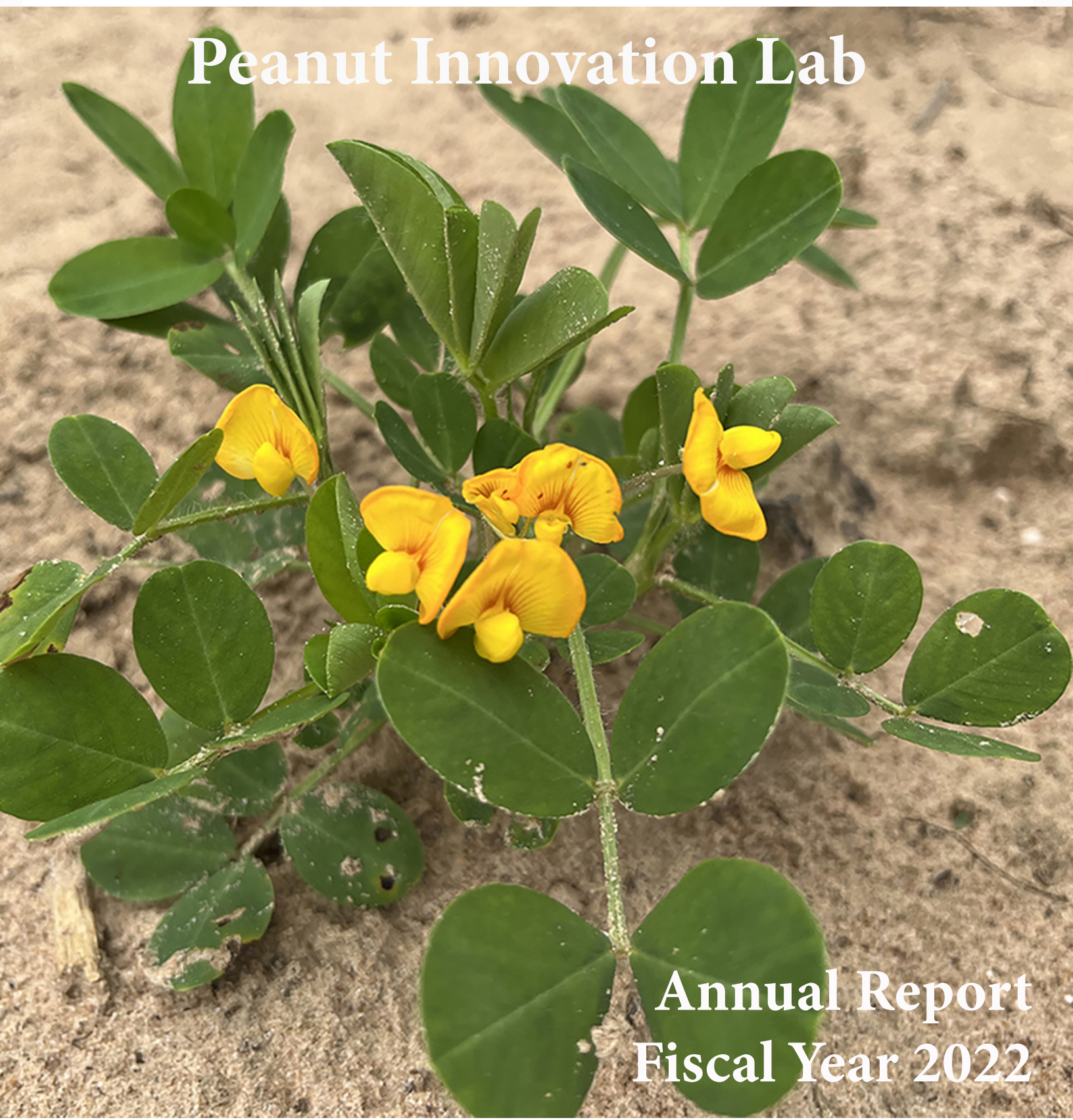
FEED THE FUTURE

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

# Peanut Innovation Lab



## Annual Report
## Fiscal Year 2022

# Feed the Future
# Innovation Lab for Peanut

(Peanut Innovation Lab)

# Annual Report – Fiscal Year 2022

(1 October 2021 – 30 September 2022)

Peanut Innovation Lab Management Entity
University of Georgia, Athens, Georgia

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# Management Entity

The Peanut Innovation Lab Management Entity is hosted by the University of Georgia's College of Agricultural and Environmental Sciences in Athens, GA. Current staff includes Dave Hoisington (director), Jamie Rhoads (assistant director), Jessica Marter-Kenyon (Gender and Youth specialist), Allen Stripling (business manager), Allison Floyd (communications coordinator), and Kristen McHugh (operations specialist).

# External Advisory Panel

The External Advisory Panel (EAP) continues to provide feedback on the research progress by participating in project launch meetings and events in-country, as well as reviewing annual reports. Current External Advisory Panel members are:

- Darlene Cowart, Corporate Food Safety director, Birdsong Peanuts, US
- Cynthia Donovan, retired associate professor, Agricultural Food and Resource Economics, Michigan State University, US
- Jeff Ehlers, program officer, Bill & Melinda Gates Foundation, US
- Andrew Emmott, independent consultant, UK
- Jeff Johnson, retired president, Birdsong Peanuts, US
- Isaac Minde, deputy director, Innovative Agricultural Research Initiative (iAGRI), Tanzania, and Professor of International Development, Michigan State University, US
- Shyam Nigam, expert consultant in agriculture for development, India
- Helga Recke, visiting fellow-CALS-AWARE, Cornell University, US
- Samara Sterling, research director, The Peanut Institute, US
- Farid Waliyar, independent consultant, retired from ICRISAT in 2014, France

The Peanut Innovation Lab director and assistant director, and the USAID agreement officer's representatives (Daniel Bailey) and activity manager (Jim Gaffney) are *ex officio* members of the External Advisory Panel.

# Program Countries

The Peanut Innovation Lab focus countries are Ghana, Malawi, Senegal and Uganda. Certain projects have research activities in Burkina Faso, India, Kenya, Mali, Niger and Togo.

# Program Partners

## United States of America

| Institution | Department | City | State |
|---|---|---|---|
| **Alcorn State University** | Department of Agriculture | Lorman | MS |
| **International Food Policy Research Institute (IFPRI)** | | Washington | DC |
| **Iowa State University** | | Ames | IA |
| **North Carolina State University (NCSU)** | Department of Crop and Soil Sciences | Raleigh | NC |
| | Department of Entomology and Plant Pathology | Raleigh | NC |
| **The Ohio State University** | Global Water Institute | Columbus | OH |
| | School of Environment and Natural Resources | Columbus | OH |
| **Pennsylvania State University** | College of Agricultural Sciences | University Park | PA |
| **Stanford University** | Center of Food Security and the Environment | Stanford | CA |
| **Texas A&M University** | Department of Soil and Crop Sciences | Lubbock | TX |
| **Texas Tech University** | Department of Plant and Soil Science | Lubbock | TX |
| **United States Department of Agriculture-Agriculture Research Service (USDA-ARS)** | Market Quality & Handling Research | Raleigh | NC |
| | National Peanut Research Laboratory (NPRL) | Dawson | GA |
| | Plant Genetic Resources Conservation Unit | Griffin | GA |
| **University of California, Santa Barbara, (UCSB)** | Department of Geography | Santa Barbara | CA |

| Institution | Department | City | State |
|---|---|---|---|
| **University of Florida** | Department of Agronomy | Gainesville | FL |
| **University of Georgia (UGA)** | Department of Agricultural and Applied Economics | Athens | GA |
| | Department of Crop and Soil Sciences | Athens | GA |
| | Department of Entomology | Athens | GA |
| | Department of Environmental Health Science | Athens | GA |
| | Department of Horticulture | Tifton | GA |
| | Department of Plant Pathology | Athens | GA |
| **University of Tennessee** | Institute of Agriculture | Knoxville | TN |
| **Virginia Polytechnic Institute and State University** | College of Agriculture & Life Sciences | Blacksburg | VA |
| | Tidewater Agricultural Research and Education Center | Suffolk | VA |
| **Washington University, St. Louis** | School of Medicine | St. Louis | MO |

## Foreign

| Institution | Department | City |
|---|---|---|
| **Burkina Faso** | | |
| | Centre National de La Recherché Scientifique et Technologique | Ouagadougou |
| | Institut de l'Environnement et de Recherches Agricoles | Ouagadougou |
| **Ghana** | | |
| Council for Scientific and Industrial Research (CSIR) | Crop Research Institute (CRI) | Kumasi |
| | Savannah Agricultural Research Institute (SARI) | Nyankpala |
| Kwame Nkrumah University of Science and Technology (KNUST) | | Kumasi |
| Project Peanut Butter | | Kumasi |
| University for Development Studies (UDS) | | Tamale |
| University of Ghana | School of Biological Science | Accra |
| **India** | | |
| International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) | | Patancheru |

| Institution | Department | City |
|---|---|---|
| **Kenya** | | |
| International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) | | Nairobi |
| **Malawi** | | |
| Department of Agricultural Research Services (DARS) | Chitedze Research Station | Chitedze |
| Horizon Farms | | Lisungwe |
| Lilongwe University of Agricultural and Natural Resources (LUANAR) | Crop and Soil Sciences Department | Bunda |
| | Department of Food Science and Technology | Bunda |
| | Food Technology and Nutrition Group | Lilongwe |
| **Mexico** | | |
| Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT) | Integrated Breeding Platform (IBP) | Mexico City |
| **Mali** | | |
| Institut d'Economie Rurale (IER) | Centres Régionaux de Recherche Agronomique (CRRA) | Bamako |
| **Mozambique** | | |
| Instituto de Investigação Agrária de Moçambique (IIAM) | Northeast Zonal Center | Nampula |
| **Niger** | | |
| Centre Régional de la Recherche Agronomique du Niger (INRA) | Centre Régional de la Recherche Agronomique (CERRA) | Niamey |
| International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) | Sahelian Centre | Niamey |
| **Senegal** | | |
| Centre de Recherche Pour le Developpement Économique et Social (CRDES) | | Dakar |
| École Nationale Supérieure d'Agriculture de Thiès (ENSA) | | Thiès |
| Institut Sénégalais de Reserches Agricoles (ISRA) | Centre d'Etude Régional pour l'Amélioration de l'Adaptation à la Sécheresse (CERAAS) | Thiès |
| | Centre National de Recherches Agronomiques (CNRA) | Bambey |
| Université Cheikh Anta Diop | Faculté des Sciences Économiques et de Gestion (FASEG) | Dakar |
| Université de Thiès | | Thiès |
| Université Gaston Berger | L'Unité de Formation et de Recherche de Sciences Économiques et de Gestion | Saint-Louis |
| **Togo** | | |
| | Institut Togolais de Recherches Agronomiques | Lomé |

| Institution | Department | City |
|---|---|---|
| **Uganda** | | |
| Makerere University | College of Agricultural and Environmental Sciences | Kampala |
| | Department of Disease Control and Environmental Health | Kampala |
| | School of Women and Gender Studies, Makerere University | Kampala |
| National Agricultural Research Organization (NARO) | National Crops Resources and Research Institute (NaCRRI) | Namulonge |
| | National Semi Arid Resources Research Institute (NaSARRI) | Soroti |
| **Zambia** | | |
| Zambia Agriculture Research Institute (ZARI) | Msekera Research Station | Chipata |

