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 2017

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

(Peanut & Mycotoxin Innovation Lab)

Annual Report – Fiscal Year 2017

(1 October 2016 – 30 September 2017)

PMIL Management Entity
The University of Georgia, Athens, Georgia
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Note from the Director

This is the last annual report for the Feed the Future Innovation Lab for Collaborative Research on Peanut Productivity and Mycotoxin Control (Peanut & Mycotoxin Innovation Lab, PMIL). The final year focused on completing the research activities, analyzing the data, and publishing the results. Along the way, all students supported by the program completed their thesis research, submitted their theses, and graduated from their universities. In total, more than 50 PhD and MSc students were supported over the five-year program. Many of these students already have found employment in their home countries, and many of their jobs are in the area of agriculture. We wish them all the best and look forward to partnering with many of them in research projects in the future.

Many technologies developed or tested over the life of the program were scaled out this year. The new dried blood-spot sampling technique is in use in projects in Uganda, Nepal and other countries. The improved SNP chip is providing useful genomic information for thousands of peanut lines, leading to new knowledge about the diversity of the materials and identifying markers linked to traits of interest in breeding programs. New varieties have been released and shared among breeders who are evaluating the potential to release them in their own countries. Various agronomic interventions are ready for larger-scale testing, to identify which production practices are appropriate to deliver to farmers. Data on which post-harvest practices lead to best quality and lowest aflatoxin contamination are available. In some cases, we now understand better the incentives that farmers need to adopt interventions and that knowledge will be important in designing strategies for large-scale adoption. Research into peanut processing has identified the points where interventions can best improve quality, and one study even contributed to a new national standard for peanut flour in Malawi.

The program continued to communicate results of research and other activities via social media, electronic newsletters, videos, and a new infographic describing the multiple benefits of peanuts.

While the PMIL came to an end in September, USAID did announce a call for proposals for a new Peanut Research Innovation Lab. While there may be some changes in scope and direction in the new program, I am sure that many of the PMIL scientists will be involved in the new program and will be able to build on the outcomes from the PMIL.

It has been a very busy, but satisfying five years. The success of PMIL belongs to the entire scientific team in all the countries. We hope that the results created will soon reach the peanut farmers both in the target countries and around the world.

Dave Hoisington, Director, PMIL

Acronyms

AFB	Aflatoxin B_1
AOR	Agreement Officer's Representative
APHIS	Animal and Plant Health Inspection Service, USA
APRES	American Peanut Research & Education Society
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
ELS	Early Leaf Spot
EMMP	Environmental Mitigation and Management Plan
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
IL	Innovation Lab
ISRA	Institut Sénégalais de Researches Agricoles, Senegal
KNUST	Kwame Nkrumah University of Science and Technology, Ghana
LLS	Late Leaf Spot
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	Savanna Agricultural Research Institute, Ghana
SNP	Single Nucleotide Polymorphism
SPAD	Soil Plant Analysis Development
SSR	Simple Sequence Repeat
STN-PCR	Single Tube Nested Polymerase Chain Reaction
TNAU	Tamil Nadu Agricultural University, India
UDS	University for Development Studies, Ghana
UFL	University of Florida, FL
UGA	University of Georgia, GA
UHPLC	Ultra-High Performance Liquid Chromatography
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

During the fifth and final year of the Peanut & Mycotoxin Innovation Lab, most of the focus was on completing the research activities, analyzing data and documenting the findings. While there is still a great deal of research that needs to be done, there are several significant findings and outcomes ready to scale for impact.

A new Multi-parent Advanced Generation Intercross (MAGIC) population is now ready to phenotype for a range of traits, including resistance to aflatoxin contamination. The improved SNP chip is available and already in use to genotype a range of materials. Coupling the SNP genomic information with phenotypic data will allow researchers better to identify the genes involved in numerous traits, and to develop suitable assays for these to use to breed improved varieties.

Efforts to identify genetic mechanisms for inhibiting *Aspergillus* infection and subsequent aflatoxin production in peanuts made good progress. Results have shown that the use of RNAi, or host-induced gene silencing, can inhibit the fungus from producing aflatoxin in infected peanut kernels. While the current approach involves genetic engineering, new approaches are being developed that would result in a non-genetically modified peanut. This, coupled with results published this year by other researchers, points to the possibility of an aflatoxin-free peanut in the future.

New peanut varieties continue to be developed in each of the national programs and many of these are moving towards release in the respective countries. Linking several of the programs with private seed producers has generated foundation seed that can be used to grow certified seed in new varieties for farmers. Crosses are underway to introduce the high oleic trait into locally adapted varieties to provide more nutritious peanuts with a longer shelf life.

Much of the student research supported by the PMIL focused on pre-harvest interventions and demonstrated the importance of proper planting dates, weed/disease/pest management, use of calcium, and optimal harvest dates for good yield and quality (including minimal aflatoxin contamination). Especially interesting were trials with dry planting (planting up to two weeks before the first rains), a technique that may help farmers where the rainy seasons are becoming more erratic.

Other student research focused on post-harvest aspects such as drying, storage and shelling. A solar dryer that was designed and put to use in villages in Ghana demonstrated potential in proper drying of peanuts and other crops, such as maize. Tarps also were supplied to farmers in Ghana, where a study showed that farmers will use the tarps to dry peanuts, resulting in less aflatoxin contamination, though the cost of the tarps and price premiums for quality peanuts are important factors in whether smallholder farmers will adopt the technology.

Student-run studies on processing practices used to make flour, oil and paste/butter indicated sources of contamination, especially in home processed products and/or provided critical information to influence standards for the country (e.g., Malawi released new standards for peanut flour based on the student's research).

A new infographic presents the numerous uses and benefits of growing and consuming peanuts, while four new videos from the research in Ghana describe how to produce better quality peanuts.

PMIL scientists participated in several international conferences, including the APRES conference in Albuquerque, NM where several students and scientists presented their research. Many of the results have already been published in refereed journals or are awaiting review. The PMIL Management Entity also hosted a delegation from Malawi at the Georgia Peanut Tour as part of the collaboration PMIL established with the USAID Agricultural Diversification Activity in that country.

Program Countries

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

Program Partners

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

Program Highlights

The final year of a research project is always an exciting time as final datasets are generated, findings solidified, and research partnerships mature. It is also a time when researchers and collaborators look to the future to consider next steps for research and scaling.

Two themes have emerged during the final months of the PMIL:

1) **Multi-year/Multi-location trials clarify results:** Environmental variability requires multiple years of data to be collected in multiple locations to improve our confidence in the results. Field based photoaflatoxin research is even more complex, since late season weather can greatly affect the results. Three years of multi-location data in Haiti greatly increased the confidence in the economic returns of timely fungicide applications over several varieties. Results in the Ghana VC project are being compiled and show significant seasonal variability, but the trend of the aflatoxin reduction through improved practices at each step has been significant, and the return on investment of the recommended improved practices appears robust. In Malawi, recommendations concerning planting density, and planting and harvest timing have been proven under diverse conditions and can be promoted to smallholders with few reservations.

2) **Partnerships are key for scaling and sustainability**: The strength of partnerships between public sector, NGOs, and private business has increased both the quality and uptake of PMIL research. In Malawi, collaboration has led to further investment through the local USAID mission under the Malawi Agriculture Diversification Program. The relationship between the national program breeder and commercial farming and processing operation, Exagris, has increased the amount of improved seed available to farmers and provided direct feedback of agronomic and market performance of varieties at scale. This has created an atmosphere of increased private sector investment. Likewise, students from LUANAR were integrated into the research agenda in the project and led to improved research.

   In Haiti, the partnerships continue to mature despite difficult financial and weather conditions during the past year. Acceso and MFK have made investments that subsidize the research costs,

and students from several universities have been given the opportunity to participate in meaningful, sophisticated research. These partnerships show resilience of the research agenda to resolve problems beyond the scope and duration of the PMIL.

Key Accomplishments

Blood detection method expands research impact: A PMIL-funded system that can detect mycotoxin exposure from dried blood samples was used to test 670 samples from an on-going Feed the Future Nutrition Innovation Lab study. The AflaCohort Study runs from 2015 to 2018 and involves 1,675 women ages 16-49 from 17 villages in the Banke district of Nepal, a region where children are particularly at risk for stunting. By measuring mycotoxin biomarkers, especially AFB-Lys adducts, in human dried blood spot samples, this project supports urgent needs of nutritional and intervention studies conducted in Asian and African countries by several Feed the Future Innovation Laboratories, USAID regional and country projects, and national programs.

Student research leads to new national standard: PMIL-supported student Tiwonge Longwe, who completed a master's degree in Food Science from the Lilongwe University of Agriculture and Natural Resources (LUANAR) in 2017, contributed data that helped the Malawi Bureau of Standards set a standard for groundnut flour. Longwe's research into blanching peanuts during processing provided insight into ideal moisture, protein and fat content, crude fiber and fatty acids, as well as the acceptable levels of ash.

Intervention system shows mounting results: Research in Ghana confirmed that the risk of aflatoxin contamination compounds at each stage of production, drying and storage. Using interventions to reduce aflatoxin accumulation, the project quantified the effectiveness of improved farmer practices (one additional weeding, applying soap to suppress pests and applying calcium); drying on the ground versus a tarp; and storing nuts in a poly sack or a sealed bag. Taking the interventions individually and in combination, the data shows which are more impactful, information that will help farmers choose pre- and post-harvest practices to prevent contamination.

Breeder consortium sharing knowledge and materials: Through PMIL, breeders in Senegal, Ghana, Uganda, Malawi, Zambia and Mozambique are sharing ideas and germplasm to solve problems. New genetic materials produced by a Senegalese scientist incorporates genetic material from peanut's wild relatives, is being evaluated by other breeding programs, and will be used to develop new varieties with improved traits of local interest.

Innovative aflatoxin solution gains attention: Scientists have gained a better understanding of the RNA interference processes that occur inside the peanut plant leading to the silencing of aflatoxin-synthesis genes. (A paper was published and another two are in progress.) We have also generated a workflow to choose and sequence genomes of representative *Aspergillus* colonizing peanut seeds in the USA and in Ethiopia (one paper published, another in progress).

Updated marker selection tool improves quality and reduces cost: Reliable genome-wide genotyping methods for cultivated peanut were developed and tested with lines and populations relevant to the project. All peanut breeders and ultimately growers should benefit from this progress in that the technology enables discovery of molecular marker-trait associations and informs the development of

marker-assisted selection tools to facilitate breeding for important traits. A 60K SNP array, constructed through a collaborative effort with ICRISAT and through ingenious SNP discovery methods pioneered by a UGA graduate student were the key initial resources. A second 48K SNP array also is now available to the entire peanut community, and the cost was reduced from $52 to $28 per sample.

Leveraged Feed the Future funds produced video reaching wide audience: Using data and analysis from the PMIL project, three farmer training videos and a mini-documentary were produced to show aflatoxin prevention interventions in practice in Ghana through the USAID Scaling Innovation through Video grant. In the first training video, a plant pathologist introduces aflatoxin, the dangers it poses to health, and preventative measures that can be taken to reduce and prevent contamination. A second video covers four basic harvest and post-harvest practices for aflatoxin prevention (timely harvest, careful drying, proper sorting and good storage), and a third describes how farmers can earn higher profits from aflatoxin-safe groundnuts. The videos have been shared with the Ghana Trade and Livelihood Coalition, Peasant Farmers Association of Ghana, Northern Development Society, Shea Network Ghana, Grameen Ghana, Netherlands Development Organization).

Aflatoxin impact on marketing (Gonja, high-resolution)

Gender impact recognized in first peanut farmer surveys in Haiti: Two large surveys of peanut farmers in Haiti have been completed with a focus on gender, productivity and household income, representing the first data to be collected on this population. Analysis of the data concluded that female-headed households are as productive in terms of peanut yields as male-headed households. In addition, higher peanut yields were reported in households where decisions are made jointly by the husband and wife.

Research Program Overview and Structure

PMIL aims to increase the productivity and profitability of peanut production for smallholder farmers and to reduce the negative impacts of mycotoxin contamination along the value chain of peanut and other crops in five Feed the Future countries – Haiti, Ghana, Malawi, Mozambique, and Zambia. The research program is organized into three main areas: (a) peanut germplasm development, (b) mycotoxin detection and peanut nutritional studies, and (c) peanut value chain interventions to increase quantity, decrease mycotoxin contamination and enhance economic returns to smallholder farmers. The FY2017 program supported 10 of the following 12 research projects. Each project is coordinated by a Principal Investigator located at a US university or USDA-ARS research station. The B3 project entitled "Aflatoxin in Peanut and Peanut Products: Comparative Study on Analytical Methods for Detection of Aflatoxin" was completed in FY2015 and B4 entitled "Randomized Controlled Trial of the Impact of Treating Moderately Malnourished Women in Pregnancy" was completed in FY2016.

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 ***– COMPLETED FY15***	Kumar Mallikarjunan	Virginia Polytechnic Institute and State University
B4. Randomized Controlled Trial of the Impact of Treating Moderately Malnourished Women in Pregnancy – ***COMPLETED FY16***	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 was to associate molecular variation with resistance to pre-harvest aflatoxin contamination and other traits on a genome-wide scale and to begin to utilize this information in breeding programs. To achieve the goal, both genotyping and highly replicated phenotyping of genetic resources and populations for aflatoxin contamination were pursued. Genotyping with genome-wide SNP (single-nucleotide polymorphism) markers was enabled by peanut genome sequence information, both from cultivated tetraploid genotypes as well as diploid progenitors of the tetraploid. Genetic populations were developed in India, Senegal, and the USA. Phenotyping was done under controlled field conditions in Nigeria, Ghana, Mali, Senegal, and the USA.

Collaborators

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

Achievements

Genotyping. A second version Affymetrix Axiom_Arachis2 single nucleotide polymorphism (SNP) array was designed and constructed through the efforts of Josh Clevenger and Peggy Ozias-Akins. Information to support the design was derived from empirical data generated with the version 1 array along with application of a new SNP discovery algorithm based on machine learning (Korani *et al*., PLOS One, submitted). The version 2 array includes 48K total markers (4,489 simple SNPs from Version 1; 7,861 interspecific SNPs from version 1; 35,650 newly discovered SNPs and the yield of polymorphic SNPs among cultivated parents is double that compared with version 1.

For example, among a nested association mapping population with US cultivars/breeding lines including two common and eight unique parents, version 1 yielded 7,460 non-redundant SNPs and version 2 yielded 14,672 non-redundant SNPs (Chu *et al*. Peanut Sci, submitted). For evaluation with the first set of 384 diverse genotypes, 30,539 polymorphic *A. hypogaea* SNPs were identified, and among these 18,426 SNPs were polymorphic within a set of 161 US mini-core and African cultivar/breeding line accessions. Furthermore, the cost per sample was reduced from $52 per sample for Arachis1 to $28 for Arachis2. The array is now available to the larger peanut community.

Phenotyping. Phenotyping for resistance to preharvest aflatoxin contamination continued in 2017. All entries have a minimum of three and a maximum of five reps for each, grown under late-season drought stress that is either naturally occurring (Africa) or simulated (US). The aflatoxin test in the USA had to be terminated in 2017 after rainout shelters were destroyed by Hurricane Irma. Materials were collected

for seed increase, however. For ICRISAT, two sets of preliminary trials (each 36 varieties) were conducted to evaluate advanced breeding lines for drought tolerance and low aflatoxin contamination. Pod yields ranged from 420–1998 kg/ha. Selections were included in regional trials for 2017 sent to Ghana, Mali and Nigeria. Also nurseries were planted for six sets of early generation population/crosses (F1-F5) containing more than 160 populations with the objective to identify short duration, drought tolerant and low aflatoxin contamination lines. Populations were advanced to next generation using main and off-seasons to develop at least 20 new populations during 2017 main season to identify drought tolerant and low aflatoxin contamination lines.

The chromosome segment substitution lines (CSSLs) developed in Senegal were phenotyped in the USA in 2017 for multiple traits (seed protein, oil, and sugar composition; branching habit, flowering pattern, flowering frequency; and other vegetative and reproductive traits). The lines also were genotyped on the Axiom_Arachis1 array. The SNP genotyping enables higher resolution delineation of regions introgressed into a Fleur 11 (predominant variety in Senegal) background and will aid in mapping of traits from the wild-progenitor accessions.

A field test of the chromosome segment substitution line population was conducted under artificial inoculation by *Aspergillus flavus* at Nioro Research Station, Senegal. After harvest, aflatoxin in the kernels was very low for all the entries since conditions were not conducive to contamination this season. The trial is being repeated at the same location. In addition, an *in vitro Aspergillus flavus* seed colonization test was conducted using a panel of 60 CSSLs and seven local lines as checks including 55-437 (ICG 1471) and Fleur 11. Two lines had a low incidence of colonization, 12CS_037 (13% colonization) and 12CS_084 (15%), significantly different to that of the check, Fleur 11 (33%). Line 12CS_037 (5% severity) also was lower in severity compared with Fleur 11 (14%).

MAGIC Population. ICRISAT-Patancheru has completed development of a Multi-parent Advanced Generation Intercross (MAGIC) population using eight diverse genotypes possessing resistance to PAC, drought tolerance, disease resistance, dormancy, early maturity and oil quality. A total of 3,000 MAGIC lines are available in F6 generation for further yield evaluation. The eight parental lines included two reportedly aflatoxin-contamination-resistant lines, 55-437 (ICG 1471) and ICGV 88145, and UGA's *in vitro* data supports the conclusion of strong resistance in 55-437 (Korani *et al*. 2017), although field data indicate an intermediate contamination ranking for both.

Capacity Building

Davis Gimode, a PhD student from Kenya, matriculated at UGA in August 2015, completed most of his coursework by summer 2016, and conducted research in Tifton from August 2016 through 2017. His research is focused on the chromosome segment substitution lines derived from interspecific hybridization and generated/studied by the co-PIs in Senegal, Daniel Fonceka and Issa Faye. In 2017 Davis presented his research at the international CROPS meeting at HudsonAlpha Institute in Huntsville, AL (A genomic selection approach to peanut breeding) and at Institute of Plant Breeding, Genetics & Genomics and Plant Center retreats (Tracking of wild allele introgressions in a peanut chromosome segment substitution line population). The project also hosted a Borlaug Fellow from Ghana, Daniel Oppong-Sekyere, for three months during which time materials from Ghana were genotyped.

Lessons Learned

The use of genotyping-by-sequencing (GBS) in cultivated peanut germplasm is not as cost-effective or high-yielding as array genotyping given the low level of SNP polymorphisms that can be detected even with an improved SNP calling pipeline and the amount of missing data encountered.

