FEED THE FUTURE

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

Innovation Lab for Collaborative Research on Peanut Productivity and Mycotoxin Control

Annual Report Fiscal Year 2015

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

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

(Peanut & Mycotoxin Innovation Lab)

Annual Report – Fiscal Year 2015

(1 October 2014 – 30 September 2015)

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

FEED THE FUTURE
PEANUT & MYCOTOXIN INNOVATION LAB

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Note from the Director

On behalf of the entire research and management 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 2015 (FY2015). Also known as the Peanut & Mycotoxin Innovation Lab or PMIL, the program is in its third year of operation. During the previous two years (FY2013-2014), efforts were focused on establishing the new project portfolio. During the past year, we were able to make significant progress in all of the supported projects. Especially gratifying was our ability to enroll a number of graduate students, hosted in a US or one of our target country universities. Each student is working on thesis research that directly relates to a PMIL project objective. Of particular significance is the selection of the PhD students to be supported by the Legumes Scholars Program, a joint scholarship program funded by PMIL, the Legume Innovation Lab and the CGIAR Research Program on Grain Legumes.

I am sure you will find that PMIL is making excellent progress in addressing key constraints facing smallholder peanut farmers in developing countries. Our efforts to employ the best of science in genomics, genetic engineering and breeding are bearing fruit with better varieties being evaluated on-station and in farmers' fields, and in some cases, ready to be released within the country. We have paid particular attention to the issue of mycotoxin contamination and have developed partnerships to provide the latest guidance on proper sampling and detection. We are particularly excited about a new simpler method for detecting aflatoxins using immunoassay strips and a handheld tablet. We believe that such technology will provide a cheaper and easier protocol to be used globally, even in the field. Our projects addressing interventions along the peanut value chain are now producing useful results allowing us to focus our efforts at specific interventions points that we believe will have maximum impacts. Finally, we held our annual research meeting with our partners in northern Haiti. Bringing our partners from all countries provided a rich environment for discussion, but also stimulated many partners in Africa to try some of approaches we were finding successful in Haiti, clearly demonstrating one of the key aspects of Innovation Labs to bring a global approach to solving problems.

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 digital newsletter, visit our website for more information, and follow us on social media.

Dave Hoisington, Director, PMIL

Acronyms

AFB	Aflatoxin B
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	Cooperative Research Support Program
CSB+	Corn Soy Blend
CSB-P	CSB plus multiple micronutrient tablet
CSIR	Counsel for Scientific and Industrial Research, Ghana
DBS	Dried Blood Sample
EAP	External Advisory Panel
FY2013	Fiscal Year 2013
FY2014	Fiscal Year 2014
FY2015	Fiscal Year 2015
FY2016	Fiscal Year 2016
GWAS	Genome-Wide Association Study
HACCP	Hazard and Critical Control Points
HIV	Human Immunodeficiency Virus
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IIAM	Instituto de Investigação Agrária de Moçambique, Mozambique
IITA	International Institute for Tropical Agriculture, Nigeria
ISRA	Institut Sénégalais de Researches 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
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
RUSF-P	Ready-to-Use Supplemental Food plus 200% micronutrients in pregnancy
RUTF	Ready-to-Use Therapeutic Food
SARI	Savannah Agricultural Research Institute, Ghana
SNP	Single Nucleotide Polymorphism
SPAD	Soil Plant Analysis Development
SNP	Single-nucleotide polymorphism
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
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
WU	Washington University, St Louis, MO
ZARI	Zambian Agricultural Research Institute, Zambia

Executive Summary

At the end of FY2015, the Peanut & Mycotoxin Innovation Lab completed its third year of its current five-year program. All research projects are progressing towards the objectives, and in some cases, important results have already been achieved. Of particular importance is the fact that the program is supporting 30 graduate students at US universities and several host-country universities.

PMIL scientists are developing and adopting the tools necessary to use modern genomics and informatics in breeding improved peanut varieties. Over 110,000 molecular markers (termed single-nucleotide polymorphisms, SNPs) were identified following the sequencing of 20 peanut varieties, eight of which were of direct relevance to PMIL. The new SNPs are being used to map genetic loci for important traits such as tolerance to drought, resistance to Aspergillus flavus (pathogen that produces aflatoxin), and several nutrition-related traits. Already, certain molecular markers for traits such as nematode resistance and high-oleic acid are being used in many breeding programs.

Building a strong breeding program in each of the targeted countries is critical for the long-term sustainability of the progress already achieved. PMIL supported visits by several breeders in Africa and the Americas to key US universities, institutes and conferences in FY2015. The breeders have also been exposed to new informatics tools, such as the Integrated Breeding Platform, and several have already adopted this tool in their programs. Breeders across Uganda, Malawi, Mozambique and Zambia are working together, sharing data, germplasm and developing joint work plans.

In mycotoxins, PMIL established new partnerships with key scientists and entrepreneurs with expertise on mycotoxin sampling and detection. Webinars given by USDA scientists on sampling theory are available on the PMIL website, a variety of aflatoxin detection methods compared, and a new, simpler detection protocol using an electronic handheld tablet is under evaluation.

New varieties and Best Management Practices (such as proper planting/harvesting dates, crop management, crop supplement applications) are being tested on-station and on-farm in each of the focus countries. Many farmers are already learning the importance of these interventions and once the data from additional cropping seasons confirms the results, we will have confidence to begin conveying these technologies more widely.

Surveys in Ghana and Malawi by MSc students indicated high levels of aflatoxin and microbial contamination in locally produced peanut products. In Malawi, training was provided to the local producers and the impact of this training is now being evaluated. In some cases, it is clear that the resulting products were of much higher quality.

As access to seed at the input side, and markets at the output side, are important, PMIL scientists have continued to establish new private sector partnerships. Some of these are more informal, working with RUTF factories in the country to source more local peanuts, while others are actual research partnerships, such as conducting joint research with ExAgris in Malawi and Acceso in Haiti.

The PMIL website, digital newsletter and social media posts remain high priorities to communicate to people around the world. PMIL scientists have participated in several webinars, Twitter chats, conferences and other media events. New publications on the history of the entire USAID supported peanut research program and peanuts in general were published and made freely available.

In summary, PMIL continues to make excellent progress towards the goals set in each of its research projects, is enhancing and building partnerships not only to see that the goals are met, but that they are surpassed, and is supporting students and scientists in developing countries to become the research leaders of the future.

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, 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 13 foreign countries (see above list). Details on the specific institutions in each US state and foreign country are provided in Appendix A.

Program Highlights

- Completed second of three annual trials on-station and on-farm in all target countries comparing selected advanced peanut varieties. Results are used to identify the varieties that will enter National Performance Trials in each country and move toward formal release by 2017.
- Identified new higher yielding and more nutritious peanut varieties. These will be entered into the release protocols for each country to provide farmers with more productive and higher quality peanut varieties. Some of the new varieties contain highly desired traits by local processors (e.g., high oleic acid content) that will provide ready markets for the enhanced production.
- Confirmed the effectiveness of a sample procedure for determining mycotoxin levels in dried blood samples. The procedure will allow increased numbers and reduced time and cost for analyzing the level of mycotoxins in human populations globally. This will raise awareness of the mycotoxin problem, allowing enhanced support at the policy and institute levels for adopting better methodologies along the value chain to reduce contamination.
- Began evaluating the use of a new tablet-based aflatoxin detection system developed by Mobile Assay in the USA. Initial results indicate that the system is highly accurate, and with the safer ethanol-based extraction procedure, would provide a good alternative to current systems relying on more complicated, costly and toxic procedures. The system would allow tests to be conducted closer to the source of the samples, reducing possible contamination due to transport and storage. A number of tablets have been distributed to all project sites and will be used in FY2016 research.
- Completed survey of peanut processors in Ghana and Malawi, identifying high levels of both aflatoxin and microbial contamination along the processing chain and in final products. The results have allowed a better definition of where interventions would be most effective, and in the case of Malawi, training of local processors in proper handling procedures has been conducted. Results from the interventions will be analyzed and disseminated in FY2016.
- Identified effects of drying and storage options on aflatoxin levels on-farm in Ghana. Results provided the best option to promote to farmers and to use in the economic incentive studies underway in the country.

Key Accomplishments

- **New molecular tools** – Over 110,000 SNPs identified for use in mapping the peanut genome. A new Affymetrix SNP array was designed and ready for production.
- **Better understanding of Aspergillus flavus diversity** – DNA sequencing of several hundreds isolates of *Aspergillus flavus* from Ethiopia, Uganda and Malawi completed and results under analysis. This will provide information to better design RNAi strategies, and provide potential atoxigenic strains for biological control of *Aspergillus flavus* and aflatoxin contamination.
- **More resistant and nutritious peanut varieties** – First groundnut rosette disease resistant Valencia peanut variety identified. Three groundnut leaf miner-resistant lines identified and used in initial crosses. New lines for introduction in to Haiti identified. Initiated testing of high oleic varieties in Mozambique and Burkina Faso.
- **New methods to detect aflatoxin contamination** – Identified best spectral wavelengths for aflatoxin screening and built prototype detection unit for a rapid, inexpensive monitoring device. Compared several aflatoxin detection methods on ease of use, cost per sample, sensitivity and reliability. Provided aflatoxin-spiked samples to labs in several countries to determine variation in aflatoxin levels detected. Developed partnership with Mobile Assay to test a new electronic tablet reader that allows for in-the-field measurement of aflatoxin levels. Validated a dried-blood sampling method, and analyzed over 3500 serum samples from Kenya and Uganda human population studies.
- **Surpassed enrollment in clinic trials** – Enrolled almost 1500 participants in the clinic trials to determine benefits of treating moderately malnourished pregnant women with a peanut butter-based nutritional supplement.
- **Best interventions identified for Ghana** – Results from second year (of three) trails on-station and on-farm in Ghana indicated that Best Management Practices significantly increase yields as compared to farmer practices in all sites. Results indicate that drying peanuts on a tarpaulin is best as compared to A-frames or other drying methods. An inexpensive solar dryer tested at UGA gave good results and will be deployed to Ghana for further evaluation.
- **Completed surveys in Ghana at household and processor levels** – Found that aflatoxin and microbial contamination of peanut and peanut products produced by local processors are high and likely due to contamination at the milling stage. Future efforts will focus on possible interventions. Based on results in Ghana, aflatoxin levels are twice as high in peanuts kept for home consumption as opposed to those destined for markets.
- **Completed surveys of local processors in Malawi** – Survey of aflatoxin and microbial contamination in locally produced peanut butter in Malawi indicated high levels of contamination. Training has been provided on best practices and follow up is being conducted to determine the impact. Established new partnerships with local private-sector peanut producers and processors.
-

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 broadly 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 FY2015 program involved the following 12 research projects coordinated by a Project Investigator located at a US university or USDA-ARS research station.

Research Project Title	Project 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	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 - 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 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

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 SNP discovery pipeline has been developed that allows true SNPs to be called with high confidence (see Clevenger, J. and P. Ozias-Akins, 2015). Re-sequencing of 20 genotypes, eight of direct relevance to the PMIL project, was undertaken to generate additional sequence for SNP discovery (see Table A1.1). Over 1 million SNPs were initially identified. After filtering for (a) low copy in the genome, (b) SNP localization within a predicted gene or within 4 kb of a predicted gene, and (c) sufficient sequence available to reconstruct the cultivated sequence with the alternate base, a total of 113,835 SNPs (58,438 SNPs for the A-genome and 55,397 SNPs for the B-genome) were identified for submission to Affymetrix for SNP array development. These SNPs are distributed randomly across the A and B genomes of peanut based on alignment with the diploid genome pseudo-molecules, with a few exceptional regions. The SNPs being used for array development will be deposited in the National Center for Biotechnology Information's Short Genetic Variations database (SNPdb), a public repository, after validation of the array. The array construction, being funded largely with ICRISAT resources, will be available as a community resource, and will be the platform used for genotyping of all lines being tested for resistance to pre-harvest aflatoxin contamination. This genotyping platform was chosen after conducting two separate experiments to explore the SNP output of GBS (genotyping-by-sequencing), both of which yielded less than 500 SNPs between the two parental lines.

Table A1.1. Peanut genotypes used for re-sequencing

Sample	Traits of Interest	Project	Genome Coverage (X)
394	PI203396 - TSWV resistance		11.2
Hanoch	Tolerant to drought, high oil content and good phenotypic pod traits	BARD	9.4
Harari	Incomplete pod filling under drought	BARD	9.3
53	Pod filling	BARD	12.1
111	Pod traits project. Low oil and bitter taste	BARD	8.8
Florida07	High oleic acid, TSWV Resistant	CAP	10.7
Florunner		CAP	12.7
N080820IJCT	High oleic acid, TSWV and sclerotinia moderately resistant	CAP	6.0
NC3033	Early leaf spot, White mold, CBR resistance	CAP	11.2
NMValencia	Large fruit size, compact bunch growth habit, large pods	CAP	11.9
Olin	High oleic acid, sclerotinia resistant	CAP	8.0
SPT06-06	Early and late lead spot Highly resistant. *A. cardenasii* in its pedigree	CAP	11.3
SSD6-2	Highly resistant to TSWV	CAP	8.5
Tifrunner	TSWV, Early and Late leaf spot resistance	CAP, PMIL	8.4
C76-16	Drought tolerant	CAP, PMIL	7.1
A72	Aflatoxin susceptible	PMIL	11.3
COC230	Drought and heat tolerant	PMIL	5.9
ICG1471	Aflatoxin resistant	PMIL	8.3
KatieSARI	West African line	PMIL	7.9
TxL054520-27		PMIL	7.9
TxL080243-06		PMIL	13.9
MEAN			**10.0**

Phenotyping for resistance to pre-harvest aflatoxin contamination is continuing 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 or imposed. A second-year test of the chromosome segment substitution lines in Senegal has been harvested; a second-year test in the US of the "aflatoxin core" was planted in June and will be harvested in late October at the end of stress. Entries from the "aflatoxin core" also were grown in Citra, Florida, by Greg MacDonald for seed increase and morphological characterization. Graduate student, Afia Karikari, is conducting characterization. Over 5,800 F_2 plants from eight-way crosses to develop a MAGIC population have been derived and these lines are being advanced by single seed descent in rainy and post-rainy seasons.