# Acronyms

| | |
|---|---|
| AAGB | Advances in Arachis Genomics and Biotechnology |
| AB-QTL | advanced backcross-quantitative trait loci |
| ANCAR | Agence Nationale de Conseil Agricole et Rural, Senegal |
| AOR | Agreement Officer's Representative |
| APPSA | African Productivity Program for Southern Africa (World Bank) |
| ARS | Agricultural Research Service |
| BMS | Breeding Management System |
| CERAAS | Centre d'Etude Régional pour l'Amélioration de l'Adaptation á la Sécheresse, Senegal |
| CERDES | Centre de Recherche Pour le Developpement Economique et Social |
| CERRA | Centre Régional de la Recherche Agronomique, Niger |
| CIMMYT | Centro Internacional de Mejoramiento de Maíz y Trigo, Mexico |
| CIRAD | Centre de Coopération Internationale en Recherche Agronomique pour le Développement, France |
| CNRA | Centre National de Recherches Agronomiques, Senegal |
| Co-PI | co-principal investigator |
| CRI | Crops Research Institute, Ghana |
| CRRA | Centres Régionaux de Recherche Agronomique, Mali |
| CRSP | collaborative research support program |
| CSIR | Council for Scientific and Industrial Research, Ghana |
| CSSL | Chromosomal Segment Substitution Line |
| DARS | Department of Agricultural Research Services, Malawi |
| EAP | External Advisory Panel |
| EBCA | Enhancing Breeding Capacity in Africa |
| ENSA | École Nationale Supériere d'Agriculture |
| ESA | East and Southern Africa |
| FENAB | Fédération Nationale pour l'Agriculture Biologique, Senegal |
| FY19 | Fiscal Year 2019 |
| GGWG | Ghana Groundnut Working Group |
| GRD | Groundnut rosette disease |
| GREAT | Gender-responsive Researchers Equipped for Agricultural Transformation |
| GRV | groundnut rosette virus |
| GWAS | genome-wide associations study |
| GxE | genotype by environment |
| HTP | high-throughput phenotyping |
| IBP | Integrated Breeding Platform |
| ICRISAT | International Crops Research Institute for the Semi-Arid Tropics, India |
| IER | Institut d'Economie Rurale, Mali |
| IFAD | International Fund for Agricultural Development |
| IFPRI | International Food Policy Research Institute, USA |
| IIAM | Instituto de Investigação Agrária de Moçambique, Mozambique |
| INRA | Institut National de la Recherche Agronomique, Mali |
| INRAN | Institut National de la Recherche Agronomique du Niger |
| IRB | Institutional Review Board |
| ISRA | Institut Sénégalais de Researches Agricoles, Senegal |
| ITRA | Institut Togolais de Recherche Agronomique, Togo |
| IVSC | *in-vitro* seed colonization |
| KNUST | Kwame Nkrumah University of Science and Technology, Ghana |
| LLS | late leaf spot |
| LUANAR | Lilongwe University of Agricultural and Natural Resources, Malawi |
| ME | Management Entity |
| NaCRRI | National Crops Resources Research Institute, Uganda |
| NARO | National Agricultural Research Organization, Uganda |
| NARS | National Agricultural Research System |
| NaSARRI | National Semi-Arid Resources Research Institute, Uganda |
| NCSU | North Carolina State University, NC |
| NIFA | National Institute for Food and Agriculture, USA |
| NPRL | National Peanut Research Lab, GA |
| OSS | optimized shrub system |
| PI | principal investigator |
| PMIL | Peanut and Mycotoxin Innovation Lab |
| QDS | quality declared seed |
| QTL | quantitative trait loci |
| SARI | Savannah Agricultural Research Institute, Ghana |
| SNP | single-nucleotide polymorphism |
| SPAD | Soil-Plant Analysis Development |
| UGA | University of Georgia, GA |
| USAID | United States Agency for International Development |
| USDA | United States Department of Agriculture |
| ZARI | Zambian Agricultural Research Institute, Zambia |

# Glossary

**Abiotic stress:** [ā-bī-ot'ik stres] negative impact to a plant by non-living sources, such as low or high temperature, deficient or excessive water, high salinity, heavy metals, and ultraviolet radiation. These hostile forces can impede plant growth and development, as well as yield loss.

**Aflatoxin:** [aflə'täksən] a class of toxic compounds that are produced by the fungi *Aspergillus flavus* and *A. parasiticus* after infecting various plant species, and can cause liver damage, cancer, stunting and even death in humans and other animals.

**Anthropometric measurements:** [an'thrō-pō-met'rik mĕzh´er-ments] a series of quantitative measurements of the muscle, bone, and adipose tissue used to assess the composition of the body. The core elements of anthropometry are height, weight, body mass index (BMI), body circumferences (waist, hip, and limbs), and skinfold thickness.

**Aggregator:** [ˈagrəˌgādər] an individual or business entity that collects and distributes product from multiple sources. Some examples of aggregators of farmers' produce: a farmers' market, a food hub, a distributor, or an individual farmer who does the product marketing for several other farmers.

**Backcrossing:** crossing of a hybrid with one of its parents or an individual genetically similar to its parent, in order to achieve offspring with a genetic identity which is closer to that of the parent.

**Biotic stress:** [bī-ot'ik stres] negative impact done to an organism by other living organisms, such as bacteria, viruses, fungi, parasites, beneficial and harmful insects, weeds, and cultivated or native plants.

**Breeder seed:** in peanut or groundnut, the nuts of plants grown by breeders to specifically increase the stock of a certain type of seed available in the future. (*See foundation seed*)

**Colchicine:** [kol´chĭ-sēn] a chemical that is often used to induce polyploidy in plants. Basically, colchicine prevents the microtubule formation during cell division, thus the chromosomes do not pull apart like they normally do.

**Complex system**: a group of entities that are inter-related, but whose behavior is intrinsically difficult to model due to the dependencies, competitions, relationships, or other types of interactions between their parts or between a given system and its environment.

**Cross sectional survey:** a study that collects data to make inferences about a population of interest at one point in time.

**Early leaf spot (ELS):** a major foliar disease caused by the fungus *Passalora arachidicola* that leads to circular brown spots with a yellow halo on the upper surface of the leaves and also on stems and pegs resulting in severe yield loss to the groundnut growers.

**Foundation seed:** in peanut, seed used by a commercial seed company to establish new production fields that will produce the seed for sale to farmers (*see breeder seed*).

**Groundnut rosette virus:** a pathogenic virus complex found in sub-Saharan Africa that is transmitted between plants by insect vectors such as the groundnut aphid (*Aphis craccivora*) and can cause significant yield loss.

**Gut microbiome:** the totality of microorganisms, bacteria, viruses, protozoa, and fungi, and their collective genetic material present in the gastrointestinal tract.

**High-throughput phenotyping (HTP):** the use of modern sensors, such as light- and color monitors, to record data on traits like plant development, architecture, plant photosynthesis, growth or biomass productivity to accelerate the in-field measurements of plant traits needed by plant breeders to determine which plant features and genomic characteristics are most critical to new plant development.

**Inoculation:** [ĭ-nok″u-la´shun] artificial exposure to an infectious disease. In peanut, inoculation may be used to artificially introduce a pathogen for testing resistance. Farmers may inoculate the soil by adding bacteria that infects the roots of the peanut plant and assists the plant's ability to fix nitrogen.

**Introgression:** [ĭn′trə-grĕsh′ən] in genetics, the movement of a gene from one species into the gene pool of another by the repeated backcrossing of an interspecific hybrid with one of its parent species.

**Late leaf spot (LLS):** a major foliar disease caused by the fungus *Nothopassalora personata* that leads to circular dark brown to black spots without a halo on the lower surface of the leaves and also on stems and pegs resulting in severe yield loss to the groundnut growers.

**Marker assisted selection or marker aided selection (MAS):** an indirect selection process where a trait of interest is selected based on a marker (morphological, biochemical or DNA/RNA variation) linked to a trait of interest (e.g. productivity, disease resistance, abiotic stress tolerance, and quality), rather than on the trait itself.

**Metabolomics:** [mə-tăb′ə-lŏm′ĭks] large-scale study of small molecules, commonly known as metabolites, within cells, biofluids, tissues or organisms. Collectively, these small molecules and their interactions within a biological system are known as the metabolome.

**Metagenomics:** [mĕt′ə-jə-nō′mĭks] the study of a collection of genetic material (genomes) from a mixed community of organisms. Metagenomics usually refers to the study of microbial communities.

**Mycotoxin:** [mī′kō-tŏk′sĭn] a toxic secondary metabolite produced by organisms of the fungus kingdom that is capable of causing disease and death in both humans and other animals.

**Nematodes:** [nem-uh-tohd] multicellular insects that live in soil and feed on plant roots.

**Normalized digital vegetative index (NDVI):** A value that quantifies vegetation by measuring the difference between near-infrared (which vegetation strongly reflects) and red light (which vegetation absorbs).

**Oleic acid:** [ō-lē'ik as'id] a monounsaturated fatty acid with good resistance to rancidity which may reduce the risk of coronary heart disease when substituted for saturated fats in cooking.

**Organoleptic characteristics:** [ōr'gă-nō-lep'tik kar-ik-tuh'ris-tiks] the aspects of food, water or other substances that create an individual experience via the senses – including taste, sight, smell, and touch.

**Polymorphism:** a discontinuous genetic variation resulting in the occurrence of several different forms or types of individuals among the members of a single species.

**Polyploid:** [pälē' ploid] a cell or nucleus that contains more than two homologous sets of chromosomes.

**Quantitative trait locus (QTL):** a region of DNA which is associated with a particular phenotypic trait, which varies in degree and which can be attributed to polygenic effects, i.e., the product of two or more genes, and their environment.

**Recombinant inbred line (RIL):** [rē-kŏm′bə-nənt ĭn′brĕd′ līn] a recombinant inbred strain (or recombinant inbred line) is an organism with chromosomes that incorporate an essentially permanent set of recombination events between chromosomes inherited from two or more parental lines.

**Resilience:** [rĭ-zĭl′yəns] the ability to absorb and recover from shocks and stresses. In plants, these stresses or shocks may be related to drought or disease.

**Reticulation:** (rĭ-tĭk′yə-lā'shun] a pattern or arrangement of interlacing lines resembling a net.

**Standardized precipitation index:** a widely used index to characterize meteorological drought on a range of timescales.

**Tomato spotted wilt virus:** an important disease of many different crops grown in temperate and subtropical regions of the world. A unique virus in a virus class by itself, TSWV can infect more than 1,000 species in 85 families.

**Weather shocks:** temperature deviations from the long-run normal values which may lead to drought, flooding, storms or other negative weather events.

# Executive Summary

As many of the travel and quarantine restrictions of the Covid-19 pandemic were lifted in early 2022, all projects resumed activities, travel and in-person meetings. From March to September, the Peanut Innovation Lab conducted four country-focused meetings in Ghana, Malawi, Senegal and Uganda. At each meeting, in-country collaborators and stakeholders discussed the results of the projects working in the country, visited field sites and had group discussions on priority areas for future research.

Some of the major achievements presented at these meetings include the following. More details are presented in the country summaries and individual projects updates.

- A total of 4062 accessions housed in the USDA genebank were genotyped using the same technology previously used to genotype 1049 lines from Africa. This work revealed that 91 of the accessions are significantly different from the African core set of 300 lines, adding to the diversity available to plant breeders. The 300 core lines and 91 additional lines from this subset were sequenced at HudsonAlpha Institute for Biotechnology using co-funding from the Peanut Research Foundation to explore the differences in genome coverage between SNP array genotyping and sequence-based genotyping.
- Photogrammetry can be used as a high-throughput phenotyping tool to select for early and late leaf spot (ELS, LLS) disease resistance and drought tolerance. Digital imaging from drones provided several vegetation indices as accurate proxies for ELS, LLS, and canopy area (plant growth).
- The latest small-scale mechanized peanut sheller/aspirator and grading table were provided to breeding programs in Ghana, Malawi, Mozambique, Senegal, Uganda and Zambia. These machines already have reduced drudgery and sped up operations on-station.
- A breeder meeting was organized in Senegal involving all breeders that contributed lines to the African core collection (a collection compiled in an earlier Innovation Lab project), as well as experts from the US and France. The group discussed specific plans for (i) further phenotyping for missing traits, (ii) developing tools for breeding programs, (iii) enlarging and sharing the core collection, (iv) improving variety adoption, and (v) improving early generation seed (EGS) production.
- Quantitative trait analysis demonstrated alleles from the wild species *Arachis batizocoi* and *A. duranensis* have potential to improve groundnut disease resistance and yield in East Africa, and crosses were made to transfer the resistance to local varieties.
- HPLC analysis of seed coat biochemicals indicated that ferulic acid had highest inhibition of *A. flavus* growth, and thus may play a role in A. *flavus* resistance.
- A KASP molecular marker array of 24 markers was shown to distinguish all 24 lines tested and should provide a quick method to confirm varietal ID and hybrids in crossing programs.
- Four common weeds were confirmed as alternative hosts for GRD through screenhouse trials – *Senna obtusifolia* (sickle pod), *Solanum nigrum* (black night shade), *Ageratum convzoides* (billy goat weed) and *Senna occidentalis* (coffee senna).

- After only two years using the Optimized Shrub System (OSS) in Senegal, the 2021 peanut rotation showed significant yield improvement (22%) and reduced aflatoxin contamination over standard farmer practices. The process requires farmers to coppice and shred native shrubs in order to incorporate the material into the soil, so researchers evaluated a locally developed and manufactured chopper to company with time and cost of manual chopping.
- The primary constraints to OSS adoption were found to be related to accessing seedlings or the knowledge of reproduction, additional labor for planting, cutting and incorporation and limited knowledge about the system, suggesting a critical bottleneck to adoption will be addressing labor and or chopping costs.
- Multilocation field trial data from Ghana indicated significant response from the use of the improved cultivar, SARINUT 2, with use of additional pest control and complete legume fertilizer. The highest ROI came from using all three interventions.
- The fourth Ghana Groundnut Working Group meeting was held in July in Tamale bringing together over 100 actors in the groundnut value chain to discuss research findings from scientists and students, as well as practical challenges facing farmers, processors and market representatives.
- Multi-date satellite Sentinel-2 data from Malawi was processed to remove clouds and, through harmonic regression, researchers were able to estimate canopy greenness throughout the season. The result exhibited significant positive correlation with yield, consistent with prior work in other crops in the region.
- Results from two years of field trials in Malawi indicate that yield can be increased with the use of inoculants and inorganic fertilizers, increased plant density, herbicide use, and fungicide applications. However, the results of these trials were not consistent across the varieties CG9 and Chitala, and more trials are needed to document the plant response to these inputs across more varieties and to determine the optimal package of multiple inputs in combination.
- An 800-household survey in northern Ghana showed that male-headed households had double the household income of women-headed households, and held 30 times as much value in agricultural assets, such as farm equipment, over women-headed households. This indicates that it may be challenging for women to invest in agricultural assets to improve productivity. Less than 20% of either gender had access to credit.
- The Ghana survey also indicated that 68% of farmers saved their own peanut seed; men saved seed more frequently (77%), women reported more awareness of improved varieties (42%), although use of improved varieties was low (9% for men, 13% for women). Men planted 50% more area (3 acres), and women were more likely to plant in rows. The results indicated limited use of inputs, low yields (especially among women), and while farmers were aware of aflatoxin, few followed practices to reduce contamination.
- Final measurements of 797 school-age children enrolled in the peanut-based school food project in northern Ghana were completed, 707 household surveys conducted, and analysis of results in progress.
- Five research briefs from surveys in Senegal were published in French that focus on 1) soil fertility management strategies employed on groundnut fields in the Groundnut Basin; 2) comparison of GPS estimated field sizes with self-reported estimates of field size from the head of household; 3) the factors that determine who has access to

groundnut fields and the implications of limited access for young and female farmers; 4) use of groundnut varieties; and 5) use of social media and perceptions of climate change among young people.

