
Aflatoxin Training	16	8	Farmers	Aug/Sep 2015	Abdulai Baako/MoA, Noah Saduli and Vincent Ninkuu/UDS	Train farmers on post-harvest best practices	Nick Magnan	Kpsinga Village, Northern Region, Ghana
Aflatoxin Training	17	8	Farmers	Aug/Sep 2015	Abdulai Baako/MoA, Noah Saduli and Vincent Ninkuu/UDS	Train farmers on post-harvest best practices	Nick Magnan	Nyong Village, Northern Region, Ghana
Aflatoxin Training	17	8	Farmers	Aug/Sep 2015	Abdulai Baako/MoA, Noah Saduli and Vincent Ninkuu/UDS	Train farmers on post-harvest best practices	Nick Magnan	Tamalegu Village, Northern Region, Ghana
Aflatoxin Training	17	8	Farmers	Aug/Sep 2015	Abdulai Baako/MoA, Noah Saduli and Vincent Ninkuu/UDS	Train farmers on post-harvest best practices	Nick Magnan	Kplung Village, Northern Region, Ghana
Aflatoxin Training	17	8	Farmers	Aug/Sep 2015	Abdulai Baako/MoA, Noah Saduli and Vincent Ninkuu/UDS	Train farmers on post-harvest best practices	Nick Magnan	Nyeko Village, Northern Region, Ghana
Aflatoxin Training	17	8	Farmers	Aug/Sep 2015	Abdulai Baako/MoA, Noah Saduli and Vincent Ninkuu/UDS	Train farmers on post-harvest best practices	Nick Magnan	Ying Village, Northern Region, Ghana
Aflatoxin Training	17	8	Farmers	Aug/Sep 2015	Abdulai Baako/MoA, Noah Saduli and Vincent Ninkuu/UDS	Train farmers on post-harvest best practices	Nick Magnan	Zion Village, Northern Region, Ghana
Aflatoxin Training	17	8	Farmers	Aug/Sep 2015	Abdulai Baako/MoA, Noah Saduli and Vincent Ninkuu/UDS	Train farmers on post-harvest best practices	Nick Magnan	Zoggu Village, Northern Region, Ghana
Aflatoxin Training	14	7	Farmers	Aug/Sep 2015	Abdulai Baako/MoA, Noah Saduli and Vincent Ninkuu/UDS	Train farmers on post-harvest best practices	Nick Magnan	Gbrimani Village, Northern Region, Ghana
Aflatoxin Training	17	8	Farmers	Aug/Sep 2015	Abdulai Baako/MoA, Noah Saduli and Vincent Ninkuu/UDS	Train farmers on post-harvest best practices	Nick Magnan	Kpakyiyli Village, Northern Region, Ghana
Aflatoxin Training	16	8	Farmers	Aug/Sep 2015	Abdulai Baako/MoA, Noah Saduli and Vincent Ninkuu/UDS	Train farmers on post-harvest best practices	Nick Magnan	Kpaliga Village, Northern Region, Ghana

Name/Type of Event	Male	Female	Trainee(s)	Dates	Trainer/Institution	Research Focus	Mentor	Training Location
Aflatoxin Training	17	8	Farmers	Aug/Sep 2015	Abdulai Baako/MoA, Noah Saduli and Vincent Ninkuu/UDS	Train farmers on post-harvest best practices	Nick Magnan	Satani Village, Northern Region, Ghana
Aflatoxin Training	17	9	Farmers	Aug/Sep 2015	Abdulai Baako/MoA, Noah Saduli and Vincent Ninkuu/UDS	Train farmers on post-harvest best practices	Nick Magnan	Yipelgu Village, Northern Region, Ghana
Aflatoxin Training	16	9	Farmers	Aug/Sep 2015	Abdulai Baako/MoA, Noah Saduli and Vincent Ninkuu/UDS	Train farmers on post-harvest best practices	Nick Magnan	Bachalbado Village, Northern Region, Ghana
Aflatoxin Training	17	9	Farmers	Aug/Sep 2015	Abdulai Baako/MoA, Noah Saduli and Vincent Ninkuu/UDS	Train farmers on post-harvest best practices	Nick Magnan	Macheliyili Village, Northern Region, Ghana
Aflatoxin Training	16	9	Farmers	Aug/Sep 2015	Abdulai Baako/MoA, Noah Saduli and Vincent Ninkuu/UDS	Train farmers on post-harvest best practices	Nick Magnan	Naaduno Village, Northern Region, Ghana
Aflatoxin Training	16	9	Farmers	Aug/Sep 2015	Abdulai Baako/MoA, Noah Saduli and Vincent Ninkuu/UDS	Train farmers on post-harvest best practices	Nick Magnan	Sambu Village, Northern Region, Ghana
Aflatoxin Training	16	9	Farmers	Aug/Sep 2015	Abdulai Baako/MoA, Noah Saduli and Vincent Ninkuu/UDS	Train farmers on post-harvest best practices	Nick Magnan	Tijo Village, Northern Region, Ghana
Aflatoxin Training	16	9	Farmers	Sep/Oct 2016	Joseph Amenini and Thomas Anobiga/MoA, Noah Saduli and Vincent Ninkuu/UDS	Train farmers on post-harvest best practices	Nick Magnan	Achobisi Kasam Village, UE Region, Ghana
Aflatoxin Training	16	9	Farmers	Sep/Oct 2016	Joseph Amenini and Thomas Anobiga/MoA, Noah Saduli and Vincent Ninkuu/UDS	Train farmers on post-harvest best practices	Nick Magnan	Asibiga Village, UE Region, Ghana
Aflatoxin Training	16	9	Farmers	Sep/Oct 2016	Joseph Amenini and Thomas Anobiga/MoA, Noah Saduli and Vincent Ninkuu/UDS	Train farmers on post-harvest best practices	Nick Magnan	Balungu-Gantorisi Village, UE Region, Ghana