Technology transfer has primarily been related to SNP marker discovery. As soon as data are generated with the SNP array, technology can be scaled to design assays adapted to different marker platforms that may be more accessible in partner countries.

Lessons Learned

The use of genotyping-by-sequencing (GBS) in cultivated peanut germplasm will not be that feasible given the low level of SNP polymorphism detected.

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

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 funded by complementary sources: 1) the study of genetic diversity of aflatoxigenic *Aspergillus* species funded by PMIL, and 2) the genetic transformation of peanut plants using RNA interference that is funded by NBCRI.
For the genetic diversity studies, samples are being analyzed from Ethiopia, Kenya, Malawi, Uganda, Zambia and the USA and fingerprinted using sequences within the aflatoxin synthesis gene cluster at the National Peanut Research Laboratory (NPRL) in Dawson, Georgia. Three African peanut varieties (CG 7, JL 24 and ICGV 90704) are being transformed at Kenyatta University in Nairobi, Kenya, using RNAi molecular constructs provided by NPRL. Scientists at the NPRL are providing training and backstopping to the African scientists in the project, many of whom have visited the NPRL for hands-on training.

Abdi Hassen a plant pathologist from Ethiopia,, works in the NPRL on RNA interference and genetic diversity of aflatoxigenic fungi. [Photo courtesy of Allison Floyd]

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

USDA-ARS National Peanut Research Lab

- US APHIS permits that allowed NPRL to import pure cultures of *Aspergillus* species and *Aspergillus* DNA were renewed to allow the importation of contaminated seeds/soil samples for laboratory analysis.
- DNA is being extracted from 100 *Aspergillus* isolates received from our collaborator in Malawi.
- A total of 680 *Aspergillus* isolates were collected from peanuts across Georgia, 400 isolates from Alabama, and 500 from Ethiopia during 2014. DNA was extracted from 244 isolates from Georgia, 350 from Ethiopia and 100 from Uganda. A total of 244 isolates from Georgia were fingerprinted using 25 newly developed InDels within the aflatoxin synthesis gene cluster and included in a manuscript submitted for publication. Another 150 isolates from Ethiopia were also fingerprinted.

- Cluster analysis of the fingerprinting data was performed, and 10 representative isolates selected for whole-genome sequencing. The most important finding was that cluster analysis by 25 InDels perfectly matched the cluster analysis of whole-genome sequencing. Therefore, these InDels can be used to identify the most abundant *Aspergillus* genotypes in a geographic region and then obtain information at the DNA sequencing level. The results were submitted for publication.
- A total of 200 *Aspergillus* isolates from Ethiopia were fingerprinted, and another 200 from Ethiopia plus 100 from Uganda are currently being fingerprinted.
- DNA is being extracted from 100 *Aspergillus* isolates sent from Malawi to NPRL for processing.
- Seed of the second generation of putative transgenic plants with RNAi constructs has been produced at NPRL, and greenhouse experiments started to determine the level of aflatoxin production.

ICRISAT-Malawi

- For Zambia, we are using 100 samples collected during May and June 2012, coinciding with the postharvest period, from four districts in the Eastern Province, where most of the groundnut production takes place. The samples were collected from farmers implementing another USAID-funded project on aflatoxin mitigation.
- In Malawi, 190 soil and groundnut samples were collected at harvest in April and May 2015 in from Chitala, Chitedze, Mwimba, and Ngabu research stations. The research stations are located in important groundnut agroecological zones of Malawi. Ngabu and Chitala are in hot humid environments, whereas Chitedze and Mwimba are mid-altitude and cooler.
- Also in Malawi, soil samples were collected in September 2015 in Chikwawa, Balaka, Mulanje, and Ntcheu districts.
- Currently, 100 isolates from soils have been shipped to the NPRL for analysis, with another 150 isolates being sub-cultured and to be sent shortly.

NARO-Uganda

- Two hundred samples of maize have been collected from Uganda and shipped to the NPRL.
- Arrangements have been made to collect peanut and maize samples from Kenya as well.
- A transformation protocol has been optimized for the peanut varieties CG 7, JL 24 and ICGV 90704.
- The first batch of putative-transgenic peanut varieties is currently on shoot elongation media. After attaining a shoot length of 2 cm, the plants will be transferred to rooting media.
- Seed multiplication for the varieties currently being used is underway.

Presentations and Publications

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**.**

A workflow to study genetic diversity of *Aspergillus* using 25 newly developed InDel markers and followed by whole-genome sequencing has also been submitted to a peer-reviewed journal for publication (Faustinelli *et al*.)

Research progress on RNAi against aflatoxins and genetic diversity of *Aspergillus* was presented at the PMIL annual meeting in Haiti, June 2015.

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

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 USA 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 being 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	University of Ouagadougou	Burkina Faso	Co-PI
Nicholas Denwar	SARI	Ghana	Co-PI
Subbarayalu Mohankumar	TNAU	India	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
Noelle Barkley	USDA-ARS	USA	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.

Uganda (with the University of Georgia)

- First Groundnut Rosette Disease (GRD) resistant Valencia line identified (Aboutalata).
- Additional Valencia, Serenut 1, Serenut 3R, and landrace varieties developed with improved groundnut rosette disease (GRD) and leaf spot resistances.
- Initiated introgression of the high oleic trait (for better nutrition and shelf-life) into the GRD and leaf spot-resistant cultivars Serenut 5R and Serenut 6T. These are now at the F_2 stage.
- Greenhouses in Uganda completed and functioning.
- Three leaf miner-resistant lines identified (SGV0023, -0064, -0075).
- Uganda lines undergoing trials in Haiti for yield and leaf spot resistance. Top performers include SGV0075, -0801, -0065, -990400, -0002, Serenut 8R, -12R, and -14R.

Haiti (with the University of Florida)

- Identified germplasm with leaf spot resistance for Haiti. A total of 573 F_2: four lines from seven unique families were screened and 50 runner types selected for transfer to Haiti.
- Ten new Valencia and Spanish types with earlier maturity selected for evaluation in Haiti.
- Developed a variety introduction plan for Haiti. While breeding peanut in Haiti should be a long-term goal due to the unique environments (soil, rainfall, disease, etc.) under which peanuts are grown, in the interim, a variety introduction plan will be followed that will systematically import and evaluate breeding lines and/or cultivars developed elsewhere for their adaptation in Haiti.
- Evaluating genotypes with traits such as root characteristics and variation for primed acclimation for drought tolerance.

Ghana and Burkina Faso (with Texas A&M)

- Two leaf spot-resistant accessions being released (BF Nagouri1 an BF Nagouri2).
- Evaluated accessions for high yield/high oleic/leaf spot resistance (for leaf spot resistance: six trials with 157 entries; for high oleic and leaf spot resistance: 300 F_2 plants).

- Initiated release procedure for high oleic Valencia in Texas.
- Completed SNP-based map of diploid peanut A-genome F_2 population.

Mozambique (with New Mexico State University)

- Submitted Serenut 5R release cultivar to the Journal of Plant Registration.
- High iron and zinc containing lines from ICRISAT crossed with the NuMex-01 high oleic Valencia.
- New Mexico State University breeding lines evaluated in Mozambique (13 lines at three locations), Malawi (five lines at two locations) and Zambia (five lines at one location).

Malawi

- Evaluated lines for GRD resistance (23 lines), leaf spot resistance (20 lines), and drought resistance (15 lines). Three trials at six locations.
- Identified three new lines with GRD resistance (ICG 13479, ICG 12276, and ICG 14708).
- Evaluated F_1 progeny including three Valencia, four Virginia, and two Spanish lines with tolerance to abiotic and abiotic stresses endemic in the east and southern Africa.
- Advanced F_1 progeny to F_2 from all three botanical groups from crosses involving donor and released material to introgress zinc and essential fatty acids.
- Participatory variety selection (PVS) was conducted at six sites using five new Valencia lines in Zambia.
- Nine field demonstrations each in Malawi and Mozambique were conducted to promote released materials.

Uganda (with University of Connecticut and University of Georgia)

- Survey of technology adoption and impact completed and publications are being written.

Lessons Learned

Uganda

- Improved varieties can significantly increase yields in farmers' fields.
- 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.
- Early bulking of seeds of pre-releases is a good practice to avert seed crisis post-release.
- The use of various media tools in the dissemination of research outputs, constraints and opportunities is important.
- Agricultural shows, seed fairs, field days and farmer visits are very good for knowledge sharing and information dissemination.
- There is a need for proper cold storage facilities to enhance germplasm conservation.
- There is a need for irrigation facilities on-station for effective drought screening and seed multiplication.

Mozambique

- There is a lot of potential for Valencia peanuts.
- The biggest requirement is to incorporate the GRD 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.

Haiti

- Limitations for plant breeding in Haiti include trained personnel, available land and equipment, and access to irrigation.

Malawi/Zambia/Mozambique

- In the NARS, there is good capacity for groundnut breeding that could be fully utilized if field techniques, information management systems and appropriate facilities as well as seed systems can be strengthened.
- There is a need to build partnerships with diverse development partners and strategically co-locate research activities in order to maximize the impact of project activities in the region.

Project Presentations and Publications

Presentations

Burow, M. D., Chopra, R., Chagoya, J., Simpson, C.E., Bertioli, D., Leal-Bertioli, S., Holbrook, C.C., Stalker, H.T. and Varshney, R. 2014. Considerations for Marker-Assisted Selection in Peanut. 7th International Meeting Advances in Arachis Genomics and Biotechnology, Savannah, Georgia.

Chintu, J.M.M., D. Siyeni, A.M.Z. Chamango, P. Okori, E.S. Monyo, W. Munthali and H. Charlie. 2015. Release of four Viginia and Three Spanish Groundnut Genotypes in Malawi. Peanuts. American Peanut Research and Education meeting, Charleston, SC.

Denwar, N.N., Oteng-Frimpong, R., Issah, D/.A./R. and Burow, M.D. 2015. Breeding adopted and high-yielding peanuts with enhanced market qualities. American Peanut Research and Education meeting, Charleston, SC.

Jelliffe, J., Bravo-Ureta, B. and Deom, C.M. 2015. "An Assessment of Groundnut Aflatoxin Contamination Awareness and Mitigation Practices in Rural Uganda." American Peanut Research and Education meeting, Charleston, SC.

Jelliffe, J., Bravo-Ureta, B., and Deom, C.M. 2015. "Adaptation and Adoption of Improved Seeds through Extension: Evidence from Farmer-Led Groundnut Multiplication in Uganda." Agricultural & Applied Economics Association and Western Agricultural Economics Association Annual Meeting, San Francisco, CA.

Kaur, G., P. Lujan, S. Sanogo and N. Puppala. 2015. Evaluating the Performance of *Sclerotinia sclerotiorum* under the Effect of Registered Fungicides. American Peanut Research and Education Society Annual Meeting, Charleston, SC.

Makweti, L., Charlie, H and Kanenga, K. 2015. Overview of Groundnut Research in Zambia. American Peanut Research and Education Society Annual Meeting, Charleston, SC.

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Okello, D.K., L.B. Akello, P.Tukamuhabwa, S.M. Ochwo, T.L. Odong, J.Adriko, C. Mwami and C.M. Deom. 2015. Regeneration Procedure for Three *Arachis hypogaea* L. Botanicals in Uganda through Embryogenesis. American Peanut Research and Education Society Annual Meeting, Charleston, SC.

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Selvaraj, M.G., Chogoya, J., Ayers, J.L., Belamkar, V., Chopra, R., Kottapalli, K.R., Sankara, P., Zagre, B., Burow, G., Payton, P., Puppala, N. and Burow, M.D. 2015. Screening of the U.S. Peanut Minicore Collection for Tolerance to Drought and Heat Stress. American Peanut Research and Education Society Annual Meeting, Charleston, SC.

Xavier, A., P.Payton, J. Mahan, K.R. Kottapalli, D.L. Rowland, C.C. Holbrook, Y.K. Cho and N. Puppala. 2015. Yield and Physiological Response of Different Peanut Genotype Under Water-limited Conditions. Peanuts. American Peanut Research and Education Society Annual Meeting, Charleston, SC.

Zurweller, B.A, Rowland, D.L., Tillman, B.L., Payton, P. 2015. Peanut genotype root architecture in response to irrigation. Peanuts. American Peanut Research and Education Society Annual Meeting, Charleston, SC.