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

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

Presentations and Publications

Publications (peer-reviewed)

Clevenger J, Chu Y, Chavarro C, Agarwal G, Bertioli DJ, Leal-Bertioli SCM, Pandey MK, Vaughn J, Abernathy B, Barkley NA, Hovav R, Burow M, Nayak S, Isleib T, Holbrook CC, Pandey M, Varshney RK, Ozias-Akins P. 2016. Signatures of selection and tetrasomic recombination in peanut resolved by genome-wide SNP genotyping. Mol Plant http://dx.doi.org/10.1016/j.molp.2016.11.015.

Pandey M, Agrawal G, Kale S, Clevenger J, Nayak S, Sriswathi M, Chitikineni A, Chavarro C, Chen X, Upadhyaya H, Vishwakarma MK, Leal-Bertioli, Liang X, Bertioli D, Guo B, Jackson S, Ozias-Akins P, Varshney RK. 2017. Development and Evaluation of a High Density Genotyping 'Axiom_*Arachis*' Array with 58K SNPs for Accelerating Genetics and Breeding in Groundnut. Sci. Rep. 7:40577 doi:10.1038/srep40577.

Clevenger JP, Marasigan K, Liakos B, Sobolev V, Vellidis G, Holbrook CC, Ozias-Akins P. 2016. RNA sequencing of contaminated seeds reveals the state of the seed permissive for pre-harvest aflatoxin contamination and points to a potential susceptibility factor. Toxins 8:317.

Korani WA, Chu Y, Holbrook C, Clevenger J, Ozias-Akins P. 2017. Genotypic Regulation of Aflatoxin Accumulation but not *Aspergillus* Fungal Growth upon Post-Harvest Infection of Peanut (*Arachis hypogaea* L.) Seeds. Toxins 9:218; doi:10.3390/toxins9070218.

Publications (peer-reviewed, submitted)

Chu Y, Holbrook CC, Isleib TG, Burow M, Culbreath AK, Tillman B, Chen J, Clevenger J, Ozias-Akins P. 2017. Phenotyping and genotyping parents of sixteen recombinant inbred peanut populations. Peanut Science (submitted)

Korani W, Clevenger JP, Chu Y, Ozias-Akins P. 2017. Machine learning as an effective method for identifying true SNPs in polyploid plants. PLOS One (submitted)

Korani W, Chu Y, Holbrook CC, Ozias-Akins P. 2017. Transcriptional profiling provides insight into genetic factors regulating post-harvest aflatoxin contamination of tetraploid peanut. Genetics (submitted)

Presentations

Korani WA, Chu Y, Holbrook C, Clevenger J, Ozias-Akins P. 2017. Alpha-linolenic acid metabolism differentially regulates post-harvest aflatoxin accumulation in peanuts. National Assoc. Plant Breeders, Aug, Davis, CA.

Clevenger JP, Korani W, Chu Y, Ozias-Akins P. 2017. Axiom_Arachis2 Genotyping Resource for Peanut. Annual Meeting of American Peanut Research and Education Society, Jul, Albuquerque, NM.

Chu Y, Holbrook CC, Isleib TG, Burow M, Culbreath AK, Tillman B, Chen J, Chavarro C, Jackson SA, Ozias-Akins P. 2017. Phenotyping and genotyping parents of sixteen recombinant inbred peanut populations. Annual Meeting of American Peanut Research and Education Society, Jul, Albuquerque, NM.

Clevenger J, Korani W, Chu Y, Karikari A, Holbrook CC, Ozias-Akins P. 2017. Aflatoxin permissive transcriptional states in peanut seeds. InterDrought-V. Feb. Hyderabad, India.

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

The overall goal of this project is to use RNA interference (RNAi) to reduce aflatoxin contamination of peanut seeds. The research has two main objectives: 1) develop RNA interference (RNAi) technology to reduce/eliminate aflatoxin accumulation in peanut (mainly funded by Feed the Future-NBCRI); and 2) analyze the genetic diversity of aflatoxigenic *Aspergillus* species in sub-Saharan African countries (Ethiopia, Kenya, Malawi, Tanzania, Uganda and Zambia) and the USA, which will allow adapting the RNAi technology to each geographic area (work mainly funded by PMIL).

The first objective was the most challenging because it had never been demonstrated that RNAi produced in a plant could silence aflatoxin-synthesis genes in the fungus *Aspergillus* and because the technology to prove this concept, including how to test its effectiveness without performing extensive and multi-year field trials, had to be developed within this project.

The second objective, though apparently straightforward, required developing the adequate molecular tools. These tools had to be effective, doable at a reasonable cost, and required logistics, permits and research agreements for work that extended across many countries. Once the proof of concept in the use of RNAi against aflatoxin is demonstrated, and the predominant genotypes of aflatoxigenic *Aspergillus* are identified in each geographic area, the technology will be transferred to and adapted for each region.

Collaborators

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

Achievements

- A method was developed and published for the single-peanut-seed challenging and aflatoxin analysis by ultra-high performance-liquid chromatography that allows researchers to evaluate the effectiveness of RNAi (RNA interference) to prevent aflatoxin accumulation on RNAi-transformed seeds. The method was recently used by a research group in India (Kumar et al 2017) to test their RNAi-transformant peanuts.
- Work that started at the NPRL in 2011 to use RNAi technology to control aflatoxins in peanut was brought to fruition, demonstrating that RNAi fragments used in peanut plants to silence aflatoxin-synthesis genes can actually prevent aflatoxin accumulation in peanut seeds, even when the seeds are infected with *Aspergillus flavus*. One article has been published (Arias et al., 2017) and a second is in preparation.
- In addition to demonstrating RNAi-mediated prevention of aflatoxin accumulation in peanuts, we began to characterize and published the type of small RNAs produced in peanut plants. We have also submitted for publication additional research on small RNAs in peanuts.
- Work at the NPRL with the support of PMIL allowed for the fast development of a workflow in the population genetics of *Aspergillus*, fungi responsible for the accumulation of aflatoxins in seeds. The now-published workflow uses the genetic fingerprinting of hundreds of *Aspergillus* isolates using insertion/deletion (InDel) markers, and the most abundant genotype representatives are selected for whole-genome sequencing. The sequencing information can be

used to design more effective RNAi-targeted sequences to control aflatoxin accumulation on specific geographic areas. This workflow, initially developed using samples from the USA, now has been applied to samples from Ethiopia, and the work was submitted for publication.

- Created and maintained a collection of more than 2000 *Aspergillus* isolates from peanut and soil, with samples from Ethiopia, Uganda, Malawi, Tanzania, Zambia and the USA; the collection is curated at the USDA-ARS-NPRL.

Capacity Building

During FY17, one graduate student from Africa and two postdoctoral scientists received training in current molecular biology techniques, then applied these techniques to specific objectives within this project.

Lessons Learned

There is a great need for the transfer of skills, from simple technologies to help farmers in Sub-Saharan African countries, to current laboratory tools to build the next generation of scientists in those countries.

Investing even a short time in providing training to foreign students can have a significant impact in their careers and their countries, e.g., the Ph.D. student Abdi Mohammed who received training at USDA-ARS-National Peanut Research Laboratory, Dawson, GA, has now been hired by Haramaya University in Ethiopia as an assistant professor.

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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 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 economically important pathogens and pests, while the primary abiotic stress addressed is drought through tolerance and avoidance (short-duration), 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 to other developing countries that request the material.

Research can bring higher yields and better 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. Developing in-country knowledge, expertise and improved infrastructure through long term relationships in the PMIL increases local capacity to continue improving peanut yields and quality.

Collaborators

Name	Institution	Country	Role
Mike Deom	University of Georgia	USA	PI
Boris Bravo-Ureta	University of Connecticut	USA	Co-PI
Mark Burow	Texas A&M University	USA	Co-PI
Patrick Okori	ICRISAT	Malawi	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
Justus Chintu	DARS	Malawi	Partner
Nicholas Denwar	CSIR-SARI	Ghana	Partner
Lutangu Makweti	ZARI	Zambia	Partner
Damaris Odeny	ICRISAT	Kenya	Partner
David Okello	NaSARRI	Uganda	Partner
Amade Muitia	IIAM	Mozambique	Partner
Phillippe Sankara	University of Ouagadougou	Burkina Faso	Partner

Achievements

Haiti (with the University of Florida)

Researchers identified 15 high yielding Bolivian landraces with ELS resistance; trained the new in-country plant breeder, Dr. Raphael Colbert; and transferred 40 breeding lines and 15 Bolivian lines to Dr. Colbert for testing and selection. Dr. Colbert has previously worked primarily on common beans, but he and his team now have proven experience in generating quality data to evaluate peanut lines in Haiti and are integrating with the Value Chain research team.

Ghana & Burkina Faso (with Texas A&M University)

- Two leaf spot-resistant peanut varieties in Ghana (one is high oleic) were analyzed.
- New populations of erect-type peanut were advanced and may combine high yield, high oleic fatty acid content, and leaf spot resistance in Ghana, Burkina Faso and Texas. Approximately 200 high oleic Spanish lines are being developed in Texas and are being increased in Ghana and Burkina Faso prior to testing. Pre-release analysis was completed for one aflatoxin-resistant line developed originally by ICRISAT and tested under the PMIL.
- Testing continued for ICRISAT drought/aflatoxin tolerant lines and US peanut mini-core accessions in Burkina Faso.
- A second backcross was done of a high-oil, wild-species hybrid and cultivated peanut, accomplished with material from wild peanut hybrid with 64% oil content.
- Increases were done of Spanish populations made to combine large seeds and high oleic oil.
- A high-oleic Valencia peanut was released in Texas. The variety, TAMVal OL, out-yielded the standard Valencia check variety, New Mexico Valencia C, by 25% in extension trials, and earned an estimated additional $82 per acre.
- Six SSR markers were validated for yield under drought stress in F_2 populations in Texas.
- KASP-based markers have been developed for the high-O/L trait and are being used for selection in developed populations.
- SNP-based map of diploid peanut from the B genome of *A. gregory* x *A. magna*, 122 F2 seed were produced.
- SNP-based map from the TxAG-6 x Florunner cross (BC_1) consisting so far of 150 SNP based markers on 20 linkage groups has been developed and genotyped, while QTL analysis is underway using leaf spot and rust data.

Malawi

- Identified eight lines tolerant to drought and three lines resistant to GRD following evaluation of NMSU breeding lines.

Mozambique (with New Mexico State University)

- High iron and zinc lines from ICRISAT were crossed with NuMex-01 high oleic Valencia, while NMSU breeding lines were evaluated in Mozambique, Malawi and Zambia.
- High oleic Valencia peanuts have been introduced in Mozambique, Malawi, Zambia and Haiti.
- New breeding lines 309-red (testa color red with high oleic content) and 309-tan (testa color tan with normal oleic content and resistance to Sclerotinia) were registered in Mozambique seed release system. The lines have a sweet taste, high oleic content and short growing season.
- Three crosses involving Valencia C (female parent) with JUG 03 (High SPAD chlorophyll) and ICG 7243 (drought tolerant) were generated and the populations were advanced to F7. Evaluations will be done at NMSU in 2018. Promising lines will be tested for adaptation and yield potential in the US, India, Malawi, Mozambique and Zambia.

Uganda (with the University of Georgia)

- Two extra early (75-85 days) high-yielding tan and red lines that are resistant to drought, GRD and LLS underwent last distinctness, uniformity and stability tests in August 2017 prior to release, which was expected in late 2017 or early 2018.
- Popular landraces (Erudurudu, Gwerinut and Acholi white) were improved and trials held in anticipation of release in 2018/2019 seasons.
- 60 advanced NaSARRI/ICRISAT lines (tan and red) were developed with multiple resistances to drought, GRD, and LLS, as well as confectionery quality, early to medium maturity and high yield. Some will be advanced for release and others will become breeding lines.
- 1.5 tons of early generation seeds (breeder and foundation) were produced on-station

- Educational materials (14,000 factsheets, 2,000 brochures, 1,300 books and manuals, 300 pocket folders, two pull-up banners, two documentaries, and two cartoon animations) were produced, printed and distributed during training, field days, and agricultural shows.

Zambia

- Two GRD resistant varieties were submitted to the Variety Release Committee for testing and release.
- National Performance Trials were conducted at nine sites for GRD resistant lines, four sites for the NuMex line and ELS-resistant variety and three sites for nutrient dense (zinc and iron) varieties.
- Nine farmer field days were conducted with 408 farmers (170 female and 238 male)
- 1673 farmers (531 female and 1142 male) attended field days at the Farmer Training Center and Msekera Research Station.
- 5000 copies of assorted materials (groundnut production guides in Chewa and English, aflatoxin brochures and One Handful infographics) were distributed to farmers and extension officers during field days.
- 35 Ugandan GRD-resistant lines were selected for evaluation in Zambia during a trip to NaSARRI in June.
- ICRISAT has supported the release proposals for ICGV-SM 01711 (moderately resistant to GRD) and ICGV-SM 01514 (early maturing and GRD-resistant).

ICRISAT- Malawi & Kenya

- Of 16 test lines screened, six were resistant to ELS and provided higher yields than the check.
- Of 36 lines screened for drought tolerance, two lines performed relatively well with higher yields than checks.
- Three new sources of resistance for GRD and three for rust were identified from ICRISAT mini-core and will be used to improve popular varieties of the region.
- Researchers screened a cross between ICGV 93437 (Nyanda, a drought tolerant line) and ICGV 95342 (rust resistant line) for drought tolerance. From the 25 lines, eight had relatively good performance based on the physiological data, grain yield, hundred seed weight, drought tolerance index and percentage yield loss reduction.
- Nutrient dense (zinc and high oleic) crosses from three botanical groups (Valencia, Virginia and Spanish) are currently at F_4. A total of 1500 F_3 leaf samples were analyzed using molecular markers for high oleic acid with more than 30% of the samples testing positive for the high-oleic marker.

Capacity Building

- *Haiti* – Quisqueya University plant breeder Raphael Colbert trained on peanut breeding at the University of Florida. Haitian agricultural consultants, buyers and professionals were trained in Cap Haitian.
- *Ghana & Burkina Faso* – A weather station was provided to the Burkina Faso Pobe station for use in drought-tolerance work. A bay for seed processing was constructed in Ghana. Several students received training in Burkina Faso, Ghana and Texas.
- *Malawi* – Collaboration with ExAgris has increased seed multiplication capacity, while the AgDiv project has installed a drip irrigation plot to increase seed production and potentially allow for multiplication during the dry season.
- *Mozambique* – Two MSc students finished coursework and returned to their jobs at IIAM.
- *Uganda* – Irrigation was installed on a 4-hectare tract, complementing a previously completed greenhouse renovation.
- *Zambia* – Lutangu Makweti`s MSc research was partly funded by PMIL.

Lessons Learned

Haiti – The environmental variability presented by the various localities in Haiti makes breeding and selection outside of Haiti much less effective than in-country breeding and selection. Valencia peanuts are preferred over long-duration varieties because they have a short growing season and allow for double cropping. This helps the growers to get paid twice instead of waiting for a long period of time.

Ghana & Burkina Faso – Co-PIs benefit from joint meetings where they can exchange ideas and materials, allowing for enhanced collaboration.

Malawi – In order to increase groundnut productivity in Malawi, it is crucial that farmers have access to improved varieties and good quality seed. Building the capacity of the groundnut improvement program (at DARS-Chitedze) to develop varieties and produce seed can greatly enhance production of groundnut. DARS-Chitedze needs an improved seed storage facility to provide better seed for the breeding program. To encourage adoption of new varieties, various stakeholders along the groundnut value chain should be involved in developing varieties suitable for the market. Agricultural shows, seed fairs and field days are very good ways for researchers and farmers to sharing knowledge and information.

Mozambique – There is a lot of potential for Valencia peanuts due to their short duration and drought tolerance. The biggest challenge is to incorporate the GRD resistance in Valencia or to grow in areas where GRD pressure is lower like in Namapa and Mapupulo.

Uganda – Development of climate-smart high yielding varieties (early maturing, drought tolerant) is key to future groundnut research and development. Community seed production through seed banks can spread improved varieties in areas usually neglected by the formal seed system.

A multi-stakeholder platform to advance the research and development agendas of groundnuts has been formed to bring key players together to speak with a unified voice in order to affect policy, research and commerce. Networking with key players in the value chain and synchronizing role played by various intervention agencies is helping to avoid duplications and successfully scale the output of such interventions at a National Level.

Capacity-building – both informal and formal – is key to grow awareness, adoption, utilization and sustainability of groundnut technologies. Capturing success stories in innovative ways and using those stories during trainings can help to teach and motivate farmers. Materials that are succinct, presented in visuals and translated into local languages can help farmers to learn faster.

Swaying farmers to adopt improved varieties requires a comprehensive approach including demonstration, education, training, and credit. Producing quality seed requires different, more rigorous management practices and access to resources and facilities than those required for crop production. Therefore, tailored training programs are also required. Integrating rapid multiplication technology and linking it with end users such as processors is improving the marginal economic value of crops and attracting private-sector interest.

There is need for the larger scale, formal market (processors) to provide pull to the seed systems. There is a need for effective seed demand forecasting to guide the supply chain. Despite the emphasis on formal channel of seed distribution, the farmer-to-farmer seed system remains dominant, but needs strengthening.

Zambia – The availability of improved seed remains a big challenge in groundnuts and thereby affects productivity. Farmer links to markets are not well developed or formalized. Aflatoxin awareness and mitigation measures should be intensified. Breeders need to identify more partners in the seed business to help with dissemination of new technologies.

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B. Mycotoxin Detection and Peanut Nutritional Studies

Project B1. AflaGoggles for Screening Aflatoxin Contamination in Maize

The Aflagoggles project created a wearable device that allowed a user to screen maize for aflatoxin contamination.

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 a portable, rapid, and non-destructive technology that will allow these farmers to detect aflatoxin in maize and peanut. Therefore, the goal of the project is to develop a portable, fluorescence spectral-based technology for rapid and non-destructive aflatoxin detection in maize (and peanut).

Collaborators

Name	Institution	Country	Role
Haibo Yao	Mississippi State University	USA	PI
Robert Brown	USDA-ARS	USA	Co-PI
Kanniah Rajasekaran	USDA-ARS	USA	Co-PI

Achievements

The project team has completed all research project objectives in previous years' project implementation. The finished portable aflatoxin contamination detection device was reviewed by the external review team in 2016. Based on the suggestions, an additional experiment was conducted in 2017. In this experiment, silk inoculated maize samples were prepared in the field during the 2016 growth season to ensure a realistic contamination level for proper evaluation. A total of 100 samples of 50 g each were screened by the detection device. With a rejection rate of less than 1.5%, the contaminated maize kernels (mean aflatoxin = 62 ppb) were sorted out from the total samples. The cleaned samples have a mean aflatoxin equal to 1.2 ppb. The results help to evaluate performance of the device in the mid-range of aflatoxin contamination.

Additionally, the project team has developed a small UVLED array that fits in a goggle-type enclosure. The UVLED array is powered by a rechargeable battery pack. The goggle prototype still is being tested and evaluated. The initial results showed inconsistent detection, therefore, further research and testing is needed in order to improve the detection accuracy.