Name/Type of Event	Male	Female	Trainee(s)	Dates	Trainer/Institution	Research Focus	Mentor	Training Location
Aflatoxin Training	16	9	Farmers	Sep/Oct 2016	Joseph Amenini and Thomas Anobiga/MoA, Noah Saduli and Vincent Ninkuu/UDS	Train farmers on post-harvest best practices	Nick Magnan	Basiengo-Amenabisi Village, UE Region, Ghana
Aflatoxin Training	16	9	Farmers	Sep/Oct 2016	Joseph Amenini and Thomas Anobiga/MoA, Noah Saduli and Vincent Ninkuu/UDS	Train farmers on post-harvest best practices	Nick Magnan	Beo Kasingo Daporyorogo Village, UE Region, Ghana
Aflatoxin Training	16	9	Farmers	Sep/Oct 2016	Joseph Amenini and Thomas Anobiga/MoA, Noah Saduli and Vincent Ninkuu/UDS	Train farmers on post-harvest best practices	Nick Magnan	Bonia Village, UE Region, Ghana
Aflatoxin Training	18	9	Farmers	Sep/Oct 2016	Joseph Amenini and Thomas Anobiga/MoA, Noah Saduli and Vincent Ninkuu/UDS	Train farmers on post-harvest best practices	Nick Magnan	Chuchuliga Tiedema Village, UE Region, Ghana
Aflatoxin Training	18	8	Farmers	Sep/Oct 2016	Joseph Amenini and Thomas Anobiga/MoA, Noah Saduli and Vincent Ninkuu/UDS	Train farmers on post-harvest best practices	Nick Magnan	Chuchulia Yipaala Village, UE Region, Ghana
Aflatoxin Training	18	9	Farmers	Sep/Oct 2016	Joseph Amenini and Thomas Anobiga/MoA, Noah Saduli and Vincent Ninkuu/UDS	Train farmers on post-harvest best practices	Nick Magnan	Chuchulia Adabinsa Village, UE Region, Ghana
Aflatoxin Training	18	8	Farmers	Sep/Oct 2016	Joseph Amenini and Thomas Anobiga/MoA, Noah Saduli and Vincent Ninkuu/UDS	Train treatment farmers on post-harvest best practices	Nick Magnan	Chuchulia Akpoteyera Village, UE Region, Ghana
Aflatoxin Training	17	8	Farmers	Sep/Oct 2016	Joseph Amenini and Thomas Anobiga/MoA, Noah Saduli and Vincent Ninkuu/UDS	Train farmers on post-harvest best practices	Nick Magnan	Dulugu Aginbisi Village, UE Region, Ghana

Name/Type of Event	Male	Female	Trainee(s)	Dates	Trainer/Institution	Research Focus	Mentor	Training Location
Aflatoxin Training	18	8	Farmers	Sep/Oct 2016	Joseph Amenini and Thomas Anobiga/MoA, Noah Saduli and Vincent Ninkuu/UDS	Train farmers on post-harvest best practices	Nick Magnan	Dulugu-Asanorebisi Village, UE Region, Ghana
Aflatoxin Training	17	8	Farmers	Sep/Oct 2016	Joseph Amenini and Thomas Anobiga/MoA, Noah Saduli and Vincent Ninkuu/UDS	Train farmers on post-harvest best practices	Nick Magnan	Feo Asimabisi Village, UE Region, Ghana
Aflatoxin Training	17	8	Farmers	Sep/Oct 2016	Joseph Amenini and Thomas Anobiga/MoA, Noah Saduli and Vincent Ninkuu/UDS	Train farmers on post-harvest best practices	Nick Magnan	Nyangua Village, UE Region, Ghana
Aflatoxin Training	16	8	Farmers	Sep/Oct 2016	Joseph Amenini and Thomas Anobiga/MoA, Noah Saduli and Vincent Ninkuu/UDS	Train farmers on post-harvest best practices	Nick Magnan	Sumbrungu Kologo Akanyebi Village, UE Region, Ghana
Aflatoxin Training	17	9	Farmers	Sep/Oct 2016	Joseph Amenini and Thomas Anobiga/MoA, Noah Saduli and Vincent Ninkuu/UDS	Train farmers on post-harvest best practices	Nick Magnan	Sumbrungu Yeobongo Nayire Village, UE Region, Ghana
Aflatoxin Training	17	8	Farmers	Sep/Oct 2016	Joseph Amenini and Thomas Anobiga/MoA, Noah Saduli and Vincent Ninkuu/UDS	Train farmers on post-harvest best practices	Nick Magnan	Tampola Village, UE Region, Ghana
Aflatoxin Training	17	8	Farmers	Sep/Oct 2016	Joseph Amenini and Thomas Anobiga/MoA, Noah Saduli and Vincent Ninkuu/UDS	Train farmers on post-harvest best practices	Nick Magnan	Vea Gunga Village, UE Region, Ghana
Aflatoxin Training	18	8	Farmers	Sep/Oct 2016	Joseph Amenini and Thomas Anobiga/MoA, Noah Saduli and Vincent Ninkuu/UDS	Train farmers on post-harvest best practices	Nick Magnan	Wiaga Yemonsa Village, UE Region, Ghana

Name/Type of Event	Male	Female	Trainee(s)	Dates	Trainer/Institution	Research Focus	Mentor	Training Location
Aflatoxin Training	18	8	Farmers	Sep/Oct 2016	Joseph Amenini and Thomas Anobiga/MoA, Noah Saduli and Vincent Ninkuu/UDS	Train farmers on post-harvest best practices	Nick Magnan	Yikene Village, UE Region, Ghana
Course Module	33	9		Fall 2015	Nelson Opoku/UDS	Practical training in aflatoxin analysis	Nick Magnan	Ghana
Course Module	3	10		Fall 2016	Nelson Opoku/UDS	Practical training in aflatoxin analysis	Nick Magnan	Ghana
NARO meeting	2	0		Sep 19-22, 2016	David Okello	NARO Groundnut program	Boris Bravo-Ureta	Kampala, UG & Soroti, UG

Institutional Development

Most institutional development consisted of scientist, student and technical training in the use and operation of various laboratory equipment necessary to complete the PMIL projects.

Technology Transfer and Scaling Partnerships

- Seed of improved varieties is being scaled by commercial partners in Haiti and Malawi and through USAID-funded collaborating partners in Ghana
- Validation of the Mobile Assay tablet and use for research has assisted in further commercialization of the technology and >$100k of sales through PMIL collaborators and partner organizations

Environmental Management and Mitigation Plan (EMMP)

The Director and Assistant Director continue to monitor compliance with the approved EMMP during visits to project sites.

During FY2015, a number of proposed herbicides and fungicides being considered for future research were submitted for approved use to USAID. A few were not considered safe and the respective project informed to revise the work plans appropriately. Training in the safe handling and use of each chemical was provided prior to the start of each experiment and during the application of the chemical. Infrastructure was put in place where needed, for example the completion of a locked storage shed on the MFK research station.

The EMMP was updated to indicate personnel changes for each area and a copy of the updated EMMP provided to all personnel.

Open Data Management Plan

In preparing the work plans for FY2016, all projects were required to identify possible datasets to be produced during the year. These were then incorporated into the Management Plan and used to follow up with each project during the year. A similar strategy is being followed in producing the FY2017 work plans.

Documents submitted as part of the open data management plan in FY2016 are listed in Appendix C.

Governance and Management

Management Entity

The Peanut & Mycotoxin Innovation Lab Management Entity is housed in the Office of Global Programs at the University of Georgia College of Agricultural and Environmental Sciences in Athens, Georgia. The University of Georgia is the Prime Contractor of the PMIL award.

The Management Entity is composed of the following staff:

- Dave Hoisington, Director
- Jamie Rhoads, Assistant Director
- Allen Stripling, Business Manager
- Allison Floyd, Communications Coordinator
- Michelle McGeehan, Web Developer
- Bonnie Klostermann, Administrative Specialist

The Director and Assistant Director hold Research Faculty positions in the Crop and Soil Sciences Department. The Web Developer is a member of the Office of Information Technology, and the Administrative Specialist is a shared position with the Office of Global Programs.