Publications

Okello D.K., Akello L.B., Tukamuhabwa P., Ochwo S.M., Odong T.L., Adriko J., Mwami C., Deom C.M. 2015. Regeneration Procedure for three *Arachis hypogaea* L. botanicals in Uganda through Embryogenesis. British Biotech J, 7:122-133, 2015. DOI: 10.9734/BBJ/2015/17418

Mugisha I.O., Akello B., Ochwo-Ssemakula M.K.N, Biruma M., Okello D.K., Otim G. 2015. Assessing the effect of the farmers' practices on the severity of groundnut rosette virus disease in Uganda. African J Ag Res, 10:995-1003.

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Neya, F. B., K. Koïta, M'bi B. Zagre, A. T. Nana, M. D. Burow, P. Sankara, and C. Simpson. 2013. Evaluation au champ de la performance de quelques lignees d'arachide (Arachis hypogaea L.) a grosses graines pour la resistance aux Cercosporioses de l'arachide dans la zone centre du Burkina Faso de 2010 à 2012. Annale de l'Université de Ouagadougou – Série C, vol. 009, Décembre 2013.

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Books

Okello D. K. Okori P., Puppala N., Ureta Bravo. B., Deom C.M., Ininda J., Anguria P., Biruma M., Asekenye C., 2015. Groundnuts seed production manual for Uganda. National Agricultural Research Organisation, Entebbe. ISBN: 978-9970-401-12-3: http://pmil.caes.uga.edu/documents/UGA203/Publication_UGA203_Deom_FY2015_GroundnutSeedProductionManualforUganda-Okello.pdf

Other Publications

Documentation of variety development in Uganda (http://paulndiho.com/2014/02/20/ugandan-groundnut-farmers-cashing-in-on-improved-new-varieties)

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-invasive 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-invasive 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

After reviewing the existing literature during the first year, the project team has been able to:

1. Identify two potential narrow bandwidth spectral bands (437 nm and 537 nm) for aflatoxin screening,
2. Develop a feasible method to use the identified narrow bandwidth spectral bands and provide initial design of the AflaGoggles, and
3. Build a prototype construction and develop screening procedures with the prototype.

Finally, the team will implement trials in 2016 to test AflaGoggles for feasibility in real world situations (USA and Nigeria) and also for continuous improvement of the screening procedures. This work is currently being implemented. Maize samples from a 2015 field are used for prototype testing.

Lessons Learned

We have tested multiple cameras from different smartphones and tablets. While the latest tablets could provide reasonable image quality for the detection, we found it is challenging to get high performance UVLED for sample fluorescence excitation. The search for a better and more reliable light source is also ongoing.

Presentations and Publications

Yao H., Z. Hruska, R. L. Brown, D. Bhatnagar, T. E. Cleveland, Hyperspectral Imaging Technology for Inspection of Plant Products Ch 9 in “Hyperspectral Imaging Technology in Food and Agriculture” editors: Park and Lu., published by Springer, 2015. ISBN: 978-1-4939-2835-4

Yao, H., Hruska, Z., & DiMavungu, J. D. (2015). Developments in Detection and Determination of Aflatoxins. World Mycotoxin Journal. 8(2), 181-191.

Yao, H. (2015). Application of Fluorescence Hyperspectral Imaging for the Detection of Aflatoxin Contamination in Corn. ASABE Annual International Meeting, Paper No. 2210486. New Orleans, LA.

Zhu, F., Yao, H., Hruska, Z., Kincaid, R., Brown, R., Bhatnagar, D., & Cleveland, T. (2015). Visible Near-infrared (VNIR) Reflectance Hyperspectral Imagery for Identifying Aflatoxin-contaminated Corn Kernels. ASABE Annual International Meeting, Paper No. 2189995. New Orleans, LA.

Zhu, F., Yao, H., Hruska, Z., Kincaid, R., Brown, R., Bhatnagar, D., & Cleveland, T. (2015). Classification of Corn Kernels Contaminated with Aflatoxins Using Fluorescence and Reflectance Hyperspectral Images Analysis. Proceedings of SPIE, Paper No. 9488-22. Baltimore, MD.

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 Nutrition Innovation Laboratory 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
Nii-Ayi Ankrah	University of Ghana	Ghana	Co-PI
Justice Kumi	University of Ghana	Ghana	Co-PI
Jeffrey Griffiths	Tufts University	USA	Co-PI
Patrick Webb	Tufts University	USA	Co-PI

Achievements

During this project year, we completed two major objectives of (1) validation of DBS method for detection of aflatoxin B_1-Lysine (AFB-Lys) adduct in animals and humans, and (2) validate the analytical protocol and examine the correlation between AFB_1 exposure and levels of AFB-Lys adduct in DBS samples in animals and human samples. F344 rats were treated with single or repeated-dose AFB_1 and DBS cards were prepared from the whole blood. Serum was also prepared from the whole blood to serve as comparison purpose between two methods in detection of AFB-Lys adduct. 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 validation studies. A significant dose and time effects of adduct levels were found in DBS cards treated with single- and repeated-dose AFB_1. Pearson correlations comparing AFB-Lys adduct levels in DBS and serum samples were 0.997 for the single-dose study, 0.998 for the repeated-dose study, and 0.843 for spiked human samples. Using Bland-Altman plot, the log difference between the results of two sample types were found to be within limit of agreement approximately 95% of the time for both human and animal samples. Our results showed that AFB-Lys adduct levels in DBS cards and serum samples from animals and from spiked human samples are comparable, and the DBS technique and analytical protocol is ready to move to field study aimed to assess AFB_1 exposure in infant and children populations. In addition, we analyzed AFB-Lys adduct for

over 3,500 serum samples collected from Kenya and Uganda human population studies conducted by our collaborators.

Lessons Learned

Although similar limit of detection of AFB-lysine adduct was achieved with the DBS cards, the recovery of the method for the whole blood DBS was generally lower (10-20%) than the serum method, which suggested that certain components in the whole blood may interfere with the recovery.

Presentations and Publications

In addition to a presentation in 2015 at the PMIL Annual Meeting in Haiti, three seminar presentations were given, including:

- Society of Toxicology Annual Meeting held in San Diego, California, March 21-25, 2015;
- Rwanda Agricultural Board in June 28, 2015; and
- American Phytopathology Society held in Pasadena, California, August 2, 2015.

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

There are numerous methods to measure the toxicity of fungal infection in various crops. A primary limitation for aflatoxin determination in peanuts is the lack of generally accepted and standardized methods for farmers to screen or for testing laboratories to quantify the level of contamination. Even among PMIL collaborators, different evaluation methods have been reported in individual studies, making the comparison of results difficult. This project conducted a systematic comparative study to evaluate and report existing/emerging analytical methods for aflatoxin determination in peanuts and peanut products. A blind test, in which the variety of peanut products was naturally and artificially contaminated with aflatoxin, was prepared to test the current available analytical methods within the collaborating institutions/analysis laboratories. Results from the project were helpful to document the existing methods, the advantages/disadvantages of each method, and which method is best for each objective.

Collaborators

Name	Institution	Country	Role
Kumar Mallikarjunan	Virginia Polytechnic Institute & State University	USA	PI
Hande Kaya Celiker	Virginia Polytechnic Institute & State University	USA	Co-PI

Achievements

The overall objective of the study is to compare existing analytical methods [Enzyme-Linked Immunosorbent Assay (ELISA), Fluorometric method, High Performance Liquid Chromatography (HPLC), lateral flow device (LFD), and the mReader] on the basis of ease of use (time required for sample prep, and interpretation), cost per sample, sensitivity, and repeatability to detect and monitor aflatoxin in peanut products; and develop a recommended procedure to be adopted by PMIL projects across the program.

Also, a survey "Capability and Capacity Questionnaire of Mycotoxin Testing Facilities" was prepared to collect information related with the present analytical methods applied to determine the aflatoxin level in peanuts used in cooperating institutions of PMIL program. The survey was broadcast via the PMIL webpage and through individual communications. Eight different labs from various countries (Ghana, India, Malawi, Uganda and USA) were selected and samples of peanut products (RUTF, peanut paste, peanut flour and peanut oil) spiked with known amounts of aflatoxin (either with aflatoxin B_1 or Aflatoxin B + G mixture) and/or infected with *Aspergillus* spp. were distributed to conduct a blind test.

Analytical methods tested were HPLC, AflaTest Fluorometer by VICAM, FluoroQuant Afla by RomerLabs, RevealQ+ LFD by Neogen, homemade ELISA, ELISA by RomerLabs and mReader by Mobile Assay.

Lessons Learned

Survey results indicate that, among the sample, the most popular method is HPLC followed by fluorometric methods (using immunoaffinity columns), ELISA test and lateral flow devices. Even though HPLC is the most common method among participants, it does require clean-up to improve the separating power of chromatography, which can be improved using immunoaffinity columns or solid phase extraction methods. The majority of the survey participants using the HPLC for aflatoxin analysis prefer the immunoaffinity column clean-up procedure prior to chromatographic analysis. Fluorescence detection is a very good alternative in terms of high sensitivity and that's why it was the second method of choice for aflatoxin analysis as it can be combined with HPLC. Both fluorometric methods like AflaTest Fluorometer by VICAM or FluoroQuant Afla by RomerLabs and HPLC require well-equipped laboratories and trained personnel. The time of analysis was reported to be an hour or more than an hour for HPLC and 30-60 minutes for fluorometric methods using immunoaffinity columns. Both techniques are also expensive; the average cost of the analysis using HPLC was $65 with the highest cost at $100, and average cost of fluorometric methods was $35 with a highest cost at $40.

ELISA test methods have an advantage that they do not require any clean-up step and offer easier operation, and also are portable for use in the field to detect mycotoxins in foods and feed. As a disadvantage, it is dependent on the individual matrices of interest. Owing to the possible interaction of antibodies to chemically similar substances in food matrix to aflatoxin, false positive results may be observed. However, compared to the other techniques, the average cost of analysis using ELISA was reported as $25 with a maximum of $45 and time for the analysis is 30-60 minutes depending on the number of samples. When rapid screening is needed, ELISA gives the shortest time for a large number of sample analyses. Even though there are many other popular testing methods, the survey done among PMIL partners showed that the Lateral Flow Devices (LFD) is the fourth most common method of choice. LFD devices are currently used for qualitative, semi-quantitative, and to some extent quantitative monitoring. One big advantage of LFD is that the test can be used in the field because the strips do not require refrigeration. This is also important for developing countries where storage and handling of testing equipment and apparatus is difficult. Large batches of samples can be interpreted in a short time (10-20 minutes) and the shelf life of strips is longer than enzyme immunoassays. Cost of the analysis is lower than other methods compared ($18-$36).

Presentations and Publications

None to report.

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 Ready-to-Use Supplementary Food (RUSF) formulated to deliver about 200% of the RDA of most micronutrients in pregnancy (RUSF-P); (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-P); or (3) the standard of care which is a fortified corn soy blend, vegetable oil and sugar with supplementary iron and folic acid tablets (CSB), 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

The study began enrolling participants in March 2014. Enrollment was slow at first, but steadily increased from November 2014 until July 2015. As of the end of August 2015 there are 15 study sites open in rural Malawi being overseen by study volunteers and health clinic staff. A total of 1486 study participants have been enrolled, with 425 graduated to date. 1039 participants have delivered and will continue to follow up until three months post-delivery. Home deliveries have been minimized to approximately 78, and approximately 80% of the birth measurements have been within 24 hours of delivery. The study is conducting home visits (278 to date) to collect adherence information, household food inventory and to obtain a 24-hour dietary recall.

Dr. Mark Manary is tracking the results of treating moderately malnourished pregnant women with nutritional supplements, including a peanut-based one.

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. We plan to re-assess in December 2015 to determine if any additional participants need to be enrolled to account for this increase in mothers who delivered within two weeks of enrollment and for which there is no follow up information.

Presentations and Publications

None to report.

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.

Innovation work to improve the quality, safety and value of peanuts in Haiti involves all phases of production, from growing to drying to marketing.

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	Acesso Peanut Enterprise Corporation	Haiti	Partner
Dominique LaForest	Meds & Food for Kids	Haiti	Partner
Francois Laroche	Kreyol Incorporated	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

- Completed second of three rounds of farmer surveys evaluating impact of various interventions and credit packages through Acceso Peanut Enterprise Corp.
- Conducted trials on fertility, disease management with fungicides and variety evaluations at two locations (Quartier Morin, Northern Haiti and Coup Gorge, Central Plateau)
- Conducted additional trials at Quartier Morin on inoculant and phosphorus fertilizers
- Performed additional research variety trials with Kreyol, Inc. and iF Foundation – variety tests
- Provided training and farmer field demonstrations in North and Central Plateau
- Provided technical training, materials and support to Acceso Peanut Enterprise Corp. This included production guides, field visits, aflatoxin training for depot managers, technical expertise in planting, harvesting, storage and aflatoxin detection
- Continued support of the aflatoxin detection facility at iF Foundation – additional training of staff and established a research/teaching mycotoxin lab at Faculté d'Agronomie et de Médecine Vétérinaire (FAMV), Université d'État d'Haïti in Bon Repos with Dr. Lemane Delva

Disease Evaluations	

Variety Performance	– Currently, there is still no conclusive candidate variety with 1) high disease resistance, 2) high yields and 3) desirable agronomic traits.
	– Local Valencia: yields just as good or better than improved Valencia lines
	  ○ Out yielded New Mexico Valencia A in every trial by ~500 lbs/A in the Central Plateau fungicide timing trial and by ~ 1000 lbs/A in both the MFK and Central Plateau variety trial
	  ○ New Mexico Valencia 309 Red, M2, M3 & M10 best candidate Valencia types for future evaluation
	– Local Runner: inferior yields to Georgia-06G in three out of four trials
	  ○ Yield gap ranged from ~200-2600 lb/A
	  ○ Despite positive trials with Ga-06G, results were poor in scaled low-input field experience

Fungicide Applications	– In the absence of resistance, minimal fungicide inputs significantly increase Valencia and Runner types – Local Valencia: two applications are sufficient to increase yields – Local Runner: four applications are needed to increase yield – but three appears most economical

Agronomic Practices	
Seeding rates	– Preliminary results indicate increased yield with higher seeding rates – three seed per foot most likely the most feasible (if germination rate is high and seed is treated)
Germination	– Have observed unaccountable variability across varieties and market types – Need research on dormancy, seedling vigor, etc. as well as improved storage conditions
Nodulation	– Wide variability across regions, varieties and planting dates – No apparent yield gain in preliminary inoculation trails
Soil Fertility	– Soil analyses confirmed that most Haitian soils have high pH and low phosphorus – Preliminary trials have not clearly demonstrated a yield benefit with fertilizer inputs – More research is needed regarding potential inputs

Lessons Learned

- Continual oversight is critical with field operations, especially research field locations
- Initiating new partnerships to engage local universities and students has been difficult, but we are hopeful to make progress in 2016

Presentations and Publications

None to date. We will be working on updates for production guides and for aflatoxin management.