Finally, based on the suggestion of the evaluation team, contaminated peanut samples were also studied during this period with both hyperspectral imaging and also near-infrared spectroscopy. For this work, a total of 270 peanut kernels were used. The kernels were treated with aflatoxin producing and non-aflatoxin producing strains of *Aspergillus flavus*. It was found with near-infrared spectroscopy the overall classification accuracy was 95.6% to separate the moldy and healthy kernels. To differentiate the infected kernels with different molds, the accuracy was 84.4%. Similar results were also observed with hyperspectral imaging analysis.

Lessons Learned

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

When designing a testing method for aflatoxin, it is important to visit focus countries in the beginning (within six months of the start date) to have a good understanding of the environment for the proposed application and to network with collaborators. The main scientific challenge is to understand the interaction between fungal infection and aflatoxin production in both toxigenic and atoxigenic fungal strains.

Publications (peer-reviewed)

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Presentations

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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 by the Feed the Future PMIL and Nutrition Innovation Laboratory (NIL). The method has been validated and applied to assess susceptibility factors in determination of human aflatoxicosis, to evaluate the linkage between aflatoxin exposure and human nutrition deficiency, growth retardation and developmental inhibition in children.

Collaborators

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

Achievements

In this final funding year, we focused on the final proposed objective, i.e. application of the method for detection of AFB-Lys adducts in a large number of DBS samples collected from an on-going cohort study in a high-risk area for childhood stunting. The AflaCohort Study, conducted by the USAID Feed the Future Nutrition Innovation Laboratory, runs from 2015 to 2018, and a total of 1,675 pregnant women ages 16-49 were recruited from 17 villages in the Banke district, Nepal. A total number of 670 DBS samples collected in three batches were processed for analysis of AFB-Lys adduct. In the first batch of 128 DBS samples, 94.53% (121/128) had detectable AFB-Lys adduct (>0.4 pg/mg albumin) with geometric mean of 1.77 pg/mg albumin and 95% confidence interval of 1.64-1.91. In the second batch of 320 DBS samples, 100% (320/320) had detectable AFB-Lys adduct (>0.4 pg/mg albumin) with geometric mean of 2.92 pg/mg albumin and 95% confidence interval of 2.77-3.08. In the third batch of 222 DBS samples, 100% (222/222) had detectable AFB-Lys adduct (>0.4 pg/mg albumin) with geometric mean of 8.94 pg/mg albumin and 95% confidence interval of 8.49-9.42. Statistically significant difference ($P< 0.01$) was found among these three batches of samples collected during different times of the year.

Results of this study are important and significant because they further demonstrate that our previously developed HPLC-florescence method is valid in detecting the AFB-Lys adducts in DBS samples collected in the field, and the method is ready for large-scale application in epidemiological studies investigating aflatoxin exposure in infants and children and outcomes of their growth and development.

Capacity Building

We completed all three objectives for development and validation of the method for measurement of AFB-Lys adduct from DBS card. The method has been moved to application for large scale of samples collected by USAID Feed the Future Innovation Laboratories. In addition, we continue supporting research projects conducted by PMIL investigators and other investigators for assessment of aflatoxin exposure for their study populations in Malawi, Nepal, and Uganda.

Lessons Learned

Although the DBS method for measuring AFB-lysine adduct was developed, funding restrictions limited adoption of the method to Nutrition Innovation Laboratory studies in Uganda and Nepal. Efforts will be devoted to the collaborations within PMIL targeted countries.

Publications (peer-reviewed)

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Presentations

Society of Toxicology Annual Meeting, Baltimore, Maryland, March 9-14, 2016.

International Symposium on Food Safety on **"**Advances in Researches of Mycotoxin and Mycotoxicoses**"**, November 28-December 1, 2016, Hangzhou, China.

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

This project was completed in FY2015.

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

This project was completed in FY2016.

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 problems with productivity, quality and aflatoxin contamination.

In this project, we developed a comprehensive production, processing and utilization strategy for peanuts in Haiti. All phases of peanut production were evaluated, including varieties specific to the region and market influences. We instituted a seed-increase program and developed 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 was done, along with evaluating the infrastructure to improve peanut handling, drying and long-term storage.

Once these improvements were evaluated, we took 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 provided training and infrastructure support to realize these improvements and ensure long-term capacity building. Surveys in all phases of the project have captured the role women play in the peanut value chain. We also establish aflatoxin-testing facilities and re-trained Haitians in how to measure aflatoxin contamination and the importance of avoiding aflatoxin. Another important capacity-building measure involved the creation of alternative products/markets for highly contaminated peanuts.

Collaborators

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

Achievements

Objective 1. Assessment of production practices and improved technologies on potential productivity increases in Haitian peanut

Surveys were conducted in cooperation with Acceso depots in northern Haiti and the Central Plateau regions to assess knowledge of peanut production among female- and male-headed households in terms of yield and post-harvest practices important for improving yield and preventing aflatoxin contamination. Analysis of the data concluded that female-headed households are as productive in terms of peanut yields as male-headed households. In addition, higher peanut yields were found in households where the decisions are made jointly by the husband and wife. No significant differences on post-harvest practices were found between men and women when it comes to the use of a tarp for drying peanuts, a technology that would reduce the likelihood of aflatoxin contamination. Farmers with more education, who had off-farm employment and whose who used of herbicides – all likely indicators of wealthier households with more available capital to invest in production – were more likely to use a tarp.

Objective 2. The impact of improved peanut varieties and fungicide applications on peanut productivity and profitability in Haiti

Analysis was done on results from trials UGA plant pathologists conducted in northern Haiti and the Central Plateau to gauge the effect of fungicide applications on peanut yield and economic profits. A varying price scheme was applied to peanut yield results to provide additional insight into potential revenues to be realized by Haitian farmers. The results showed overwhelmingly that net farm-level incomes increase significantly given a small up-front investment in disease management.

Objective 3. Disease management, fertility, seed spacing and variety trials

Research-based trials were conducted in northern Haiti and the Central Plateau regions to assess the impacts of managing diseases (leafspot and rust), the addition of phosphorus fertilizer, changes in row and seed spacing, and comparison of local and improved varieties. Results from the disease-management trials indicated that foliar disease presence tends to increase while yields decrease with fewer fungicide inputs (83% and 43% for the local Haitian runner and Georgia-06G without fungicide treatment). A minimum of three to four fungicide applications can provide comparable levels of disease control and increase yields for the local and improved runner varieties. The amount of sound mature kernels is not significantly affected by disease management and the improved US runner variety, Georgia-06G, yields significantly more than the local Haitian runner. Similar results were observed for Valencia peanuts, although fewer fungicide applications (only two or three compared to three or four) were needed due to the shorter maturities of the Valencia varieties. There was no difference between the local variety and improved varieties in terms of yield and disease tolerance. Fertility trials showed no improvement of yield with the addition of fertilizers, but residual fertility of the research trial field could have masked results. Response to phosphorus has been noted in earlier research. Yield of local runner is less affected by planting density than the local Valencia. Although there were between-row by within-row interactions, within-row spacing appears to be more important than between-row for the local Valencia, and while decreasing between-row spacing also tended to increase yield of the local Valencia, it appears that the 18-inch row spacing is almost as high as the 12-inch row spacing. Final recommendations will depend on the return on investment; however, these data suggest that 18-inch row spacing planted as three to six seed/ft. would be the most practical option for growers in Haiti. It should be noted that these trials were conducted with seeds of extremely high quality, and this is not often the case in many grower situations in Haiti. Therefore, recommended seeding rates may need to be slightly higher than normal in order to compensate for the lower seed quality (germination).

Objective 4. Improve ability to detect aflatoxin contamination in peanuts, and utilize aflatoxin contaminated peanuts.

We continue to support the labs at iF Foundation, Meds & Food for Kids, Faculté d'Agronomie et de Médecine Vétérinaire (FAMV), and Université d'État d'Haïti in Bon Repos in aflatoxin detection methodology and in conducting feeding trials of contaminated peanut meal to dairy cows and chickens. Eggs from four different diet groups from a demonstration farm in Haiti were tested for aflatoxin residues using high performance liquid chromatography (HPLC). According to the results of analyses, only aflatoxin B1 and traces of aflatoxin G1 were found in the eggs. The highest aflatoxin B1 amount detected was 0.11 ppb and the trace of aflatoxin G1 detected was not quantifiable. The results indicate that residues of aflatoxin in the eggs were well below the level set by the US Food and Drug Administration. However, due to the negative impacts that aflatoxin has on chickens, further experiments concerning how one might process contaminated peanuts to minimize these effects are needed. Also, any aflatoxin present in feedstuffs will carryover into dairy milk, thus negating the use of peanut meal for dairy cow feed.

Capacity Building

The integration of agronomy students from local universities pursuing their final year research project has been significant in local capacity development for research design and implementation. In total, 34 undergraduate students from four universities in the north of Haiti participated in the intern program managed by MFK.

Lessons Learned

- Survey data suggest higher education levels appear to be linked to an increase in the adoption of post-harvest practices and productivity.
- Yield can be increased, adoption is limited due to social and financial constraints.
- The facilities at MFK and Coup Gorge are good for disease and variety evaluation, but high residual fertility is problematic when evaluating the impact of fertilizers and seed spacing. Farmer fields would be better.
- Aflatoxin in animal feed continues to be a major challenge for dealing with high aflatoxin contaminated peanuts.

Publications (peer-reviewed)

Kostandini G, Rhoads J, MacDonald G, Johnson R, Carroll E, Pressoir G. 2018. Peanut production among small farmers and gender differences in peanut productivity and post-harvest practices: Evidence from Haiti. (*under review*)

Fulmer A, Kemerait R, Brenneman T, MacDonald G, Rhoads J. 2018 Haiti Peanut Research Report: Efforts to improve peanut production in Haiti by investigating management options for foliar diseases, low soil fertility and other yield limiting agronomic issues. (*in preparation*)

Publications (theses)

North JM. 2017. The impact of improved peanut varieties and fungicide applications in peanut productivity and profitability in Haiti. Master of Science, University of Georgia.

Lai YT. 2017. Dietary aflatoxin carryover into eggs from Haitian chickens. Master of Professional Studies, Cornell University

Churchill K. 2017. The carry-over of aflatoxins in dairy feed to milk of modern Holstein dairy cows. PhD Dissertation, Cornell University.

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 impacts 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 villages, and within 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.

A solar dryer designed by Maxwell Lamptey was tested in northern Ghana as a method for reducing aflatoxin in the peanut supply.

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

Results from the project are providing farmers in Ghana with information on documented interventions that reduce aflatoxin contamination 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
George Mahama	CSIR-Crops Research Institute	Ghana	Co-PI
Maria Balota	Virginia Polytechnic Institute and State University	USA	Co-PI
Rick Brandenburg	North Carolina State University	USA	Co-PI
Boris Bravo-Ureta	University of Connecticut	USA	Co-PI
Kenneth Boote	University of Florida	USA	Co-PI
Jinru Chen	University of Georgia	USA	Co-PI
Greg MacDonald	University of Florida	USA	Co-PI
Kumar Mallikarjunan	Virginia Polytechnic Institute and State University	USA	Co-PI
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

The goal of this objective included comparing farmer practices (FP) and improved practices (IP) in the field (planting dates either in a single season or major vs minor seasons), FP vs IP for drying (ground drying vs drying on tarps), and comparisons of storage using traditional bags vs hermetically sealed bags to reduce aflatoxin contamination. Five villages were used (two near CRI-Kumasi, two near SARI-Tamale, and one near SARI-Wa) with approximately 10 farmers in each village to compare FP with IP. Farmers served as replications in the villages. Within each planting date, the FP was compared with an IP program that included applying local soap for disease/aphid-rosette suppression, applying calcium for pod/kernel development and strength to minimize insect damage, and weeding by hand one additional time. A full complement of data was recorded prior to and at harvest relative to pests in the field, yield, pod and kernel formation, and aflatoxin contamination. Each intervention was compared for economic impact, and pod/kernel quality evaluated after storage and aflatoxin contamination quantified after each step in the process (field, drying, and storing).

Results from two villages in central Ghana compare the effectiveness of FP and IP.

- Peanut yield and estimated economic returns were higher with the IP compared to the FP.
- Minor but significant differences in aflatoxin concentration in peanut farmer stock were noted when sampling occurred immediately after harvest and prior to drying (1.0 versus 0.5 µg/kg, p = 0.0015 at Drobonso and 0.3 versus 0.5 µg/kg, p = 0.0290 at Ejura).
- In both villages, aflatoxin levels increased during drying. At Drobonso, benefits of effective drying on plastic tarpaulins (29-80 µg/kg aflatoxin) became apparent compared with ground

drying (153-226 µg/kg) regardless of the level of aflatoxin coming out of the field at harvest. These respective drying practices resulted in 8-31 µg/kg and 68-93 µg/kg at Ejura.

- As these peanuts continued through the supply chain, the concentration following relatively low input in the field, drying on the ground, and storage in readily available poly sacks with limited protection resulted in an average aflatoxin concentration of 1407 µg/kg at Drobonso.
- Use of IP at all stages resulted in the lowest aflatoxin concentration (53 µg/kg) at this location. Adopting a single IP or two of the three possible IPs resulted in aflatoxin concentrations between 100 and 548 µg/kg. At Ejura, using FP at all steps resulted in aflatoxin concentration of 766 µg/kg versus only 15 µg/kg when IP were included in the field and during drying and storage.

These results from two villages in central Ghana show how each step in the value chain impacts the concentration of aflatoxin in the final product. Peanut after storage will be consumed directly by individuals in the household or will enter the market in some form. Economic return captured at harvest could change during storage, depending on quality and seasonal price dynamics, especially if buyers consider aflatoxin contamination in their decision-making process. Whether farmers adopt improved practices to reduce aflatoxin may be determined by the market valuation of low-aflatoxin peanut and resulting better prices (see Project C3). While productivity interventions showed the least impact on aflatoxin contamination, the increase in yield and profitability may be required for farmers to investment in drying and storing technologies that have greater impact on quality.

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

Trials were conducted at CRI-Kumasi, SARI-Tamale, and SARI-Wa associated with various scientific disciplines. Some of these trials are associated with graduate student thesis projects. Summaries of key findings from several projects will follow.

WEED CONTROL: Most peanut farmers in Ghana cultivate small farm sizes because most rely mainly on manual weed control. Thus, research was conducted to determine the interactive effect of chemical or manual weed control and fungicide application on weed suppression and peanut growth, yield and quality. At six weeks after planting, pre-emergent application of S-Metolachlor combined with hand-weeding reduced weed density by 88%, pre- and post-emergent application by 89%, and hand-weeding only by 30% relative to the non-weeded control. The three most locally important weeds of peanut, Benghal dayflower (*Commelina benghalensis*), purple nutsedge (*Cyperus rotundus*) and wild poinsettia (*Euphorbia heterophylla*) were well controlled with Imazethapyr, while S-Metolachlor was more effective on Benghal dayflower and grasses. Yield did not differ significantly among treatments. However, economic analysis proved including chemical weed control was more profitable than hand-weeding alone. Two hand-weedings cost GH₵ 1,668.2/ha (US$ 417) and required 66.6 person-days/ha; herbicides in combination with HW reduced cost by 53-60% and time to average of 25 person-days/ha compared to manual while pre- and post-emergent herbicides used together reduced cost by 94% and required 1.3 person-days/ha for weed control. Aflatoxin levels of fresh and dried seeds were very low (< 2.0 PPB). Fungicide treatment did not interact with weed-control practices with respect to peanut growth and yield, most likely because environmental conditions during 2015 minor season were relatively dry and did not favor disease development. The experiment was repeated in the major season of 2016 at different locations with a local check.

PROCESSED GROUNDNUT QUALITY: Peanut paste is a delicacy in Ghana, and this study aimed to assess peanut paste quality in Northern Ghana, where quality has been inconsistent. Twenty-four peanut paste samples were acquired from six major markets, while a control sample was prepared in the Food Science and Technology Laboratory of KNUST using Nkate-sari variety of peanut. A survey was conducted using structured questionnaires to collect processors methods, while samples were tested for aflatoxin and microbial load. There was no sorting, grading or blanching during processing, and 75% of producers used untreated stream water during processing.

Ninety-six percent of traders acquired raw peanuts from the market already de-shelled.

Moisture, crude protein and carbohydrate content of the samples ranged from 5.05 ± 0.07 to 6.45 ± 0.21, 23.67±0.05 to 31.56 ±0.78 and 19.44 ±1.19 to 27.65 ±0.96 respectively. Statistical analysis showed no significant difference ($p>0.05$) between ash, carbohydrate and protein content. Aflatoxin analysis of the Tamale central, Bolga central, Wa Gonomuni, Tamale Aboabu and Wa central market samples showed concentrations of 2.89 ppb, 8.6 ppb, 55.39 ppb, 103.44 ppb and 126.55 ppb respectively. Total aerobic count ranged from 2.5×10^3 CFU/g to 9.9×10^3 CFU/g. Coliform counts were below the acceptable limit of 10 CFU/g. Fungal enumeration was less than 101 CFU/g in all samples except for Navrongo central market samples. *Aspergillus parasiticus* was isolated in Wa gonomuni, Wa central market and Tamale Aboabu market samples, respectively. *Blastomyces dermatitidis* was found in Bolga central market samples. Even though some samples had high nutrient composition, contamination levels were significant due to poor production practices.

SOLAR DRYER: A solar dryer was constructed and tested to show that the technology can be used effectively for improving peanut safety and preserving peanut quality in Ghana. An indirect, passive, wooden dryer, with a galvanized steel panel (4.5 m^2) and four wire mesh shelves (2.62 m^2 each), was built in Kumasi and evaluated for its capacity to dry freshly-harvested in-shell peanuts on a single layer (8.5 kg) and then in four layers (4x18 kg). Equal amounts of peanuts, dried simultaneously on a concrete floor under the open sun, served as comparisons.

The moisture content of solar-dried peanuts decreased from 35.85% to 5.25% and 32% to 4.25% in the single-layer and four-layer drying, respectively, over four days. Faster drying rates were observed when peanuts had relatively higher moisture contents with R^2 values ranging from 0.72 to 0.95. The average daily solar radiation ranged from 360 to 592.99 W/m^2 and daily energies generated were from 42.24 to 69.16 MJ. The drying efficiency ranged from 1.5% to 6.47% in the single-layer drying and 23.07% to 24.93% in the four-layer drying, whereas the thermal efficiency was 3.15% to 21.60% in the single-layer drying and 3.08% to 24.93% in the four-layer drying.

Peanuts from the solar dryer had lower free fatty acid and peroxide values and higher germination rates compared to peanuts dried in the open sun, suggesting a potentially valuable quality improvement, likely from the reduced variability of high daytime temperatures.