- Farmer field schools focused on peanut agronomy and gender empowerment were completed in two communities in northern Ghana, four mechanical peanut planters were delivered to the two communities (two to each) and farmers were trained on how to use them.
- In a photovoice project in Uganda, final photos (15) from Nwoya and Tororo villages were selected out of an original 1,200 photos representing food safety, gender, and youth opportunities and challenges of peanut agriculture in the study communities. Community fairs will take place in each village in October to present and discuss the photos.
- An extensive baseline survey and methodology was developed and fielded in Senegal to understand details of farmers' lives, their best practices around peanut farming, how they view their own time and activities, and their family structure. Phase 1 time-use data was collected and phase 2 is undergoing collection.

# Focus Country Key Accomplishments

## Ghana

The Peanut Innovation Lab has six projects continuing work in Ghana in all four Areas of Inquiry (Variety Development, Value-Added Gains, Nutrition and Gender & Youth), as well as regional and continent-wide projects with activities in Ghana. Fifteen graduate students (four female, 11 male) supported by the project are from Ghana.

As part of the coordinated pan-African effort, CSIR-SARI is evaluating lines for pest and disease resistance, tolerance to water-stress, days to maturity, harvest index and yield in replicated field trials near Tamale. Lines that show advantageous traits are being crossed to local varieties and advanced to large-scale field trials. A project evaluating high-throughput phenotyping tools found that handheld and UAV imaging techniques are very effective in determining several foliar diseases and even predicting yield of groundnuts in the field. The CSIR-SARI and CSIR-CRI groundnut breeding programs were provided a groundnut sheller/aspirator and grading table developed by Frank's Designs for Peanuts to speed up seed processing.

A project evaluating new peanut-based ready-to-eat school foods on child cognitive learning completed the trials at six schools near Tamale. Preliminary data analysis indicates significant increase in school attendance during the trials and improvement in attention during class. Early results indicate improvement in cognition, as well.

A project studying gender time poverty differences in northern Ghana completed its final round of household surveys and has identified several key differences in men's and women's perspectives on time use.

Key accomplishments from FY2022 include:

- The third set of field trials of the African core set of 300 lines were completed, identifying several lines with more disease resistance than local varieties.
- The second version of the Ghana Groundnut Risk Index Tool was completed and is being tested further.
- Farmer field schools focused on peanut agronomy and gender empowerment were completed in two communities in northern Ghana, four mechanical peanut planters were delivered to the two communities (two to each) and farmers were trained on how to use them.
- Multilocation field trial data showed significant response from an improved cultivar (SARINUT 2), additional pest control and complete legume fertilizer; the highest ROI came from all three interventions.
- Photogrammetry was found to be useful as a high-throughput phenotyping tool to increase peanut genetic gains for early and late leaf spot (ELS, LLS) disease resistance and drought tolerance. Drone digital imaging provided several vegetation indices as accurate proxies for ELS, LLS, and canopy area (plant growth).
- The fourth Ghana Groundnut Working Group meeting was held in July in Tamale bringing together over 100 actors in the groundnut value chain to discuss research findings from scientists and students, as well as practical challenges facing farmers, processors and market representatives.

- An 800-household survey in northern Ghana showed that male-headed households had double the household income of women-headed households, and held 30 times as much value in agricultural assets, such as farm equipment, over women-headed households. This indicates that it may be challenging for women to invest in agricultural assets to improve productivity. Less than 20% of either gender had access to credit.
- The Ghana survey also indicated that 68% of farmers saved their own peanut seed; men saved seed more frequently (77%), women reported more awareness of improved varieties (42%), although use of improved varieties was low (9% for men, 13% for women). Men planted 50% more area (3 acres), and women were more likely to plant in rows. The results indicated limited use of inputs, low yields (especially among women), and while farmers were aware of aflatoxin, few followed practices to reduce contamination.
- Three molecular markers were validated as tightly linked to late leafspot resistance using the CS16 x Chinese populations in Ghana.
- Final measurements of 797 school age children enrolled in the peanut-based school food project were completed, 707 household surveys conducted, and analysis in progress.
- The 55-437 x TxL054520-27 population combining tolerance to water stress and high oleic content was evaluated in Ghana using conventional and high-throughput phenotyping methods; several lines had higher pod yield compared to other varieties.
- Mechanized sheller/aspirator and grading tables were provided to breeding programs in CSIR-CRI and CSIR-SARI, which has reduced drudgery and sped up operations on-station.

## Malawi

The Peanut Innovation Lab has two projects in Malawi focused on remote sensing and evaluating input packages for groundnut farmers. These projects are closely aligned with the local USAID Mission-funded Agriculture Diversification Activity (AgDiv), providing technical support to partners and building linkages between the private sector, LUANAR and DARS.

There is one graduate student (male) directly supported by the project and four graduate students (1 female, 3 male) supported in collaboration with AgDiv.

As part of the coordinated pan-African effort, DARS is evaluating the African core set of 300 lines for pest and disease resistance, tolerance to drought-stress, days to maturity, harvest index and yield in replicated field trials. Well-performing lines are being crossed to local varieties and advanced to large-scale field trials.

The DARS-Chitedze groundnut breeding program was provided a groundnut sheller/aspirator and grading table developed by Frank's Designs for Peanuts to speed up seed processing.

Key Accomplishments in FY2022 include:

- Researchers completed the second year of field trials with the African core set of 300 lines. Data of pest and disease, drought stress and yield were collected and analyzed jointly with the other regional breeders in late 2022.

- Results from the analysis of data collected from 800 peanut, maize and soybean fields indicated that satellite images can determine the crop species from mid-season onwards, but only explain a portion of yield variation and plant stress.
- Results from two years of field trials indicate that yield can be increased with the use of inoculants and inorganic fertilizers, increased plant density, herbicide use, and fungicide applications. However, the results of these trials were not consistent across the varieties CG9 and Chitala and more trials are needed to document further how plants respond to these inputs across more varieties and to determine the optimal package of inputs in combination.
- Mechanized sheller/aspirator and grading tables were provided to the breeding program in DARS-Chitedze, which has reduced drudgery and sped up operations on-station.

## Niger

The Peanut Innovation Lab has one project partnering with ICRISAT in Niger. Two graduate students (1 female, 1 male) supported by the project are from Niger.

As part of the project to determine the role of the groundnut seed coat in *Aspergillus flavus* resistance, ICRISAT is conducting field trials at its research station in Niger to help coordinate the levels of *A. flavus* resistance under field conditions with the presence of biochemical markers identified in the project.

Key accomplishments from FY2022 include:

- Lines screened under well-watered and water-stress conditions and identified as drought tolerant were evaluated in field trials.

## Senegal

The Peanut Innovation Lab has five specific projects working in Senegal across three Areas of Inquiry (Variety Development, Value-Added Gains and Gender & Youth). The lab is supporting 19 graduate students (8 female, 11 male).

Researchers at CERAAS are leading the West African component of a continent-wide genetic diversity study that links NARS to evaluate lines for pest and disease resistance, tolerance to drought-stress, days to maturity, harvest index and yield in replicated field trials. Well-performing lines will be crossed to local varieties and advanced to large-scale field trials. Two additional projects involve the use of cutting-edge genomic technology to develop genetic markers and introduce alleles from the wild relatives of peanuts that will improve the genetic diversity of cultivated peanut and offer new mechanisms for disease resistance, drought tolerance and other traits. A project is evaluating high-throughput phenotyping tools including UAVs to identify more efficient screening options for various traits followed in the breeding program. The ISRA-Bambey and ISRA-CERAAS groundnut programs were provided groundnut shellers and grading tables developed by Frank's Designs for Peanuts to speed up seed processing.

The Optimized Shrub System, an agronomic system that purposely plants native shrubs in crop fields and incorporates shredded shrub material into the soil, continued to be studied in on-farm trials. Graduate student research will determine the effects on yield stability, improved soil

fertility and water availability. The project collaborators have reached out to numerous NGOs, farmer associations and other institutions to introduce farmers to the technology.

Researchers are studying youth and youth migration in relation to peanut production. A separate project looks at time use and time poverty among different groups. This information will help to design interventions that enhance gender and youth equality in the peanut value chain.

Key Accomplishments in FY2022 include:

- Researchers are analyzing a comprehensive dataset of phenotyping data on the African core set of 300 lines from field trials in five environments: rainy and dry seasons in Senegal, and rainy seasons in Ghana, Mali and Niger. Seed provided to Burkina Faso, Togo and a second location in Ghana for field trials next season.
- Researchers analyzing secondary data compiled a research brief about how climate shocks affect young groundnut farmers and the productivity of their crops.
- The primary constraints to OSS adoption are related to accessing seedlings, knowledge of how to produce seedlings; additional labor for planting, cutting and incorporation; and limited knowledge of the system, suggesting a critical bottleneck to adoption will be addressing labor and or chopping costs.
- A breeder meeting was organized in Senegal involving all breeders that contributed lines to the African core collection, as well as experts from the US and France. Discussions provided specific plans for (i) further phenotyping for desirable traits, (ii) developing tools for breeding programs, (iii) enlarging and sharing the core collection, (iv) improving variety adoption, and (v) improving Early Generation Seed production.
- Field trials at Bambey and Nioro using a multispectral camera on an unmanned aerial vehicle (UAV) and two handheld sensors at the ground level showed a significant association between the methods, showing potential for drone-based surveyance methods.
- Marker trait association of the Fleur 11 x IpaCor (*Arachis ipaensis* x *A. correntina*) population phenotyped in Niori, Senegal showed significant association on chromosomes A02, A08 and A10 for leaf spot resistance.
- Several peanut varieties were found to respond positively to OSS plus fertilizer and OSS significantly reduced aflatoxin contamination under field conditions.
- After two years of shrub establishment, the 2021 peanut rotation showed significant yield improvement (22%) over standard farmer practices. A locally developed and manufactured chopper was evaluated relative to manual chopping for time and cost.
- Five research briefs were published in French that focus on 1) soil fertility management strategies employed on groundnut fields; 2) comparison of GPS estimated field sizes with household head self-reported estimates of field size; 3) the determinants of household member access to groundnut fields and the implications of limited access for groundnut productivity of young adult and female producers; 4) farmer use of groundnut varieties; and 5) young adult use of social media and perceptions of climate change.
- An extensive baseline survey and methodology was developed to understand farmers' lives, their practices around peanut farming, how they view their time, and their family structure. Phase 1 time-use data was collected and phase 2 is undergoing collection.
- Mechanized sheller/aspirator and grading tables were provided to breeding programs in ISRA-CERAAS and ISRA-Bambey, which has reduced drudgery and sped up operations on-station.

## Uganda

The Peanut Innovation Lab has six projects specifically working in Uganda, covering all four Areas of Inquiry (Variety Development, Value-Added Gains, Nutrition and Gender & Youth). The lab is supporting six graduate students (four female, two male) in the country.

Researchers at NARO are leading the East African component of a continent-wide genetic diversity study that links NARS to evaluate lines for pest and disease resistance, tolerance to drought-stress, days to maturity, harvest index and yield in replicated field trials. Well-performing lines will be crossed to local varieties and advanced to large-scale field trials. Two additional projects involve the use of cutting-edge genomic technology for marker development and introduction of alleles from the wild relatives of peanuts to improve the genetic diversity of cultivated peanut with the potential to offer new mechanisms for disease resistance, drought tolerance and other traits. A project is evaluating high-throughput phenotyping tools for breeders to use as more efficient screening options for various traits. The NARO-NaSARRI groundnut breeding program was provided a groundnut sheller/aspirator and grading table developed by Frank's Designs for Peanuts to speed up seed processing.

In work to combat GRD, molecular markers for GRV resistance are being developed through a collaboration with ICRISAT-Kenya and the HudsonAlpha Institute in the USA. Another project is identifying alternative hosts for GRV to help develop better disease management strategies.

A nutrition study is evaluating the role of groundnuts play in improving the human gut microbiome in young children in several primary schools near Kampala. This work will improve our understanding of groundnut's value in improving human health and nutrition.

Photovoice, a participatory research method involving photos and discussion groups, explored youth involvement in the peanut value chain. Through taking photos and discussing them, youth in villages are encouraged and empowered through their role in the value chain.