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

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 northern and central Ghana. Interventions at each step of the supply chain are being implemented and aflatoxin contamination determined. Research is conducted at two institutions associated with the Savanna Agricultural Research Institute (SARI) and at 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 of peanut throughout the supply chain. Improved productivity and quality of peanut coupled with acceptable levels of aflatoxin in peanut products improve access to local, regional, national and international markets leading to enhanced 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	Kwame Nkrumah University of Science and Technology	Ghana	Co-PI
Grace Bolfrey-Arku	CSIR-Crops Research Institute	Ghana	Co-PI
William Ellis	Kwame Nkrumah University of Science and Technology	Ghana	Co-PI
Moses Mochiah	CSIR-Crops Research Institute	Ghana	Co-PI
Jessie Naab	CSIR-Savanna Agricultural 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

Name	Institution	Country	Role
Greg MacDonald	University of Florida	USA	Co-PI
Kumar Mallikarjunan	Virginia Polytechnic Institute and State University	USA	Co-PI
Robert 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

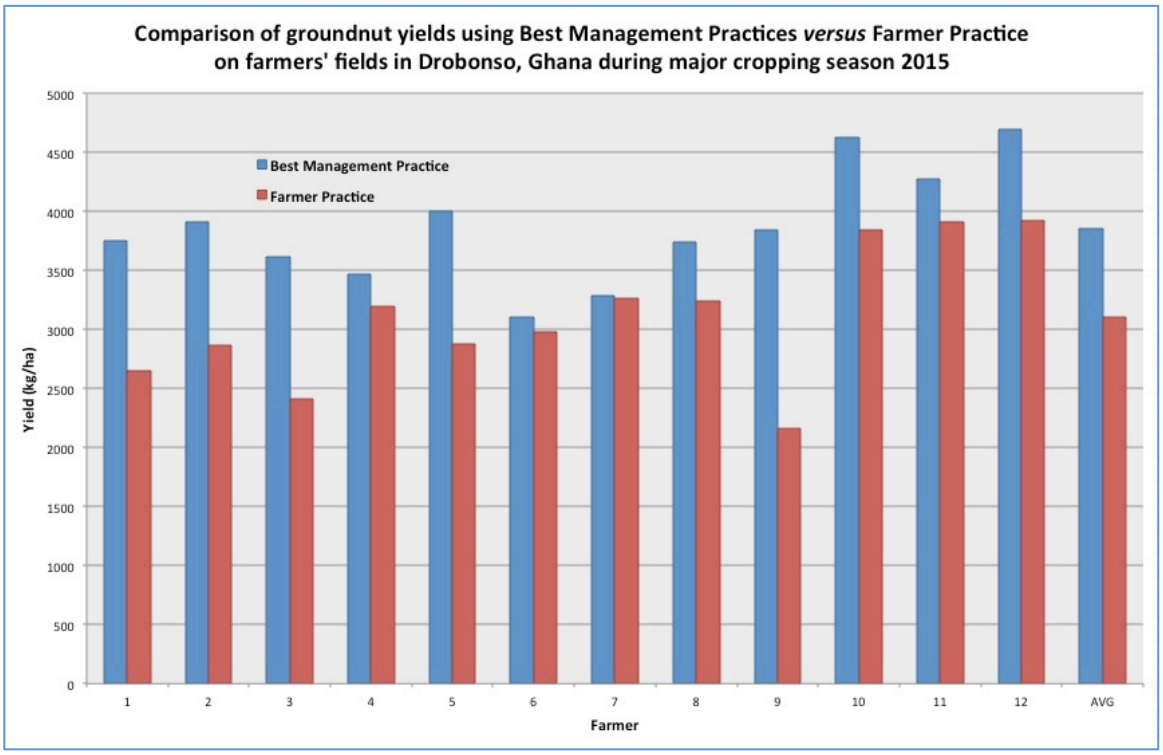
Objective 1. Evaluate the effect of on-farm interventions at production, drying, storage and processing steps on aflatoxin contamination in the peanut

Results associated with research in villages conducted by CRI-Kumasi, SARI-Tamale, and SARI-Wa will focus on two components. While a full complement of trials is currently in place for 2015, some experiments have not been harvested at time of reporting and aflatoxin samples have not been processed. The majority of this summary in this report is relative to 2014 trials. The first component includes yield and economic return from farmer practices and improved practices (referred to as best management practices or BMPs) in the field for the 2014 growing season. Secondly, the impacts of BMPs on aflatoxin contamination at the field, drying and storage steps in the village value chain are compared. Planting dates in northern Ghana (SARI-Tamale and SARI-Wa) and major versus minor seasons in central Ghana (CRI-Kumasi) resulted in differences in yield and economic return. Higher yield and economic return were noted for the BMPs (local soap for leaf spot/aphid-rosette suppression, inclusion of fertilizer, and one additional weeding) compared to the traditional farmer practice regardless of region (North or Central), seeding date (time of season or major versus minor season), and village.

Economist Boris Bravo-Ureta meets with producers in Ghana, where researchers are evaluating the effectiveness of interventions to reduce or eliminate aflatoxin contamination in peanuts. [Photo courtesy of Boris Bravo-Ureta]

In this analysis, farmers in each village were considered replications for data relative to yield, economic return (gross return less inputs for farmer practice or BMPs), and aflatoxin contamination.

These data suggest that even though the BMPs increased costs of production and pest management, increased revenue was realized. Similar results are often observed in other countries and cropping systems when proven interventions or BMPs are incorporated into production systems.
The challenge will be determining if farmers have access to the BMPs, if they can absorb the initial cost of the BMPs, and if they can be convinced that the BMPs are indeed profitable. With respect to aflatoxin mitigation, higher levels of aflatoxin were often observed in central Ghana relative to northern Ghana. When sampling in the field, aflatoxin levels were non-detectable in most cases. This was not unexpected given the variation often observed when sampling in the field. Drying with tarps resulted in considerably less aflatoxin going into storage. This was expected. Also, storage in hermetically sealed bags often resulted in less aflatoxin than traditional storage in poly sacks. Research during the 2015 and 2016 seasons should confirm these findings or demonstrate the variation in response to the BMPs introduced to farmers.



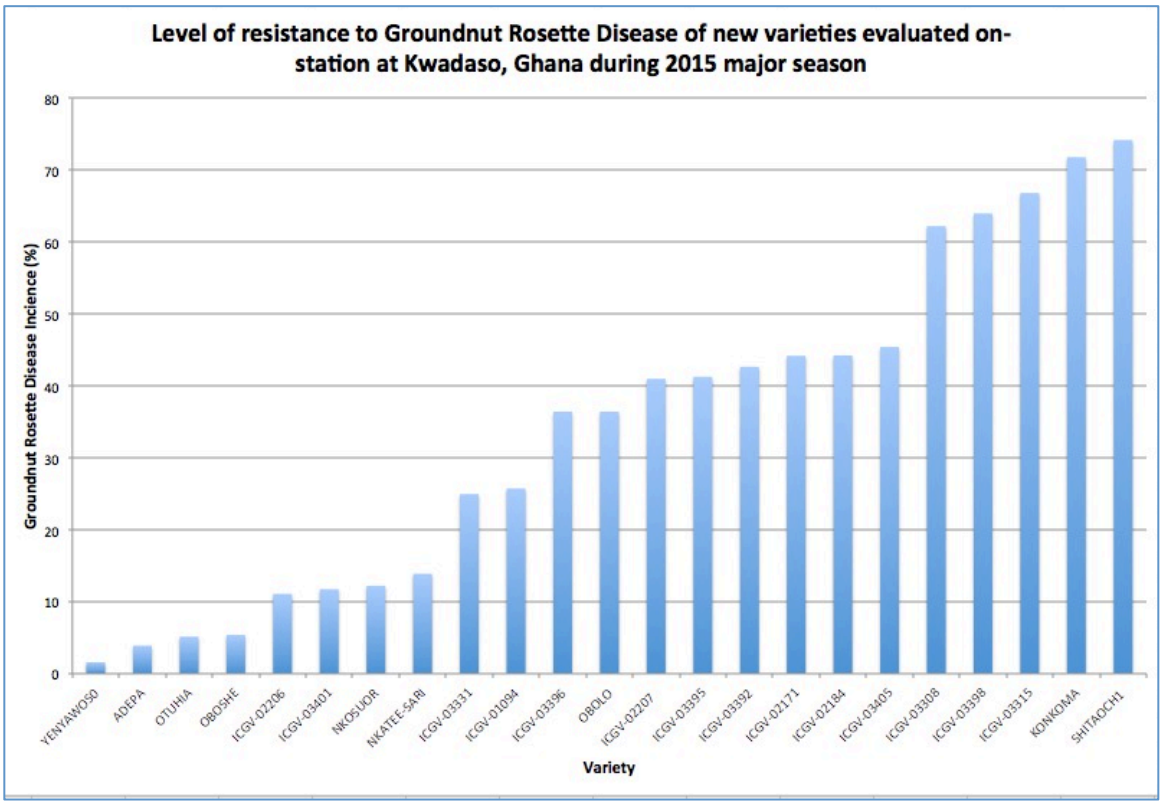
Lower yields in the north with later planting were expected because of limited rainfall later in the growing season (only one sowing is possible in the north). However, yield was higher in the Central Region during the minor season compared with the major season. Historically, yield of peanut in the major season has often exceeded that of yield in the minor season. This was not the case in 2014 and preliminary results for 2015 suggest a similar trend. From a risk management standpoint, growers face greater challenges because of the pressure on the minor season to produce an adequate supply of peanuts for the community is greater. Changing weather patterns are contributing to the risks involved with groundnut production in Ghana.

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

Results from this objective indicate that on-field production showed no detectable aflatoxin for both practices. The BMP showed significant ($p<0.05$) reduction of aflatoxin relative to the traditional practices

for both drying and storage in both major and minor seasons. Aflatoxin level was influenced by the type of drying technique. Thus, aflatoxin increased in the following order: tarpaulin, A-frame, then drying on bare ground.

Objective 3. Evaluate new peanut germplasm from ICRISAT, US and African breeders



Yield and aflatoxin contamination were evaluated for new varieties on research stations coordinated and implemented cooperatively by CRI-Kumasi, SARI-Tamale, and SARI-Wa. Results from 2014 documented differences in yield and pest reaction among 20 lines and varieties. Three lines from ICRISAT had less aflatoxin (although all lines had less than 5 ppb) than the other entries. The source of germplasm showed significant difference with aflatoxin resistance. Germplasm that showed higher incidence of groundnut rosette disease had slightly higher aflatoxin levels compared to those with lower incidence, although the incidence of rosette showed a significant positive correlation to lower aflatoxin resistance in field.

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) during 2014, reaching 40, 85, and 60 farmers in the village value chain trials outlined in Objective 1. In southern Ghana, topics of discussion included site selection, land preparation, planting of healthy and viable seed, row planting, application of local soaps (e.g. Alata soap) to manage aphids (vector of rosette disease), application of oyster shell powder at flowering stage and weed management (at least two times before harvesting), timely harvest, drying on tarpaulin, drying to a required moisture content (<10%) and if possible storing in hermetic bags under hygienic conditions. In northern Ghana, site and land preparation, improved agronomic practices such as row spacing using garden lines at planting, control of

leaf spots using appropriate fungicides, control of soil arthropods using appropriate insecticides (e.g. chlorpyrifos), improved plant nutrition with addition of fertilizers (e.g. calcium, etc). Participants were also taken through determination of pod maturity for harvesting using the hull-scraping method, as well as the importance of timely harvesting, proper drying and appropriate storage on aflatoxin contamination.

Objective 5. Analyze the economics of each aflatoxin reduction intervention
The socioeconomic survey instrument was prepared during FY2015 and will be conducted in early FY2016. Technicians were trained in late August 2015 for survey deployment in September-November 2015.

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 years. 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

It is important to maintain frequent contact with all investigators to ensure that experiments are conducted as planned and results recorded and analyzed as required. Farmers are interested in the project, but are anxious to know the recommendations as soon as possible.