COMPOSTING: Results of laboratory-scale trials revealed that composting had the potential to be employed to decontaminate aflatoxin-containing agricultural waste in developing countries, where aflatoxin-contaminated peanut waste is often used as mulching material or a soil amendment, which introduces aflatoxins and aflatoxin-producing mold into subsequent farming seasons. Composting highly-contaminated peanut meal at 40 degrees C for six weeks caused levels of aflatoxin B1, B2, G1 and G to drop from 154.9 to 72.2µg/kg, from 17.6 to 7.4µg/kg, from 6.9 to 1.2µg/kg, and from 2.1 to 0.0µg/kg, respectively. *Aspergillus flavus* and *A. parasiticus* counts and total mold counts decreased from 103-105 to <10 CFU/g. Composting time and the type of starters used in the research significantly influenced aflatoxin content, while the presence of an accelerator did not affect aflatoxin levels. The highest level of toxin decontamination occurred in the first week when compost temperature and

ammonia concentration were high. Micronutrient contents of resulting composts were within the accepted range for crop fertilizers, except for calcium. Heavy metal content was below the maximum allowable levels except nickel in one of the samples. Therefore, composting of aflatoxin contaminated agricultural waste appears to be an effective means of reducing risk of accumulation.

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

New varieties and experimental lines were compared on research stations coordinated and implemented cooperatively at CRI-Kumasi, SARI-Tamale and SARI-Wa. These trials involved 20 to 30 entries including local cultivars. Results over three years showed significant difference ($p < 0.05$) among groundnut germplasm for pest reaction and yield. The majority of the groundnut germplasm took five days to emerge. Shitaochi (also known as Chinese), however, had the least number of days to emergence while Otuhia and Adepa had the longest. Considering days to 50% flowering, the majority of germplasm recorded 27 days, with Otuhia recording 31 days. The range for incidence of rosette was between 2% and 74%. Yenyawoso and Shitaochi recorded the least and highest incidence of rosette, respectively. Also, three lines from ICRISAT (ICGV-03308, ICGV-03315 and ICGV-03398) had greater than 60% incidence of rosette over the other entries. Results showed differences in unfilled pod, pod and kernel damage as well as grain yield as a result of arthropod pest reaction among 23 lines and varieties. Generally, germplasm that showed lower incidence of rosette had higher yield compared to those with higher incidence of rosette. The highest grain yield was recorded from Oboshe (3157kg/ha) while the least were from ICGV-03395.

The groundnut breeding program at CSIR-CRI requested aflatoxin resistant lines from ICRISAT, Mali. After more than four seasons of on-station evaluation in the Forest, Transition and Coastal Savanna zones and two seasons of on-farm evaluations, one accession was selected based on its agronomic performance, tolerance to rosette disease, aflatoxin level at harvest and after storage and earliness (85-90 days to maturity). The line proposed for release is ICGV 03401. At CSIR-SARI, ICGV 86124, ICGV IS 96814, PC 79 79 and NC7 have shown high levels of resistance to pests and are also high-yielding. These lines compare well with the high-yielding Nkate-sari, but yield higher than the most popular variety Shitaochi.

Objective 4. Disseminate best practices to farmers and other stakeholders

Farmer Field Schools (FFSs) were held at each village at planting, mid-season and harvest to demonstrate improved varieties, pest management and production interventions during the season, and aflatoxin mitigation techniques. A concise guide in English and appropriate local languages was distributed through FFSs, the Ministry of Forestry and Agriculture (MOFA), and the PMIL website.

From October 2013 to 2017, groundnut IPM production and aflatoxin mitigation technologies were transferred through FFSs to more than 100 farmers and 10 MOFA extension staff which extended the reach to 1500 farmers and extension staff households at Ejura/Sekyedumase, and Drobonso in the Ashanti region.

Surveys of PMIL Collaborating (PMIL-C) farmers, PMIL Spill-over (PMIL-SO) farmers, and General/Other (GO) farmers were conducted in October 2016 (see Objective 1, example in Ejura and Drobonso) to determine how information derived from PMIL interactions was disseminated. In all, 112 farmers were surveyed: 26 PMIL-C farmers, 21 PMIL-SO farmers, and 65 GO farmers). 96% of PMIL-C farmers had heard about aflatoxin while only 52% of PMIL-SO farmers and 22% of GO farmers had heard about this issue. Most farmers removed moldy grain (the source of aflatoxin) prior to consuming or marketing

peanut. PMIL-C farmers were using improved technologies or recommendations more than PMIL-SO and GO farmers. Approximately 85% of PMIL-C and PMIL-SO farmers used tarps for drying while only 42% of GO farmers used this technique. Hermetically sealed bags were used by 46%, 5%, and 2% of PMIL-C, PMIL-SO, and GO farmers, respectively, while 4%, 9%, and 14% of these respective groups used poly bags. Fifty-two percent of PMIL-C farmers used fertilizer bags while PMIL-SO and GO farmers used this type of storage bag 86% and 79% of the time, respectively.

Objective 5. Analyze the economics of each aflatoxin reduction intervention

In fall 2015, 600 groundnut producers from 50 villages across five districts in central Ghana were surveyed. Obtaining a clean data set ready for analysis has proven to be a challenge, and continued into spring of 2017. The final dataset was still being analyzed at the close of FY 2017. The main focus of the analysis is the prevalence and awareness of aflatoxin among smallholder farmers. Additional data from KNUST researchers on aflatoxin was also provided by collaborators and will be included in the final analysis. The results of this analysis will be incorporated into Jeremy Jelliffe's PhD dissertation and a manuscript that will be generated and submitted for publication to a peer-reviewed journal upon completion of this work.

Data received from field-experiment trials of alternative management practices in Northern (SARI) and Central (CRI) regions continued for the 2017 growing season. Processing has been done and final analysis of the data is complete. Manuscripts are being prepared to include the results from the analysis, which will be submitted for publication to a peer-reviewed journal.

Initial data on aflatoxin awareness and related practices from surveys of farmers participating in the PMIL village studies, nearby farmers (to measure spillover effect), and a control group, showed significantly higher knowledge of aflatoxin and proper sorting techniques in the participating and spillover groups than in the control.

Data from Ghana will also be compared, when possible, with information collected in Malawi, Mozambique and Zambia.

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

Traders and processors along the peanut value chain were surveyed to assess current practices in aflatoxin mitigation. Seventy-three percent of the processors had perceptions of the causes of defects in raw peanuts. They identified insect attack and inadequate rains as the highest (27%) causes of defects in peanuts, and this was followed by improper drying (23%).

There were no significant associations between the age and experience of the processors and the perception of the causes of defects of peanuts respectively ($p=0.39$) and ($p=0.49$). There were also no significant associations between the processors' ethnic background (hometown) and their perception of the causes of defects ($p=0.10$). Thus, most processors considered that improper drying and insect attack were the major causes of defects in peanuts. Consequently, post-harvest handling activities such as drying and storage of peanuts are raw material supply issues that should be addressed in the value chain using standard quality management systems. Data from the survey showed that 40% of the respondents thought there were no food safety issues associated with the consumption of defective peanuts while 33% associated the consumption of defective peanuts with stomach pains among other health issues.

Objective 7. Includes development of human and institutional capacity to conduct research in peanut in Ghana.

To date, seven students completed coursework and thesis/dissertation for a graduate degree, two in doctoral programs. The students studied at University of Ghana or KNUST in Ghana, UGA or Virginia Tech in the US.

Lessons Learned

Complex projects with many partnering organizations in multiple locations need explicit data collection criteria and would benefit from implementation of new technology, such as tablet-based survey tools, such as the World Bank system implemented in the Malawi project, and field data collection, such as the Breeding Management System software.

Publications

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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 more than 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 individuals or households do or do not adopt control measures.

Collaborators

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

Achievements

We were able to purchase groundnuts from farmers in 2016-2017. Using the additional funding from PMIL for 2016-2017, we extended our previous research on technological and market interventions to reduce aflatoxin risks. Perhaps the most surprising and disappointing finding from the original study was that the market intervention— offering a 15% price premium for groundnuts testing low in aflatoxin— did not incite farmers to sell their groundnuts to our buyer. Only seven of nearly 1,000 farmers did so.

In the 2016-2017 round of the study, we made our buying protocol more flexible and transparent by giving farmers a longer window in which to sell their production, and by offering a flat rate premium of 25 GHC per bag rather than a percentage premium for low aflatoxin groundnuts. As a result, we were much more successful at purchasing groundnuts. Among farmers not offered the premium, 20% sold us at least some of their production. Among those offered the premium, 57% did.

Aflatoxin levels dropped with a second round of interventions in 2016-2017. In 2015-2016, aflatoxin levels were extremely low throughout Ghana. In our control group, the mean was 2.8 ppb (at baseline it was 60 ppb). This made it very difficult for our interventions to have any effect on aflatoxin contamination, and detection of such effects even more difficult. In 2016-2017, levels were even lower in Upper East Region (1.56 ppb) but higher in Northern Region (5.5 ppb) making it much more likely our interventions could have detectable impacts there.

We find that for Northern Region farmers, the free tarp intervention lowered aflatoxin levels by an average of more than 30% and the market premium lowered aflatoxin levels by an average of more than 20%. Looking at critical thresholds, we find that the free-tarps treatment decreased the prevalence of aflatoxin levels above the Ghanaian standard of 15 ppb by 8% and levels above the EU standard of 4 ppb by 6%. The market-premium treatment decreased the prevalence by 5% and 6%, respectively.

In this year of the study, all sample farmers had the same information on aflatoxin, its consequences, and post-harvest practices for its prevention. Thus, the effects on aflatoxin levels reported here are due to the tarps or market premium offer conditional on information receipt. Given the strong effect of information on post-harvest practices we found in the first year of our study, it is likely the impacts would be even higher if measured against a pure experimental control.

Educational videos were produced and published. With a Scaling Innovation through Video grant from USAID, we produced a series of short videos on aflatoxin and aflatoxin prevention. One set of videos is aimed at extension agents or farmers themselves, and another is aimed at researchers and development practitioners working on aflatoxin prevention. We screened these videos for field staff of Ghana Trade and Livelihood Coalition, Peasant Farmers Association of Ghana, Northern Development Society, Grameen Ghana, Shea Network Ghana, and Netherlands Development Organization. We are planning to disseminate them more widely in the near future.

Capacity Building

While not a primary research outcome focus of this project, a laboratory and training program for aflatoxin analysis was established at the University for Development Studies. A practical course listed in the Biotechnology Department and Food Processing Technology Department was established in 2015/2016 and continues to the present.

Lessons Learned

From our analysis of our data collected after our 2015 intervention and cursory analysis of data collected after our 2016 intervention, we have learned the following four major things:

Aflatoxin levels vary greatly from year to year. In our three years of aflatoxin testing from the same farmers, we found levels to vary greatly from year to year. Tests from the 2014 growing season revealed very high levels (100 ppb in Northern Region and 25 ppb in Upper East), whereas tests from both the 2015 and 2016 growing season revealed low levels. This makes it difficult to make general claims from any impact evaluation that uses aflatoxin levels as an outcome of interest. If aflatoxin levels are low across the board, as they were in our two years of post-intervention data collection, it is difficult to show impact. Furthermore, it is unclear if impacts are proportionate; it is likely that the impacts are much larger when aflatoxin levels are generally high, as they were after the 2014 season.

Basic training substantially improves post-harvest practices. In our first year of interventions we found vast improvements in post-harvest practices by farmers receiving information about aflatoxin and aflatoxin prevention. We did not find strong evidence that giving farmers free tarps or offering them a market premium for groundnuts testing low in aflatoxin had an additional effect.

Buyer flexibility can encourage farmers to sell groundnuts. Offering farmers a price premium (in advance of harvest) for low aflatoxin groundnuts had no effect on post-harvest practices the first year we offered (after the 2015 harvest). Only seven farmers sold us their groundnuts when we offered to purchase them two to three months after harvest. After the 2016 harvest, we were more flexible in our purchases, offering to come within one week of the farmer's call any time between three to seven months after harvest. We also offered a flat rate of 25 GHC per bag (the market value of bags ranges from 100-300 GHC depending on season) rather than a percentage bonus to make the premium easier to understand. Many more farmers were interested in selling us groundnuts under these conditions. In the three groups not offered the market premium, 20%reported successfully selling to our agent. In the group offered the market premium 57% did, indicating that the premium could entice farmers to change their marketing behavior.

Our analysis indicates farmers are resistant to sell because either groundnut sales are unplanned, idiosyncratic, and incremental, or farmers want to hold groundnuts longer to sell them at a higher price as supply dwindles (or both). These behaviors will make it difficult to connect smallholder farmers to value chains that reward quality, and low aflatoxin levels in particular. Such buyers are going to want to buy large quantities shortly after harvest.

Farmers will use free technology, but are resistant to invest even when subsidized. We hypothesized that training farmers about aflatoxin and good post-harvest practices, as well as offering a price premium for safe groundnuts, would incite farmers to purchase drying tarps. We found in a technology pilot at the onset of the study that tarps are an inexpensive, easy and effective way to lower aflatoxin levels. Even at subsidized prices ($2 to $5 depending on quality), farmer demand for tarps was very low. However, when we distributed them free-of-charge farmers gladly accepted them and used them for the intended purpose.

Free tarp distribution and market incentives can both be effective at lowering aflatoxin levels, but tarps are a more feasible (and effective) option. In the second year of our study we found that in areas where background aflatoxin levels are not already extremely low, our interventions—coupled with training— result in lower aflatoxin levels. The mechanism by which free tarps work is straightforward. Very few farmers will purchase tarps, even at a discount. But if farmers receive free tarps most will dry their groundnuts on them, and doing so decreases the risk of aflatoxin contamination. Tarps are cheap and relatively easy to distribute, and thus a viable strategy for the government, buyers looking to purchase safer groundnuts, and NGOs.

Market interventions are effective, but results were less dramatic. Farmers, given information, can and will react to market incentives to produce safer groundnuts. However, we had to make many visits at different times after harvest to purchase groundnuts. Furthermore, we had to test many small lots of groundnuts in the field. These activities are expensive, and not scalable as is. Further research into technological (e.g., low cost portable testing) and institutional (e.g., farmer groups agreeing to use good post-harvest practices and market their production jointly) is necessary to better understand how market forces can be leveraged to reduce aflatoxin levels.

Presentations and Publications

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

This project addresses a wide range of production, post-harvest handling, and processing issues relative to peanuts in Malawi, Zambia, and Mozambique that can impact aflatoxin contamination levels, yield, and profitability. The strength of this project is that interventions were evaluated throughout the value chain and the cumulative effect of these efforts measured against traditional production and marketing practices. Through linkages with various partners, farmer education was emphasized and connections with various industries and marketing groups 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 has been limited. Additional agencies such as the National Small Farmer Association of Malawi (NASFAM), 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 has limited availability. Limited marketing due to high aflatoxin contamination exacerbated the problem by reducing farmer incentive to implement current production recommendations and limiting commercial processing and marketing.

Our project, with its multidisciplinary team, took 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 was expanded and emphasized implementation. Researchers collaborated in numerous ways throughout the three countries, creating a regional project providing research data with even wider scale application. Key components included 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. The project addressed 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 Agricultural Research Station	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

To date, six students completed degrees in pre-harvest fields (one PhD) and six students completed degrees in post-harvest areas.

Pre-harvest Interventions

- Research projects completed in three countries.
- Long-term training provided in country for five MSc students and one PhD student.
- Multiple refereed journal articles published.
- Cohesive and comprehensive field research program has provided well-defined production programs for planting date, plant populations, crop rotations, soil amendments, impact of drought stress and pest management, and harvest dates to produce profitable and high quality peanuts.
- Strong linkages have been developed with the private sector that has improved graduate student field research, increased improved cultivar seed multiplication and varietal research, as well as assisted in technology transfer to smallholder farms.

Post-harvest Interventions

Malawi

- Groundnut flour standards were developed and practices of blanching and variable temperature roasts were compared against the standards for quality measures of aflatoxin, microbial levels and rancidity or shelf life.

- Different extraction methods for producing peanut oil were analyzed for their efficiency in preventing aflatoxin carryover.
- Farmers were surveyed about their knowledge of how drying and storage can affect aflatoxin contamination. Drying and storage technologies were tested for their effectiveness in limiting aflatoxin contamination.
- Development and Evaluation of Technologies and Practices for Cleaning and Sorting Groundnuts

Mozambique

- Planting and harvest dates were evaluated for impact on yield and quality, demonstrating the yield loss when farmers wait too long to plant (until after a more-valuable cash crop is in the ground) or leave mature peanuts in the ground too long (while they harvest other crops.)

Zambia

- Tests were conducted using six common methods for drying peanuts. Concrete slab and papyrus mat surfaces showed higher drying performance at 2.13 and 2.07% dry basis per hour, therefore, concrete slab and papyrus mat surfaces with depth of 3.6cm were the most effective drying methods to reduce aflatoxin contamination.
- A market survey was conducted for the prevalence of aflatoxins in three peanut products: raw peanuts, powdered (milled flour) peanuts and roasted peanuts sold in open markets of 14 districts. Faculty at the University of Zambia conducted the survey and continues to analyze the data in order to prepare a manuscript.
- Three Zambian groundnut varieties (Kadonongo, Makulu Red and Chalimbana) were analyzed for shelf life stability of peanut butter. The study was conducted by an MSc Chemistry student who is currently working on his thesis.
- A study of two Zambian peanut varieties (Kadonongo and Chalimbana) is looking at the ecological fungal changes occurring in the raw peanuts and processed peanut butters (during production and storage) using molecular techniques. The master's student in molecular biology who is conducting the research also is assessing the aflatoxin contents and changes over time. She continues work on her thesis.
- A master's student in human nutrition conducted a study on groundnut-processing practices and aflatoxin exposure among children age 6 months to 35 months in a peri-urban community in Lusaka. The student is doing data analysis and thesis writing
- A bachelor of science student in food science and technology studied the physicochemical properties and sensory evaluation of peanut butter made from three Zambian groundnut varieties (Kadonongo, Makulu Red and Chalimbana). The student completed her dissertation, and there is a manuscript under preparation for possible journal publication.

USA (University of Georgia)

- Storage quality of lightly roasted, shelled peanuts was compared with raw shelled nuts.

Lessons Learned

Malawi

- The majority of groundnut flour processors are unaware of aflatoxin and practices required to reduce aflatoxin risk. A survey of the market found that the majority of flours do not meet quality and safety standards.

- While commercial oil extraction yields oil with low aflatoxin levels, simple village-scale methods lend a false sense of security that aflatoxin levels are low when they can be significant. A study of simple methods, such as blanching, filtration and ethanol cleansing showed the most effective ways to reduce aflatoxin to acceptable levels.
- Groundnuts dried together with vines took 14 days to dry compared with threshed nuts that took only three days to dry, but also had a high percentage of splits, discoloration and mold. Storage studies reveal that the use of polyethylene bags for storing groundnuts might result in high aflatoxin contamination as compared to storing the groundnuts in hermetically sealed bags and in the traditional granary.