Other departments within the university, especially the Office of Sponsored Programs and the Contracts and Grants Division, further support the team.

External Advisory Panel and Evaluation Team

The PMIL External Advisory Panel is responsible for unbiased advice on technical matters within our portfolio of projects. This team of independent experts helps the PMIL Director and USAID by identifying opportunities for partnerships, research portfolio gaps and solutions, and suggesting ideas for promoting the PMIL program goals. The External Advisory Panel meets physically at least once each year, normally at the PMIL Annual Research Meeting, and at least one other time virtually. Many of the External Advisory Panel members participate in visits to PMIL research sites in the various countries.

Current External Advisory Panel members are:

- Martha Byanyima, SPS and Agribusiness Expert, Common Market for Eastern and Southern Africa (COMESA), Uganda
- Kitty Cardwell, Director of the National Institute for Microbial Forensics and Food and Agricultural Biosecurity at Oklahoma State University USA
- Jeff Ehlers, Program Officer, Bill & Melinda Gates Foundation, USA
- Andrew Emmott, Independent Consultant, UK
- Jeff Johnson, President, Birdsong Peanuts, USA
- John McDermott, Director, CGIAR Research Program on Agriculture for Nutrition and Health, USA
- Isaac Minde, Deputy Director, Innovative Agricultural Research Initiative (iAGRI), Tanzania, and Professor of International Development, Michigan State University, USA
- Shyam Nigam, Expert Consultant in Agriculture for Development, India
- David Wright, Extension Specialist and Professor of Agronomy, University of Florida, USA

The PMIL Director and Assistant Director, and the USAID Agreement Officer's Representative (Jennifer Long) are *ex officio* members of the External Advisory Panel.

In February 2016, a four-member External Evaluation Team began to review the PMIL program, interviewing all the PIs either in person or via video conference and visiting all the partner countries. The results, published in August, noted that evaluation team members were "impressed" with the successes of PMIL and offered advice for future direction, if a program is funded. This constructive analysis was well received by the management entity."

Program Research Meetings

PMIL conducted its third program-wide annual meeting in Tamale, Ghana in August 2016. This was the second annual meeting to be held in a target country, allowing many collaborators from Africa and the US the chance to see work taking place in fields and research labs across Ghana. Meeting attendees included PIs, the Management Entity team, USAID Agreement Officer's Representative, External Advisory Panel members, additional country collaborators, and guests. Local media covered the event, highlighting the opening remarks from Stephen K. Nutsugah, the director of PMIL program partner the Savanna Agricultural Research Institute.

Partners from across Africa and the U.S. gathered in Tamale, Ghana, in August 2016 for project updates and site visits. (Photo by Allison Floyd)

During the meeting, PIs updated one another on work plans and budgets, renewed collaborations, and visited sites in Tamale and Kumasi. As part of the meeting, 14 PMIL-supported Ghanaian graduate students made oral presentations to the PIs and collaborators, who asked questions about and provided feedback on the students' work.

The Director and Assistant Director traveled to partner countries several times throughout the year, visiting with collaborating scientists, discussing progress and solving problems in consultation with the PIs. The complexity of the three value-chain projects in Haiti, Ghana and Southern Africa challenges USA-based PIs to find enough time and resources to visit and interact with the local teams, making ME support important to the overall success of the projects.

PMIL continued to share information about the work of the program, keep apprised of developments in the field and seek collaboration with other agencies, nonprofit organizations and industry by participated in several meetings throughout the year.

In addition to attending the Georgia Peanut Farm Show in January and the Georgia Peanut Tour in September, the ME hosted visits from Sen. Johnny Isakson's office, the Duke TIP program in July, and the Syngenta Foundation in October. Representatives of the ME traveled to visit with Birdsong Peanuts, Mars and others to gain market insight and feedback.

As the Chair of the Innovation Lab Council, the PMIL Director planned the annual meeting of the group in Washington, D.C., September 13-14. In addition to meeting with each other and staff from the Bureau of Food Security, the directors held a one-day workshop to introduce USAID employees to the work of the labs.

Project Monitoring and Evaluation

PMIL monitoring and evaluation is a continual process during the year. Annual evaluation of all projects is done during the annual project meetings where all projects are presented and discussed, and comments received from the External Advisory Panel. Work plans for the next year are initially discussed during the annual meeting, and follow up electronically with the External Advisory Panel, Management Entity and AOR.

During FY2016, at least one member of the PMIL ME visited all of the target countries, as well as several other collaborating locations in Africa and the USA.

In February 2016, the Director and Assistant Director visited Zambia and Malawi, where they met with collaborators and visited research sites. The Director and Assistant Director then attended the annual project meeting for the Ghana Value Chain project, where PIs presented updates of their work and findings, as well as thoughts on the final year of the program. Participants visited research sites in Tamale (SARI &UDS), Kumasi (CRI & KNUST) and Accra (University of Ghana).

The Assistant Director traveled to Haiti in May 2016 for the annual project meeting there and to Mozambique later that month to meet with collaborators.

Communications

Communications Highlights from the year include:

- Produced an instructional video to reinforce proper sampling technique and testing procedures for the Mobile Assay mReader, which PMIL has deployed to research partners throughout Haiti and Africa.
- Updated PMIL informational brochure to reflect up-to-date information.
- Created posters which describe different aspects of PMIL's work and approach to peanut innovation.

- Created a new large banner focused on the geographic areas of PMIL's work and the areas of interest – Nutrition, Climate Smart Agriculture, Food Safety, Post-Harvest Innovation and Public-Private Partnership.
- Continued publishing monthly digital newsletter that now goes to 380 subscribers. Articles from the newsletter were republished by numerous other media, drawing attention to the work of PMIL scientists and student researchers.
- Created a daily newsletter to draw attention to time-sensitive news, such as job postings, abstract solicitations and grant opportunities that have deadlines.
- Continued social media presence:
    - Blog – Publishing short news items about opportunities in international development, peanut and mycotoxin research and PMIL successes, the blog reached 1,770 readers in 92 countries
    - Social media – Facebook and Twitter followers grew to 450. Social media is used primarily to promote learning opportunities and engage with the community.
    - Flickr – New photo albums uploaded to show work in Africa and provide collaborators access to images.
    - YouTube – 13 videos.
- Published 10 feature articles about PMIL, five Q&As with researchers and dozens of brief items.
- The program was featured in Georgia Research magazine.

Information Technology

The Peanut & Mycotoxin Innovation Lab's Information Technology continues to be part of the University of Georgia's College of Agricultural & Environmental Sciences enterprise system at no cost to PMIL. This provides:

- Helpline and support staff for desktop support issues.
- Servers, long term data storage, firewalls, remote site nightly back up, end of life equipment replacement, and System Administration staffing.
- Adobe Experience Manager (AEM) Website Content Management System (CMS) in development for spring/summer release including web design and development support staff.
- WordPress blog design and support staff.