Presentations and Publications

Mochiah, B., M. Owusu-Akyaw, J.Y. Asibuo, G. Bolfrey-Arku, K. Osei, J.N.L. Lamptey, I. Adama, and B.W. Amoabeng, M. Abudulai, J. B. Naab, S. Narh, R.L. Brandenburg, D.L Jordan, K. Boote and G. Macdonald. 2015. Historical contribution of the Peanut CRSP and PMIL to peanut growers in Ghana. Proc. Am. Peanut Res. and Educ. Soc. 47: 122.

Abudulai, M., J.B. Naab, D.L. Jordan, R.L. Brandenburg, K.J. Boote, and G. Macdonald. 2015. Effects of herbicide and fungicide applications on leaf spot diseases and peanut yield in Ghana. Proc. Am. Peanut Res. and Educ. Soc. 47: 121.

Dzomeku, I.K., M. Abdulai, J. Naab, G. Bolfrey-Arku, M. Mochiah, K. Boote, G. Macdonald, D. Jordan, and R. Brandenburg. 2015. Pest management strategies in peanut in Northern Ghana. Proc. Am. Peanut Res. and Educ. Soc. 47: 126.

Appaw, W.O., W.O. Ellis, R. Akromah, M. Mochiah, I. Adama, M. Owusu-Akyaw, M. Abudulai, J. Naab, Y. Mohammed, A. Budu, K. Mallikarjunan, M. Balota, J. Chen, R. Phillips, M. Chinnan, B. Bravo-Ureta, K. Boote, G. Macdonald, R.L. Brandenburg, and D.L Jordan. 2015. Aflatoxin assessment in peanut in the Ghana PMIL value chain: preliminary findings. Proc. Am. Peanut Res. and Educ. Soc. 47: 26.

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, women are the main purchasers of groundnuts, and 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
Gissele Gajate-Garrido	International Food Policy Research Institute	USA	Co-PI
Vivian Hoffmann	International Food Policy Research Institute	USA	Co-PI
Grace Motey	University for Development Studies	Ghana	Partner
Nelson Opoku	University for Development Studies	Ghana	Partner

Achievements

- Technology pilot completed with 40 farmers. Technology (tarps) chosen based on results of aflatoxin analysis
    - Tarps reduced aflatoxin contamination by 60%
    - Effects especially large in Northern Region
    - Drying racks were ineffective
- Baseline survey conducted with 1,005 farmers (November 2014- January 2015).
- Groundnut samples collected from 1,005 farmers (November 2014- January 2015).
- Groundnut samples tested for aflatoxin (December 2014-April 2015)
    - Median level is low (10 PPB), with large outliers (mean is 74 PPB, 90th percentile is 33 PPB).
    - Aflatoxin level is much lower in groundnuts destined for market than those being saved for home consumption
- Tarps procured for intervention (July-August 2015)

Lessons Learned

- Aflatoxin levels vary greatly, and are hard to predict using farmer characteristics and even reported post-harvest practices
    - This will make it difficult to see treatment effects on aflatoxin levels

    - To increase the likelihood of detecting treatment effects we have taken several measures:
        - All treatments will be assigned at the household, rather than village level
        - We will pay special attention to intermediate behavioral outcomes like sorting and drying practices
        - We are offering all treatment farmers the opportunity to purchase tarps, and recording these purchases so we can use tarp purchase as an outcome variable
- Farmers are extremely cash constrained
    - So far, uptake of tarps is very low at a price of $2.50 even though farmers understand their value for drying groundnuts
- Drying practices are generally good in Upper East region, and aflatoxin levels are low there (mean = 25 PPB)
    - They are, however, generally above export limits (20 PPB for US, 4 PPB for Europe)
- Drying practices are generally poor in Northern region, and aflatoxin levels are high there (mean = 106 PPB).
- Farmers sort groundnuts, with higher quality nuts marketed and lower quality nuts kept for household consumption
    - Aflatoxin levels are twice as high in groundnuts kept for home consumption (90 PPB) than they are in groundnuts destined for market (45 PPB)
    - We will purchase any high-aflatoxin groundnuts kept for household consumption as a result of our intervention (the protocol has been approved by IFPRI's IRB)

Presentations and Publications

As the project is early on, we have not collected sufficient data to conduct analysis. We expect to be able to write a paper or brief on the results of the pilot study in December 2015-January 2016.

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 Lilongwe University of Agriculture and Natural Resources (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 Small Farmer Association of Malawi), the Ministry of Agriculture, Exagris, Afri-Nut, TWIN of the U.K., the Clinton Development Initiative and others are all 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 farmer 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
Trust Donga	Lilongwe University of Agriculture and Natural Resources	Malawi	Co-PI
Agnes Mwangwela	Lilongwe University of Agriculture and Natural Resources	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

Several key components of the project were achieved in this reporting period. Most critically was the initiation of 11 graduate student study programs across three institutions. These graduate student projects form the foundation for the research effort across the value chain.

Graduate student research projects in the pre-harvest project include studies on the relationship of aflatoxin contamination with crop rotation and plant stresses, the use of biochar in the field to reduce contamination and the use of weather data to forecast aflatoxin risk. Data on the plant stress and crop rotation studies are under analysis. All projects are finalizing plans for the 2015-2016 field season.

Projects associated with post-harvest include collecting peanut butter samples from small-scale processors in Malawi and analyzing them for

Tchiyiwe Moyo-Chunda, a graduate student at Lilongwe University of Agriculture and Natural Resources, tests local peanut butter for aflatoxin and poor quality in order to train local processors. [Photo courtesy of Tchiyiwe Moyo-Chunda]

aflatoxin, microbial load and other quality parameters as specified in the Malawi Bureau of Standards. The same samples have also been analyzed for flavor (Gas Chromatography Mass Spectrometry or GC-MS) and texture at University of Georgia. Small-scale processors have been trained on safe and quality peanut butter processing. Preparatory work has commenced for processing of aflatoxin-safe groundnut flour and cooking oil. Proximate analysis and consumer acceptance of vegetables seasoned with blanched groundnuts has been conducted. In addition, studies were conducted on the effects of storage temperature (room versus 40°C), packaging material (nylon versus high-density plastic) and processing treatment (raw shelled versus lightly roasted) on the sensory attributes of peanuts during 18 weeks. Also completed was a set up of the methods of GC-MS analysis, preliminary tests on the Peroxide Value and TBARS tests (Thiobarbituric Acid Reactive Substances, a measure of lipid peroxidation) of squeezed peanut oil and the method for TBARS has to be modified to suit our analysis objective.

Other post-harvest research includes assessing storage methods for in-shell peanuts at Bunda, including: traditional basket, traditional khokwe (silo), conventional grain storage bags, and hermetically sealed poly-bags. Temperature and humidity will be monitored during storage. Six drying methods were evaluated at Bunda in the months of June and July. The methods arranged in order of drying rates from high to low are: circular pattern, windrow, rack, Mandela, A frame, and stack pole. Six drying surfaces were evaluated at Bunda in the month of June and July. The surfaces arranged in order of drying rates are: concrete slab, black plastic sheet, raised ground surface, bare ground, galvanized iron roof, and galvanized iron sheet on ground. Samples of the dried peanuts are now being analyzed for mold growth, aflatoxin, and quality in terms of hardness, brittleness, ease of skin removal, pod-splitting and flavor.

Lessons Learned

Blanching of groundnuts will not affect consumer acceptance of vegetables seasoned with groundnut flour.

Presentations and Publications

Brandenburg, R. L, D. L. Jordan and A. Emmott. 2015. Developing value chain teams to address aflatoxin management strategies in peanuts production and processing in Africa. XVIII International Plant Protection Congress. 24-27 Aug, Berlin, Germany

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 levels of farm productivity and profits. Productivity and profits can be improved in various ways, including gains in marketable yields. 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 available 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 for Year 2.
- 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

Kwabena Amponsah and Neha Paliwal. “Technology And Managerial Gaps In The Adoption Of Improved Groundnut Varieties In Malawi and Uganda.” Selected Paper prepared for presentation for the 2015 Agricultural & Applied Economics Association and Western Agricultural Economics Association Annual Meeting, San Francisco, CA, July 26-28.

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	Discipline	Research Focus	Mentor	Training Location
Shirin Malek	F	Canada	California State University Chico	2014-2015 2015-2016			Mark Manary	Malawi
Abdi Hassen	M	Ethiopia	Hawassa University, Awassa, Ethiopia	Aug-Oct/2014, Aug/2015-Feb/2015	Plant Pathology	Detection of aflatoxin types and molecular diversity of *Aspergillus* species from Ethiopia	Renee Arias	USDA-ARS National Peanut Research Lab, Dawson, GA, USA
Maxwell Lamptey	M	Ghana	Crops Research Institute, Kumasi, Ghana	Apr-Sep/2015	Agricultural mechanization	Develop and evaluate a solar dryer for peanuts.	Jinru Chen	University of Georgia, Griffin, GA USA
Paul Macharia	M	Kenya	Kenyatta University	2015	Biotechnology	Peanut-genetic transformation and molecular tools.	Renee Arias	USDA-ARS National Peanut Research Lab, Dawson, GA, USA
Esther Mambo	F	Malawi	University of Malawi-Chancellor College	2015	Pathology	Isolation and characterization of *Aspergillus*.	Renee Arias	International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Malawi
Joseph Maulana	M	Malawi	University of Malawi	2015-2016	Nutrition		Mark Manary	Malawi
Amos Acur	M	Uganda		2015	Molecular diversity	Processing peanut samples for genetic diversity.	Renee Arias	USDA-ARS National Peanut Research Lab, Dawson, GA, USA
Shelby Benko	F	USA	California Polytechnic State University	2013-2014	Nutrition		Mark Manary	Malawi

Name	Gender	Home Country	Home Institution	Dates	Discipline	Research Focus	Mentor	Training Location
Christina Brumme	F	USA	Emory	2013-2014	Nutrition		Mark Manary	Malawi
Alyson Chow	F	USA	California Polytechnic State University	2013-2014	Nutrition		Mark Manary	Malawi
Kaylynn Crawford	F	USA	California Polytechnic State University	2015-2016	Nutrition		Mark Manary	Malawi
Rachel Eckert	F	USA	California Polytechnic State University	2013-2014 2014-2015	Nutrition		Mark Manary	Malawi
Jocelyn Fry	F	USA	California Polytechnic State University	2014-2015	Nutrition		Mark Manary	Malawi
Cambria Glotz	F	USA	California Polytechnic State University	2013-2014 2014-2015 2015-2016	Nutrition		Mark Manary	Malawi
Leah Hackney	F	USA	California Polytechnic State University	2013-2014	Nutrition		Mark Manary	Malawi
Zakirah Hasan	M	USA	California Polytechnic State University	2015-2016	Nutrition		Mark Manary	Malawi
LaTanya Johnson	F	USA	Albany State University	2014-2015	Biotechnology	DNA extraction from *Aspergillus* and from plants, PCR screenings, and DNA fingerprinting.	Renee Arias	USDA-National Peanut Research Laboratory, Dawson, GA USA
Megan Kitagawa	F	USA	California Polytechnic State University	2014-2015 2015-2016	Nutrition		Mark Manary	Malawi
Colette Long	F	USA	California Polytechnic State University	2014-2015	Nutrition		Mark Manary	Malawi

Name	Gender	Home Country	Home Institution	Dates	Discipline	Research Focus	Mentor	Training Location
Beatrice Lunday	F	USA	California Polytechnic State University	2013-2014 2014-2015	Nutrition		Mark Manary	Malawi
Garrett Morris	M	USA	California Polytechnic State University	2013-2014	Nutrition		Mark Manary	Malawi
Anna Nakayma	F	USA	California Polytechnic State University	2014-2015	Nutrition		Mark Manary	Malawi
Stephanie Nash	F	USA	California Polytechnic State University	2015-2016	Nutrition		Mark Manary	Malawi
Lindsey Ngo	F	USA	California Polytechnic State University	2014-2015	Nutrition		Mark Manary	Malawi
LaSinda Powell	F	USA	Albany State University	2014-2015	Biotechnology	RNAi Silencing of Aflatoxin Synthesis.	Renee Arias	USDA-National Peanut Research Laboratory, Dawson, GA USA
Rosy Rojas	F	USA	California Polytechnic State University	2014-2015	Nutrition		Mark Manary	Malawi
Andrea Swan	F	USA	California Polytechnic State University	2014-2015	Nutrition		Mark Manary	Malawi
Katie Tolstad	F	USA	California Polytechnic State University	2013-2014	Nutrition		Mark Manary	Malawi
Monica Wang	F	USA	Emory University	2014-2015	Molecular diversity	Bioinformatics assisting in genetic diversity analyses.	Renee Arias	USDA-National Peanut Research Laboratory, Dawson, GA USA

Name	Gender	Home Country	Home Institution	Dates	Discipline	Research Focus	Mentor	Training Location
Simon Zhao	M	USA	California Polytechnic State University	2014-2015	Nutrition		Mark Manary	Malawi
Fengle Zhu	M	USA		2015	Engineering	AflaGoggles for Aflatoxin Detection	Haibo Yao	Mississippi State University, Stennis Space Center, MS USA

Long-Term Training (by country)