Mozambique

- Early planting and timely harvest showed significantly improved yields and reduction of aflatoxin. Contrary to a common misconception of farmers in the region, harvesting 10 days past maturity brought in 30.7% to 36.6% fewer of the pods, compared to timely harvest. Farmers and extension agents can use this knowledge to weigh the cost of delaying another activity or hiring labor to harvest peanuts on time.

Zambia

- Existing drying methods/surfaces were identified and evaluated for optimal materials and peanut depth to reduce aflatoxin contamination. Concrete slab and locally made papyrus mats were found to be an improvement over bare ground.

USA (University of Georgia)

- Hermetic storage extends shelf life of both blanched and unblanched peanuts for 24 weeks. Woven poly bags should be avoided due to limited oxygen barrier and likelihood of rancidity.

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Kusakala, C Matumba L, Mwangwela A. Response Surface Optimization of Aqueous-Ethanolic Decontamination of Aflatoxin in Peanut Oil. Poster Presentation at American Peanut Research and Education Society 49th annual meeting in Albuquerque, New Mexico, USA, July 2017.

Longwe T, Mwangwela A. Effect of blanching on composition, physical and functionality of full fat groundnut flour. Presentation at APRES 49th annual meeting in Albuquerque, USA. Jul 12 2017.

Mkandawire LM, Mhango W, Saka VW, Kabambe VH, Goodman J, Brandenburg R. 2017. The effect of plant population and harvesting dates on aflatoxin contamination in groundnut. An oral presentation made at the 49th Annual Meeting of the American Peanut Research and Education Society, July 11-13, Albuquerque, New Mexico; USA.

Mkandawire LM, Mhango W, Saka VW, Kabambe VH, Juma S, Goodman J, Brandenburg R. 2016. The effects of plant density on growth and yield of groundnut (*Arachis hypogea*). Poster presented at the 5th Biennial General meeting of RUFORUM in Cape Town, South Africa. 16 -22 October, 2016.

Sibakwe C, Donga T, Njoroge S, Msuku WAB, Brandenburg R. 2016. The role of drought stress on aflatoxin contamination in groundnut and *Aspergillus flavus* population in soil during pre-harvest. Poster presented at the 5th Biennial General meeting of RUFORUM in Cape Town, South Africa. 16 -22 October, 2016.

Uyen P, Wang S, Adhikari K, Chinnan M, Mallikarjunan K. Quality changes in peanuts as affected by blanching, storage temperature, packaging materials and storage time SPISE International Sensory Analysis Symposium, Ho Chi Minh City Vietnam, July 29-31, 2016

Wang S, Adhikari K, Chinnan M. Storage quality evaluation of lightly roasted blanched peanuts when compared to raw shelled peanuts. IFT Annual Meeting at Chicago, July 16-20, 2016

Yawe J, Simate I, Shindano J and Mkandawire NL. 2017. Assessment of existing drying and storage systems for raw groundnuts: A case study of Chongwe District. The 2017 International Multidisciplinary Conference. Raddison Blu. Lusaka. 23rd to 25th August 2017. Paper Presentation

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 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 is that a major constraint to a healthy groundnut value chain in much of Africa is low farm productivity and profit. Productivity and profit can be improved in various ways, including by increasing 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 was 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

The project has taken shape under two primary objectives: 1) Compiling, organizing and analyzing existing productivity data through collaboration with other PMIL initiatives (including Ghana), particularly the breeder network, and 2) implementation of a baseline survey in Mozambique.

Objective 1:

- A database for the project has been completed and will be made available to researchers.
- Data collection over the last year by country included:
    - Malawi: Information received for planting and harvest date, planting density, drought stress, and varietal trials for most recent growing seasons.
    - Zambia: Communications with local researchers continued, but data was not made available for analysis.
    - Mozambique: Additional data was received, but not included in the ongoing analysis because it is different than the data already available and could not be merged to conduct a unified analysis.
- The following research manuscripts are in final stage of preparation for submission to scholarly journals:
    - Groundnut Yields from Alternative Seed Varieties: Economic Evidence from Mozambique and Malawi. Bravo-Ureta, B. E., J. Jelliffe, E. Owusu, A. Muitia, C. Sibakwe, N. Puppala, C. Deom, J. Chintu. Objective: To examine productivity of interventions designed to decrease aflatoxin based on seed varietal trials conducted in Mozambique and Malawi.
        1) Mozambique (720 observations):
            a) Outcome variable: Yield in four study locations (Namapa, Nampula, Montepuez and Ancuabe) for four seasons 2012/13, 2013/14, 2014/15 and 2015/16 (unbalanced panel).
            b) Treatment variables: - Groundnut varieties (JL-24, ICGV-SM01513, ICGV-SM01514, ICGV-SM99568 and ICGV12991; Planting dates (December 15, December 24, January 3 and January 13).
        2) Malawi (60 observations):
            a) Outcome variable: - Yield over two growing seasons (2014 to 2016)
            b) Treatment variables: - Groundnut varieties (ICGV-SM01514, Chitala, Baka, Kakoma, and ICGV-SM99566); Moisture stress (no, mild, moderate/minimal and prolonged drought).

    - Productivity and Profitability Effects of Alternative Groundnut Management Practices in Malawi and Ghana. Bravo-Ureta, B. E., J. Jelliffe, E. Owusu, L. Mkandawire, M. Abudulai, B. Mochiah, D. Jordan, R. Brandenburg . Objective: To examine cost and benefits of alternative management interventions designed to improve productivity and profits in Malawi and Ghana.

1) Malawi (384 observations):
    a) Outcome variable: Gross Margin in two study locations (Mpatsanjoka and Lisungwi) for two seasons- 2015/16 to 2016/17 (balanced panel).
    b) Treatment variables: - Season (dry, rainy); Days to harvest; Planting density (89,000 plants/ha, 178,000 plants/ha, 285,000 plants/ha).
2) Ghana North (144 observations):
    a) Outcome variable: Gross Margin for 2015/16 growing season in Zankali and Kpalbe);
    b) Treatment variables: Fertility Management Practices (Yara Legume, Oyster Shell, Farmer Practice).
3) Ghana South (48 observations):
    a) Outcome variable: Gross Margin for 2015/16 growing season in two locations (Drobonso and Ejisu)
    b) Treatment variables: Fertility Management Practices (soap & oyster shell, FP)

Objective 2:

Analysis of the data from the June 2016 Mozambique diagnostic survey started and preliminary results are incorporated into a graduate student dissertation research proposal. The final analysis will be included in a journal article. Initial findings indicate low-level mean productivity and technical efficiency among smallholder farmers in northern Mozambique. These results are consistent with reports from local experts and research findings from farm-level trials. This survey will serve as a baseline for future interventions.

Lessons Learned

It is critical to have closer coordination from the beginning across similar projects regarding objectives, data collection approach, and eventual analysis. Undertaking similar objectives across different landscapes can be a real strength of programs like PMIL, but to be able to take full advantage of comparative work requires harmonization of protocols from the outset.

The training received and given regarding the World Bank Survey Solutions tool has clearly shown that this type of approach should be implemented whenever possible. An example of a promising area of application is for the data collection for variety trials. Training peanut breeders and technicians on how to use Survey Solutions would significantly enhance the value of the final data they generate.

Presentations and Publications

Okello, DK, CM Deom, N Puppala, E. Monyo and B. Bravo-Ureta. 2017. Registration of Serenut 6T Groundnut. Journal of Plant Registrations.

Jelliffe, J.L., B.E. Bravo-Ureta, C.M. Deom and D.K. Okello. 2016. The Sustainability of Project Outcomes from Farmer-led Dissemination of High-Yielding Groundnut Rosette Disease Resistant Groundnut Varieties. Selected Paper, 5th Conference of the African Association of Agricultural Economists, September 23-26, 2016. Addis Ababa, Ethiopia.

Jelliffe, J.L., B.E. Bravo-Ureta, C.M. Deom and D.K. Okello. (under review). Adoption of High-Yielding Groundnut Varieties: The Sustainability of a Farmer-Led Multiplication-Dissemination Program in Eastern Uganda." International Journal of Agricultural Sustainability.

Associate Award Research Project Reports

No Associate Awards were active in the final year.

Human and Institutional Capacity Development

Short-Term Training (by country)

Name	Gender	Home Country	Home Institution	Dates	Discipline	Research Focus	Mentor	Training Location
Abdi Hassen	M	Ethiopia	Hawassa University, Awassa, Ethiopia	06/28/2017-07/08/2017		Detection of aflatoxin types and molecular diversity of *Aspergillus* species from Ethiopia	Renee Arias	USDA-ARS National Peanut Research Lab, Dawson, GA, USA
Fidele Neya	M	Burkina Faso	University of Ouagadougou		Plant Pathology	Training in genomics, specifically identification and use of SNP-based markers	Carl Deom	Texas A&M Agrilife Research
Maxwell Lamptey	M	Ghana	Crops Research Institute, Kumasi, Ghana	Apr-Sep/2015	Agricultural mechanization	Develop and evaluate a solar dryer for peanuts	Jinru Chen/David Jordan	University of Georgia, Griffin, GA USA
Junior Abraham	M	Haiti	Universite ROI Henri Christophe	2017	Agriculture Science	Internship and undergraduate thesis (Seed Spacing)	Greg MacDonald	Quartier Morin. Med and Food for Kids
Wendy Antoine	M	Haiti	Universite Roi Henri Christophe	April 2017	Agriculture Science	Internship and undergraduate Thesis (Planting Methods)	Rick Macajoux/Alex Carroll/Greg MacDonald	Quartier Morin/Med and Food for Kids
Gary Benoit	M	Haiti	Universite Roi Henri Christophe	Spring 2016		Internship and undergraduate thesis (Runner Fungicide Timing Study)	Greg Macdonald	Med and Food for Kids
Emile Blaise	F	Haiti	Universite ROI Henri Christophe	2017	Agriculture Science	Internship and undergraduate thesis (Seed Spacing)	Greg MacDonald	Med and Food for Kids
Rolcky Butois	M	Haiti	Universite Chretienne du Nord d'Haiti	October 2016	Agriculture Science	Internship and undergraduate thesis (Runner Fungicide Timing Study)	Rick Macajous/Alex Carroll/ Greg MacDonald	Quartier Morin/ Med and Food for Kids

Name	Gender	Home Country	Home Institution	Dates	Discipline	Research Focus	Mentor	Training Location
Fedeline Charles	F	Haiti	Universite ROI Henri Christophe	2017	Agriculture Science	Internship and undergraduate Thesis (Runner Fungicide Timing)	Greg MacDonald	Quartier Morin/Med and Food for Kids
Pierre Richard Charles	M	Haiti	Universite Episcopale d'Haiti	April 2017	Agriculture Science	Internship and undergraduate thesis (Planting Method)	Rick Macajoux/ Alex Carroll/Greg MacDonald	Mirebalais
Rodson Charles	M	Haiti	Universite Solidarite d'Haiti	March 2017	Agriculture Science	Internship and undergraduate thesis (Runner Fungicide Study)	Rick Macajoux/ Alex Carroll/Greg MacDonald	Quartier Morin/Med and Food for Kids
Exan Desamours	M	Haiti	Universite Roi Henri Christophe	Fall 2016		Internship and undergraduate thesis (Runner Fungicide Timing Study)	Greg MacDonald	Med and Food for Kids
Dapheney Dolce	F	Haiti	Universite Roi Henri Christophe	March 2017	Agriculture Science	Internship and undergraduate thesis (Soil Fertility)	Rick Macajoux/ Alex Carroll/Greg MacDonald	Quartier Morin/Med and Food for Kids
Laine Dorinvil	M	Haiti	Universite Roi Henri Christophe	Fall 2016		Internship and undergraduate thesis (Top 6 Valencia Study at Quartier-Morin)	Greg MacDonald	Med and Food for Kids
Ruth Eustache	F	Haiti	Universite ROI Henri Christophe	April 2017	Agriculture Science	Internship and undergraduate thesis (Seed Spacing)	Rick Macajoux/ Alex Carroll/Greg MacDonald	Quartier Morin/Med and Food for Kids
Jean Baptiste Fontilus	M	Haiti	Universite Chretienne du Nord d'Haiti	January 2017	Agriculture Science	Internship and undergraduate thesis (Top 6 Valencia Study at Quartier-Morin)	Rick Macajoux/ Alex Carrol/Greg MacDonald	Quartier Morin/Med and Food for Kids
Rosiny Frederick	M	Haiti	Universite ROI Henri Christophe	2017	Agriculture Science	Internship and undergraduate thesis (Seed Spacing)	Greg MacDonald	Quartier Morin/Med and Food for Kids

Name	Gender	Home Country	Home Institution	Dates	Discipline	Research Focus	Mentor	Training Location
Pierre Galet	M	Haiti	Universite Chretienne du Nord d'Haiti	Fall 2016		Internship and undergraduate thesis (Plant and Seed Spacing Study)	Greg MacDonald	Med and Food for Kids
Daphenie Jean	F	Haiti	Universite ROI Henri Christophe	2017	Agriculture Science	Internship and undergraduate thesis (Runner Fungicide Timing)	Greg MacDonald	Med and Food for Kids
Rodlin Jean	M	Haiti	Universite ROI Henri Christophe	2017	Agriculture Science	Internship and undergraduate thesis (Seed Spacing)	Greg MacDonald	Med and Food for Kids
Ronald Jean	M	Haiti	Universite d'Etat d'Haiti, Campus ROI Henri Christophe	April 2017	Agriculture Science	Internship and undergraduate thesis (Soil Fertility)	Rick Macajoux/ Alex Carroll/Greg MacDonald	Quartier Morin/Med and Food for Kids
Joseph Job	M	Haiti	Universite ROI Henri Christophe	April 2017	Agriculture Science	Internship and undergraduate thesis (Planting Method)	Rick Macajoux/ Alex Carroll/Greg MacDonald	Quartier Morin/Med and Food for Kids
Fredo Joseph	M	Haiti	Universite ROI Henri Christophe	2017	Agriculture Science	Internship and undergraduate thesis (Seed Spacing)	Greg MacDonald	Quartier Morin/Med and Food for Kids
Jean Jones Joseph	M	Haiti	Universite Chretienne du Nord d'Haiti	October 2016	Agriculture Science	Internship and undergraduate thesis (Advance Breeding Line Study: Tillman Variety)	Rick Macajoux/ Alex Carroll/ Greg MacDonald	Quartier Morin/Med and Food for Kids
Judeline Joseph	F	Haiti	Universite Chretienne du Nord d'Haiti	Fall 2016		Internship and undergraduate thesis (Soil Amendment Study)	Greg MacDonald	Med and Food for Kids
Myrvelisa Jules	F	Haiti	Universite ROI Henri Christophe	April 2017	Agriculture Science	Internship and undergraduate thesis (Seed Spacing)	Rick Macajoux/ Alex Carroll/Greg MacDonald	Quartier Morin/Med and Food for Kids
Elize Leandre	M	Haiti	Universite Chretienne du Nord d'Haiti	2017	Agriculture Science	Internship and undergraduate thesis (Valencia Fungicide Timing)	Greg MacDonald	Quartier Morin/Med and Food for Kids

Name	Gender	Home Country	Home Institution	Dates	Discipline	Research Focus	Mentor	Training Location
Yonel Louis	M	Haiti	Universite Chretienne du Nord d'Haiti	April 2017	Agriculture	Internship and undergraduate thesis (ICRISAT Variety)	Rick Macajoux/ Alex Carroll/Greg MacDonald	Quartier Morin/Med and Food for Kids
Rico Mondestin	M	Haiti	Universite ROI Henri Christophe	2017	Agriculture Science	Internship and undergraduate thesis (Seed Spacing)	Greg MacDonald	Quartier Morin/Med and Food for Kids
Galeine Queranor	F	Haiti	Universite Roi Henri Christophe			Internship and undergraduate thesis (Valencia Fungicide Timing Study)	Greg MacDonald	Med and Food for Kids
Junie Pachoute	F	Haiti	Universite ROI Henri Christophe	2017	Agriculture Science	Internship and undergraduate thesis (Seed Spacing)	Greg MacDonald	Med and Food for Kids
Frisnel Pierre	M	Haiti	Universite Roi Henri Christophe	Fall 2016		Internship and undergraduate thesis (Top 6 Valencia Study at Quartier-Morin)	Greg MacDonald	Med and Food for Kids
Kinson Pierre	M	Haiti	Universite ROI Henri Christophe	2017	Agriculture Science	Internship and undergraduate thesis (Runner Fungicide Timing)	Greg MacDonald	Med & Food for Kids
Telson Richard	M	Haiti	Unviersite Solidarite d'Haiti	March 2017	Agriculture Science	Internship and undergraduate thesis (Valencia Fungicide Timing)	Rick Macajoux/ Alex Carroll/Greg MacDonald	Quartier Morin/Med and Food for Kids
Norvilmar St Firmin	M	Haiti	Universte Roi Henri Christophe	March 2017	Agriculture Science	Internship and undergraduate thesis (Planting methods)	Rick Macajoux/ Alex Carroll/Greg MacDonald	Quartier Morin/Med and Food for Kids
Rodemane Saint Louis	F	Haiti	Universite Roi Henri Christophe	Fall 2016		Internship and undergraduate thesis (Top 6 Valencia study)	Greg MacDonald	Med and Food for Kids
Marilene Saint-Juste	F	Haiti	Universite Roi Henri Christophe	Fall 2016		Internship and undergraduate thesis (Valencia Fungicide Timing Study)	Greg MacDonald	Med and Food for Kids

Name	Gender	Home Country	Home Institution	Dates	Discipline	Research Focus	Mentor	Training Location
Rodnie Valmy	F	Haiti	Unviersite ROI Henri Christophe	Spring 2016		Internship and undergraduate thesis (Top 6 Valencia Study)	Greg MacDonald	Med and Food for Kids
David Githanga	M	Kenya	University of Nairobi	September 7 – September 15, 2017		Aflatoxin Detection	JS Wang	University of Georgia
Paul Macharia	M	Kenya	Kenyatta University	2015	Biotechnology	Peanut-genetic transformation and molecular tools	Renee Arias	USDA-ARE National Peanut Research Lab, Dawson, Ga USA
Daniel Mwalwayo	M	Malawi	Malawi National Standard Bureau	October 11-October 30, 2016		Aflatoxin Detection	JS Wang	University of Georgia
Vincent Mlotha	M	Malawi	Lilongwe University of Agriculture and Natural Resources			Sensory and Aflatoxin techniques	Agnes Mwangwela	University of Georgia; Virginia Tech
Amos Acur	M	Uganda	NARO, Uganda	2015	Molecular diversity	Isolation and genetic fingerprinting of *Arpergillus*	Renee Arias	USDA-ARS National Peanut Research Lab, Dawson, GA, USA
Jonothan Farr	M	USA	Georgia Southwestern Univeristy			Learn molecular tools and help with research projects	Renee Arias	USDA-ARS National Peanut Research Lab, Dawson, GA, USA
LaTanya Johnson	F	USA	Albany State University	2014-2015	Biotechnology	DNA extraction from *Aspergillus* and from plants, PCR screenings, and DNA fingerprinting	Renee Arias	USDA-National Peanut Research Laboratory, Dawson, GA USA
Austin Page	M	USA	Albany State University		Biology	Learn molecular tools to help with research projects	Renee Arias	USDA-National Peanut Research Laboratory, Dawson, GA USA
Emily Urban	F	USA	University of Georgia	2016		Survey preparation and facilitation	Boris Bravo-Ureta	
Loveness Nyanga	F	Zimbabwe	University of Zimbabwe	January 15-February 6, 2017		Aflatoxin Detection	JS Wang	University of Georgia