Key Accomplishments in FY2022 include:

- The third year of field trials with the entire set of 940 African lines and core set of 300 lines confirmed several lines with high resistance to LLS and GRD. These lines are being used in crosses with local varieties.
- In evaluating high throughput phenotyping tools, results from analyzing 200 lines from the African core collection under field conditions at Nakabango, Uganda, which is a hotspot for groundnut rosette disease, and NaSARRI, Uganda (LLS hotspot), identified several red-green-blue (RGB) image- and red/near infra-red reflectance-based methods that are more accurate for screening GRD and LLS.
- Quantitative trait analysis demonstrated the potential for alleles from the wild species *Arachis batizocoi* and *A. duranensis* to improve groundnut disease resistance and yield in East Africa, and crosses were made to transfer the resistance to local varieties.
- Four common weeds were confirmed as alternative hosts for GRD through screenhouse trials – *Senna obtusifolia* (sickle pod), *Solanum nigrum* (black night shade), *Ageratum convzoides* (billy goat weed) and *Senna occidentalis* (coffee senna).
- In a photovoice project, 15 final photos from Nwoya and Tororo villages were selected out of an original 1,200 photos that participants took to show food safety, gender, and youth opportunities and challenges of peanut agriculture in the study communities.

Community fairs will take place in each village in October to present and discuss the photos.

- In the gut microbiome project, samples were collected from the 115 children (59 girls and 56 boys) recruited for the study and metabolomics analysis using ultra-high-performance-liquid-chromatography (UHPLC) initiated to check if peanut supplement modified the concentration of short-chain fatty acids in children's fecal samples.
- Mechanized sheller/aspirator and grading tables were provided to the breeding program in NARO-NaSARRI, which has reduced drudgery and sped up operations on-station.

## USA

All Peanut Innovation Lab projects involve partnerships between US and in-country scientists and students. Several projects have significant research activities conducted in US institutes to complement activities in partner countries. While all US scientists are involved in data analysis, many are also involved in the genotyping and sequencing of lines and populations, production of new crosses between cultivated and wild species, development and screening of new mapping populations, identification of seed biochemicals associated with *A. flavus* resistance, correlating satellite imagery with groundnut health, analysis of gut microbiome samples, or pilot testing of time trackers. In addition, the Management Entity is coordinating several capacity-building activities.

Currently, the lab supports eight graduate students (five female, three male) and three post-doctoral fellows (three female) at US universities. One of the students (male) is from Ghana and two students (one female, one male) are from Senegal.

Key Accomplishments in FY2022 include:

- A total of 4062 accessions housed in the USDA genebank were genotyped using the same technology previously used to genotype 1049 lines from Africa. This work revealed that 91 of the accessions are significantly different from the African core set of 300 lines, adding to the diversity available to plant breeders. The 300 core lines and 91 additional lines from this subset were sequenced at HudsonAlpha Institute for Biotechnology using co-funding from the Peanut Research Foundation to explore the differences in genome coverage between SNP array genotyping and sequence-based genotyping.
- A KASP marker array of 24 markers was shown to distinguish all 24 lines tested and should provide a quick method to confirm varietal ID and hybrids in crossing programs.
- Four lines from a set of 58 lines obtained from the USDA S9 PI station that had tan seed coat colors similar to the *A. flavus* resistant line 55-437 were found to have a greater level of *A. flavus* inhibition than the resistant check based on in-vitro seed colonization assays.
- HPLC analysis of seed coat biochemicals indicated that ferulic acid had highest inhibition of *A. flavus* growth, and thus may play a role in *A. flavus* resistance.
- New models of the groundnut sheller/aspirator and grading table were manufactured and sent to the breeding programs in Ghana, Malawi, Mozambique, Uganda, Senegal and Zambia.

# Research Program Overview and Structure

The Peanut Innovation Lab contributes to the Global Food Security Strategy by increasing the production, sustainability, profitability and use of peanut in targeted developing countries and the US. This is achieved through research linkages between US and developing country scientists in four Areas of Inquiry: 1) improved peanut varieties, 2) increased value-added gains along the peanut value chain, 3) increased understanding of the value of peanut consumption in human nutrition, and 4) increased understanding of gender and youth dimensions along the peanut value chain.

**Area of Inquiry 1 (Improved Varieties)** builds partnerships between peanut breeding programs in the US and target countries to use modern genomic and information technologies in the breeding programs. The objective is to enhance the capacity of peanut breeding programs in each country to develop new varieties using modern approaches, and to test and release varieties that increase yields and address the local, national and regional demands of the country.

**Area of Inquiry 2 (Value-Added Gains)** builds partnerships between the public and private sector and establishes new partnerships in seed production and local processing. Research focuses on seed production of improved varieties, best management practices to optimize quantity and quality of the crop by smallholder farmers, and effective practices for harvesting, drying, storage and shelling.

**Area of Inquiry 3 (Nutrition)** uses linkages with the US Peanut Institute to assess the benefits of peanut-based foods for school feeding programs and impacts of peanut consumption on human microbiota.

**Area of Inquiry 4 (Gender and Youth)** seeks to improve our understanding of the roles that gender and youth play in mediating interactions with peanut value chains in each target country. Research and training efforts also focus on improving the gender-sensitivity and responsiveness of Peanut Innovation Lab scientists, students, partners and programs.

# Theory of Change and Impact Pathways

The main objective of the Peanut Innovation Lab is to support research that leads to the increased production, sustainability and profitability of peanuts in targeted developing countries. This objective is met through joint research and capacity building between US and developing country partners. Ultimately, the results are a part of the US government goals as defined under the Global Food Security Strategy.

Significant outputs from the Peanut Innovation Lab research include:

- molecular markers for drought and disease resistance,
- novel germplasm that contains genetic materials from wild relatives,
- phenotyping tools to identify more rapidly the best varieties under field conditions,
- improved varieties with enhanced productivity and nutritional traits,
- extensive datasets from innovative social science approaches, particularly related to cross-cutting themes of gender and youth, and
- new agronomical practices that combine inputs such as inoculants, fertilizers, and weed/pest/disease management.

These outputs are developed in collaboration with the intended users (national program scientists), increasing the chance they will be adopted rapidly. The Peanut Innovation Lab is training researchers in partner countries to use molecular technologies and providing guidance in crossing new germplasm, application of phenotyping tools, and appropriate use of agronomic packages. The Innovation Lab also invests in building capacity within partner countries by supplying most of the technologies (e.g., phenotyping tools) as part of the research project. Through the uptake of the new technologies, researchers will be able to develop improved varieties that allow farmers to meet market opportunities and deal with unpredictable environmental stresses. As farmers adopt new varieties, they will experience larger and more reliable yields. Increased production makes more food available for consumption in the household and for sale in local markets, creating income to meet other household needs.

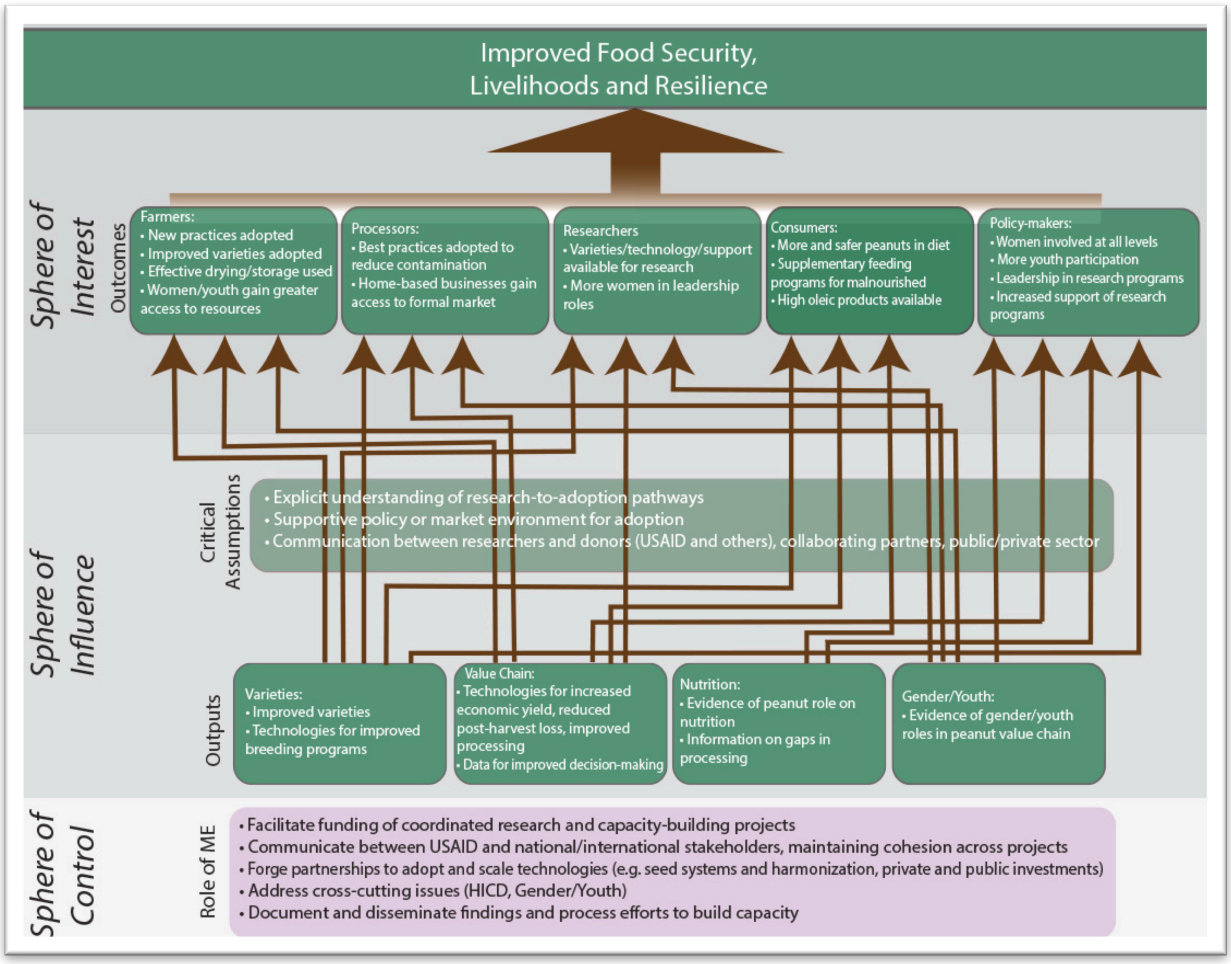
A major assumption is that government support for groundnut production and consumption continues and even increases. Government stability will also be important to maintain market opportunities and public funding.

Other outputs from the Peanut Innovation Lab research include appropriately scaled mechanization for shelling and grading groundnuts, an output that will be delivered to potential users, such as national programs and the private sector. Mechanization is seen as an important step in improving the production and profitability of peanut and as the uptake of appropriate technology happens, production of quality peanuts will grow. This will lead to more opportunities to reach markets (in-country, regional and global), increasing the economic returns for all value-chain actors.

Another output – new peanut-based school foods – will be distributed in public and private schools. Training in how to manufacture and process these foods will foster local entrepreneurs, leading to opportunities for in-country production and marketing.

Finally, research on the effects of peanut consumption on cognitive learning and gut health and on gender and youth involvement along the peanut value chain will bring in new knowledge that

our research partners can use to address key constraints in peanut value chain, improving overall production and the inclusivity of related interventions. Knowledge will be disseminated to stakeholders via Peanut Innovation Lab and other project workshops, policy reports, etc. Key information could lead to policies favorable to peanut production, use and consumption, including gender equality and addressing youth issues.



# A. Varietal Development Research Project Reports

## Project A1. Adoption of the Breeding Management System (BMS) by national programs [COMPLETED]

### Research Locations

NARO-NaSARRI, Soroti, Uganda; DARS-Chitedze Research Station, Chitedze, Malawi; ZARI, Chipata, Zambia; IIAM, Nampula, Mozambique

### Description

This completed project, commissioned in early 2018 for one year, improved the efficiency of plant breeding programs in target countries by enabling plant breeders to access a modern analytical pipeline, breeding technologies/materials and related information in a centralized, integrated and practical manner, and to deliver improved varieties that meet local farmers' needs and market demand.

Specifically, the project provided the necessary hardware and software for breeding programs in three countries (Malawi, Mozambique and Zambia) that are part of the peanut breeding network in Africa. The project is jointly implemented with the Integrated Breeding Platform (IBP) and involves the deployment and use of the Breeding Management System (BMS) developed by the IBP.

### Theory of Change/Impact Pathway(s)

Use of digital informatics software will lead to more efficient and effective breeding programs, resulting in better varieties in less time. These varieties can then reach farmers faster, giving them higher yields that improve their household food security.