Having the enterprise system and staffing in place has allowed us to focus on frontend web design and data management. Major projects for IT this year included redesign of the program's website (which was necessary as all of the University of Georgia College of Agricultural and Environmental Science migrated to a content management system) and creation of a database that will give peanut researchers and others access to hundreds of written resources such as reports and papers. Creation of this database pulls together valuable information that was difficult to find or not accessible and maintains it in a way that is easily searchable.

Other Topics

The PMIL Director is a member of CGIAR Research Program on Grain Legumes Research Management Committee, and is the Chair of the Board for the Global Crop Breeding Support Service that is developing and deploying the Integrated Breeding Platform's Breeding Management System. Both of the responsibilities provide opportunities to integrate PMIL research in these important CGIAR initiatives.

Issues

No major issues have arisen during the past year. Administrative issues in implementing the sub-award contracts for some of the projects in partner countries have been reduced since fixed-term contracts were issued directly by UGA.

Future Directions

The next fiscal year (last year of the program) will see a finalization of the on-going research activities across the PMIL projects. The final results from the on-station and on-farm trials of value chain interventions and varietal tests will be obtained, analyzed and organized into appropriate manuscripts for publication in refereed journals and/or developed into informational materials (e.g., infographics, production guides) for dissemination to stakeholders.

Efforts will continue to identify new partners and opportunities for future research needs particularly in the areas of seed systems, and processing and product development.

Appendices

Appendix A. Program Partners

A1. United States of America

Institution	Department	City	State
Auburn University	Department of Agronomy & Soils	Auburn	AL
California Polytechnic State University	Food Science and Nutrition	San Luis Obispo	CA
University of Connecticut	Agricultural and Resource Economics	Storrs	CT
International Food Policy Research Institute (IFPRI)		Washington	DC
University of Florida	Agronomy Department	Gainesville	FL
Premier Steppe Ferme		Lake Worth	FL
University of Florida	North Florida Research and Education Center	Marianna	FL
Frank's Designs for Peanuts, LLC		Mexico Beach	FL
University of Georgia	Center for Applied Genetic Technologies	Athens	GA
University of Georgia	Department of Plant Pathology	Athens	GA
University of Georgia	Center for Applied Genetic Technologies	Athens	GA
University of Georgia	Department of Agricultural and Applied Economics	Athens	GA
University of Georgia	Department of Environmental Health Science	Athens	GA
United States Department of Agriculture-Agriculture Research Service (USDA-ARS)	National Peanut Research Laboratory	Dawson	GA
United States Department of Agriculture-Agriculture Research Service (USDA-ARS)	Plant Genetic Resources Conservation Unit	Griffin	GA
University of Georgia	Department of Food Science and Technology	Griffin	GA
United States Department of Agriculture-Agriculture Research Service (USDA-ARS)	Coastal Plain Experiment Station	Tifton	GA
University of Georgia	Plant Pathology	Tifton	GA
University of Georgia	Department of Plant Pathology	Tifton	GA
University of Georgia	National Environmentally Sound Production Agriculture Laboratory (NESPAL)	Tifton	GA
University of Georgia	Department of Entomology	Tifton	GA

Institution	Department	City	State
United States Department of Agriculture-Agriculture Research Service (USDA-ARS)	Food and Feed Safety Research	New Orleans	LA
Tufts University	School of Nutrition Science and Policy	Boston	MA
IMPAQ International		Columbia	MD
Meds & Food for Kids		St Louis	MO
Washington University School of Medicine	College of Medicine	St. Louis	MO
Mississippi State University	Geosystems Research Institute	Stennis Space Center	MS
United States Department of Agriculture - Agriculture Research Service (USDA-ARS)	Genomics & Bioinformatics Research Unit	Stonesville	MS
North Carolina State University	Department of Entomology	Raleigh	NC
North Carolina State University	Department of Crop Science	Raleigh	NC
New Mexico State University	Agricultural Science Center	Clovis	NM
Cornell University	Animal Science	Ithaca	NY
Texas A&M University	Lubbock Research & Extension Center	Lubbock	TX
Texas A&M University	AgriLife Research	Stephenville	TX
Virginia Polytechnic Institute and State University	Biological Systems Engineering	Blacksburg	VA
Virginia Polytechnic Institute and State University	Tidewater Agricultural Research & Extension Center	Suffolk	VA

A2. Foreign

Institution	Department	City
Burkina Faso		
Université de Ouagadougou	Département de Phytopathologie	Ouagadougou
Ethiopia		
Haramaya University		
Ghana		
Counsel for Scientific and Industrial Research (CSIR)	Crops Research Institute (CRI)	Kumasi
Kwame Nkrumah University of Science and Technology (KNUST)	Department of Crop and Soil Sciences	Kumasi
Kwame Nkrumah University of Science and Technology (KNUST)	Food Science and Biotechnology	Kumasi
University of Ghana	Institute of Statistical, Social, and Economic Research	Legon
University of Ghana	Department of Nutrition and Food Science	Legon

Institution	Department	City
Counsel for Scientific and Industrial Research (CSIR)	University for Development Studies	Tamale
Counsel for Scientific and Industrial Research (CSIR)	Savanna Agricultural Research Institute (SARI)	Wa
Haiti		
TechnoServe		Petionville
Meds & Food for Kids		Quartier Morin
Partners in Health/Zanmi Agrikol		Corporant
Acceso Peanut Enterprise Corporation		Petionville
India		
Tamil Nadu Agricultural University	Department of Plant Biotechnology	Chennai
International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)	Grain Legumes Research Program	Hyderabad
International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)	Center of Excellence in Genomics	Hyderabad
Kenya		
International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)	East and Southern Africa Regional Program	Nairobi
Kenyatta University	Plant Transformation Lab	Nairobi
Malawi		
University of Malawi	College of Medicine	Blantyre
Afri-Nut		Lilongwe
Lilongwe University of Agriculture and Natural Resources (LUANAR)	Department of Home Economics & Human Nutrition	Lilongwe
Chitedze Agriculture Research Service		Lilongwe
Exagris Africa Ltd.		Lilongwe
International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)	Chitedze Agricultural Research Station	Lilongwe
National Smallholder Farmers Association of Malawi (NASFAM)		Lilongwe
Mali		
International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)	West and Central Africa Regional Program	Bamako
Mozambique		
Universidade Edwardo Mondlane		Maputo
Instituto de Investigação Agrária de Moçambique (IIAM)		Maputo
IKURU Farmer's Cooperative		Nampula
Lurio University		Nampula
Instituto de Investigação Agrária de Moçambique (IIAM)	Northeast Zonal Center	Nampula
Nigeria		
International Institute of Tropical Agriculture (IITA)		Ibadan

Institution	Department	City
Senegal		
Institut Sénégalais de Reserches Agricoles (ISRA)	Centre National de Recherches Agronomiques (CNRA)	Bambey
Institut Sénégalais de Reserches Agricoles (ISRA)	Centre d'étude régional pour l'amélioration de l'adaptation à la sécheresse (CERAAS)	Thies
Uganda		
National Agricultural Research Organization (NARO)	National Crops Resources Research Institute (NaCRRI)	Kampala
National Agricultural Research Organization (NARO)	Savanna Agricultural Research Institute (SARI)	Nyankpala
National Agricultural Research Organization (NARO)	National Semi Arid Resources Research Institute (NaSARRI)	Soroti
Bulogo Women's Group		Kamuli district
Zambia		
Eastern Province Farmer's Cooperative Ltd.	Katopola Farm Institute	Chipata
Zambia Agriculture Research Institute (ZARI)		Chipata
Zambia Agriculture Research Institute (ZARI)	Mt. Makulu Central Research Station	Lusaka
University of Zambia	School of Agricultural Sciences	Lusaka