Degree Long-Term Training (by country)

Name	Gender	Home Country	Degree	Graduation Date	Discipline	Research Focus	Mentor	Training Institution
Paola Faustinelli	F	Argentina	PhD	2012	Plant Biotechnology		Renee Arias	University of Cordoba, Argentina
Fidele Neya	M	Burkina Faso	PhD	April 2017	Plant Pathology		Carl Deom	Universite de Ouagadougou, Burkina Faso
Samson Nakone	M	Burkina Faso	MS		Plant Pathology		Carl Deom	Universite de Ouagadougou, Burkina Faso
Kouha Hamidou Sogoba	F	Burkina Faso	MS		Plant Pathology		Carl Deom	Universite de Ouagadougou, Burkina Faso
Adama Zongo	M	Burkina Faso	PhD	2014			Carl Deom	
Wenjie Cai	F	China	MS	May 2018	Environmental Health Science		JS Wang	University of Georgia
Fengle Zhu	F	China	PhD	July 2014	Biosystems Engineering		Haibo Yao	Zhejiang University, China
Carolina Chavarro	F	Columbia	PhD	August 2017	Plant Breeding, Genetics and Genomics		Peggy Ozias-Akins	University of Georgia , Tifton GA USA
Alibu Abdul-Hafiz	M	Ghana	BSc	November 2016	BioTechnology		Nelson Opoku	University for Development Studies
Yussif Abubakari	M	Ghana	MPhil	November 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	July 2016	Food & Postharvest Engineering	Determining the utility of drying methods including fabricating a solar dryer to reduce aflatoxin in peanut	David Jordan	Kwame Nkrumah University of Science and Technology, Kumasi, Ghana
Boadi Gershon Afoakwah	M	Ghana	BSc	July 2017	Biotechnology and Molecular Biology		Nicholas Magnan	University for Development Studies (UDS)
Esther Yeboah Akoto	F	Ghana	MSc	December 2016	Food Science	Deactivation of aflatoxin-contaminated peanut waste via composting	Jinru Chen	University of Georgia. Griffin, GA USA

Name	Gender	Home Country	Degree	Graduation Date	Discipline	Research Focus	Mentor	Training Institution
Theophilus Alale	M	Ghana	MPhil	November 2015	Biotechnology		Nelson Opoku	University for Development Studies (UDS)
Abraham Anane	M	Ghana	BSc	July 2017	Biotechnology and Molecular Biology		Nicholas Magnan	University for Development Studies (UDS)
James Addy Appenahier	M	Ghana	BSc	July 2017	Biotechnology and Molecular Biology		Nicholas Magnan	University for Development Studies (UDS)
Obed Boadi Asumah	M	Ghana	BSc	July 2017	Biotechnology and Molecular Biology		Nicholas Magnan	University for Development Studies (UDS)
Stephen Arthur	M	Ghana	MPhil	Jul 2017	Agronomy	Influence of herbicides and fungicides on pest reaction, yield, and aflatoxin in peanut	David Jordan	Kwame Nkrumah University of Science and Technology, Kumasi, Ghana
Ayinu Asumah	M	Ghana	BSc	July 2016	Biotechnology and Molecular Biology		Nicholas Magnan	University for Development Studies (UDS)
Abigail Awusiwa	F	Ghana	BSc	July 2017	Biotechnology and Molecular Biology		Nicholas Magnan	University for Development Studies(UDS)
K. Emmanuel Ayenor	M	Ghana	BSc	July 2017	Biotechnology and Molecular Biology		Nicholas Magnan	University for Development Studies
Raphael Kwasi Ayim	M	Ghana	BSc	July 2017	Biotechnology and Molecular Biology		Nicholas Magnan	University for Development Studies (UDS)
Erica Azatorwu	F	Ghana	BSc	July 2017	Biotechnology and Molecular Biology		Nicholas Magnan	University for Development Studies (UDS)
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
Eric Biney	M	Ghana	BSc	July 2017	Biotechnology and Molecular Biology		Nicholas Magnan	University for Development Studies (UDA)
Clara Darko	F	Ghana	PhD	December 2016	Agriculture Engineering/ Post-harvest Processing	Comparison of storage systems for in-shell, shelled, and blanched peanuts	Kumar Mallikarjunan/ David Jordan	Virginia Tech

Name	Gender	Home Country	Degree	Graduation Date	Discipline	Research Focus	Mentor	Training Institution
Isaac Darko	M	Ghana	MPhil	November 2016	Agriculture Engineering		Kumar Mallikarjunan/ David Jordan	Kwame Nkrumah University of Science and Technology, Kumasi, Ghana
Loretta Darkwah	F	Ghana	MSc		Food Science	Groundnut processing	Agnes Budu, F.K. Saalia	University of Ghana, Accra, Ghana
Joshua Kweku Ayim	M	Ghana	BSc	July 2017	Biotechnology and Molecular Biology		Nicholas Magnan	University for Development Studies (UDS)
Afia Karikari		Ghana	PhD		Breeding		James Asibuo	Crops Research Institute
Dominic Ndela Ngagmayan	M	Ghana	BSc	November 2016	Biotechnology		Nelson Opoku	University for Development Studies
B.A. Charles Neequaye	M	Ghana	BSc	November 2016	Biotechnology		Nelson Opoku	University for Development Studies (UDS)
Vincent Ninkuu	M	Ghana	MPhil	January 2017	Biotechnology	Leading enumerator teams, conducting laboratory testing, and doing data analysis	Nelson Opoku	University for Development Studies (UDS)
William Ofori Appaw	M	Ghana	MPhil	November 2017	Food Science and Technology	Includes evaluation of pre- and post-harvest interventions to reduce aflatoxin in peanut	David Jordan	Kwame Nkrumah University of Science and Technology, Kumasi, Ghana
Eric Owusu	M	Ghana	PhD	May 2020	Ag Economics		Boris Bravo-Ureta	University of Connecticut
Noah Saduli	M	Ghana	MPhil	October 2016	Biotechnology	Leading enumerator teams, conducting laboratory testing, and doing data analysis	Nelson Opoku	University for Development Studies, (UDS)
Theophilus Tengey	M	Ghana	PhD	August 15, 2018	Plant and Soil Science	DNA markers for resistance to leaf spot	Carl Deom	Texas Tech University
Maxwell Yorke	M	Ghana	BSc	November 2016	Biotechnology		Nelson Opoku	University for Development Studies
Paul Karanja	M	Kenya	MSc	December 2014	Plant Biotechnology	Genetic transformation of peanut using RNA interference construct provided by NPRL	Renee Arias	Kenyatta University, Kenya

Name	Gender	Home Country	Degree	Graduation Date	Discipline	Research Focus	Mentor	Training Institution
Davis Gimode	M	Kenya	PhD	May 2019	Plant Breeding, Genetics and Genomics	Peanut genomics	Peggy Ozias-Akins	University of Georgia, Tifton, GA USA
Ruth Wagina	F	Kenya	PhD	May 2020	Environmental Health Science		J.S. Wang	University of Georgia
Andrew Abraham	M	Malawi	MSc	September 2016	Crop Science	Effect of rotations and harvest date on pre-harvest aflatoxin contamination	W. Mhango, V. Saka/R. Brandenburg	Lilongwe University of Agriculture and Natural Resources, Lilongwe, Malawi
Kelita Phambala	F	Malawi	BS	2016	Agronomy	Isolation of *Aspergillus* from soil and peanuts	Sam Njoroge/ Renee Arias	
Ruth Phiri	F	Malawi	BS	2016	Agronomy	Isolation of *Aspergillus* from soil and peanuts	Sam Njoroge/ Renee Arias	
Kobby Amponsah	M	Malawi	MSc	2015	Economics	Research Technician working on the productivity effects of improved groundnut seed varieties	Boris Bravo-Ureta	University of Connecticut
Albert Jere	M	Malawi	BSc	November 2017	Nutrition and Food Sciences	Effects of blanching and variety of peanut on sensory characteristics of cooked pumpkin leaves seasoned with peanut flour	Agnes Mwangwela	Lilongwe University of Agriculture and Natural Resources, Lilongwe, Malawi
Prince Chadza	M	Malawi	BS	July 2017	Agriculture Engineering		Agnes Mwangwela	Lilongwe University of Agriculture and Natural Resources, Lilongwe, Malawi
Monica Chimbaza	F	Malawi	MSc	June 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,

Name	Gender	Home Country	Degree	Graduation Date	Discipline	Research Focus	Mentor	Training Institution
								Malawi
Jeremy Jelliffe	M	Malawi	PhD	December 2017	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
Esther Mambo	F	Malawi	BS	2014	Biology	Isolation of *Aspergillus* from soil and peanut samples	Renee Arias	University of Malawi, Chancellor College
Dickson Mbughi	M	Malawi					Renee Arias	
Lydia Mkandawire	F	Malawi	MSc	November 2017	Agronomy		Agnes Mwangwela/R. Brandenburg	Lilongwe University of Agriculture and Natural Resources, Lilongwe, Malawi
Tchiyiwe Moyo	F	Malawi	MSc	February 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
Chancy Sibakwe	M	Malawi	MSc	September 2016	Entomology	Biotic/Abiotic stress impacts on pre-harvest aflatoxin contamination	W. Mhango, V. Saka/R. Brandenburg	Lilongwe University of Agriculture and Natural Resources, Lilongwe, Malawi
Longwe Tiwonge	F	Malawi	MSc	April 2017	Food Science	Baseline evaluation of peanut flour quality and processor knowledge of aflatoxin	Agnes Mwangwela	Lilongwe University of Agriculture and Natural Resources, Lilongwe, Malawi
Emmanuel Zuza, Jr.	M	Malawi	MSc	November 2016	Crop Production		Rick Brandenburg	University Eduardo Mondlane
Rita Valentim Manjonda	F	Mozambique	MS	December 2017	Agronomy	Reproductive efficiency of Valencia peanuts under terminal drought	Carl Deom	Khon Kaen University, Khon Kaen, Thailand
Maria	F	Mozambi	MS	December	Agronomy	Reproductive efficiency of	Carl Deom	Khon Kaen University,

Name	Gender	Home Country	Degree	Graduation Date	Discipline	Research Focus	Mentor	Training Institution
Jacinta De Carvalho Mopecane		que		2017		Valencia peanuts under terminal drought		Khon Kaen, Thailand
Salva Samegque Inacio	F	Mozambique	MSc	July 2018	Plant Breeding	Performance of high oleic acid breeding lines		Lilongwe University of Agriculture and Natural Resources, Lilongwe, Malawi
Deok Han	M	South Korea	PhD	May 2016	Electrical Engineering	Hyperspectral and multispectral imaging, remote sensing	Haibo Yao	Mississippi State University/Stennis Space Center
Imana Power	F	Suriname	PhD	December 2014-November 2016	Plant Pathology	Research on RNA interference	Renee Arias	University of Georgia, USA
Eric Simning	M	Tanzania	MSc		Economics	Research Technician working on the productivity effects of improved groundnut seed varieties	Boris Bravo-Ureta	
Yen Tswen Lai	F	Taiwan	MPS	May 2017	Animal Science		Greg MacDonald	Cornell University
Neha Paliwal		Uganda	MSc		Economics	Research technician working on the productivity effects of improved groundnut seed varieties	Boris Bravo-Ureta	
John Yawe	M	Uganda	MSc	May 2017	Agriculture Engineering/ Post-Harvest Processing	Assessment of existing drying and storage systems for peanuts	Mkandawire/ Simate / R. Brandenburg	University of Zambia
Jennifer Chagoya	F	USA	MS	December 2016	Crop Science	Breeding for tolerance to drought stress	Carl Deom	Texas Tech University
Kathryn Churchill	F	USA	PhD	December 2017	Animal Science		Greg MacDonald	Cornell University
Abraham Fulmer	M	USA	PhD	August 2017	Plant pathology	Leaf spots in peanut	Bob Kemerait	University of Georgia, Tifton, GA, USA
Chandler	F	USA	MS	May 2021	Plant Breeding,	Peanut interspecific	Peggy Ozias-	University of Georgia,

Name	Gender	Home Country	Degree	Graduation Date	Discipline	Research Focus	Mentor	Training Institution
Maddox					Genetics and Genomics	hybrids for introgression of pest and disease resistance	Akins	Tifton, GA USA
John M. North	M	USA	MS	December 2017	Agriculture Economics		Greg MacDonald	University of Georgia
LaSindia Powell	F	USA	BS	June 2016	Forensic Science	DNA extraction, analysis by fingerprinting of *Aspergillus* DNA	Renee Arias	Albany State University, USA
Amanda Seawright	F	USA	MSc	May 2016	Environmental Science	Aflatoxin detections in peanuts and grains	Jia-Sheng Wang	University of Georgia, Athens, GA USA
Monica Wang	F	USA	BS	June 2015	Chemistry/Biology	Bioinformatics	Renee Arias	Emory University, USA
Kathy Xue	F	USA	PhD, MPH	May 2017	Toxicology	Aflatoxin detection in dried blood samples	Jia-Sheng Wang	University of Georgia, Athens, GA USA
Hendrix Chalwe	M	Zambia	PhD	May 2018	Agronomy	Modeling of pre-harvest aflatoxin contamination in peanuts	Alice Mweetwa/R. Brandenburg	University of Zambia, Lusaka, Zambia
Abigail Hamiwe	F	Zambia	MSc	July 2017	Biological Sciences-Molecular Biology	Microbiological contamination of peanut butters/Fungal and aflatoxin changes in Peanut Butters made from 2 varieties from Zambia	Nyambe Mkandawire, John Shindano	University of Zambia Lusaka, Zambia
Gaspard Kwizera	M	Zambia	MSc	July 2017	Human Nutrition/Post Harvest Processing	Peanut processing at the household level	Nyambe Mkandawire, John Shindano	University of Zambia Lusaka, Zambia
Lutangu Makweti	M	Zambia	MSc	November 2017	Plant Breeding		Carl Deom	
Tambudzai Makwelele	F	Zambia	BSc	October 2017	Food Science & Technology	Physio-chemical Properties and Sensory Evaluation of Peanut Butter made from three Zambian Groundnut Varieties	John Shindano/Nyambe Lisulo Mkandawire/Koushik/R. Brandenburg	University of Zambia Lusaka, Zambia
Munsanda Ngulube	F	Zambia	MSc	October 2017	Agronomy	Use of biochar and gypsum to reduce aflatoxin in peanuts	Alice Mweetwa/R. Brandenburg	University of Zambia, Lusaka, Zambia

Non – Degree Long-Term Training (by country)

Name	Gender	Home Country	Training Institution	Dates	Discipline	Research Focus	Mentor	Training Location
Dr. Paola Faustinelli	F	Argentina	University of Cordoba, Argentina	March 2015-October 2017	Post Doc/Plant Biotechnology	RNA interference and genetic diversity of *Aspergillus*	Renee Arias	Texas A&M Agrilife Research
Dr. Imana Power	F	Suriname	University of Georgia, USA	December 2014-November 2016	Post Doc/Plant Pathology	RNA interference	Renee Arias	University of Georgia, Griffin, GA USA
Dr. Raphael Colbert	M	USA		2017		Peanut Crossing and breeding Techniques	Carl Deom	

Workshops and Courses

Event	M	F	Trainee(s)	Dates	Trainer/Institution	Research Focus	Mentor	Training Location
APRES 2017	0	5		07/11/17-07/13/2017			Agnes Mwangwela	Albuquerque, NM
CLC-Bio-Software	5	3		05/17/2016	Monica Wang	Training Bioinformatics	Renee Arias	Dawson, GA
Stakeholder Workshop	11	24	Extension staff, Research Technicians	December 14-18, 2018	Justus Chintu, Donald Siyeni/DARS, Malawi	Groundnut Trials and Demostrations	Carl Deom	Salima, Malawi
Training of Extension staff and Technicians	19	11	Extension staff and Research Technicians	April 18-22, 2016	Justus Chintu, Donald Siyeni/DARS,Malawi	Trial Management, Groundnut Production	Carl Deom	Salima, Malawi
Field Days	52	98	Farmers	April 2016	Justus Chintu	New Groundnut Varieties, PVS, Production practices for high productivity	Carl Deom	Ntcheu, Lilongwe, and Karonga, Malawi
Plot Harvesting	12	16		November 2015	Students and Women	Harvesting	Carl Deom	Gampela and POBE, Burkina Faso
Field Monitoring	12	10		July 30, 2016 to harvesting time	M. Almissa, Students and Farmers	Plot Notes	Carl Deom	Gampela and POBE, Burkina Faso
Field monitoring	8	20		Aug 29, 2016	P. Sankara	Planting and Field Plot Design	Carl Deom	Gampela, Burkina Faso
	46	24	World Vision-Mbale Butaleja cluster	March 2016	D.K. Okello and P. Osia,/ NASRRI	Groundnut Production System	Carl Deom	Uganda
	33	28	World Vision Sorotu cluster	February 2016	D.K. Okello and P. Osia/ NASRRI	Groundnut Production System	Carl Deom	Uganda
	10	7	Technicians East and Southern Africa	May 2016	D.K. Okello/ NASRRI	Legume Breeding Systems	Carl Deom	East and Central African
	9	4	Students Interns(certificate, Diploma, Bachelors	May 2- July 30, 2016	D.K. Okello/ NASRRI	Groundnut Value Chain	Carl Deom	Uganda
	11	16	Danish Refugee Council-Amuria	May 2016	D.K. Okleeo, P.Anguria, and P. Osia/NASRRI	Seed Systems, Agronomy	Carl Deom	Uganda
	32	38	ZOA Amuru	June 2016	P. Osia and S. Ocuga/NASRRI	Seed Systems, Agronomy, Crop Protection	Carl Deom	Uganda
	14	18	LSB Dokolo	June 2016	D.K. Okello and P. Anguria/NASRRI	Seed Systems	Carl Deom	Uganda