### Collaborators

David Okello Kalule (PI), NARO-NaSARRI, Uganda; Justus Chintu, DARS, Malawi; Lutangu Makweti, ZARI, Zambia; Amade Muitia, IIAM, Mozambique; Graham McLaren, IBP, Mexico

## Project A2. Assessment of breeding program needs and seed production [COMPLETED]

### Research Locations

NARO-NaSARRI, Soroti, Uganda; DARS-Chitedze Research Station, Lilongwe, Malawi; ZARI, Chipata, Zambia; IIAM, Nampula, Mozambique; CSIR-CRI, Kumasi, Ghana; CSIR-SARI, Tamale, Ghana; ISRA-CERAAS, Thiès, Senegal

### Description

This second completed commissioned one-year project produced breeder and foundation seed of improved varieties, assessed and prioritized national peanut breeding program needs in the target countries for effective participation in future Peanut Innovation Lab projects.

### Theory of Change/Impact Pathway(s)

Addressing the key constraints in breeding programs will lead to more efficient and effective programs, resulting in better varieties in less time. Improving the production of early generation seed (which is used by breeders or commercial seed producers) makes it easier to produce quality certified seed for farmers. When farmers have quicker access to higher quality varieties, they experience higher yields that improve household food security.

### Collaborators

David Okello Kalule (PI), NARO-NaSARRI, Uganda; James Asibou, CSIR-CRI & Richard Oteng Frimpong, CSIR-SARI, Ghana; Justus Chintu, DARS, Malawi; Issa Faye, ISRA & Daniel Fonceka, CERAAS, Senegal; Lutangu Makweti, ZARI, Zambia; Amade Muitia, IIAM, Mozambique

## Project A3. SNP genotyping of African peanut germplasm

### Research Locations

ISRA-CERAAS, Thiès, Senegal; University of Georgia, Tifton, GA, USA

### Description

The project, commissioned at the beginning of the Peanut Innovation Lab, is genotyping a wide array of African peanut germplasm using the high-density, 48K Axiom_Arachis2 SNP array. The SNP array, recently created by a project led by the PI, allows the efficient detection of 30,539 SNPs (single nucleotide polymorphisms) in the peanut genome at a reasonable price per line. The array already has been used to genotype several peanut populations segregating for resistance to nematodes, tomato spotted wilt virus, late leaf spot, and white mold, and for several seed traits, as well as a set of lines used to screen for low aflatoxin contamination.

Genotyping diverse germplasm relevant to the Peanut Innovation Lab allows breeders to take advantage of the latest genetic technologies in peanut to catalog genetic diversity among varieties, identify regions of the genome that hold positive or negative traits or alleles fixed in a breeding program, enable genome-wide background selection, identify a subset of polymorphisms to be developed for single-marker analysis for specific traits, and construct genetic maps of populations segregating for important traits.

Applying genomic information in peanut breeding will accelerate the incorporation of alleles for biotic and abiotic stress tolerance and seed quality traits resulting in a healthier and higher value crop.

### Theory of Change/Impact Pathway(s)

Information on the genetic makeup of varieties allows breeders to broaden the diversity in their programs. This results in more resilient varieties delivered to farmers, increased yields, and ultimately improved household food security.

### Collaborators

Peggy Ozias-Akins (PI), UGA, GA; Daniel Fonceka, ISRA-CERAAS & Issa Faye, ISRA, Senegal; David Okello Kalule, NARO-NaSARRI, Uganda; James Asibuo & Richard Oteng Frimpong, CSIR-CRI, Ghana; Amade Muitia, IIAM, Mozambique; Justus Chintu, DARS,

Malawi; Lutangu Makweti, ZARI, Zambia; Dramane Sako CRRA/IER, Mal; Adama Coulibaly, INRAN, Niger; Essohouna Banla, Togo

### Achievements

All 1049 lines were genotyped using the SNP chip, and a set of 300 lines identified to represent the diversity of the entire set has been distributed to all breeders under separately funded projects (see Projects A6 and A7). The selected set of 300 lines was re-genotyped with the SNP chip to ensure that the lines distributed to the breeding programs remain uniform. Genotyping of the US materials of African origin (see Project A4) is completed and all data being analyzed. Initial results were shared with all breeders at the African Breeders Workshop held in Saly, Senegal in September 2022.

### Capacity Building

The project continues to interact closely with CERAAS and other African scientists and students.

### Lessons Learned

Generating sufficient quantities of seed for a collective study is challenging with peanut, especially when providing seed to match the planting windows of the geographically diverse programs.

### Presentations and Publications

Chintu, J. M. M. (October 2020). Evaluation of Diverse Groundnut Genotypes in Malawi. Presentation at DARS Annual Review and Planning, Blantyre, Malawi.

Oteng-Frimpong, R. (2020). Establishing the true identity of groundnut varieties in East and West Africa – the case of 'Chinese'.

## Project A4. Leveraging genetic resources to enhance peanut breeding in Africa and the US

### Research Locations

NARO-NaSARRI, Soroti, Uganda; ISRA-CERAAS, Thiès, Senegal; University of Georgia, Tifton, GA, USA

### Description

The objective of this project is to genotype more than 2650 accessions of African origin conserved in the USDA peanut germplasm collection, then to combine data with the genotypes generated from African breeding materials under Project A3. The project is jointly funded with the Peanut Research Foundation, a US peanut industry supported foundation. Through a USDA NIFA-sponsored project, 276 African accessions also are being genotyped.

The work will determine how related these 2900+ lines are to each other and to those in current African breeding programs, allowing breeders to make informed decisions on how to increase diversity in their programs.

### Theory of Change/Impact Pathway(s)

Information on the genetic makeup of varieties allows breeders a more diverse base of traits to use in their programs. This results in more resilient varieties delivered to farmers, increased yields, and ultimately improved household food security.

### Collaborators

Peggy Ozias-Akins (PI), UGA, Tifton, GA; Corley Holbrook, USDA-ARS, Tifton, GA; Shyam Tallury, Plant Genetic Resources Conservation Unit, Griffin, GA; Josh Clevenger, HudsonAlpha Institute of Biotechnology, Huntsville, AL; Ye Chu, UGA, Tifton, GA, ; Jean-Marcel Ribaut, Integrated Breeding Platform, CIMMYT, El Batán Texcoco, Mexico; Ethalinda Cannon, Iowa State University, Ames, IA; Jean-Francois Rami, CIRAD, Montpellier, France; Daniel Fonceka, CERAAS, Senegal; David Okello Kalule, NARO-NaSARRI, Uganda

### Achievements

A total of 4062 accessions were genotyped using the same SNP chip used in project A3 above and all data uploaded to PeanutBase for public release. Ninety-one lines were determined to cover gaps in the diversity found across the 300 lines. The 300 core lines and the additional lines from this subset were sequenced at HudsonAlpha Institute for Biotechnology using co-funding from the Peanut Research Foundation. Sequenced-based genotyping using RipTide libraries has been conducted on 275 lines from the African core set and 91 from the US germplasm collection that fill gaps in diversity. A hapmap file is being generated so that we can explore the differences in genome coverage between SNP array genotyping and sequence-based genotyping.

### Capacity Building

The project is an excellent collaboration between the USDA germplasm curator (Shyam Tallury), USDA peanut breeder (Corley Holbrook), ISRA-CERAAS / CIRAD scientist (Daniel Fonceka), UGA geneticists (Peggy Ozias-Akins and Ye Chu) and HudsonAlpha scientist (Josh Clevenger). A graduate student with Daniel Fonceka is participating in the data analysis and manuscript preparation.

### Lessons Learned

The COVID-19 restrictions required some changes although communications have improved with the use of virtual technology.

### Presentations and Publications

None to report

## Project A5. Integration of high throughput phenotyping (HTP) for enhancing breeding programs

### Research Locations

NARO-NaSARRI, Soroti, Uganda; CSIR-SARI, Kumasi, Ghana; KNUST, Kumasi, Ghana; CSIR-SARI, Tamale, Ghana; ISRA-CERAAS, Thiès, Senegal; ISRA-CNRA, Bambey, Senegal

## Description

Peanut yield and quality are low in much of Africa. With basic agricultural inputs unavailable, soils depleted of phosphorus and other essential plant nutrients, scarce precipitation, and high disease pressure, peanut production can be improved through the development of new cultivars with more efficient use of water and nutrients, and disease resistance. Breeding efforts can benefit from the development of high throughput phenotyping tools using new, yet inexpensive, technologies and sensors.

The project objectives include: 1) developing high-throughput phenotyping (HTP) tools for field selection for disease, drought, and variety performance; 2) developing effective HTP systems to determine peanut maturity and oleic fatty acid content – necessary steps towards quality control in seed production; 3) enhancing the breeding capabilities in Africa by procuring relatively inexpensive sensors and the software needed to retrieve data, as well as training researchers in how to use the tools; and 4) improving youth and gender awareness about innovative plant breeding and variety development by collaborating with 4-H youth clubs in Senegal and Ghana and the Youth Farmers Association of Uganda.

## Theory of Change/Impact Pathway(s)

The ability to determine the performance characteristics for large number of lines allows breeders to select the best individual ones. Phenotyping tools used in this project will allow breeding programs to utilize the tools in their research. This results in more resilient varieties delivered to farmers, increased yields, and ultimately improved household food security.

## Collaborators

Maria Balota (PI), Virginia Tech, VA; David Okello Kalule, NARO-NaSARRI, Uganda; Richard Oteng-Frimpong, CSIR-SARI, Ghana; Richard Akromah, KNUST, Ghana; Daniel Fonceka, ISRA-CERAAS and Issa Faye, ISRA-CNRA, Senegal

## Achievements

*Ghana*

As in Uganda, photogrammetry was found to be a high-throughput phenotyping tool to increase peanut genetic gains for early and late leaf spot (ELS, LLS) disease resistance and drought tolerance. A preliminary study using a drone carrying an RGB found several vegetation indices to be accurate proxies for ELS, LLS, and canopy area (plant growth).

*Senegal*

Field trials at Bambey and Nioro comparing two high throughput field phenotyping methods, one using onboard multispectral camera on an unmanned aerial vehicle (UAV) and a second one using two handheld sensors (GreenSeeker, SPAD 502) at the ground level showed a significant association between the two methods, indicating the potential for drone-based surveyance methods.

*Uganda*

Results from analyzing 200 lines from the African core collection under field conditions at Nakabango, Uganda, which is a hotspot for groundnut rosette disease, and NaSARRI, Uganda (LLS hotspot), identified several red-green-blue (RGB) image- and red/near infra-red reflectance-based methods that are more accurate for screening GRD and LLS in the field than

traditional methods. A genome-wide association study identified genomic regions associated with the image-derived indices on chromosomes A04 and B04. A putative gene Aradu.P5PIT, a disease resistance protein located next to single nucleotide polymorphisms (SNP) of leaf photosynthesis was detected by both visual scores and CSI (associated with canopy yellowness). These image derived indices and associated genes present an opportunity to improve phenotyping using objective measures and apply molecular tools to improve breeding of GRD resistant groundnut varieties.

### Capacity Building

During this project several sensors were purchased and are now available for breeding selection within each peanut breeding program in Ghana, Senegal and Uganda. Recently, a DJI drone was purchased for the Co-PI and graduate student in Uganda to continue the work.

### Lessons Learned

Even though there were no in-person meetings since 2020, constant communication through Zoom conferencing and email worked very well.

### Presentations and Publications


Chapu, I. (2021). High-Throughput Phenotyping for Selection in Breeding: A Case of Groundnut (Archis hypogaea L.). Thesis Defense, Makerere Univ., Kampala, Uganda. 31 March 2021.

Chapu, I., et al. (July 2021). High-throughput phenotyping enables indirect selection for leaf spot and groundnut rosette disease resistance in peanut breeding program in Uganda. Presentation at the 53rd annual meeting of the American Peanut Research and Education Society, July 12-16, 2021, Dallas, TX (Virtual).

Chapu, I., et al. (June 2021). High-throughput phenotyping for breeding: a case of groundnuts. Presentation at Peanut Innovation Lab Annual Meeting (Virtual).

Diop, A., et al. (July 2021). High Throughput Phenotyping Methods on Peanuts Fields. Presentation at the 53rd annual meeting of the American Peanut Research and Education Society, July 12-16, 2021, Dallas, TX (Virtual).

Oteng-Frimpong, R., et al. (July 2021). Enhancing the Efficiency in Data Collection in Peanut Through Whole-Plot Data Capture: The Case of Above Ground Biomass and Foliar Diseases. Presentation at APRES 53rd Annual Meeting, (Virtual).

Sie, E. K., et al. (July 2021). Photogrammetry Enables Indirect Selection and Increase Genetic Gains for Leaf Spot Tolerance in Peanut Breeding Program in Ghana. Presentation at American Peanut Research and Education Society, Dallas, TX (Virtual).


## Project A6. Enhancing the genetic potential of peanut production in Eastern and Southern Africa

### Research Locations

NARO-NaSARRI, Soroti, Uganda; DARS-Chitedze Research Station, Chitedze, Malawi; ZARI, Chipata, Zambia; IIAM, Nampula, Mozambique; ISRA-CERAAS, Thiès, Senegal

### Description

The use of molecular markers to identify diverse genetic traits and improve crops is a proven and successful approach. Following a drastic reduction in genotyping costs and increased analytical power over the last decade, genome-wide association studies (GWAS) are a powerful way to dissect target traits and identify favorable alleles/genomic regions that are responsible for the trait. In peanut, genetic variations have mainly been identified and exploited, until now, by

breeders using bi-parental populations because of the lack of polymorphism in the cultivated species, and of suitable and cost-effective genotyping technologies. Recent advances in peanut genomics – including the sequencing of cultivated peanut and the development of a high-density genotyping Axiom_Arachis array with thousands of polymorphic SNP for cultivated peanut – open the way for high-throughput genotyping in peanut, allowing effective genetic dissection of target traits and the identification of major genes and/or QTLs for marker-assisted breeding.