Appendix B. List of Awards to Partners

B1. US Partners (by State)

Institution		Project Name	Start Date (mm/dd/yy)	End Date (mm/dd/yy)	FY 2016 Budget	Total Budget
Connecticut					**$98,043**	**$336,253**
University of Connecticut (U Conn)	A3.	An Integrated Global Breeding and Genomics Approach to Intensifying Peanut Production and Quality *(sub-award from UGA)*	11/26/13	7/30/17	$0	$19,000
	C2.	Using Applied Research and Technology Transfer to Minimize Aflatoxin Contamination and Increase Production, Quality and Marketing of Peanut in Ghana *(sub-award from NCSU)*	5/1/14	7/30/17	$31,934	$109,232
	C5.	Productivity and Profitability Growth in Peanut Production: A Farm Level Analysis in Malawi, Mozambique and Zambia	8/1/14	7/30/17	$66,109	$208,021
District of Columbia					**$0**	**$172,818**
International Food Policy Research Institute	C3.	Producer and Consumer Interventions to Decrease Peanut Mycotoxin Risk in Ghana *(sub-award from UGA)*	2/7/14	12/31/16	$0	$172,818
Florida					**$141,154**	**$575,917**
University of Florida (UFL)	A3.	An Integrated Global Breeding and Genomics Approach to Intensifying Peanut Production and Quality *(sub-award from UGA)*	11/26/13	7/30/17	$95,541	$329,028
	C1.	Production to Consumption – Technologies to Improve Peanut Production, Processing and Utilization in Haiti	12/1/13	7/30/17	$20,824	$109,211
	C2.	Using Applied Research and Technology Transfer to Minimize Aflatoxin Contamination and Increase Production, Quality and Marketing of Peanut in Ghana *(sub-award from NCSU)*	5/1/14	7/30/17	$24,789	$137,678
Georgia					**$555,967**	**$2,913,928**
University of Georgia (UGA)	A1.	Translational Genomics to Reduce Pre-harvest Aflatoxin Contamination of Peanut	11/1/13	7/30/17	$88,280	$497,740
	A3.	An Integrated Global Breeding and Genomics Approach to Intensifying Peanut Production and Quality	11/26/13	7/30/17	$23,725	$229,414
	B2.	Development and Validation of Methods for Detection of Mycotoxins Exposure in Dried Spotted Blood Samples	9/26/13	8/31/16	$119,228	$750,000
	C1.	Production to Consumption – Technologies to Improve Peanut Production, Processing and Utilization in Haiti *(sub-award from UFL)*	12/1/13	7/30/17	$79,850	$306,011

Institution		Project Name	Start Date (mm/dd/yy)	End Date (mm/dd/yy)	FY 2016 Budget	Total Budget
	C2.	Using Applied Research and Technology Transfer to Minimize Aflatoxin Contamination and Increase Production, Quality and Marketing of Peanut in Ghana *(sub-award from NCSU)*	5/1/14	7/30/17	$44,799	$193,100
	C2.	Using Applied Research and Technology Transfer to Minimize Aflatoxin Contamination and Increase Production, Quality and Marketing of Peanut in Ghana *(sub-award from NCSU)*	5/1/14	7/30/17	$19,805	$80,172
	C3.	Producer and Consumer Interventions to Decrease Peanut Mycotoxin Risk in Ghana	2/7/14	12/31/16	$10,099	$179,124
	C4.	Aflatoxin Management Interventions, Education and Analysis at Various Steps Along the Peanut Value Chain in Malawi, Mozambique and Zambia *(sub-award from NCSU)*	7/1/14	7/30/17	$86,813	$302,297
USDA-ARS National Peanut Research Laboratory (NPRL)	A2.	Silencing of Aflatoxin Synthesis through RNA Interference (RNAi) in Peanut Plants	2/7/14	7/30/17	$83,377	$376,070
USDA-ARS Plant Genetic Resources Conservation Unit	A3.	An Integrated Global Breeding and Genomics Approach to Intensifying Peanut Production and Quality *(sub-award from UGA)*	11/26/13	7/30/17	$0	$0
Maryland					**$45,716**	**$46,716**
IMPAQ International	C3.	Producer and Consumer Interventions to Decrease Peanut Mycotoxin Risk in Ghana	10/1/14	9/30/15	**$45,716**	**$45,716**
Mississippi					**$0**	**$377,431**
Mississippi State University (MSU)	B1.	AflaGoggles for Screening Aflatoxin Contamination in Maize	10/1/14	7/30/17	$0	$333,971
USDA-ARS Southern Regional Research Center	B1.	AflaGoggles for Screening Aflatoxin Contamination in Maize *(sub-award from MSU)*	10/1/14	7/30/17	$0	$43,460
Missouri					**$59,022**	**$181,500**
Washington University (WUSTL)	B4.	Randomized Controlled Trial of the Impact of Treating Moderately Malnourished Women in Pregnancy	11/1/13	10/31/16	$59,022	$181,500
New Mexico					**$52,709**	**$215,839**
New Mexico State University (NMSU)	A3.	An Integrated Global Breeding and Genomics Approach to Intensifying Peanut Production and Quality *(sub-award from UGA)*	11/26/13	7/30/17	$52,709	$215,839
New York					**$58,295**	**$271,251**
Cornell University	C1.	Production to Consumption – Technologies to Improve Peanut Production, Processing and Utilization in Haiti *(sub-award from UFL)*	12/1/13	7/30/17	$58,295	$271,251

Institution		Project Name	Start Date (mm/dd/yy)	End Date (mm/dd/yy)	FY 2016 Budget	Total Budget
North Carolina					**$84,394**	**$401,239**
North Carolina State University (NCSU)	C2.	Using Applied Research and Technology Transfer to Minimize Aflatoxin Contamination and Increase Production, Quality and Marketing of Peanut in Ghana	5/1/14	7/30/17	$6,557	$150,812
	C4.	Aflatoxin Management Interventions, Education and Analysis at Various Steps Along the Peanut Value Chain in Malawi, Mozambique and Zambia	7/1/14	7/30/17	$77,837	$290,427
Texas					**$65,418**	**$249,503**
Texas A&M University (TAMU)	A3.	An Integrated Global Breeding and Genomics Approach to Intensifying Peanut Production and Quality *(sub-award from UGA)*	11/26/13	7/30/17	$65,418	$249,503
Virginia					**$29,855**	**$245,561**
Virginia Tech (VT)	A3.	An Integrated Global Breeding and Genomics Approach to Intensifying Peanut Production and Quality *(sub-award from UGA)*	11/26/13	7/30/17	$4,876	$12,304
	B3.	Aflatoxin in Peanut and Peanut Products: Comparative Study on Analytical Methods for Detection of Aflatoxin	7/1/14	12/31/15	$0	$80,000
	C2.	Using Applied Research and Technology Transfer to Minimize Aflatoxin Contamination and Increase Production, Quality and Marketing of Peanut in Ghana *(sub-award from NCSU)*	5/1/14	7/30/17	24,979	$98,614
	C4.	Aflatoxin Management Interventions, Education and Analysis at Various Steps Along the Peanut Value Chain in Malawi, Mozambique and Zambia *(sub-award from NCSU)*	7/1/14	7/30/17	$0	$154,643