Event	M	F	Trainee(s)	Dates	Trainer/Institution	Research Focus	Mentor	Training Location
ZOA Farmer Training	73	48	Farmers	August 24, 2016	P. Osia and S. Ocuga/NASRRI	Seed Systems and Crop Protections	Carl Deom	Uganda
	25	7	Haitian Peanut Research Agronomist	June 21, 2016	/MFK & PMIL	Experimental Design and best management practices	Greg MacDonald	Quartier-Morin, Haiti
Enumerator Workshop	6	3		June 3, 2016, June 6-8, 2016	Boris Bravo-Ureta, Jermy Jelliffe	Familiarize enumerators with the survey instrument	Boris Bravo-Ureta	Nampula, Mozambique
Aflatoxin Training	9	16	Farmers	August/September 2015	Abdulai Baako/MoA, Noah Saduli/UDS, Vincent Ninkuu/UDS	Train treatment farmers on post-harvest best practices	Nick Magnan	Digbila Village, Northern Region, Ghana
Aflatoxin Training	17	8	Farmers	August/September 2015	Abdulai Baako/MoA, Noah Saduli/UDS, Vincent Ninkuu/UDS	Train treatment farmers on post-harvest best practices	Nick Magnan	Geluwei Village, Northern Region, Ghana
Aflatoxin Training	16	8	Farmers	August/September 2015	Abdulai Baako/MoA, Noah Saduli/UDS, Vincent Ninkuu/UDS	Train treatment farmers on post-harvest best practices	Nick Magnan	Kpsinga Village, Northern Region, Ghana
Aflatoxin Training	17	8	Farmers	August/September 2015	Abdulai Baako/MoA, Noah Saduli/UDS, Vincent Ninkuu/UDS	Train treatment farmers on post-harvest best practices	Nick Magnan	Nyong Village, Northern Region, Ghana
Aflatoxin Training	17	8	Farmers	August/September 2015	Abdulai Baako/MoA, Noah Saduli/UDS, Vincent Ninkuu/UDS	Train treatment farmers on post-harvest best practices	Nick Magnan	Tamalegu Village, Northern Region, Ghana
Aflatoxin Training	17	8	Farmers	August/September 2015	Abdulai Baako/MoA, Noah Saduli/UDS, Vincent Ninkuu/UDS	Train treatment farmers on post-harvest best practices	Nick Magnan	Kplung Village, Northern Region, Ghana
Aflatoxin Training	17	8	Farmers	August/September 2015	Abdulai Baako/MoA, Noah Saduli/UDS, Vincent Ninkuu/UDS	Train treatment farmers on post-harvest best practices	Nick Magnan	Nyeko Village, Northern Region, Ghana
Aflatoxin Training	17	8	Farmers	August/September 2015	Abdulai Baako/MoA, Noah Saduli/UDS, Vincent Ninkuu/UDS	Train treatment farmers on post-harvest best practices	Nick Magnan	Ying Village, Northern Region, Ghana
Aflatoxin Training	17	8	Farmers	August/September 2015	Abdulai Baako/MoA, Noah Saduli/UDS, Vincent Ninkuu/UDS	Train treatment farmers on post-harvest best practices	Nick Magnan	Zion Village, Northern Region, Ghana
Aflatoxin Training	17	8	Farmers	August/September 2015	Abdulai Baako/MoA, Noah Saduli/UDS, Vincent Ninkuu/UDS	Train treatment farmers on post-harvest best practices	Nick Magnan	Zoggu Village, Northern Region, Ghana

Event	M	F	Trainee(s)	Dates	Trainer/Institution	Research Focus	Mentor	Training Location
Aflatoxin Training	14	7	Farmers	August/September 2015	Abdulai Baako/MoA, Noah Saduli/UDS, Vincent Ninkuu/UDS	Train treatment farmers on post-harvest best practices	Nick Magnan	Gbrimani Village, Northern Region, Ghana
Aflatoxin Training	17	8	Farmers	August/September 2015	Abdulai Baako/MoA, Noah Saduli/UDS, Vincent Ninkuu/UDS	Train treatment farmers on post-harvest best practices	Nick Magnan	Kpakyiyli Village, Northern Region, Ghana
Aflatoxin Training	16	8	Farmers	August/September 2015	Abdulai Baako/MoA, Noah Saduli/UDS, Vincent Ninkuu/UDS	Train treatment farmers on post-harvest best practices	Nick Magnan	Kpaliga Village, Northern Region, Ghana
Aflatoxin Training	17	8	Farmers	August/September 2015	Abdulai Baako/MoA, Noah Saduli/UDS, Vincent Ninkuu/UDS	Train treatment farmers on post-harvest best practices	Nick Magnan	Satani Village, Northern Region, Ghana
Aflatoxin Training	17	9	Farmers	August/September 2015	Abdulai Baako/MoA, Noah Saduli/UDS, Vincent Ninkuu/UDS	Train treatment farmers on post-harvest best practices	Nick Magnan	Yipelgu Village, Northern Region, Ghana
Aflatoxin Training	16	9	Farmers	August/September 2015	Abdulai Baako/MoA, Noah Saduli/UDS, Vincent Ninkuu/UDS	Train treatment farmers on post-harvest best practices	Nick Magnan	Bachalbado Village, Northern Region, Ghana
Aflatoxin Training	17	9	Farmers	August/September 2015	Abdulai Baako/MoA, Noah Saduli/UDS, Vincent Ninkuu/UDS	Train treatment farmers on post-harvest best practices	Nick Magnan	Macheliyili Village, Northern Region, Ghana
Aflatoxin Training	16	9	Farmers	August/September 2015	Abdulai Baako/MoA, Noah Saduli/UDS, Vincent Ninkuu/UDS	Train treatment farmers on post-harvest best practices	Nick Magnan	Naaduno Village, Northern Region, Ghana
Aflatoxin Training	16	9	Farmers	August/September 2015	Abdulai Baako/MoA, Noah Saduli/UDS, Vincent Ninkuu/UDS	Train treatment farmers on post-harvest best practices	Nick Magnan	Sambu Village, Northern Region, Ghana
Aflatoxin Training	16	9	Farmers	August/September 2015	Abdulai Baako/MoA, Noah Saduli/UDS, Vincent Ninkuu/UDS	Train treatment farmers on post-harvest best practices	Nick Magnan	Tijo Village, Northern Region, Ghana
Aflatoxin Training	16	9	Farmers	September/October 2016	Josepth Amenini and Thomas Anobiga/MoA, Noah Saduli/UDS, Vincent Ninkuu/UDS	Train treatment farmers on post-harvest best practices	Nick Magnan	Achobisi Kasam Village, UE Region, Ghana
Aflatoxin Training	16	9	Farmers	September/October 2016	Josepth Amenini and Thomas Anobiga/MoA, Noah Saduli/UDS, Vincent Ninkuu/UDS	Train treatment farmers on post-harvest best practices	Nick Magnan	Asibiga Village, UE Region, Ghana

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

Event	M	F	Trainee(s)	Dates	Trainer/Institution	Research Focus	Mentor	Training Location
Aflatoxin Training	18	8	Farmers	September/October 2016	Josepth Amenini and Thomas Anobiga/MoA, Noah Saduli/UDS, Vincent Ninkuu/UDS	Train treatment farmers on post-harvest best practices	Nick Magnan	Dulugu-Asanorebisi Village, UE Region, Ghana
Aflatoxin Training	17	8	Farmers	September/October 2016	Josepth Amenini and Thomas Anobiga/MoA, Noah Saduli/UDS, Vincent Ninkuu/UDS	Train treatment farmers on post-harvest best practices	Nick Magnan	Feo Asimabisi Village, UE Region, Ghana
Aflatoxin Training	17	8	Farmers	September/October 2016	Josepth Amenini and Thomas Anobiga/MoA, Noah Saduli/UDS, Vincent Ninkuu/UDS	Train treatment farmers on post-harvest best practices	Nick Magnan	Nyangua Village, UE Region, Ghana
Aflatoxin Training	16	8	Farmers	September/October 2016	Josepth Amenini and Thomas Anobiga/MoA, Noah Saduli/UDS, Vincent Ninkuu/UDS	Train treatment farmers on post-harvest best practices	Nick Magnan	Sumbrungu Kologo Akanyebi Village, UE Region, Ghana
Aflatoxin Training	17	9	Farmers	September/October 2016	Josepth Amenini and Thomas Anobiga/MoA, Noah Saduli/UDS, Vincent Ninkuu/UDS	Train treatment farmers on post-harvest best practices	Nick Magnan	Sumbrungu Yeobongo Nayire Village, UE Region, Ghana
Aflatoxin Training	17	8	Farmers	September/October 2016	Josepth Amenini and Thomas Anobiga/MoA, Noah Saduli/UDS, Vincent Ninkuu/UDS	Train treatment farmers on post-harvest best practices	Nick Magnan	Tampola Village, UE Region, Ghana
Aflatoxin Training	17	8	Farmers	September/October 2016	Josepth Amenini and Thomas Anobiga/MoA, Noah Saduli/UDS, Vincent Ninkuu/UDS	Train treatment farmers on post-harvest best practices	Nick Magnan	Vea Gunga Village, UE Region, Ghana
Aflatoxin Training	18	8	Farmers	September/October 2016	Josepth Amenini and Thomas Anobiga/MoA, Noah Saduli/UDS, Vincent Ninkuu/UDS	Train treatment farmers on post-harvest best practices	Nick Magnan	Wiaga Yemonsa Village, UE Region, Ghana
Aflatoxin Training	18	8	Farmers	September/October 2016	Josepth Amenini and Thomas Anobiga/MoA, Noah Saduli/UDS, Vincent Ninkuu/UDS	Train treatment farmers on post-harvest best practices	Nick Magnan	Yikene Village, UE Region, Ghana
Workshop/Symposium	60	70	Professionals	November 28-December 1 2016		Introduce DBS method	JS Wang	Hangzhou, China

Event	M	F	Trainee(s)	Dates	Trainer/Institution	Research Focus	Mentor	Training Location
Course Module	33	9		Fall 2015	Nelson Opoku/UDS	Practical training in aflatoxin analysis	Nick Magnan	Ghana
Course Module	3	10		Fall 2016	Nelson Opoku/UDS	Practical training in aflatoxin analysis	Nick Magnan	Ghana
NARO meeting	2	0		September 19-22, 2016	David Okello	NARO Groundnut program	Boris Bravo-Ureta	Kampala, UG & Soroti, UG
Forecasting	3	1		2017	/ISSD:NARO	Seed demand forecasting	Carl Deom	Uganda
Breeding	3	0		2017	/ICRISAT:TLIII	Breeding Management Systems	Carl Deom	Uganda
Improvement	1	1		2017	/ICRISAT:TLIII	Gender in Groundnut Improvement	Carl Deom	Kenya
Breeding	2	0		2017	/ICRISAT	Breeding Management Systems	Carl Deom	Kenya
Production	10	10	Ag professionals	2017		Exposed Ag Professional s wotking in peanuts to modern production practices	Carl Deom	Haiti
Seed Quality	77	23	Para seed inspectors	2017		New attributes of newly released groundnuts	Carl Deom	Malawi
Prevention	660	339	Farmers	2017		Aflatoxin prevention refresher course	Nicholas Magnan	Ghana
Prevention	10	0	Student enumerators	2017		Training on delivering the aflatoxin prevention refresher course	Nicholas Magnan	Ghana
Prevention	13	12	Field Staff and Farmers	2017		Aflatoxin Prevention (using video)	Nicholas Magnan	Ghana
Aflatoxin Testing	70	70	3rd and 4th year students at UDS	2017		Practical aflatoxin testing and analysis	Nicholas Magnan	Ghana
Training	0	5	Nurses	2013-2017		3 times each year in anthropometry, data collection and management, and nutritional education	Mark Manary	Malawi
Workshop/Symposium	60	60	Professionals	June 2017		Introduce DBS method	JS Wang	Wuxi, China
Annual Meeting	50	50	Professionals	March 2017		Introduce DBS method and results	JS Wang	Baltimore, Maryland

Technology Transfer and Scaling Partnerships

PMIL partners have formed the cornerstone of the Malawi Agriculture Diversification Project funded by the USAID Malawi Mission. This project includes technical evaluation of the commercial groundnut seed sector, evaluation an integration of drip technology for groundnut seed production, development of improved technology package and a rigorous impact evaluation, including cost benefit analysis of technology adoption on household income.

Seed of improved varieties continues be scaled by commercial partners in Haiti and Malawi and through USAID-funded collaborating partners in Ghana.

Environmental Management and Mitigation Plan (EMMP)

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

During FY2017, the EMMP was updated to indicate personnel changes for each area and a copy of the updated EMMP provided to all personnel.

Open Data Management Plan

As part of the reporting process, publications and other information materials, along with associated datasets, were identified. The publications and information materials that were published prior to this report have been uploaded into the Digital Experience Clearinghouse by the Management Entity. Associated datasets are being assembled and uploaded to the Digital Data Library by the Management Entity.

Governance and Management

Management Entity

The Peanut & Mycotoxin Innovation Lab Management Entity (ME) 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:

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

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

Other entities 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 members participate in visits to PMIL research sites in the various countries.

Current External Advisory Panel members are:

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

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

Program Research Meetings

Due to funding limitations and the nearing of completion of the project, an annual meeting was not conducted as intended in Southern Africa.

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

Relevant visits:

- Site visit, Malawi/Zambia, October 2016, Director received project updates, including student presentations as they neared completion of their research.
- American Peanut Council/Peanut Foundation Winter meeting, Washington, D.C., December, Director attended organization meeting.
- Site visit, Malawi/Zambia/Mozambique, January, Director and Assistant Director visited sites, including research plots in Nampula and Maputo, Mozambique.

- Feed the Future IL Regional meeting, Senegal, February, Director attended annual gathering.
- Advances in Arachis Through Genetics & Biotechnology meeting, Córdoba, Argentina, March, Director attended.
- AgDiv Meeting, Malawi, March, Assistant Director attended, along with PIs Brandenburg and Bravo-Ureta.
- American Peanut Research & Education Society meeting, July, Director and Asst. Director attended, hosting several collaborators, including delegation from Malawi.
- IL directors meeting, Washington, D.C., Director and Asst. Director attended.
- Georgia Peanut Tour, South Georgia, ME attended, with Malawi/AgDiv delegation.

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

In addition to attending the Georgia Peanut Farm Show in January and the Georgia Peanut Tour in September, the Director participated in a roundtable discussion held by U.S. Rep. Austin Scott and U.S. Sen. Johnny Isakson's offices. The Director and Assistant Director communicated regularly with industry leaders from Birdsong Peanuts, Mars and others to gain market insight and feedback.

With a focus toward capacity-building, PMIL helped partners travel to conferences and other educational events. Six Malawian grad students attended and presented at the APRES meeting in New Mexico in July 2017, while a separate delegation from Malawi, including peanut breeder Justus Chintu, attended the Georgia Peanut Tour in September.

Project Monitoring and Evaluation

PMIL monitoring and evaluation is a continual process during the year. Annual evaluation of all projects is usually done during the annual project meetings where all projects are presented and discussed, and comments received from the External Advisory Panel. However, as there was no annual meeting during the project year, the above mentioned site visits and collaborative visits by the Director and Assistant Director were used to monitor progress during this last year.

Communications

Highlighting the work of Feed the Future and PMIL, as well as helping PIs and partners spread knowledge of research findings, are important parts of the ME's communications strategy.

Highlights of this year's communications activities include:

- Created an additional two infographics in a series, one that discussed the challenges of sampling for aflatoxin contamination, and one that stresses the impact that the whole peanut plant has on farming households and consumers.
- Created table-top science banners for USAID meeting surrounding IL directors' gathering.
- Created posters which describe different aspects of PMIL's work and approach to peanut innovation for the APRES meeting.
- Continued publishing monthly digital newsletter that now goes to more than 400 subscribers. Articles from the newsletter were re-published by numerous other media, drawing attention to the work of PMIL scientists and student researchers.

- Continued a daily newsletter to draw attention to time-sensitive news, such as job postings, abstract solicitations and grant opportunities that have deadlines.
- Continued social media presence:
    - Blog – Publishing short news items about opportunities in international development, peanut and mycotoxin research, and PMIL successes.
    - Social media – Facebook and Twitter followers grew to more than 500 and a new Instagram account launched. Social media is used primarily to celebrate partners' accomplishments and spread the word about learning opportunities.
    - Flickr – New photo albums uploaded to show work in Africa and provide collaborators access to images.
    - YouTube – 29 videos, including some in local languages. All are close-captioned.
- Published 24 feature articles about PMIL in the lab's newsletter, many of which were also published by Agrilinks.

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 backup, end of life equipment replacement, and System Administration staffing.
- WordPress blog design and support staff.

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

Other Topics

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

The Assistant Director is an advisory member of an International Development Research Centre funded project led by Laval University to research and promote aflatoxin control measures in the peanut, sorghum and maize value chains in Haiti, including engagement with the Government of Haiti to establish national regulatory limits.

Issues

No major issues have arisen during the past year, although the delay in receiving funds for the final year did create some issue in travel and data analysis by some partners. The granting of a no-cost extension until end of September did allow most of the planned activities to be concluded. Administrative issues in implementing the sub-award contracts for some of the projects in partner countries have been reduced since fixed-term contracts were issued directly by UGA.

Future Directions

PMIL is compiling final reports with anticipation that these findings will strategically inform the future Feed the Future Innovation Lab for Peanut Research.