Name	Gender	Home Country	Degree	Graduation Date	Discipline	Research Focus	Mentor	Training Institution
Clara Darko	F		PhD		Post-harvest Processing	Comparison of storage systems for in-shell, shelled, and blanched peanuts.	Kumar Mallikarjunan	Virginia Tech
Yussif Abubakari	M	Ghana	MPhil	Jul 2016	Food Science and Technology	Effects of applications of calcium to reduce aflatoxin contamination in peanut.	David Jordan	Kwame Nkrumah University of Science and Technology, 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	Kwame Nkrumah University of Science and Technology, 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
Stephan Arthur	M	Ghana	MPhil	Jul 2016	Agronomy	Influence of herbicides and fungicides on pest reaction, yield, and	David Jordan	Kwame Nkrumah University of Science and Technology,

						aflatoxin contamination in peanut.		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		Ghana	PhD		Breeding		James Asibuo	Crops Research Institute
Yaa Klu	F	Ghana	PhD	Oct 2014	Food Science and Technology	Use of peanut butter to deliver probiotics	Jinru Chen	University of Georgia, Griffin, GA USA
Vincent Ninkuu	M	Ghana	MPhil	2015	Economics	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	Includes evaluation of pre- and post-harvest interventions to reduce aflatoxin contamination in peanut.	David Jordan	Kwame Nkrumah University of Science and Technology, Kumasi, Ghana
Noah Saduli	M	Ghana	MPhil	2015	Economics	Leading enumerator teams, conducting laboratory testing, and doing data analysis.	Nelson Opoku	University for Development Studies, Tamale, Ghana
Davis Gimode	M	Kenya	PhD	Aug 2020	Plant Breeding, Genetics and Genomics	Peanut genomics	Peggy Ozias-Akins	University of Georgia, Tfiton, 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	Lilongwe University of Agriculture and Natural Resources, Lilongwe, Malawi
Kobby Amponsah		Malawi	MSc	2015	Economics	Research Technician working on the productivity effects of improved groundnut	Boris Bravo-Ureta	

						seed varieties.		
Chancy Sibakwe	M	Malawi	MSc	Sep 2016	Entomology	Biotic/Abiotic stress impacts on pre-harvest aflatoxin contamination	W. Mhango, V. Saka	Lilongwe University of Agriculture and Natural Resources, Lilongwe, Malawi
Monica Chimbaza	F	Malawi	MSc	Mar 2017	Agricultural Engineering	Drying and storage technologies for reducing aflatoxin in peanuts	Wellam Kamthunzi	Lilongwe University of Agriculture and Natural Resources, 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	Lilongwe University of Agriculture and Natural Resources, Lilongwe, Malawi
Jeremy Jilleffe	M	Malawi	PhD	2015	Economics	Economics of interventions to reduce aflatoxin contamination in peanuts.	Boris Bravo-Ureta	University of Connecticut, Storrs, CT USA
Chikondi Magombo		Malawi	MSc	Mar 2017	Food Science	Processing and uses of peanut flour	Agnes Mwangwela	Lilongwe University of Agriculture and Natural Resources, Lilongwe, Malawi
Tchiyiwe Moyo	F	Malawi	MSc	Feb 2016	Food Science	Baseline evaluation of peanut butter quality and processor knowledge of aflatoxin	Agnes Mwangwela	Lilongwe University of Agriculture and Natural Resources, Lilongwe, Malawi
Christy Thakwalakwa	F	Malawi	PhD	Jun 2015	Nutrition		Mark Manary	University of Tampere
Eric Simning	M	Tanzania	MSc		Economics	Research Technician working on the productivity effects of improved groundnut seed varieties.	Boris Bravo-Ureta	
Neha Paliwal		Uganda	MSc		Economics	Research Technician working on the	Boris Bravo-Ureta	

						productivity effects of improved groundnut seed varieties.		
Abraham Fuller	M	USA	PhD		Plant pathology	Leaf spots in peanut	Bob Kemerait	University of Georgia, Tifton, GA USA
Amanda Seawright	F	USA	MSc	2017		Aflatoxin detections in peanuts and grains	Jia-Sheng Wang	University of Georgia, Athens, GA USA
Kathy Xue	F	USA	PhD	2019		Aflatoxin detection in dried blood samples	Jia-Sheng Wang	University of Georgia, Athens, GA USA
Hendrix Chalwe	M	Zambia	PhD	Jul 2015	Agronomy	Modeling of pre-harvest aflatoxin contamination in peanuts	Alice Mweetwa	University of Zambia, Lusaka, Zambia
John Yawe	M	Zambia	MSc		Post-harvest Processing	Assessment of existing drying and storage systems for peanuts	Mkandawire, Simate	University of Zambia, Lusaka, Zambia
Munsanda Ngulube		Zambia	MSc	Jan 2016	Agronomy	Use of biochar and gypsum to reduce aflatoxin in peanuts	Alice Mweetwa	University of Zambia, Lusaka, Zambia

Institutional Development

- In Egypt, JS Wang assessed the capacity and needs for Egypt Ministry of Health Central Laboratory and provided laboratory protocols for analysis of blood aflatoxin levels.
- In Ghana, training was conducted with 375 farmers in 20 villages in the Northern Region on aflatoxin risks and post-harvest techniques for aflatoxin reduction. An additional partnership was established with Dr. James Asibuo at the Crops Research Institute in Kumasi, Ghana. Dr. Asibuo is serving on the graduate committee of PhD student, Afia Karikari. A part of Afia's research will be conducted with Dr. Asibuo in Ghana.
- In Haiti, aflatoxin testing facilities were further improved at the iF Foundation and, Meds & Food for Kids laboratories near Cap Haitian. Agronomists and technicians at Meds & Food for Kids, iF Foundation, Acceso Peanut Enterprise Corp. and Zanmi Agrikol received on-going training in trial design, implementation and data collection. Undergraduate agronomy student interns from Université de Roi Henri Christophe in Cap Haitian initiated collaborative trials on plant spacing with Meds & Food for Kids.
- In Uganda, two greenhouses were renovated at the National Semi Arid Resources Research Institute (NaSARRI) station in Soroti to increase the number of crosses in the breeding program.
- In Zambia, screening for groundnut rosette disease was strengthened by developing the capacity of ZARI in Chipata to use the infector row technique to look for the disease. This required establishing an insectivory for aphid rearing that will be deployed in the 2015-16 cropping season.

Technology Transfer and Scaling Partnerships

Since this is still the early phase of the project, most technologies are also in the early phases of development and evaluation. Each project has also developed the groundwork for adoption and scaling of technologies through appropriate partnerships.

Single/Partial Kernel Aflatoxin Detection

The USDA-ARS Peanut lab in Dawson was able to develop an Ultra-High Pressure Liquid Chromatography (UHPLC) method for quantification of aflatoxin in single or partial kernels. This is an essential lab technique for improved evaluation of aflatoxin resistant variety development and can be shared with collaborating labs.

Variety Development

Development and adoption of peanut varieties requires a systematic pipeline from breeder to grower that includes commercialization of seed multiplication. Due to high seeding rates, relatively low seed yield and traditional practice of self-saved seed, commercialization of peanut seed has proven difficult in the smallholder setting. However, variety development with traits such as disease resistance or drought tolerance has the highest likelihood of improving farmer livelihoods of most any agronomic interventions.

In Uganda, several varieties with desirable traits such as resistance to groundnut rosette disease and high oleic acid ratio have been evaluated in several contexts and released for farmer adoption (e.g.,

Serenut 5R and 6T). Even more importantly, networks of seed producers are engaged in commercialization of these varieties through the Local Seed Business Groups of the Integrated Seed Sector Development project.

In Haiti, ongoing evaluations in multiple locations have yielded some potential varieties for commercialization. Relationships with the Acceso Peanut Enterprise Corp., Kreyol, Inc. and the iF Foundation have been established to scale varieties as they are identified.

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 Committee

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 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, National Program Leader, United States Department of Agriculture (USDA), USA
- Jeff Ehlers, Program Officer, Bill & Melinda Gates Foundation, USA
- Andrew Emmott, Senior Associate, Twin and Twin Trading Ltd., 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.

Program Research Meetings

PMIL conducted its program-wide annual meeting in Cap Haitian, Haiti in June 2015. This was the first of three regional meetings to be held in the target countries by the completion of the project, and was a great success. Several collaborators from Africa attended the meeting along with most PIs, Management Entity team, USAID Agreement Officer's Representative, External Advisory Panel members, and additional country collaborators, allowing for a chance to get updated on work plans and budgets, renew collaborations, and to see the work being done in Haiti. The integration of research with the NGO and private sector collaborators was a special focus, which has led to new research projects, specifically in Malawi.

Prior to the annual meeting, PMIL took advantage of the collaborators' presence and organized a special public meeting in Port au Prince, Haiti entitled, "Priorities for Addressing Mycotoxins in Haiti." PMIL's work on peanuts and risk exposure was showcased, as well as presentations from the private sector and the major public agriculture university. The primary finding of the meeting was that while much is known about the potential for risks of mycotoxins in peanuts, as well as other crops, more information is needed about human exposure and impacts to prioritize policy and programming. Private sector participants expressed a concern for the burdens of aflatoxin management in the face of limited public regulations or enforcement and limited knowledge within the informal market sector.

Also in 2015, PMIL collaborators from the US, Haiti, Burkina Faso, Ghana, Malawi, Zambia, Mozambique and Uganda participated in the annual American Peanut Research and Education Society (APRES) meeting held in July in Charleston, South Carolina, where all collaborators made presentations on their ongoing research. Preceding the conference, PMIL helped organize a visit to the University of Florida research station at Citra, Florida, where the USDA germplasm collection is being grown for further phenotyping under the supervision of Greg MacDonald. A majority of the global peanut breeding community was on hand to see the collection and discuss priorities for their breeding programs.

An additional meeting concerning aflatoxin sampling was organized at the APRES conference. Retired USDA scientist Tom Whitaker presented a follow-up to the webinar organized in December 2014 about his work to reduce sample error when testing for aflatoxin. A recording of that webinar is available on the PMIL website and has had over 200 views.

In October 2014, a meeting was organized in Washington, DC for the Innovation Lab Council, representing all Feed the Future Innovation Labs, in order to improve collaboration between labs, USAID and other US Government agencies. PMIL's Director was elected as the President of the Council and has worked during the year to develop the Council's Terms of Reference, enhance visibility of all Innovation Labs via a common website, and organize the annual Innovation Labs Council meeting held in Lilongwe, Malawi in April of 2015. Most of the Innovation Labs were represented as well as most regional

missions. A key outcome was to improve communication of Innovation Labs' activities with the country mission offices so as to integrate research with programs better.

PMIL continued to increase awareness of its research program and seek collaboration through the Partnership for Aflatoxin Control in Africa (PACA), a secretariat of the African Union. The Assistant Director participated in the annual meeting in Addis Ababa, Ethiopia in October 2014 and a workshop "Revitalizing the Groundnut Value Chain in West Africa through Aflatoxin Control" in Dakar, Senegal, in September 2015. This trip also allowed the Assistant Director the opportunity to visit CERAAS and the ISRA research station in Thiès and Bambey, respectively, as well as tour the Peanut Basin region.

PMIL also had strong representation at the Georgia Peanut Tour in September 2015, including several students and a contingent from Malawi, including the Minster of Agriculture, himself a US-trained peanut breeder.

Finally, several PMIL scientists attended the Advances in Arachis through Genomics and Biotechnology (AAGB) conference in Savannah, Georgia. The PMIL Director gave a presentation during the opening session and organized a session on the use of transgenic approaches to solve aflatoxin contamination in peanuts.

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 FY2015, 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.

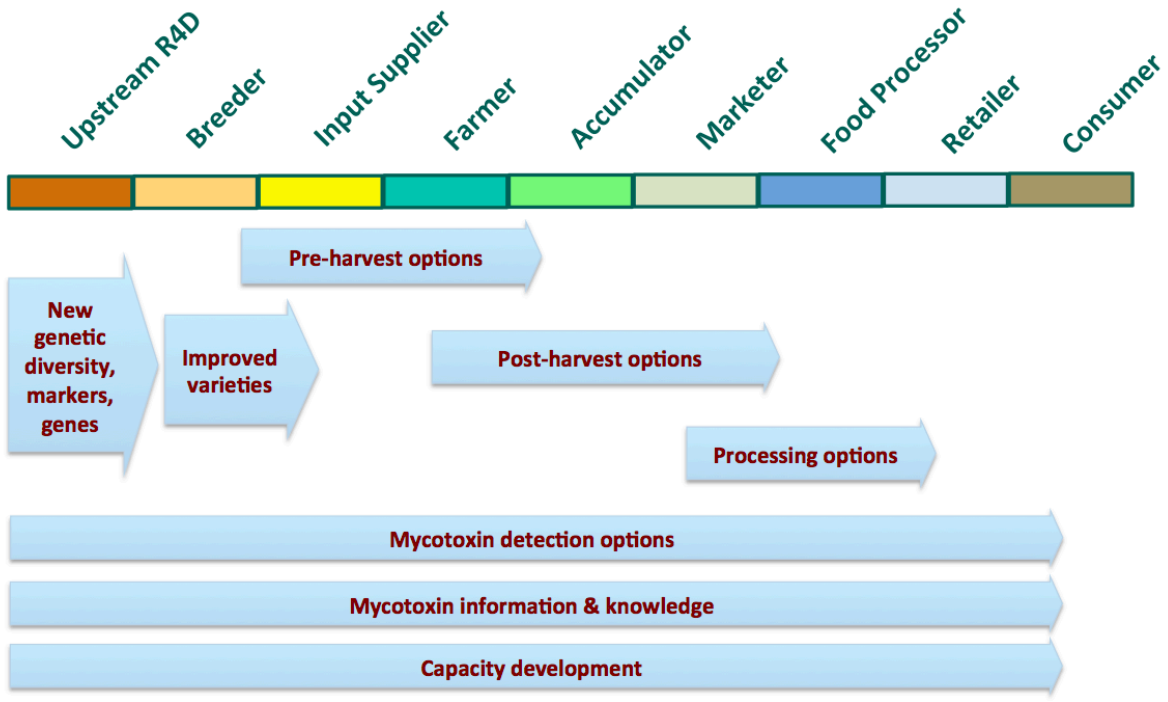
In January 2014, the Director and Assistant Director visited Haiti to prepare for the annual meeting and visited the collaborators and local mission.