B2. Non-US Partners (by Country)

Institution		Project Name	Start Date (mm/dd/yy)	End Date (mm/dd/yy)	FY2016 Budget	Total Budget
Burkina Faso					**$10,062**	**$45,418**
Université de Ouagadougou	A3.	An Integrated Global Breeding and Genomics Approach to Intensifying Peanut Production and Quality *(sub-award from UGA)*	11/26/13	7/30/17	$10,062	$45,418
Ghana					**$199,523**	**$727,490**
Crop Research Institute	C2.	Using Applied Research and Technology Transfer to Minimize Aflatoxin Contamination and Increase Production, Quality and Marketing of Peanut in Ghana *(sub-award from NCSU)*	5/1/14	7/30/17	$59,003	$179,503

Institution		Project Name	Start Date (mm/dd/yy)	End Date (mm/dd/yy)	FY2016 Budget	Total Budget
Kwame Nkrumah University of Science and Technology	C2.	Using Applied Research and Technology Transfer to Minimize Aflatoxin Contamination and Increase Production, Quality and Marketing of Peanut in Ghana *(sub-award from NCSU)*	5/1/14	7/30/17	$47,750	$215,650
Savanna Agriculture Research Institute	A3.	An Integrated Global Breeding and Genomics Approach to Intensifying Peanut Production and Quality *(sub-award from UGA)*	11/26/13	7/30/17	$13,770	$59,437
	C2.	Using Applied Research and Technology Transfer to Minimize Aflatoxin Contamination and Increase Production, Quality and Marketing of Peanut in Ghana *(sub-award from NCSU)*	5/1/14	7/30/17	$68,000	$250,750
University of Ghana	C2.	Using Applied Research and Technology Transfer to Minimize Aflatoxin Contamination and Increase Production, Quality and Marketing of Peanut in Ghana *(sub-award from NCSU)*	5/1/14	7/30/17	$11,000	$32,150
Haiti					**$61,750**	**$304,250**
Med & Food for Kids	C1.	Production to Consumption – Technologies to Improve Peanut Production, Processing and Utilization in Haiti *(sub-award from UFL)*	12/1/13	7/30/17	$61,750	$304,250
India					**$0**	**$277,367**
International Crops Research Institute for the Semi-Arid Tropics	A1.	Translational Genomics to Reduce Pre-harvest Aflatoxin Contamination of Peanut *(sub-award from UGA)*	11/1/13	7/30/17	$0	$272,607
Tamil Nadu Agriculture University	A3.	An Integrated Global Breeding and Genomics Approach to Intensifying Peanut Production and Quality *(sub-award from UGA)*	11/26/13	7/30/17	$0	$4,760
Malawi					**$323,366**	**$1,098,918**
Lilongwe University of Agriculture and Natural Resources	C4.	Aflatoxin Management Interventions, Education and Analysis at Various Steps Along the Peanut Value Chain in Malawi, Mozambique and Zambia *(sub-award from NCSU)*	7/1/14	7/30/17	$159,943	$350,162
Chitedze Agriculture Research Service	A3.	An Integrated Global Breeding and Genomics Approach to Intensifying Peanut Production and Quality *(sub-award from UGA)*	11/26/13	7/30/17	$45,305	$88,061
	C4.	Aflatoxin Management Interventions, Education and Analysis at Various Steps Along the Peanut Value Chain in Malawi, Mozambique and Zambia *(sub-award from NCSU)*	7/1/14	7/30/17	$7,143	$19,286
ExAgris Africa Limited	C4.	Aflatoxin Management Interventions, Education and Analysis at Various Steps Along the Peanut Value Chain in Malawi, Mozambique and Zambia *(sub-award from NCSU)*	7/1/14	7/30/17	$16,200	$29,700

International Crops Research Institute for the Semi-Arid Tropics	A2.	Silencing of Aflatoxin Synthesis through RNA Interference (RNAi) in Peanut Plants *(sub-award from NPRL)*	2/7/14	7/30/17	$5,550	$98,183
	A3.	An Integrated Global Breeding and Genomics Approach to Intensifying Peanut Production and Quality *(sub-award from UGA)*	11/26/13	7/30/17	$49,725	$305,169
	C4.	Aflatoxin Management Interventions, Education and Analysis at Various Steps Along the Peanut Value Chain in Malawi, Mozambique and Zambia *(sub-award from NCSU)*	7/1/14	7/30/17	$0	$89,857
University of Malawi	B4.	Randomized Controlled Trial of the Impact of Treating Moderately Malnourished Women in Pregnancy *(sub-award from WUSTL)*	11/1/13	10/31/16	$39,500	$118,500
Mozambique					**$86,220**	**$234,789**
Instituto de Investigação Agrária de Moçambique (IIAM)	A3.	An Integrated Global Breeding and Genomics Approach to Intensifying Peanut Production and Quality *(sub-award from UGA)*	11/26/13	7/30/17	$35,000	$135,000
	C4.	Aflatoxin Management Interventions, Education and Analysis at Various Steps Along the Peanut Value Chain in Malawi, Mozambique and Zambia *(sub-award from NCSU)*	7/1/14	7/30/17	$33,220	$80,289
	C5.	Productivity and Profitability Growth in Peanut Production: A Farm Level Analysis in Malawi, Mozambique and Zambia *(sub-award from U Conn)*	8/1/14	7/30/17	$18,000	$19,500
Nigeria					**$0**	**$22,425**
International Institute of Tropical Agriculture	B1.	AflaGoggles for Screening Aflatoxin Contamination in Maize *(sub-award from MSU)*	10/1/14	9/30/15	$0	$22,425
Senegal					**$16,500**	**$100,000**
Senegal Agriculture Research Institute	A1.	Translational Genomics to Reduce Pre-harvest Aflatoxin Contamination of Peanut *(sub-award from UGA)*	11/1/13	7/30/17	$16,500	$100,000
Uganda					**$127,256**	**$369,643**
National Agriculture Research Organization	A3.	An Integrated Global Breeding and Genomics Approach to Intensifying Peanut Production and Quality *(sub-award from UGA)*	11/26/13	7/30/17	$0	$9,000
National Crops Resources Research Institute	A2.	Silencing of Aflatoxin Synthesis through RNA Interference (RNAi) in Peanut Plants *(sub-award from NPRL)*	2/7/14	7/30/17	$5,060	$25,747
National Semi Arid Resources Research Institute	A3.	An Integrated Global Breeding and Genomics Approach to Intensifying Peanut Production and Quality *(sub-award from UGA)*	11/26/13	7/30/17	$110,196	$298,896
Bulogo Women's Group	A3.	An Integrated Global Breeding and Genomics Approach to Intensifying Peanut Production and Quality *(sub-award from UGA)*	11/26/13	7/30/17	$12,000	$36,000