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
IMPAQ International		Columbia	MD
International Food Policy Research Institute (IFPRI)		Washington	DC
University of Florida	Agronomy Department	Gainesville	FL
Premier Steppe Ferme		Lake Worth	FL
University of Florida	North Florida Research and Education Center	Marianna	FL
Frank's Designs for Peanuts, LLC		Mexico Beach	FL
University of Georgia	Center for Applied Genetic Technologies	Athens	GA
University of Georgia	Department of Plant Pathology	Athens	GA
University of Georgia	Center for Applied Genetic Technologies	Athens	GA
University of Georgia	Department of Agricultural and Applied Economics	Athens	GA
University of Georgia	Department of Environmental Health Science	Athens	GA
United States Department of Agriculture-Agriculture Research Service (USDA-ARS)	National Peanut Research Laboratory	Dawson	GA
United States Department of Agriculture-Agriculture Research Service (USDA-ARS)	Plant Genetic Resources Conservation Unit	Griffin	GA
University of Georgia	Department of Food Science and Technology	Griffin	GA
United States Department of Agriculture-Agriculture Research Service (USDA-ARS)	Coastal Plain Experiment Station	Tifton	GA
University of Georgia	Plant Pathology	Tifton	GA
University of Georgia	Department of Plant Pathology	Tifton	GA
University of Georgia	National Environmentally Sound Production Agriculture Laboratory (NESPAL)	Tifton	GA
University of Georgia	Department of Entomology	Tifton	GA
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

Institution	Department	City	State
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

A2. 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
Haiti		
TechnoServe		Petionville
Meds & Food for Kids		Quartier Morin
Partners in Health/Zanmi Agrikol		Corporant
Acceso Peanut Enterprise Corporation		Petionville
India		
Tamil Nadu Agricultural University	Department of Plant Biotechnology	Chennai
International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)	Grain Legumes Research Program	Hyderabad
International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)	Center of Excellence in Genomics	Hyderabad
Kenya		

Institution	Department	City
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 Smallholder Farmers Association of Malawi (NASFAM)		Lilongwe
Mali		
International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)	West and Central Africa Regional Program	Bamako
Mozambique		
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
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)	Savanna Agricultural Research Institute (SARI)	Nyankpala
National Agricultural Research Organization (NARO)	National Semi Arid Resources Research Institute (NaSARRI)	Soroti
Bulogo Women's Group		
Zambia		
Eastern Province Farmer's Cooperative Ltd.	Katopola Farm Institute	Chipata
Zambia Agriculture Research Institute (ZARI)		Chipata
Zambia Agriculture Research Institute (ZARI)	Mt. Makulu Central Research Station	Lusaka
University of Zambia	School of Agricultural Sciences	Lusaka

Appendix B. List of Awards to Partners

B1. US Partners (by State)

Institution		Project Name	Start Date (mm/dd/yy)	End Date (mm/dd/yy)	FY 2017 Expenditures	Total Expenditures
Connecticut					**$185,754**	**$358,558**
University of Connecticut (U Conn)	A3.	An Integrated Global Breeding and Genomics Approach to Intensifying Peanut Production and Quality *(sub-award from UGA)*	11/26/13	9/30/17	$0	$19,000
	C2.	Using Applied Research and Technology Transfer to Minimize Aflatoxin Contamination and Increase Production, Quality and Marketing of Peanut in Ghana *(sub-award from NCSU)*	5/1/14	9/30/17	$72,753	$124,860
	C5.	Productivity and Profitability Growth in Peanut Production: A Farm Level Analysis in Malawi, Mozambique and Zambia	8/1/14	9/30/17	$113,001	$214,698
District of Columbia					**$90,366**	**$262,217**
International Food Policy Research Institute	C3.	Producer and Consumer Interventions to Decrease Peanut Mycotoxin Risk in Ghana *(sub-award from UGA)*	2/7/14	9/30/17	$90,366	$262,217
Florida					**$95,991**	**$380,736**
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	9/30/17	$64,611	$257,083
	C1.	Production to Consumption – Technologies to Improve Peanut Production, Processing and Utilization in Haiti	12/1/13	9/30/17	$6,011	$40,887
	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	9/30/17	$25,369	$82,766
Georgia					**$905,389**	**$2,686,702**
University of Georgia (UGA)	A1.	Translational Genomics to Reduce Pre-harvest Aflatoxin Contamination of Peanut	11/1/13	9/30/17	$238,055	$466,562
	A3.	An Integrated Global Breeding and Genomics Approach to Intensifying Peanut Production and Quality	11/26/13	9/30/17	$27,984	$186,061
	B2.	Development and Validation of Methods for Detection of Mycotoxins Exposure in Dried Spotted Blood Samples	9/26/13	9/30/17	$181,254	$776,152

Institution		Project Name	Start Date (mm/dd/yy)	End Date (mm/dd/yy)	FY 2017 Expenditures	Total Expenditures
	C1.	Production to Consumption – Technologies to Improve Peanut Production, Processing and Utilization in Haiti *(sub-award from UFL)*	12/1/13	9/30/17	$92,498	$267,858
	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	9/30/17	$59,808	$167,927
	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	9/30/17	$15,862	$63,205
	C3.	Producer and Consumer Interventions to Decrease Peanut Mycotoxin Risk in Ghana	2/7/14	9/30/17	$19,031	$83,229
	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/..0./14	9/30/17	$76,782	$257,297
USDA-ARS National Peanut Research Laboratory (NPRL)	A2.	Silencing of Aflatoxin Synthesis through RNA Interference (RNAi) in Peanut Plants	2/7/14	9/30/17	$194,115	$418,411
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	9/30/17	$0	$0
Maryland					**$0**	**$23,208**
IMPAQ International	C3.	Producer and Consumer Interventions to Decrease Peanut Mycotoxin Risk in Ghana	10/1/14	9/30/17	$**0**	**$23,208**
Mississippi					**$104,023**	**$399,836**
Mississippi State University (MSU)	B1.	AflaGoggles for Screening Aflatoxin Contamination in Maize	10/1/14	9/30/17	$75,476	$356,376
USDA-ARS Southern Regional Research Center	B1.	AflaGoggles for Screening Aflatoxin Contamination in Maize *(sub-award from MSU)*	10/1/14	9/30/17	$28,547	$43,460
Missouri					**$51**	**$181,500**
Washington University (WU)	B4.	Randomized Controlled Trial of the Impact of Treating Moderately Malnourished Women in Pregnancy	11/1/13	7/31/17	$51	$181,500
New Mexico					**$46,506**	**$208,128**
New Mexico State University (NMSU)	A3.	An Integrated Global Breeding and Genomics Approach to Intensifying Peanut Production and Quality *(sub-award from UGA)*	11/26/13	9/30/17	$46,506	$208,128
New York					**$26,141**	**$270,669**
Cornell University	C1.	Production to Consumption – Technologies to Improve Peanut Production, Processing and Utilization in Haiti *(sub-award from UFL)*	12/1/13	9/30/17	$26,141	$270,669

Institution		Project Name	Start Date (mm/dd/yy)	End Date (mm/dd/yy)	FY 2017 Expenditures	Total Expenditures
North Carolina					**$100,912**	**$375,484**
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	9/30/17	$14,560	$123,392
	C4.	Aflatoxin Management Interventions, Education and Analysis at Various Steps Along the Peanut Value Chain in Malawi, Mozambique and Zambia	7/1/14	9/30/17	$86,352	$252,092
Texas					**$27,397**	**$211,571**
Texas A&M University (TAMU)	A3.	An Integrated Global Breeding and Genomics Approach to Intensifying Peanut Production and Quality *(sub-award from UGA)*	11/26/13	9/30/17	$27,397	$211,571
Virginia					**$45,256**	**$290,044**
Virginia Tech (VT)	A3.	An Integrated Global Breeding and Genomics Approach to Intensifying Peanut Production and Quality *(sub-award from UGA)*	11/26/13	9/30/17	$0	$11,065
	B3.	Aflatoxin in Peanut and Peanut Products: Comparative Study on Analytical Methods for Detection of Aflatoxin	7/1/14	12/31/15	$0	$79,431
	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	9/30/17	$10,015	$81,117
	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	9/30/17	$35,241	$118,431

B2. Non-US Partners (by Country)

Institution		Project Name	Start Date (mm/dd/yy)	End Date (mm/dd/yy)	FY2017 Expenditures	Total Expenditures
Burkina Faso					**$32,271**	**$42,386**
University of Ouagadougou	A3.	An Integrated Global Breeding and Genomics Approach to Intensifying Peanut Production and Quality *(sub-award from UGA)*	11/26/13	9/30/17	$32,271	$42,386
Ghana					**$188,033**	**$697,511**
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	9/30/17	$42,025	$178,380

Institution		Project Name	Start Date (mm/dd/yy)	End Date (mm/dd/yy)	FY2017 Expenditures	Total Expenditures
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	9/30/17	$35,000	$209,942
Savanna Agriculture Research Institute	A3.	An Integrated Global Breeding and Genomics Approach to Intensifying Peanut Production and Quality *(sub-award from UGA)*	11/26/13	9/30/17	$43,084	$50.982
	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	9/30/17	$50,742	$228,650
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	9/30/17	$17,182	$29,557
Haiti					**$76,262**	**$273,642**
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	9/30/17	$76,262	$273,642
India					**$144,836**	**$327,668**
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	9/30/17	$144,836	$327,668
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	9/30/17	$0	$0
Malawi					**$261,963**	**$1,047,007**
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	9/30/17	$118,392	$330,325
Chitedze Agriculture Research Service	A3.	An Integrated Global Breeding and Genomics Approach to Intensifying Peanut Production and Quality *(sub-award from UGA)*	11/26/13	9/30/17	$30,000	$75,305
	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	9/30/17	$6,789	$13,219
ExAgris Africa Limited	C4.	Aflatoxin Management Interventions, Education and Analysis at Various Steps Along the Peanut Value Chain in Malawi, Mozambique and Zambia *(sub-award from NCSU)*	7/1/14	9/30/17	$14,433	$28,633

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	9/30/17	$40,410	$64,328
	A3.	An Integrated Global Breeding and Genomics Approach to Intensifying Peanut Production and Quality *(sub-award from UGA)*	11/26/13	9/30/17	$45,000	$300,444
	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	9/30/17	$6,939	$116,252
University of Malawi	B4.	Randomized Controlled Trial of the Impact of Treating Moderately Malnourished Women in Pregnancy *(sub-award from WU)*	11/1/13	7/30/17	$0	$118,501
Mozambique					**$58,753**	**$171,677**
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	9/30/17	$22,000	$107,001
	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	9/30/17	$36,753	$45,503
	C5.	Productivity and Profitability Growth in Peanut Production: A Farm Level Analysis in Malawi, Mozambique and Zambia *(sub-award from U Conn)*	8/1/14	9/30/17	$0	$12,973
Universidade Eduardo Mondlane	C4.	Aflatoxin Management Interventions, Education and Analysis at Various Steps Along the Peanut Value Chain in Malawi, Mozambique and Zambia *(sub-award from NCSU)*	10/10/15	09/30/17	$0	$6,200
Nigeria					**$0**	**$0**
International Institute of Tropical Agriculture	B1.	AflaGoggles for Screening Aflatoxin Contamination in Maize *(sub-award from MSU)*	10/1/14	9/30/17	$0	$0
Senegal					**$15,500**	**$96,000**
Senegal Agriculture Research Institute	A1.	Translational Genomics to Reduce Pre-harvest Aflatoxin Contamination of Peanut *(sub-award from UGA)*	11/1/13	9/30/17	$15,500	$96,000
Uganda					**$50,659**	**$323,917**
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	9/30/17	$0	$0
National Crops Resources Research Institute	A2.	Silencing of Aflatoxin Synthesis through RNA Interference (RNAi) in Peanut Plants *(sub-award from NPRL)*	2/7/14	9/30/17	$7,659	$16,659
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	9/30/17	$43,000	$283,258

Bulogo Women's Group	A3.	An Integrated Global Breeding and Genomics Approach to Intensifying Peanut Production and Quality *(sub-award from UGA)*	11/26/13	9/30/17	$0	$24,000
Zambia					**$139,080**	**$307,482**
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	9/30/17	$112,080	$241,670
Zambia Agriculture Research Institute	A3.	An Integrated Global Breeding and Genomics Approach to Intensifying Peanut Production and Quality *(sub-award from UGA)*	7/1/14	9/30/17	$27,000	$65,812
	C5.	Productivity and Profitability Growth in Peanut Production: A Farm Level Analysis in Malawi, Mozambique and Zambia *(sub-award from U Conn)*	8/1/14	9/30/17	$0	$0

Appendix C. Success Stories

C1. Regional breeding network helps develop improved peanut varieties

While peanut is a traditional ingredient in many African dishes and a protein-rich supplement to the diet, the job of breeding peanut plants for disease resistance and other advantageous qualities can be frustrating. Smallholder farmers often save seed from season to season, though those local varieties often produce low yields, and most national programs are underfunded and are lucky if the legume breeder works exclusively with peanut.

That reality makes a consortium of peanut breeders in East and Southern Africa – a team that the Peanut and Mycotoxin Innovation Lab (PMIL) helps to support and nurture – so innovative and important.

The consortium includes David Kalule Okello, the chief peanut breeder in Uganda, working with colleagues Justus Chintu in Malawi, Amade Muitia in Mozambique, and Lutangu Makweti in Zambia.

David Okello (blue and white shirt) shows students from Makerere University germinating F2 plants from the Zambian Landrace Improvement Program. (Photo courtesy of Lutangu Makweti

PMIL and its predecessor, the Peanut CRSP, have partnered with Okello since 2006, when he began to lead the groundnut improvement program at the National Semi Arid Resources Research Institute (NaSARRI) in Uganda.

Under Okello's leadership of the peanut breeding program, NaSARRI has released 10 cultivars – the Serenut 5-14 series, which possess important agronomic traits including resistance to Groundnut Rosette Disease and late leaf spot, show increased yields and are very popular and well received by farmers.

Germplasm from these lines has been shared with breeders across Africa, as well as with PMIL collaborators in Haiti, to evaluate and potentially release locally or make crosses to improve the local varieties.

In June, for example, Makweti and his technician traveled from Zambia to Uganda to visit Okello's program. Okello shared six of his improved varieties with his Zambian colleagues to evaluate back home, while also planning to make crosses of improved Zambian varieties with his own rosette-resistant materials.

Joining Okello in the innovation lab, Chintu, Muitia and Makweti all have been part of the present PMIL prgram. This has allowed them to travel to the US to visit the USDA germplasm evaluation project, develop deeper relations with US breeding partners to assist with use of advanced marker assisted technologies, and even prepare collaborative research proposals to expand their regional program.

The breeders have also reached out recently to fellow peanut scientists in Senegal, Issa Faye and Daniel Fonceka also part of the PMIL program, to access novel genetic materials produced by the Senegal program for evaluation in East and Southern Africa. Some of these materials have already been released as new varieties in Senegal and may offer improved traits for all breeding programs.

PMIL has encouraged and supported this consortium of young, ambitious and talented breeders that will continue to strengthen and provide long lasting and sustainable improvements to food/economic security and agriculture in sub-Saharan Africa and internationally.

C2. PMIL student research contributes to national standard for peanut flour

When the Malawi Bureau of Standards set new requirements this year for the quality of groundnut flour sold in the marketplace, regulators relied on data collected by a Peanut & Mycotoxin Innovation Lab-sponsored student, Tiwonge Longwe.

In her master's thesis research, Longwe explored the effect that blanching has on removing aflatoxin from contaminated peanuts – or groundnuts as they are called in most of Africa – and also establish baseline measures for quality. Longwe recently completed her studies at Lilongwe University of Agriculture and Natural Resources.

Cooks use groundnut flour to add protein to stews, stir-fry and cereals, such as porridge.

But, the product can be at particular risk of contamination if processors mill moldy or rotten nuts in with higher quality nuts to try to mask the bad taste. One of the most concerning contaminants is aflatoxin, which causes childhood stunting and cancer.

Tiwonge Longwe, a student at Lilongwe University for Agriculture and Natural Resources, evaluates the aflatoxin level of groundnut flour from the market. Longwe's research helped the national bureau of standards set a baseline for quality and safety in groundnut flour. (Photo courtesy of Tiwonge Longwe)

"In trying to encourage processors to reduce the risk, blanching followed by sorting was suggested," Longwe said. In her experiments, blanching the nuts through a light, dry roast and removing the skins, and then sorting out the kernels with visible damage reduced aflatoxin to non-detectable levels without changing the way flour mixes or cooks in any way that would keep cooks from using flour from blanched nuts.

Longwe's research not only showed the beneficial effect of blanching, but also captured the ideal moisture, protein, fat and fiber content, as well as the maximum amount of ash and free fatty acids that should be allowed.

The Malawi Bureau of Standards already had a regulation for raw groundnuts and processed peanut butter; the new standard for flour follows the same aflatoxin cap – 5 ppb for the most dangerous kind of aflatoxin (B1) and 10 ppb for all strains of aflatoxin – that applies to groundnuts and peanut butter, and requires that flour be free of any E. coli or Salmonella.

The regulation also includes quality standards, such as color, taste and odor, as well as particle size.

"During our (work) to draft and review this standard, we needed scientific research-based evidence to set minimum and maximum limits for the aforesaid requirements; hence, consulting PMIL/Longwe of

LUANAR that provided the information they had," said William Kasapila, chair of the Technical Committee that drafted the regulation.

"In addition, we got information about aflatoxin and peroxide values for groundnut flour from Longwe's work before regulating limits," he said.

Initially, the regulating agency hadn't intended to address free fatty acids and peroxide, but Longwe and LUANAR Associate Professor of Food Science and Dean of Faculty Agnes Mwangwela advised how those two factors can indicate the likelihood of rancidity.

The regulation went into effect in early 2017.

Fellow LUANAR student Chikondi Magombo also contributed to the standard and improved food safety by creating a training program for processors. Magombo's work involved collecting samples from groundnut processors, testing those samples for contaminants and creating a training program that addressed specific best practices required to create high-quality flour.

By setting these public standards, all manufacturers will be held to a higher standard that will protect consumers and hopefully lead to higher consumer confidence and demand for these highly nutritious traditional foods.

C3. Extension agent obtains advanced degree and implements what she learned

As a mid-career agricultural extension agent in Malawi, Lydia Mkandawire returned to school to get a master's degree and research some of the fundamental questions limiting the advice she could give to farmers.

After receiving a master's degree in agronomy from Lilongwe University of Agriculture and Natural Resources, she's back on the job, sharing her knowledge and using her research findings to improve productivity in her own fields.

With support from the Peanut & Mycotoxin Innovation Lab (PMIL), Mkandawire performed peanut field trials on farms owned by Exagris, a commercial seed producer in Malawi. Her work, advised by LUANAR faculty and the PMIL Southern Africa Value Chain Principal Investigator, Rick Brandenburg of North Carolina State University, created a template for how LUANAR students might perform research on Exagris' farms in the future, working alongside the company's commercial seed production and research fields.

Mkandawire's research included several variables, but the main question was about planting density. Testing populations of 89,000 plants per hectare; 178,000 plants per hectare; and 285,000 plants per hectare, Mkandwire found that yield increased steadily with higher planting density at two research locations in different agroecological zones over two planting seasons.

Lydia Mkandawire explains her research at the Exagris farm near Bunda in Malawi. As an agricultural extension agent, Mkandawire found a gap in the information she had to give growers about planting density, planting time and other factors, so she returned to the university to get a master's degree. Her findings have influenced practices on her own farm. (Photo by Allison Floyd)

Her highest yield that year was 1,289 kg/ha at a farm in the low-lying eastern area near Lake Malawi.

Smallholder farmers in Malawi usually plant at low density due to the expense of the added inputs, but knowing that they will find a return on the investment, farmers might choose to buy more seed and plant a denser stand of peanuts. These same findings were of critical interest to Exagris' commercial operations and also will be integrated into their outgrower program where thousands of farmers in proximity to the farms will begin growing peanuts.

Mkandawire's research also shows that planting date impacts yield more than many farmers are aware. In Malawi, farmers often wait to plant peanut until after the rains have started and after they have planted corn, tobacco and other high-value crops, but she found that peanut planted early, before the start of the rainy season had 10 to 20% higher yield than peanut planted later.

Even before she completed her thesis and returned to work in extension, Mkandawire began to implement changes in her own farming operation based on the data she collected.

On her own 10-hectare farm, she planted peanut at the highest plant density explored in her research, and harvested the large crop she expected from the results of her field trials.

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