In late January, the Assistant Director participated in the Ghana value chain organizational meetings with the PI and most collaborators, visiting Tamale (SARI &UDS), Kumasi (CRI & KNUST) and Accra (University of Ghana).

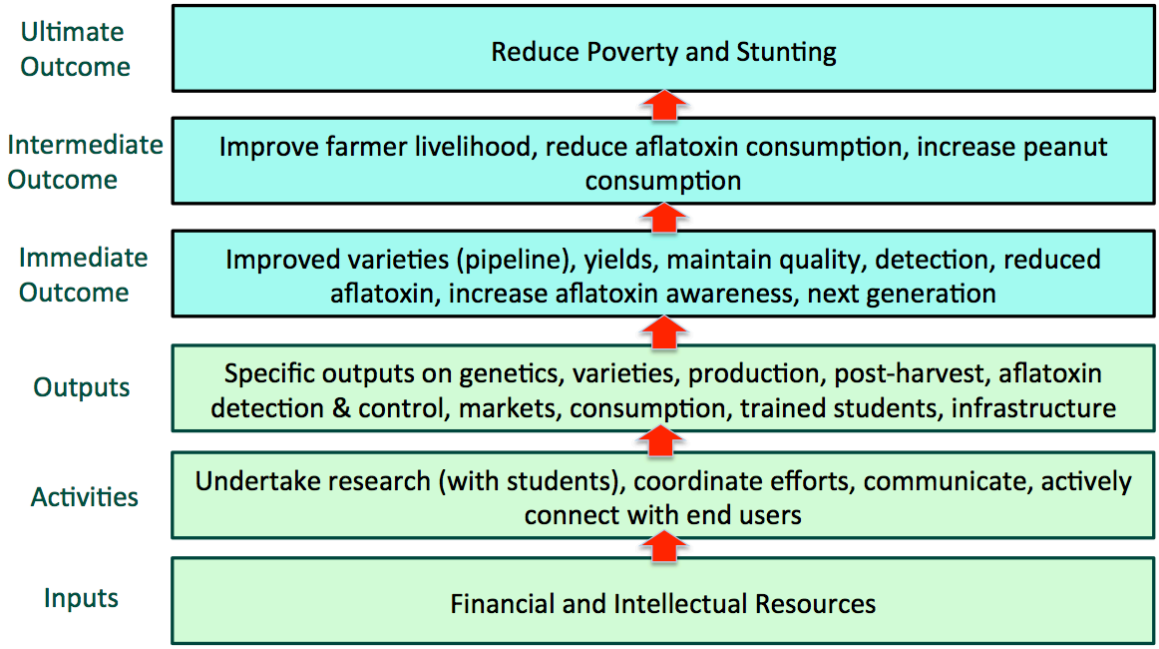
In March and April the Director and Assistant Director had several visits to the Southern Africa region, in preparation and participation in the Innovation Lab Council meeting in Lilongwe, Malawi. Visits included all current partners in Zambia, Malawi and Mozambique.

In August, the Director participated in the Ghana Value Chain meeting and visited collaborators in Tamale, Wa, Kumasi and Accra.

In addition to site visits, some simple graphics were developed to help communicate PMIL's logic model as part of a value chain approach. Below is description of the value chain and PMIL's areas of focus.



PMIL activities align with the highest level Feed the Future goals of reducing poverty and childhood stunting by improving peanut cultivation and access to safe, nutritious peanut-based foods. Below is a logic model of how PMIL contributes to this agenda.



Communications

Communications Highlights from the year include:

- Updated PMIL informational brochure.
- Continued publishing monthly digital newsletter with a circulation growth of 225 subscribers to our present total of 353.
- Continued social media presence:
    - Blog – 166 new posts reaching 80 countries
    - Facebook – 358 new posts, and added 134 new followers to present total of 334
    - Flickr – 22 new photo albums uploaded, and lost 21 followers to present total of 9
    - LinkedIn – 32 members
    - Slideshare – 4 new posts, and 7 followers
    - Twitter – 374 new posts, and added 25 new followers to present total of 217
    - Participated in Twitter Chat with Agrilinks in May
    - YouTube – 11 new videos, 3 followers
- Published seven feature articles about PMIL
- Six articles were published about PMIL in the media both in the U.S. and internationally.

- Published one article in the USAID Feed the Future Newsletter and worked to strengthen media relations with the main FTF communications team.
- Social media was automated so that newsletter automatically is tweeted, and Twitter automatically posts to Facebook.

Information Technology

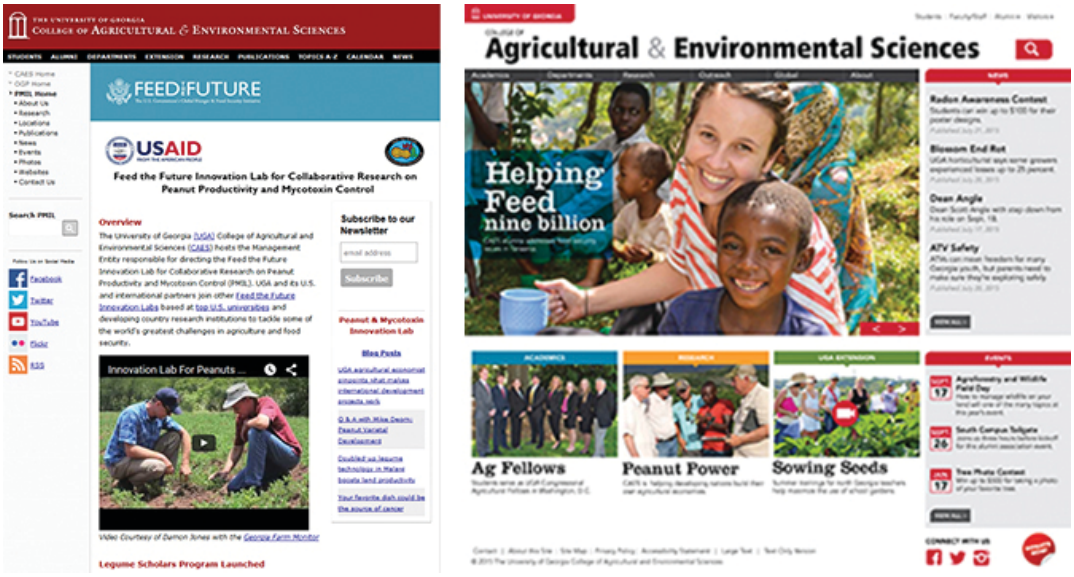
The Peanut & Mycotoxin Innovation Lab's Information Technology continues to be part of the University of Georgia's College of Agricultural & Environmental Sciences enterprise system at no cost to PMIL. This provides:

- 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, including:

- Review of ADS579 Data Management plan, meeting attendance, and suggested improvements.
- Review of KDAD joint Innovation Lab website portal and suggested improvements.
- Participation in new website CMS design meetings and suggested improvements.
- Continued support for PMIL website, one of the top websites for UGA's College of Agricultural and Environmental Sciences.

- Work to build a history of PMIL/PCRSP documentation on server for long-term retention.
- Compilation of a list, and electronic copy, of all publications from 2007 to the present.
- Development of a publications database to house each publication's details, including abstracts, with key-word search ability. Will be used in the future on website.
- Continued support for WordPress blog for PMIL communications to partners and others.
- Continued support for Mail Chimp HTML newsletter and distribution lists.
- Set up of listserv addresses for email communications to PMIL participants.
- Decommissioning of Copper Project web-based Project Management Software.
- Set up of File-Works.com file storage system for document sharing among PMIL collaborators.
- Acquisition of a GoToMeeting subscription for all PMIL collaborators to use for video/audio conferences.



PMIL Current website (www.pmil.caes.uga), example of CAES website in new CMS

Other Topics

The responses to the Legume Scholars Program (a jointly-funded graduate scholarship program with the Legume Innovation Lab and CGIAR Research Program on Grain Legumes) request for nominations demonstrated the interest in legume research, and the selection of the awardees has initiated a community of legume research students. One of the awardees is pursuing his PhD at the University of Georgia in peanut processing.

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. Certain unanticipated administrative issues in implementing the sub-award contracts for some of the projects did result in delays in these projects, but all approved project contracts were signed by the end of FY2015 and efforts are now underway to accelerate the research activities. The Management Team is working closely with the respective Principal Investigators to identify mechanisms to ensure that the planned outputs will be produced according to the original timeline.

Future Directions

The next fiscal year will see a continuation 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, leading to plans for scaling up and out of the best technologies.

Training workshops in mycotoxin sampling and detection (especially with the Mobile Assay tablet) will be organized in each country/region. The results with the tablets will be closely monitored so that adjustments can be made.

The adoption of new data management technologies such as the IBP will continue to be encouraged across the PMIL breeding and genomics projects, both in the USA and partner countries. Beyond breeding, data management will be further strengthened in all PMIL projects during the year to address the new data requirements.

As markets, both existing and new, are critical to encourage adoption of new varieties and crop managements interventions, efforts will continue to identify private sector partners and opportunities to define future research needs in the areas of processing and product development. Recent agreements the Mars Company and Hershey's have made to invest in aflatoxin-control efforts offer excellent opportunities to develop improved peanut opportunities in Africa, and discussions are already in progress with these companies.

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
Kreyol, Incorporated		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
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 Sate 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

A3. Foreign

Institution	Department	City
Burkina Faso		
University of Ouagadougou	Departement de Phytopathologie	Quagadougou
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
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

Institution	Department	City
Haiti		
TechnoServe		Petionville
Meds & Food for Kids		Quartier Morin
Partners in Health/Zanmi Agrikol		Corporant
Accesso 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	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 Small Holder 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		
Edwardo Mondlane University		Maputo
Instituto de investigação Agrária de Moçambique (IIAM)		Maputo
IKURU Farmer's Cooperative		Nampula
Lurio University		Nampula
Mozambique Agricultural Research Institute	Northeast Zonal Center	Nampula
Nigeria		
International Institute of Tropical Agriculture (IITA)		Ibadan
Senegal		
Institut Senegalais de Researches Agricoles (ISRA)	Centre National de Recherches Agronomiques (CNRA)	Bambey

Institution	Department	City
Institut Senegalais de Researches Agricoles (ISRA)	Centre d'etude regional pour l'amelioration de l'adaptation a la secheresse (CERAAS)	Thies
Uganda		
National Agricultural Research Organization (NARO)	National Crops Resources Research Institute (NaCRRI)	Kampala
National Agricultural Research Organization (NARO)	Savannah Agricultural Research Institute (SARI)	Nyankpala
National Agricultural Research Organization (NARO)	National Semi Arid Resources Research Institute (NaSARRI)	Soroti
Zambia		
Eastern Province Farmer's Cooperative Ltd.	Katopola Farm Institute	Chipata
Zambia Agriculture Research Institute (ZARI)	Mt. Makulu Central Research Station	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 2015 Budget	Total Budget
Connecticut					**$44,308**	**$112,100**
University of Connecticut	A3.	An Integrated Global Breeding and Genomics Approach to Intensifying Peanut Production and Quality *(sub-award from UGA)*	11/26/13	7/30/17	$11,327	$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	7/31/17	$32,981	$93,100
District of Columbia					**$12,813**	**$231,375**
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	$12,813	$231,375
Florida					**$149,983**	**$596,681**
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	$78.973	$310,778
	C1.	Production to Consumption – Technologies to Improve Peanut Production, Processing and Utilization in Haiti	12/1/13	7/30/17	$25234	$127,238
	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	7/31/17	$45776	$158,665
Georgia					**$763,294**	**$2,876,498**
University of Georgia (UGA)	A1.	Translational Genomics to Reduce Pre-harvest Aflatoxin Contamination of Peanut	11/1/13	7/30/17	$121,838	$527,652
	A3.	An Integrated Global Breeding and Genomics Approach to Intensifying Peanut Production and Quality	11/26/13	7/30/17	$52,984	$263,501
	B2.	Development and Validation of Methods for Detection of Mycotoxins Exposure in Dried Spotted Blood Samples	9/26/13	8/31/16	$233,056	$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	$297,261

Institution		Project Name	Start Date (mm/dd/yy)	End Date (mm/dd/yy)	FY 2015 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	7/31/17	$52,152	$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	7/31/17	$25,543	$88,500
	C3.	Producer and Consumer Interventions to Decrease Peanut Mycotoxin Risk in Ghana	2/7/14	12/31/16	$15,055	$68,625
	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	$88,171	$297,548
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	$84,645	$350,311
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	$10,000	$40,000
Mississippi					**$178,788**	**$377,431**
Mississippi State University (MSU)	B1.	AflaGoggles for Screening Aflatoxin Contamination in Maize	10/1/14	9/30/15	$156,828	$333,971
USDA-ARS Southern Regional Research Center	B1.	AflaGoggles for Screening Aflatoxin Contamination in Maize *(sub-award from MSU)*	10/1/14	9/30/15	$21,960	$43,460
Missouri					**$58,429**	**$181,500**
Washington University (WU)	B3.	Randomized Controlled Trial of the Impact of Treating Moderately Malnourished Women in Pregnancy	11/1/13	10/31/16	$58,429	$181,500
New Mexico					**$52,709**	**$215,839**
New Mexico State 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	$52,709	$215,839
New York					**$89,100**	**$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	$89,100	$271,251