Zambia					**$132,311**	**$331,226**
University of Zambia	C4.	Aflatoxin Management Interventions, Education and Analysis at Various Steps Along the Peanut Value Chain in Malawi, Mozambique and Zambia *(sub-award from NCSU)*	7/1/14	7/30/17	$93,500	$256,154
Zambia Agriculture Research Institute	A3.	An Integrated Global Breeding and Genomics Approach to Intensifying Peanut Production and Quality *(sub-award from UGA)*	7/1/14	7/30/17	$38,811	$75,072
	C5.	Productivity and Profitability Growth in Peanut Production: A Farm Level Analysis in Malawi, Mozambique and Zambia *(sub-award from U Conn)*	8/1/14	7/30/17	$0	$0

Appendix C. Data submitted under the Open Data Management Plan

PMIL Project	Dataset Type Generated by Project	Institution and Contact Person Responsible for data	Description	Data Privacy & Use Restrictions	Submission Date	Submitted By	Official Dataset Name	Dataset Tracking Number
RNAi Silencing of Aflatoxin Synthesis/Arias	1. Genomic sequence data	National Peanut Research Lab-Dawson/Renee Arias	Genomic sequences of Aspergillus flavus accessions collected in Georgia USA during 2015-16	None	4/6/16	Michelle McGeehan	Genomic sequences of Aspergillus flavus accessions in Georgia USA	216-1
Haiti Value Chain/MacDonald	7. Anthropometric health data from subjects	Cornell University/Brown			7/29/16	Jeremy Schwartzbord	Haiti Cross-sectional Survey	248-11

Appendix D. Success Stories

D1. Peanut SNP Chip – high-throughput genomic technology for global peanut researchers

Mapping of the genome of cultivated peanut's progenitors marked a great accomplishment for research of the crop. But that work means little to farmers unless breeders can use the genetic information to create varieties that deal with real-world problems.

Work through the Translational Genomics project of the Feed the Future's Peanut & Mycotoxin Innovation Lab – a project led by Peggy Ozias-Akins, professor at the University of Georgia – is making the knowledge gained through genome mapping accessible to breeders, which will accelerate variety development and create peanut varieties with the traits farmers need.

This year, researchers were able to define a complete array of SNPs, or single-nucleotide polymorphisms, markers can then be linked to important traits, such as tolerance to drought or resistance to diseases and pests. While researchers and breeders have used genetic markers and marker-assisted selection extensively in other crops, the complexity of the peanut genome made that work more difficult for many of the world's peanut scientists.

Without genetic markers, breeders must grow plants to see if they show the desired trait, time-consuming, expensive work that often is less accurate than checking to see if the right markers are there.

The recently developed SNP array now makes molecular markers available to scientists throughout the world even if they don't have state-of-the-art equipment or expertise in molecular genetics. Essentially, the SNP array creates a toolkit for breeders to analyze their peanut germplasm for specific traits, rather than buying expensive lab equipment and repeating genetic research in their own labs around the world.

For example, if a breeder is looking for resistance to a certain disease, he can sample plants and submit them to a service provider for SNP analysis using the array to see if the plants contain the appropriate genes for the trait. The breeder then selects only the plants that have the trait to advance further.

The benefits are obvious for a single trait, but begin to compound when selecting for multiple traits, such as high oleic content, disease resistance, drought tolerance, low aflatoxin contamination, etc.

Leading up to the development of the complete array, graduate students, Carolina Chavarro and Josh Clevenger, working with Ozias-Akins, re-sequenced the genome of 20 genotypes, eight of direct relevance to the Peanut & Mycotoxin Innovation Lab, to generate additional sequence information for SNP discovery. Ultimately, they identified a total of 58,233 SNPs to be included in the array.

The SNPs used for array development will be deposited in the National Center for Biotechnology Information's Short Genetic Variations database (SNPdb), a public repository. Researchers are planning to use the array to genotype all lines being tested for resistance to pre-harvest aflatoxin contamination.

Until now, technology transfer has primarily been related to SNP marker discovery, but with the availability of the SNP array, breeders in partner countries can now be provided with a useful marker platform to accelerate their breeding programs.

The array makes trait selection practical, so breeders throughout the world can select and use genes that benefit a peanut plant in disease resistance, drought tolerance, seed size and nutritional quality.

The array is giving everyone working on peanuts the ability to do modern genetic analysis to find markers that can accelerate crop improvement.

D2. Non-destructive, free-of-cost aflatoxin detection system

A project to create a non-destructive test for aflatoxin contamination has proven the concept that bad maize kernels will visibly glow under certain UV light.

One of the challenges with detecting aflatoxin in crops – a byproduct of the *Aspergillus flavus* fungus that infects cereals, legumes and many other crops – is that the mold doesn't spread evenly. A single nut or kernel may have a high level of contamination, while all those around it are toxin-free. And while highly contaminated nuts or kernels may show clear signs, the human eye can't always see the damage mold left behind. Many of the current tests require that kernels be destroyed or ground up, a process that takes time and requires the sacrifice of a portion of the crop to serve as a test sample.

Haibo Yao explains the aflabox to a student at PMIL's annual meeting in Ghana in August 2016. (Photo by Allison Floyd)

A portable, fluorescence spectral-based technology developed by Haibo Yao, a Feed the Future Peanut & Mycotoxin Innovation Lab scientist and associate research professor at Mississippi State University, allows a person to see individual aflatoxin-contaminated corn kernels without prepping the sample in any way.

At first, Yao envisioned goggles that would allow a tester to see the fluorescence emitted by the toxin. That concept has evolved into a handheld device, currently a small box, that uses UV LEDs to cause the contaminated kernels to fluoresce and the camera in an off-the-shelf tablet to detect and display the image.

The method is non-invasive and might ultimately allow large-scale aflatoxin screening – for example, at a buying point – for only the initial cost of investing in the equipment. To test the device, 5 kilograms of maize was divided into 100 samples, each weighing about 50 grams. Each sample was mixed with one or more aflatoxin-contaminated maize kernels. The mixed samples then were scanned with the fluorescence spectral imaging system, and the software installed on the tablet used an algorithm developed by the team to determine if each kernel was contaminated. The resulting image displayed on the tablet clearly indicated the "glowing" or contaminated kernels in the sample.

Then, the contaminated kernels were removed by hand from each sample, and the clean and contaminated kernels tested for the presence of aflatoxin.

By locating and removing just 1 percent 'bad' kernels from the total 5-kilogram sample, the researchers were able to reduce the overall aflatoxin contamination by 30 percent.