Accessions identified through another project (A3) will be tested in diverse environments and conditions in at least four countries in Eastern and Southern Africa through this project and four in West Africa through Daniel Fonceka's project to generate relevant information and data around diversity and the genetic basis for target traits, empowering peanut breeding programs, and the development of new genes/markers for molecular breeding. The overall objective of the project is to characterize and document a unique pool of material that can be used as a new source of germplasm and alleles to improve peanut breeding in Eastern and Southern Africa.

This coordinated effort across strong, existing networks will enable us to: 1) assess diversity and identify germplasm from the core panel to be introduced to national breeding programs; 2) dissect the genetic control of target trait variation via association studies, and identify trait-linked markers for breeding purposes; 3) based on performance, identify potential new donor lines for local breeding programs; and 4) increase capacities for a vibrant network of peanut breeders in Eastern and Southern Africa to apply modern genetic approaches in breeding, and to collectively share and analyze data.

### Theory of Change/Impact Pathway(s)

Information on the genetic makeup of varieties and use of core sets based on this information allows breeders to broaden the diversity in their programs. This results in more resilient varieties delivered to farmers, increased yields, and ultimately improved household food security.

### Collaborators

David Okello Kalule (PI), NARO- NaSARRI, Uganda; Lutangu Makweti, ZARI, Zambia; Amade Muitia, IIAM, Mozambique; Justus Chintu, DARS, Malawi**;** Jean-Marcel Ribaut, IBP, Mexico**;** Peggy Ozias-Akins, UGA, GA**;** Daniel Fonceka, ISRA-CERAAS, Senegal

### Achievements

The African core set of 300 lines was phenotyped in four countries (Malawi, Mozambique, Uganda and Zambia). Numerous contrasting crosses were made to create new diverse varieties based on the developed product profiles. The genomic region responsible for groundnut rosette resistance has been tentatively identified based on GWAS analysis of the core set, paving the way for marker-assisted selection for this important disease across Africa. The ESA breeders were trained in MET data analyses, and the BMS fully adopted as the preferred suite for data capture, analysis and repository.

### Capacity Building

Mechanized sheller/aspirator and sizing tables were provided to each breeding program which has reduced drudgery and sped up operations on-station. The project supported one PhD and 2 MSc students who are scheduled to obtain their degrees before the end of the project.

### Lessons Learned

Contingency planning especially for ladybug and spider mites attacks is important. Field visits to partners sites enabled all breeders to see the progress and challenges. There is a need for irrigation to supplement the more erratic rainfall being experienced in the region. For the African core set to be more useful, trait-based mining is necessary to group the diversities.

### Presentations and Publications


Achola, E., et al. (2021). American Peanut Research and Education Society 2021 Virtual Annual meeting, 12-16th July, 2021. Makerere University, Kampala.

Chemutai, R. M. (May 2021). Response of micronutrient dense groundnut lines to major foliar diseases in Uganda and Malawi. Makerere University.

Deom, C. M. & Puppala, N. (January 2021). Registration of 'Naronut 2T' Groundnut(pp.62–67). Journal of Plant Registrations, 15, Hoboken, NJ 07030, USA. doi:doi.org/10.1002/plr2.20086

Kalule, Okello D. (June 2021). Target Product Profiles for Groundnut in Uganda. Presentation at Feed the Future Innovation Lab for Peanut 2021 Annual Research Meeting, (Virtual).


## Project A7. Enhancing the genetic potential of peanut production in West Africa

### Research Locations

NARO-NaSARRI, Soroti, Uganda; CSIR-SARI, Tamale, Ghana; ISRA-CNRA, Bambey, Senegal; INRAN-CERRA Niamey, Niger; IER-CRRA, Bamako, Mali

### Description

Africa is known to be a secondary center of diversity for cultivated peanut. Peanut breeders from different countries in Africa each hold small parts of this diversity which, put together, represent unique genetic resources that could be used to map traits of interest and add value to breeding programs. A panel of accessions will be tested across a range of environments and conditions (at least four countries in West Africa through this project and four in Eastern and Southern Africa through David Okello Kalule's project) to generate relevant information and data around diversity and the genetic basis for target traits, leading to a broadening of the genetic base for peanut breeding programs, and the development of new genes/markers for molecular breeding. The overall objective of the project is to characterize and document a unique pool of material that can be used as a new source of germplasm and alleles to improve peanut breeding in West Africa.

The accessions come from a set of 300 peanut lines from across Africa that have gone through phenotypic and genotypic evaluation in Senegal and Uganda. The set represents as much of the groundnut diversity across the African continent as possible but provides a set of a suitable size for multi-site evaluation in replicated trials. Breeders will evaluate this African core panel under local conditions in several countries in West Africa, including Ghana, Mali, Niger, and Senegal.

Core panel performance will be evaluated running single and multi-environments (GxE) analysis from phenotyping data. Diversity analysis, bringing together phenotypic and genotypic data from this very diverse set of African accessions, will allow for a better understanding of the genetic diversity used by each breeding program in West Africa, and thus provide breeders with opportunities to enlarge the genetic pool of material they use as parental lines for new crosses.

The same set of data will also allow genome-wide association studies (GWAS) to be run which will identify the genomic regions involved in the expression of target agronomic traits within a single environment, and across comparable ones. For simple inherited traits, association analysis could result in the identification of trait-linked markers that would be, after validation, suitable for crossing a trait into a variety. Genomic regions of interest for further gene pyramiding will also be identified for quantitative traits. Considering the performance of the core panel, some accessions performing well under specific local conditions might be considered as suitable donor lines for new crosses, or even ready to go directly into the national registration process.

### Theory of Change/Impact Pathway(s)

Information on the genetic makeup of varieties and use of core sets based on this information allows breeders to broaden the diversity in their programs. This results in more resilient varieties delivered to farmers, increased yields, and ultimately improved household food security.

### Collaborators

Daniel Fonceka (PI) and Aissatou Sambou, ISRA-CERAAS and Issa Faye, ISRA-CNRA, Senegal; Richard Oteng-Frimpong, CSIR-SARI, Ghana; Adama Coulibaly, INRAN-CERRA, Niger; Dramane Sako, IER-CRRA, Mali; Jean-Marcel Ribaut, IBP, Mexico; Peggy Ozias-Akins, UGA, GA; Josh Clevenger, HudsonAlpha Institute of Biotechnology, Huntsville, AL; Jean-Francois Rami & Joel Nguepjop, CIRAD, France

### Achievements

Data was collected for the 2021 trials, curated and combined with all data produced to date. All data produced from the beginning of the project are now available except those for the on-going trials in Senegal, Burkina Faso and Togo. Data analysis is on-going and preliminary results indicate that the African core collection is of very high value for variety development. A breeder meeting was organized just before the Senegal annual meeting involving all breeders who contributed lines to the collection, as well as experts from the US and France. The group discussed specific plans to (i) further phenotype for the missing traits, (ii) develop tools for breeding programs, (iii) enlarge and share the core collection, (iv) improve variety adoption, and (v) improve early-generation seed production.

### Capacity Building

A workshop was conducted in Saly, Senegal in September involving all breeders in the network and several experts from France and the US. Each breeder was able to work on the data analysis of their results.

### Lessons Learned

Trust, rather than a signed document, is needed to build a network. The project has consolidated a real community of breeders that share resources and knowledge and that appreciate to work together. It is very important to keep this momentum going for the next phase and to share the benefits of the core collection to countries/breeding programs that are not yet part of the network.

### Presentations and Publications

None to report.

# Project A8. Use of novel genetic diversity for peanut varietal development in East Africa

## Research Locations

NARO-NaSARRI, Soroti, Uganda; ISRA-CERAAS, Thiès, Senegal; University of Georgia, Athens GA, USA

## Description

In this project, wild relatives of peanut are used to provide new alleles to improve cultivated species through resistance to ELS, LLS and GRD. New lines containing some of these wild species are available at UGA and will be tested in Uganda. Three wild-derived advanced populations and several lines with resistant alleles have been produced in CERAAS (Senegal), and will be available for testing in Uganda. Selected, resistant progenies will be crossed with preferred peanut lines to produce cultivars with higher levels of resistance to leaf spots and GRD.

## Theory of Change/Impact Pathway(s)

Access to new and diverse germplasm allows breeders to broaden the diversity in their programs. This results in more resilient varieties delivered to farmers, increased yields, and ultimately improved household food security.

## Collaborators

Soraya Leal-Bertioli (PI), David Bertioli, Mike Deom, Scott Jackson, Rajagopalbabu Srinivasan, Peggy Ozias-Akins, UGA, GA; David Okello Kalule, NARO-NaSARRI, Uganda; Daniel Fonceka, ISRA-CERAAS, Senegal; and Josh Clevenger, HudsonAlpha Institute, AL

## Achievements

Quantitative trait analysis demonstrated the potential for alleles from the wild species *Arachis batizocoi* and *A. duranensis* to improve groundnut disease resistance and yield in East Africa. Crosses have been made using the best wild species genotypes and locally preferred varieties. Crosses were initiated to generate local inter-specific lines and future varieties. This is the first fully fledged breeding program in East Africa to involve valuable alleles from the wild species and inter-specific crosses. All germplasm is being made available to regional, pan-African and global breeding programs. Samples of several lines were sent to UGA for nematode analyses, however, no nematodes were detected.

## Capacity Building

One MSc completed her degree and is now pursuing doctoral training in USA. One student attended the annual meeting of the American Peanut Research and Education Society (APRES) and made a presentation within the Joe Sugg Graduate Student Competition. Students also benefited from seminars and workshops series conducted by the eminent scientists and the US project team.

## Lessons Learned

None reported.

### Presentations and Publications

Bertioli, S., et al. (September 2021). Legacy genetics of *Arachis cardenasii* in the peanut crop shows the profound benefits of international seed exchange(pp.1). PNAS, 118(38), USA. doi:doi.org/10.1073/pnas.2104899118.

Essandoh, D. A., et al. (March 2021). Performance of Interspecific Derivatives of Arachis SPP in Uganda and Identification of Candidate Regions Associated with Groundnut Rosette and Late Leaf Spot Resistance. Makerere University.

Essandoh, D. A., et al. (July 2021). Identification and genetic mapping of novel sources of resistance to groundnut rosette and late leaf spot diseases in a collection of Arachis wild derivatives. Presentation at APRES, (Virtual).

## Project A9. Incorporating new wild alleles to improve elite West African peanut cultivars

### Research Locations

ISRA-CERAAS, Thiès, Senegal; University of Georgia, Athens, GA, USA

### Description

Genetic variation in peanut is limited due to its recent, unique, polyploid origin, which limits crop improvement through breeding. Wild relatives of peanut are a rich source of alleles that have arisen over millions of years of natural selection in diverse environments. However, in early generation hybrids, the valuable wild alleles are masked by the more numerous unfavorable wild alleles that confer poor growth habit, small seed size, etc. These “cryptic” favorable wild alleles can be discovered through multiple cycles of backcrossing and screening for favorable traits when the wild alleles are incorporated with a substantially cultivated peanut genetic background.

Previous projects using this strategy have developed varieties that are resistant to late and early leaf spot. From the first highly backcrossed population, six new varieties were released in Senegal – with improved yield stability, haulm mass, higher yield and larger seeds. The proposed work will build on these successes, evaluating a previously developed set of lines and laying the foundation to produce new ones. Promising lines will be tested for cultivar release and/or incorporated into breeding programs. Materials produced will form a publicly available resource.

### Theory of Change/Impact Pathway(s)

Access to new and diverse germplasm allows breeders to broaden the diversity in their programs. This results in more resilient varieties delivered to farmers, increased yields, and ultimately improved household food security.

### Collaborators

David Bertioli (PI), Soraya Leal-Bertioli, Scott Jackson and Peggy Ozias-Akins, UGA, GA; Daniel Fonceka, ISRA-CERAAS, Senegal

### Achievements

An ABQTL population from Fleur 11 x IpaCor (Arachis ipaensis x A. correntina) was produced and phenotyped for leaf spot resistance at the ISRA/Nioro research station. The population was also genotyped with the Arachis Axiom SNP Array V2. Preliminary marker trait association showed significant association on chromosomes A02, A08 and A10 for leaf spot resistance. Seven selected BC4F4 lines from Fleur 11 x CS16 are also being evaluated at the Nioro station in a randomized complete block design. Data collection on disease severity as well as flowering

and yield components is in progress. The following additional lines carrying nematode resistance were sent to Senegal for field evaluation: 54_BC3F3:54_B, 125_BC3F3:125_B, 131_BC3F3:131_A, 138_BC3F3:138_B, 160_BC3F3:160_A, and 218_BC3F3:218_B.

### Capacity Building

None reported.

### Lessons Learned

None reported.