Institution		Project Name	Start Date (mm/dd/yy)	End Date (mm/dd/yy)	FY 2015 Budget	Total Budget
North Carolina					**$124,548**	**$471,011**
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	7/31/17	$43,120	$180,585
	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	$81,428	$290,426
Texas					**$59,933**	**$241,505**
Texas A&M 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	$59,933	$241,505
Virginia					**$102,229**	**$318,855**
Virginia Tech	A3.	An Integrated Global Breeding and Genomics Approach to Intensifying Peanut Production and Quality *(sub-award from UGA)*	11/26/13	7/30/17	$3,095	$10,631
	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	7/31/17	$29,405	$99,593
	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	$69,729	$208,631

B2. Non-US Partners (by Country)

Institution		Project Name	Start Date (mm/dd/yy)	End Date (mm/dd/yy)	FY2015 Budget	Total Budget
Burkina Faso					**$12,309**	**$51,717**
University of 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	$12,309	$51,717
Ghana					**$212,325**	**$694,065**
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	7/31/17	$38,500	$160,500

Institution		Project Name	Start Date (mm/dd/yy)	End Date (mm/dd/yy)	FY2015 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	7/31/17	$87,310	$205,650
Savannah 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	$15,465	$57,608
	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	7/31/17	$59,500	$240,750
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	7/31/17	$11,550	$29,557
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					**$94,321**	**$388,238**
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	$91,416	$372,350
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	$2,905	$15,888
Malawi					**$300,641**	**$1,007,583**
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	$82,500	$234,785
Chitedze Agriculture Research Service	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	$5,000	$15,000
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	$45,663	$126,401

Institution	Project Name	Start Date (mm/dd/yy)	End Date (mm/dd/yy)	FY2015 Budget	Total Budget
	A3. An Integrated Global Breeding and Genomics Approach to Intensifying Peanut Production and Quality *(sub-award from UGA)*	11/26/13	7/30/17	$90,809	$355,864
	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	$37,169	$157,033
University of Malawi	B3. Randomized Controlled Trial of the Impact of Treating Moderately Malnourished Women in Pregnancy *(sub-award from WU)*	11/1/13	10/31/16	$39,500	$118,500
Mozambique				**$44,999**	**$199,072**
Mozambique Agricultural Research Institute (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	$9,999	$64,072
Nigeria				**$16,675**	**$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	$16,675	$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				**$81,030**	**$305,177**
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	$9,000	$34,000
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	$7,418	$23,288
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	$64,612	$247,889
Zambia				**$71,035**	**$232,505**
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	$71,035	$232,505

Appendix C. Success Stories

C1. Contamination of locally produced peanut-based products in Ghana

Peanuts and peanut-based products are highly nutritious foods consumed around the world. In Ghana, local processors use locally-grown peanuts to produce three popular products – peanut oil, kulikuli (a local snack food) and khebab powder (a seasoning). With the goal of improving food quality, the Peanut & Mycotoxin Innovation Lab supported a study to assess the levels of microbial and mycotoxin contamination in these products. The study was conducted by Sylvia Baah-Tuahene as part of her master's research project at the University of Ghana under Dr. Agnes Budu and Professor F. K. Saalia.

The study consisted of a cross-sectional survey in Greater Accra, Northern Ghana and the Ashanti region near Kumasi. A pre-tested, semi-structured questionnaire was used to collect information on the processing methods and knowledge of good manufacturing and hygienic practices. Samples were collected from 10 local processors in each of the three regions, and at the various stages of traditional peanut processing – raw peanuts, roasted peanuts, peanut cake, peanut oil, kulikuli and khebab powder.

A local peanut processor prepares to work. In Ghana, many processors are women and, though they have been working for years, have no formal education. A PMIL project surveyed the quality of these products to develop training programs to improve food quality and safety.

Samples were then analyzed in the CSIR Food Research Institute's microbiology laboratory and in the Department of Nutrition and Food Science at the University of Ghana in Accra.

All of the processors surveyed were female. Over 65% were above the age of 35 years old, 93% had no formal education, and 50% had been processing peanuts for at least 20 years. Even though almost all of the processors had no formal education, most did have adequate knowledge and understanding of the causes of defects in peanuts, how to control those problems and many of the food safety issues related to peanut consumption. In most cases, the processor's chief goal was to extract and sell peanut oil, and use the peanut cake obtained after oil extraction to make and sell

kulikuli and khebab powder.

From the laboratory results, there were significant differences in the physical and chemical properties (e.g., impurities, moisture content, chemical composition and texture) among the various samples, likely due to the use of different peanut cultivars and processing methods. More critical were the high levels of microbial and aflatoxin contamination detected. All of the kulikuli and khebab powder samples had unacceptably high levels of microbial contamination, including *E. coli* and other faecal coliforms.

Aflatoxin contamination levels of the products were also far in excess of regulatory limits, ranging from over 550 ppb in raw peanuts to around 100 ppb in most all samples of peanut cake, kulikuli and khebab powder. Peanut paste and peanut oil generally had the lowest levels, although some samples of peanut oil from the Northern region were as high as 65 ppb. Levels in raw peanuts were surprisingly low in our samples from Accra compared to the other regions, suggesting that sorting can be effective, however, the level of aflatoxin detected in the processed products did not vary much between regions, nor were these correlated to the level in the raw peanuts used by the processor. This implies that even though most processors sort the raw peanuts to remove highly contaminated nuts, other steps such as milling, lead to aflatoxin contamination.

Based on the results from this study, it is recommended that peanut processors be further educated and provided practical training on the importance of good manufacturing and hygienic practices. The manual sorting procedures developed by the Peanut & Mycotoxin Innovation Lab need to be more widely promoted and adopted by processors. Further research should be done at the level of the local millers to determine exactly how contamination occurs and what might be done to reduce this. This could be especially important since millers often process many types of commodities, including corn that is also often contaminated by mycotoxins.

Future research by the Peanut & Mycotoxin Innovation Lab will focus on developing a HACCP system for traditional processing of peanut oil and its by-products that can be used to train local processors, and ultimately reduce the levels of microbial and aflatoxin contamination of these important and popular foods.

Ghanaian women process peanuts for oil. Peanuts also make popular products like khebab powder, left, or kulikuli, below. [Photo courtesy of Sylvia Baah-Tuahene.]

C2. Impact of adoption of improved peanut varieties in Uganda

The impact of research often can be measured only several years after the research project ends. This is the case with the work undertaken by the previous Peanut Collaborative Research Support Program that supported a farmer-led seed multiplication and dissemination project for groundnut growers implemented by the non-governmental organization AT Uganda Ltd. between 2000 and 2004 in the Northeastern region of Uganda.

PMIL Director Dave Hoisington discusses performance of new peanut varieties with a smallholder farmer in his field in northern Ghana. A survey found that farmers introduced to new peanut varieties were still benefitting 10 years later. [Photo courtesy of David Okello]

The Peanut & Mycotoxin Innovation Lab supports a project to determine the benefits of the Peanut CRSP project for smallholder farmers in participating villages and households by examining the adoption of improved groundnut varieties and effect of adoption on productivity. Our findings suggest that the adoption levels for improved seeds and associated yields are significantly higher for participating farmers, after controlling for other relevant factors. We also included questions on aflatoxin to gain insights related to awareness and the use of mitigation practices by farmers.

The study relies on data collected in 2004 and 2013 from participating farm households as well as a set of non-participating or control households. The control sample is composed of both neighbors (located in the same villages as participants) and non-neighbors (located in non-participating villages).

We found that participating farmers allocated 21% more of their available land to improved groundnut varieties. The results also show that, for improved varieties, beneficiaries produce 32% higher yields than their non-participating neighbors, and 55% higher yields relative to non-neighbor controls. This implies that the project led to significant increases in profitability for participating farmers.

In addition, we observed significant spillover from the project, which is clearly revealed by the yield difference between non-participating neighboring households and non-neighbor controls. Effectively, the beneficiaries of the project transferred some benefits to the neighbor control group over the course of the 10-year period following the project. This is itself an important result suggesting that farmer-led

programs offer additional advantages to developing communities and may provide a cost-effective means of information and technology dissemination.

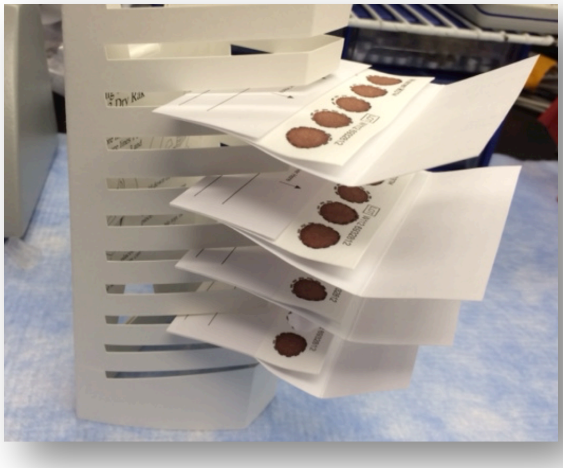
The results reveal the lasting impact of the program over the 10-year period. The sustainability of development interventions is often considered an important objective, but is rarely documented because the data required is simply not available. In other words, having data spanning a considerable time gap between the project's conclusion and the follow-up survey with minor attrition makes it possible to examine the sustainability of the original intervention.

The 2013 data also contains information about aflatoxin awareness. Based on the survey responses we concluded that there is very little knowledge of aflatoxin among all farmers interviewed. Many farmers indicated that they discard the moldy or rotten peanuts; but, on the other hand, very few farmers implement key aflatoxin mitigation practices (e.g., proper drying or storage). Apparently, additional efforts are needed to raise awareness and provide training to farmers in the groundnut growing regions of Northeastern Uganda, a notion that has been reaffirmed by our local collaborators. Moreover, the data suggests that overall yields are much lower for all groups, including those that use improved varieties, when compared to test plots.

Finally, this research provides evidence to support continued training and extension in the region, which remains an essential tool for farmers the world over.

C3. Validated Dried Blood Sample Methodology for Determining Aflatoxin Levels in Humans

The Peanut and Mycotoxin Innovation Lab had significant success in validating a method for measuring mycotoxin biomarkers, especially aflatoxin-lysine adducts, in human dried blood spot samples. This is part of an overall goal to support urgent needs of nutritional and intervention studies conducted in Asia and Africa countries by several Feed the Future Innovation Labs, USAID projects, and national programs.



Dried blood spot samples ready for extraction to determine aflatoxin concentration.

Mycotoxins are toxic fungal metabolites and are ubiquitous food contaminants, especially in peanuts and corn. These important mycotoxins have been strongly associated with acute human toxicosis, growth retardation and developmental inhibition in children, immune suppressive effects, as well as increased rates of many types of primary cancers.

In particular, aflatoxins are among the most potent and commonly occurring mycotoxins. Aflatoxin B_1 (AFB_1) is acutely toxic to all species of animals and humans, and chronic aflatoxicosis is characterized by liver damage, growth retardation and developmental inhibition in children, formations of liver cirrhosis and hepatocellular carcinoma. AFB_1 also has anti-nutritional effect and reduced vitamins and proteins in animals and humans. Further, AFB_1 has potent immunotoxic effect, which may aggravate infectious disease rates. Accurate assessment of aflatoxin exposure and evaluation of various intervention strategies are critical for improving food safety and human health. To address this need, the project scientists developed and validated a sensitive and reliable method to analyze mycotoxin biomarkers, especially for AFB_1 -lysine adduct in human dried blood spots (DBS) samples to assess susceptibility factors in determination of human aflatoxicosis, to evaluate the linkage between AF exposure and human nutrition deficiency, stunting in children, and to examine roles of aflatoxin exposure as it affects human immunity.

The DBS sampling technique has several advantages over conventional blood or plasma sampling. It is less invasive, uses smaller blood volumes, utilizes simple storage methods, minimizes shipping expenses, offers convenient sampling, and reduces the risk of blood borne pathogens. There has been a significant push in recent years for use of the DBS sampling technique in the field of biomedical research, including clinical and epidemiological studies. Having a sensitive and reliable method to evaluate mycotoxins exposures in use of these DBS samples would add value to these samples. However, there is no report about measurement of mycotoxins and their biomarkers in DBS due to many technical challenges.

During this past year, we validated the DBS method for detection of aflatoxin B_1-lysine adduct in animals and humans, and confirmed the correlation between AFB_1 exposure and levels of aflatoxin B_1-lysine adduct in DBS samples in animals and human samples. Our results showed that aflatoxin B_1-lysine adduct levels in DBS cards and serum samples from animals and from spiked human samples are comparable 95% of the time, and the DBS technique and analytical protocol has already progressed to a field study aimed to assess AFB_1 exposure in infant and children populations. In that regard, we have already analyzed aflatoxin B_1-lysine adduct in over 3,500 serum samples collected from Kenya and Uganda human population studies conducted by our collaborators.

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