Currently, the process is qualitative, showing only the presence/absence of aflatoxin, but further research is underway to connect the quantity and intensity of the fluorescence with the level of aflatoxin contamination. This would allow a test to estimate to the actual amount of aflatoxin present in a sample. The scientists also are researching how well the system will work to screen peanut samples.

While significant work is required before the device will be ready to release to partners, the team is encouraged by the potential for a no-cost aflatoxin test for rapid and more effective screening of large batches of commodities. Ultimately, farmers, buyers and others along the value chain will be able to quickly assess the quality of the material they have to sell, buy or process.

D3. Low-cost electronic tablet-based aflatoxin detection system

The Mobile Assay system has allowed many PMIL-supported student researchers to finish their work in less time and with less cost, including Alidu Abdul-Hafiz at the University for Development Studies in Ghana and Emmanuel Zuza at Universidade Eduardo Mondlane in Mozambique. (Top photo by Allison Floyd; bottom photo submitted)

Aflatoxin testing has historically been relatively expensive and required significant laboratory infrastructure and technical expertise.

In many lower income countries struggling with aflatoxin management, this required researchers and processors who needed aflatoxin analysis to collect a sample in the field, prepare and package it to prevent continued mold growth by drying and/or freezing the sample, and shipping it to an external laboratory, sometimes even in another country. This added to the costs and the potential for inaccurate results from later contamination. In addition, they would often have to wait weeks or months for results. Meanwhile, processors cannot hold their product waiting for results, especially when the product may even be stored in less than ideal conditions where contamination may occur.

The Feed the Future Peanut & Mycotoxin Innovation Lab was searching for a method that could reduce costs and democratize the analysis to regional labs, without the need for investing in expensive laboratory equipment and infrastructure that would then require expert maintenance and expensive consumables. Mobile Assay, a Colorado-based start-up company developed a mobile app for basic tablet computers that uses the internal camera to quantify the results of commercially available lateral flow strip tests made by Neogen Corporation. An additional benefit is that the sample preparation uses ethanol as a solvent, rather than methanol, providing a less toxic option.

The strips also have a long shelf life and do not need to be refrigerated. The app, called "mReader," has a simple user interface and also links the results of the analysis with a cloud-based account, which allows for storage of the data, remote troubleshooting and quality control.

The Peanut & Mycotoxin Innovation Lab scientists JS Wang at the University of Georgia and Kumar Mallikarjunan at Virginia Polytechnic Institute and State University validated the results of the mReader for several peanut-based products, which required slightly different protocols than for cereals, which were the primary targeted use of the test strips.

When comparing the results of the mReader to uHPLC, the gold standard for mycotoxin analysis, Amanda Seawright, a graduate student working with Wang, found the mReader to be more than adequate. In some cases, it was more accurate and consistent than the immunoaffinity column method that is the preferred commercial method in the US. Even though the stated limited of the test strip for peanuts is 50 ppb, using dilutions, Seawright was able to accurately detect levels in both spiked and naturally contaminated samples well over 500 ppb.
By partnering with a previously funded scaling project funded by the Bill & Melinda Gates Foundation, Mobile Assay has made the cost of the lateral flow test strips very affordable (currently $4.50/strip) and the tablets are inexpensive, run on battery power and do not require calibration. The Peanut & Mycotoxin Innovation Lab has deployed several of the mReaders and associated technology packages in nine countries for research use. The implementation has been so successful, that many collaborators are asking new research questions, checking local product quality, and offering the test as a commercial service. The same mReader app can be calibrated for use with other strips for other mycotoxins and other tests, which makes the platform very adaptable for use in developing countries with very little investment.

D4. Value chain connects profitability with aflatoxin prevention practices

Research on the value chain in Ghana has shown the interrelated approaches that are necessary to reduce aflatoxin in peanuts and provided understanding that can foster development of seed-to-table interventions to improve the quality and quantity of the crop.


Men dry peanut plants in Ghana. Proper drying is key to preventing aflatoxin contamination. (Photo by Dave Hoisington)

Research shows aflatoxin prevention interventions are most effective at the post-harvest stage, however farmers need the increased yield from improved varieties and growing techniques, and possibly a price premium for quality peanuts to be able to afford those interventions.

While planting date, rainfall and temperature during the growing season certainly impact the growth of *A. flavus* and development of aflatoxin, the way that the crop is dried and stored seems to have a much greater impact on contamination levels.

Also, incentives at the buying point for low-aflatoxin peanuts must be carefully tailored to account for the cultural and economic practice of storing peanuts as a type of savings and selling off in small lots when cash is needed.

In the central Ghana village of Drobonso, researchers compared the level of aflatoxin in the crop that employed improved pest management and fertility compared with the traditional farmer practice. Although the improved practices brought in higher yield, quality and economic return ($978 compared to $778 per hectare), the crops had only a minor difference in aflatoxin concentration when sampled immediately after harvest. That increased economic return may be even greater because improved practices reduce the amount of sort-outs.

Women separate peanuts from the plant after harvest in Ghana. (Photo by Dave Hoisington)

Aflatoxin levels rose once the crop was dried, and rose higher without the use of inexpensive solutions, such as tarps to allow drying off the bare ground. Regardless of the level of aflatoxin at harvest, the crop dried on the ground had a higher level (153-226 µg/kg) compared with the peanuts dried on plastic tarps (29-80 µg/kg aflatoxin).

As these peanuts continued through the value chain, the crop that had few inputs in the field, was dried on the ground, and was stored in poly sacks with limited protection from the elements (the control treatment closest to current farmer practices) had an aflatoxin concentration of 1407 µg/kg. The peanuts that were grown under improved growing practices, dried on tarps and stored in hermetically-sealed bags had the lowest aflatoxin concentration (53 µg/kg). Adopting a single improved practice or two of the three possible improved practices resulted in aflatoxin concentrations between 100 and 600 µg/kg, creating further evidence of the necessity of linking all practices.

Farmers have very limited resources to invest in those drying and storage improvements, however. When PMIL scientists offered tarps for free, all farmers took them and over two-thirds used them to dry their groundnuts as instructed. But when tarps were offered at a subsidized price of $2.50, only 10% of farmers bought them. This shows how few resources are available to invest in aflatoxin preventing interventions and/or how little farmers understand and value aflatoxin control. Producing a more plentiful or valuable crop could be key in giving farmers' flexibility to invest in aflatoxin-preventing technologies.

At the same time, work on the value chain also has shown a disconnect between incentives offered at the buying point for low-aflatoxin nuts and farmers' desire to make the most profit from their crops.

Very few farmers (less than 5%) offered a 15% premium over market price for groundnuts with aflatoxin levels below 15 ppb agreed to sell to the buyer when offered two to three months after harvest. The growers said they had already sold, were waiting for prices to increase, or were holding onto their crop as a form of savings.

The fact that farmers keep groundnuts in storage to speculate on prices and sell small quantities of nuts when cash is needed is an important factor in tailoring incentives for low-aflatoxin peanuts at the buying point.

Presenting incentives at each step in the value chain to deliver a high quality and safe peanut crop is critical if effective and sustainable value chains are to exist.

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