### Presentations and Publications

Bertioli, D. (September 2021). Legacy genetics of *Arachis cardenasii* in the peanut crop shows the profound benefits of international seed exchange. PNAS, 118(38), USA. doi:doi.org/10.1073/pnas.2104899118.

## Project A10. Developing *Aspergillus flavus*-resistant peanut using seed coat biochemical markers

### Research Locations

ICRISAT, Niamey, Niger; ICRISAT, Patancheru, India; Texas Tech University, Lubbock, TX, USA

### Description

The project studies the development of the seed coat of peanut and whether increasing naturally occurring biochemicals in the seed coat can increase the resistance to *Aspergillus flavus*, the fungus that can produce aflatoxin. The aim of the project is to fortify the seed coat with cell wall/antimicrobial compounds to confer pre- and post-harvest *A. flavus* resistance in peanut. Specific objectives of the project are to: 1) discover seed coat biochemical(s) associated with *A. flavus* resistance; 2) develop biochemical Marker Assisted Selection (bMAS) pipeline for breeders in target countries, and 3) develop *A. flavu*s resistant line(s) for field deployment in target countries.

### Theory of Change/Impact Pathway(s)

The information gained from the research will allow researchers to identify lines that have new resistance to pathogen infection and reduced mycotoxin contamination. These lines can be used by breeders to develop more resilient varieties and release these to farmers. Use of the new varieties as food and feed will reduce the effects of mycotoxins to human and animal health.

### Collaborators

Venugopal Mendu (PI), Texas Tech University, TX; Mark Burow, Texas A&M University, TX; Hamidou Falalou, ICRISAT, Niger; Hari Sudini, ICRISAT, India

### Achievements

To develop *Aspergillus flavus* resistant varieties for Africa, two sources of *A. flavus* seed coat resistance (55-427, PI 544346) were crossed with three varieties: TMV-2, Schubert (high oleic) and NkatieSARI (leaf spot resistant). F4 generation seed of the TMV-2 x 55-427 cross was produced and are ready for phenotyping. F3 seed of the NKatieSARI x PI 544346 cross was

produced and will be genotyped to confirm hybridity. Selected F3 generation seed of the Schubert x PI 544346 cross that were confirmed for high oleic were planted to produce F4 seeds.

Four lines from a set of 58 lines obtained from the USDA S9 PI station that had tan seed coat colors similar to the *A. flavus* resistant line 55-437 were found to have a greater level of A. flavus inhibition than the resistant check based on in-vitro seed colonization assays.

HPLC analysis of seed coat biochemicals from four lines (3 *A. flavus*-resistant and 1 susceptible) identified differences in several phenolic acid levels. Seven phenolic acids (syringic, sinapinic, caffeic acid, p-coumaric, T-O-coumaric, vanillic and ferulic acid) out of the 10 identified were tested for effects on *A. flavus* growth. None of the phenolic acids completely inhibited *A. flavus* growth, although, ferulic acid had the highest inhibition (~80%) with a EC50 of 1.2 mg.ml. Further studies are needed to confirm the role of ferulic acid in *A. flavus* resistance.

### Capacity Building

A PhD student from Ghana is pursuing his degree at Texas Tech University.

### Lessons Learned

The travel restrictions under the Covid pandemic made it difficult to fully manage the project and ensure good progress in each country.

### Presentations and Publications

Commey, L., Mendu, V., Sudini, H., Burow, M., Falalou, H., & Tengey, T. K. (July 2021). Insoluble polyphenols mediate *Aspergillus flavus* resistance in peanut. American Peanut Research Society, Dallas, Texas.

## Project A11. Mapping Groundnut Rosette Virus (GRV) resistance for marker-assisted selection

### Research Locations

NARO-NaSARRI, Soroti, Uganda; DARS-Chitedze Research Station, Chitedze, Malawi; ICRISAT, Nairobi, Kenya; University of Georgia, Athens, GA, USA

### Description

Groundnut rosette disease (GRD) caused by the groundnut rosette virus (GRV) complex is the most destructive peanut disease in sub-Saharan Africa. Resistance has been introduced into locally grown varieties and is a perfect target for genomics-assisted selection to integrate resistance into future varieties. The genetic mapping resources are available for marker development, but the capacity to develop a marker tightly linked to resistance needs to be developed and implemented using the latest genomics technology and expertise.

The project will develop diagnostic molecular markers that can be used to select for GRD resistance using existing recombinant inbred lines (RIL) populations that are segregating for resistance to GRD, but not the virus vector. We will combine strong phenotypic data with classical QTL mapping using high density SNP markers from the Axiom_Arachis2 SNP array. In addition, we will carry out QTL-seq analysis using bulked tails of the phenotypic distribution. This analysis will provide population-specific markers as well as whole genome selection for the

resistant parent, ICGV-SM 90704. Markers will be evaluated in GRD hotspots in Malawi and Uganda. Additional results will be accrued from association analysis of an African diversity set that is being screened in Uganda as part of another initiative led by David Okello Kalule and Daniel Fonceka. The total effort is expected to produce strongly linked marker(s) to GRD resistance that can be deployed in breeding programs in collaboration with Intertek genotyping services. The marker(s) will be used to select efficiently for resistance so that other high-value traits can be introgressed into locally adopted varieties for rapid genetic improvement.

### Theory of Change/Impact Pathway(s)

Tools to select for resistance to GRD will allow breeders to develop more resistant varieties. These varieties can then be delivered to farmers, increasing yields, and ultimately improving household food security.

### Collaborators

Josh Clevenger (PI), HudsonAlpha Institute, AL; Damaris Odeny, ICRISAT, Kenya; Peggy Ozias-Akins, UGA, GA; David Okello Kalule, NARO-NaSARRI, Uganda

### Achievements

The mapping population segregating for GRV resistance was grown under field conditions at Serere, Uganda for an additional round of phenotyping. Unfortunately, the disease pressure was not as strong as desired and even the infector rows were free of disease. The population itself has about 57,000 high quality, segregating SNP markers called on it and imputed. An analysis of the imputation accuracy showed >90% accurate imputed SNPs with missing data as low as 75% across an accession. We therefore have an excellent genotype dataset on this population and just need robust phenotyping data to finalize the mapping and marker development.

### Capacity Building

Training in sequence analysis and GWAS was offered to PhD students in Uganda and Kenya.

### Lessons Learned

Due to the COVID-19 restrictions, we met over Zoom and found that we communicated more often than in previous years. This has led to better coordination of the project.

### Presentations and Publications

Achola, E., et al. (July 2021). Genome Wide Association Studies reveal novel loci for resistance to Groundnut Rosette Disease in cultivated peanut (*Arachis hypogaea* L.). Presentation at APRES, (Virtual).

Makweti, L. et al. (July 2021). Understanding the genetics of resistance to groundnut rosette disease. Presentation at APRES, (Virtual).

## Project A12. Breeding for tolerance to water deficit, resistance to leaf spot and improved oil composition in peanut

### Research Locations

CSIR-SARI, Tamale, Ghana; ISRA-CNRA, Bambey, Senegal; Texas A&M University, Lubbock, TX, USA

## Description

Drought-stress and leaf spots are two of the major contributing factors to the yield deficit of peanuts in Africa. This project enhances genetic diversity of peanuts to reduce the impacts of these stresses through the use of wild species, genetic populations generated in the USA and West Africa, and selected ICRISAT breeding lines. Genes for tolerance to water deficit, resistance to leaf spots, and enhanced oil composition will be transferred to breeding programs in Ghana and Senegal and used to develop improved varieties. DNA markers will be identified for tolerance to water deficit stress and resistance to leafspots. DNA markers will be shared with national programs and training provided for use in selecting for these traits and for the high oleic acid content. Multi-location trials will be conducted with the goal of identifying release candidates for new varieties.

## Theory of Change/Impact Pathway(s)

Using tools to select for better yield under drought and pest pressure results in more resilient varieties delivered to farmers, increased yields, and ultimately improved household food security.

## Collaborators

Mark Burow (PI) and Charles E. Simpson, Texas A&M University, TX; Richard Oteng-Frimpong, CSIR-SARI, Ghana; Issa Faye, ISRA-CNRA, Senegal

## Achievements

*Novel crosses for tolerance to water stress* – Several crosses have been successful between accessions of *A. vallsii, A. pflugeae* and *A. paraguariensis* that may have tolerance to drought (and that do have demonstrated high oil content) into cultivated peanut. Crosses are underway involving the diploid *A. pflueae* X *A. paraguariensis* hybrid with *A.dardani*. As *A. dardani* survives the dry season in northeast Brazil, we expect that this cross will introduce some alleles for tolerance to drought stress into cultivated peanut.

*High oleic varieties* – Fatty acid analyses were conducted for SARINUT 1 and SARINUT 2, indicating that both varieties are mixtures of low and high oleic acid seed and will require work to purify the high oleic seed before release. Amino acid profiles were also conducted on both varieties. Oleic acid calibration curves were produced using a Piteba oil press and Misco digital refractometer and are being validated. Curves for linoleic and palmitic acid are in progress.

*Tolerance to water stress* – The 55-437 x TxL054520-27 population combining tolerance to water stress and high oleic was evaluated in Ghana using conventional and high-throughput phenotyping methods. A number of lines were found to be superior for pod yield compared to the checks. In Senegal, lines from crosses between Fleur 11 x 73-30 and ICGV 96894 x 73-30 had fresh seed dormancy and will be further evaluated for performance under water stress conditions.

*Resistance to leaf spot* – Several lines from the cross between NkatieSari X Schubert have been selected and are being advanced to preliminary yield trials in Ghana. Most of the lines were selected based on high oleic acid content and leafspot resistance. In Texas, a range of high oleic lines were identified across market types. High-yielding, early maturing, high oleic Spanish types look promising. Several lines from the BC3 x Schubert and TS32 populations had leaf spot

ratings superior to the resistant checks under field trials in Ghana and Texas. In Senegal, 188 high oleic F5 lines from the Turquie x Schubert cross were evaluated with several lies outperforming the checks. The best lines are scheduled for multi-location trials in the next season. Three molecular markers were validated as tightly linked to late leafspot resistance using the CS16 x Chinese populations in Ghana.

*Genomic tools* – A KASP marker array of 24 markers was shown to distinguish all 24 accessions tested and should provide a quick method to confirm varietal ID and hybrids in crossing programs. The Arachis Axiom Array 2 SNP chip identified 9600 polymorphisms that are being used to produce a high-resolution map of the cross. GWAS in being used to analyze a set of lines and date collected in Texas, Oklahoma and Virginia. Over 500 markers were found associated with yield, grade and water stress.

## Capacity Building

Co-PI Issa Faye attended the 2022 APRES meeting in Irving, TX and gave a presentation on the progress of the development and evaluation of high oleic lines in Senegal and prospects for a utilization of high oleic peanut varieties in Senegal. During his visit in Lubbock, he was trained on how to use the refractometer to assay for high oleic content in peanut. He was also trained on other methods for assessing high oleic, KASP markers and NIRs methods. At Stephenville, he visited John Cason and Charles Simpson breeding programs and peanut wild species collections maintained in greenhouse. PI Burow visited ISRA breeding program at Nioro and Bambey. At Bambey, Burow completed a demo on how to use the Frank's Design for Peanuts shelling and grading machines to help ISRA's breeding program team to use those new equipments acquired under the PIL project.At Bambey, Burow completed a demo on how to use the Frank's Design for Peanuts shelling and grading machines to help ISRA's breeding program team to use the new equipment acquired under the PIL project.

## Lessons Learned

Although improved electronic communications helped see things through the pandemic, ability to travel in person allowed for better coordination.

## Presentations and Publications


Burow, M., et al. (July 2021). Field Measurements, Yield, and Grade of the U.S. Minicore under Water Deficit Stress. APRES, (Virtual).

Denwar, N., et al. (April 2021). Evaluation and selection of interspecific lines of groundnut (*Arachis hypogaea* L). for resistance to leaf spot disease and for yield improvement(pp.873). Plants, 10, Basel, Switzerland. doi:10.3390/plants10050873

Faye, I., et al. (July 2021). Analysis of Vegetative and Reproductive Traits Revealed a Positive Transgression and Strong Correlations Between Traits in a Population of Recombinant Inbred Lines in Groundnut (*Arachis hypogaea* L.). APRES, (Virtual).

Ndela, D., et al. (July 2021). Evaluation of selected F6 peanut progenies of BC3-derived introgression lines and Spanish parents for resistance to *Aspergillus flavus* infection. APRES, (Virtual).

Oteng-Frimpong, R., et al. (July 2021). Enhancing the Efficiency in Data Collection in Peanut Through Whole-Plot Data Capture: The Case of Above Ground Biomass and Foliar Diseases. APRES, (Virtual).

# B. Value-Added Gains Research Project Reports

## Project B1. Updating of the NCSU Risk Index Tool [COMPLETED]

### Research Locations

NCSU, Raleigh, NC, USA

### Description

This completed commissioned project updated the existing web-based North Carolina State University (NCSU) risk index software tool into a form that can be used in other US states and Peanut Innovation Lab countries to help farmers make informed decisions about production practices, including disease and pest management. The tool is being updated to allow extension specialists and others more easily to add data required for decision-making, thus making the tool available in other countries.

### Theory of Change/Impact Pathway(s)

The risk tool is intended to be used by extension agents and farmers to determine the best management practices to use in the upcoming cropping season. Successful use of the tool would result in increased and more profitable yields for farmers.

### Collaborators

David Jordan (PI), Greg Buol, Gail Wilkerson, Rick Brandenburg, Barbara Shew, NCSU, NC

## Project B2. Groundnut rosette disease (GRD) alternative host

### Research Locations

NARO-NaSARRI, Soroti, Uganda; NARO-NaCRRI, Kampala, Uganda; University of Georgia, Athens, GA, USA

### Description

The objective of this project is to identify alternate host(s) of groundnut rosette disease, which is the most destructive viral disease of groundnut in sub-Saharan Africa. This project will analyze possible hosts from major groundnut producing areas in Uganda where the disease occurs at a high incidence each growing season.

### Theory of Change/Impact Pathway(s)

Groundnut rosette virus only exists in Africa, although the aphid vector of the diseases exists in many parts of the world, and most peanut varieties are susceptible. Identification of the alternate host would allow researchers to develop more sustainable strategies to contain the disease. Such knowledge would also identify strategies for restricting migration of the disease to countries outside of Africa. Reducing the risk creates more sustainable yields around the globe.

### Collaborators

Mike Deom (PI) and Paul Severns, UGA, GA; David Okello Kalule, NARO-NaSARRI; Michael Hilary Otim, NARO-NaCRRI, Uganda

### Achievements

Four common weeds were confirmed as alternative hosts for GRD through screenhouse trials – *Senna obtusifolia* (sickle pod), *Solanum nigrum* (black night shade), *Ageratum convzoides* (billy goat weed) and *Senna occidentalis* (coffee senna).

### Capacity Building

A graduate student at Makerere University has submitted his final thesis and is preparing a publication.

### Lessons Learned

Student/mentor interaction is important to validate methods and keep student focused.

### Presentations and Publications

Deom, C. M. & Kalule, D. O. (August 2021). Overview of Groundnut Rosette Disease: Past, Present and Future. Presentation at 53rd Annual Meeting of the American Peanut Research and Education Society., (Webinar).

Kalule, David Okello. (January 2021). Registration of 'Naronut 2T' Groundnut (pp.62–67). Journal of Plant Registrations, 15(2021), Hoboken, NJ 07030, USA. doi:doi.org/10.1002/plr2.20086

## Project B3. Optimized Shrub System (OSS): an innovation for landscape regeneration and improved resilience for the peanut-basin of Senegal

### Research Locations

University of Thiès (ENSA), Thiès, Senegal; ISRA-CNRA, Bambey, Senegal, The Ohio State University, Columbus, OH, USA

### Description

This project aims to further refine and overcome challenges to adoption of the Optimized Shrub System (OSS), which increases the density of native shrubs purposely planted in farmers' fields and incorporates shredded shrub material into the soil, resulting in yield stability in the face of drought, improved soil fertility and resilience of the peanut/millet cropping system.

The project involves participatory surveys and focus sessions to gather information and design local adaptations to the OSS, measuring the effectiveness of OSS adoption by conducting on-farm trials with 20 households, researching peanut varieties best adapted for OSS on long-term plots, and conducting outreach.

### Theory of Change/Impact Pathway(s)

Understanding the factors that prevent farmers from adopting the shrub system may help produce new strategies to achieve widespread use. The increased density of the shrub system shows evidence of improved resilience to drought and yield improvements.

### Collaborators

Richard Dick (PI) and Amanda Davey, The Ohio State University, OH; Ibrahima Diedhiou and Idrissa Wade, University of Thiès, Thiès, Senegal**;** Issa Faye and Alfred Tine, ISRA- CNRA, Bambey, Senegal

## Achievements

*Senegal* – On-farm pilot testing of OSS continued with farmer-engagement, monitoring, and data collection. Workshops were held in April at both locations (Meckhe and Nioro) to review the 2021 cropping season and prepare for the upcoming season of millet. In review, the first year (2019) showed no improvements on peanut yield as expected, but 2020's millet crop did show significant yield improvements (32% over non-treated farmer fields). After two years of shrub establishment, the 2021 peanut rotation did show significant yield improvement (22%) over standard farmer practices. While total shrub survival has declined, it remained at roughly 80% across species and locations. The 2022 rotation was millet planted in May/June following the first cutting and incorporation of the shrubs. The recommended practices were followed through the season and yield and yield components of the millet were collected and will be added to the analysis. A significant change in 2022 was the implementation of a locally developed and manufactured chopper which was evaluated relative to manual chopping for time and cost in both locations.

The second objective of evaluating peanut cultivars (traditional and improved), fertilizer recommendations (four treatments) and aflatoxin contamination at the long-term OSS plots in both the North (Keur Matar) and South (Nioro) of the Peanut Basin was collected in 2020 and 2022. The 2020 data showed that all varieties responded positively to OSS and fertilizer and OSS significantly reduced aflatoxin contamination. The data from 2022 will soon be added to this analysis.

A third objective relative to understanding socioeconomic constraints to adoption was also continued with additional results from Year 3. The primary constraints are related to accessing seedlings or the knowledge of reproduction, additional labor for planting, cutting and incorporation and limited knowledge diffusion of the system. While the survey sample size is limited, a cost-benefit analysis of both full cost (include added labor) and non-costed showed positive benefits accruing in both scenarios by Year 3 suggesting a critical bottleneck to adoption will be addressing labor and or chopping costs.

## Capacity Building

Two prototype mechanical choppers were produced and procured for ENSA. Three technicians were trained by the manufacturer in St. Louis, who then trained four farmer/operators at the two study locations.

## Lessons Learned

Active on-going participation of farmers is essential for successful demonstration trials of agroecological technologies.

## Presentations and Publications

Diedhiou, I. (February 2021). Optimized Shrub System (OSS): an Innovation for Landscape Regeneration and Improved Resilience for the Peanut-Basin of Senegal. Presentation at Innovation Lab Workshop, Thiès, Senegal.

Ndiaye, N. Z. (October 2020). Effect of the optimized system in Guiera senegalensis on indicators of soil quality and agrophysiological performance of the northern groundnut basin. ENSA, Thiès, Senegal.

# Project B4. Peanut production packages for Ghana

## Research Locations

CSIR-SARI, Tamale, Ghana; CSIR-CRI, Kumasi, Ghana; KNUST, Kumasi, Ghana

## Description

Peanut yields continue to be low in Ghana compared with those of other countries where new technologies and resources are available to farmers. Food safety also is compromised through aflatoxin contamination in Ghana because of poor drying and storing techniques. Previous research through the Peanut CRSP and PMIL focused on variety development, integrated pest management, and aflatoxin reduction throughout the peanut value chain. Deployment of new technologies in Ghana has been effective in some areas but continues to be limited across the country. A major challenge is a weak seed supply chain that can deliver improved varieties and production packages that can increase yield, quality, and farmer income.

To address these and other important issues facing farmers and the agriculture sector associated with peanut, this project is focused on four objectives: (1) improving and scaling-up production packages that increase peanut production and quality, (2) evaluating peanut-cereal cropping intensity and sequence to promote increased income and food security, (3) developing and deploying a risk tool for peanut production, and (4) improving linkages among public and private sector partners along the peanut value chain. Through these four objectives, a framework for collaboration among partners in Ghana will be fostered, farmers will receive pertinent information that will enable them to increase yield and improve food safety, and human capacity will be enhanced.

## Theory of Change/Impact Pathway(s)

Adoption of technologies that improve peanut production is limited due to access to inputs, such as improved varieties, but also lack of knowledge about cost/benefits of technologies used as a package. This research will generate and share knowledge related the package-based approach that may help improve productivity.

## Collaborators

David Jordan (PI) and Rick Brandenburg, North Carolina State University, Raleigh, NC; Moses Brandford Mochiah, CSIR-Crops Research Institute, Kumasi, Ghana; Jerry Nboyine, CSIR-Savanna Agricultural Research Institute, Tamale, Ghana; Richard Akromah, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana; Greg MacDonald, University of Florida, Gainesville, FL; Maria Balota, Virginia Tech, Suffolk, VA

## Achievements

Relative to the first objective of evaluating and scaling production packages, the third-year field trials were completed, and summary productivity and ROI analysis are underway. Initial pooled, multilocation data show significant response from the improved cultivar (SARINUT 2), use of additional pest control and particularly use of complete legume fertilizer, with highest ROI from all three interventions.

Similarly, under the second objective relating to peanut/maize rotations, the final year of multilocation field trials was completed. Interestingly, initial pooled data suggest that ROI in this scenario was not from the improved cultivar, however for these trials Yenyawoso was used rather than SARINUT 2. Additional data is being analyzed for the student's dissertation and publication.

An initial model for the Risk Tool has been completed for both the southern bimodal region and northern unimodal regions. A survey project with Alcorn State and SARI (see Project B7) has been completed giving a better baseline for technology adoption and ROI to complement small plot trial results. Two peer-reviewed articles were published under this objective, one focused on the North Carolina Peanut Risk Tool that was the foundation for the technology and a second on the development of risk tools for five different countries, including Ghana.

The fourth annual Ghana Groundnut Working Group (GGWG) was held in Tamale at the end of July in conjunction with the Peanut IL annual meeting. The meeting was attended by over 100 participants, including new participation from NGOs, processors and farmers. Participants set priorities for research needed into value chain questions and actions needed to make the GGWG relevant and sustainable following the completion of the Innovation Lab project. To that end, committees were formed to address communications, membership and future meetings.

### Capacity Building

The fourth GGWG meeting was held in July in Tamale bringing together a wide assortment of actors in the groundnut value chain, which facilitated the sharing of both research findings from scientists and students, and practical challenges from farmers, processors and market actors.

### Lessons Learned

While the attendance of the fourth GGWG had expanded due to outreach to new actors, plans for better addressing needs across the sector through enhanced visibility, communications strategies, practical initiatives for private sector and NGO engagement, and financial sustainability remain critical to maintain momentum and future viability.

### Presentations and Publications

Jordan, D., et al. (March 2022), A Risk Tool and Production Log Created using Microsoft Excel to Manage Pests in Peanut (Arachis hypogaea), Journal of Integrated Pest Management, doi.org/10.1093/jipm/pmac006

Jordan, D., et al. (August 2022) Examples of Risk Tools for Pests in Peanut (Arachis hypogaea) Developed for Five Countries Using Microsoft Excel, Journal of Integrated Pest Management, doi.org/10.1093/jipm/pmac017

## Project B5. Satellite image analysis for peanut

### Research Locations

LUANAR & Horizon Farms, Malawi; Stanford University, Stanford, CA, USA

### Description

This project assesses the potential for using satellite imagery to determine several important cropping components for peanuts in smallholder farms. The information gained from satellite imaging could ultimately be linked with the decision risk tools to improve decision-making and

the deployment of actions to maximize yields and minimize aflatoxin contamination. GPS field coordinates, along with yield and crop quality data from several hundred smallholder farms, will be submitted annually to collaborators at Stanford University for analysis of satellite images to estimate plant responses and assess the potential benefit of using satellite imagery.

### Theory of Change/Impact Pathway(s)

If remote sensing data is proven accurate enough to detect various crops and their health and potential yield, it may offer a wide array of applications, including crop-forecasting estimates, index insurance, impact analysis of programs, etc.

### Collaborators

Rick Brandenburg (PI), David Jordan and Dominic Reisig, North Carolina State University, Raleigh, NC; David Lobell, Stanford University, Stanford, CA; Jeremy Venable, Malawi Agricultural Diversification Activity, Lilongwe, Malawi; Wezi Mhango, Lilongwe University of Agriculture and Natural Resources, Lilongwe, Malawi; Andrew Goodman, Horizon Farms, Mitundu, Malawi

### Achievements

Through two growing seasons of data collection, the project has been able to achieve most of the objectives and identify additional next steps to improve future efforts in this area, including two primary challenges to effective use of the technology.

First, during the rainy season when crops are growing, there is a high likelihood of cloud cover limiting the ability of the satellite to collect data from the areas of interest. The Sentinel-2 satellites pass these areas only a limited number of times (~1x/week) during the growing season and therefore we are only able to obtain images from a few cloudless days. Multi-date Sentinel-2 data were processed to remove clouds and harmonic regression was used to estimate canopy greenness throughout the season. The peak greenness was found to exhibit significant positive correlation with yield, consistent with prior work in other crops in the region.

The second challenge is that ground-collected data for yield was relatively noisy for comparison to the satellite data. Multiple crop cuts from each field should be randomly taken to reduce noise from the inherent heterogeneity of the field. Measuring weed coverage and total groundnut biomass for a subset of fields would help to understand sources of error and improve estimates.

Future work in this area should include newer satellite imagery, which has higher resolution and greater frequency of coverage.

### Capacity Building

This project did not provide any short-term capacity building. Our enhanced understanding of satellite imagery can certainly contribute to future studies with LUANAR to investigate the use of additional satellite and drone images for yield and plant health assessment.

### Lessons Learned

The use of satellite technology in an environment with a single rainy season and significant cloud cover limited consistent data collection, which impacted our ability to assess certain growth stages. The use higher resolution and higher frequency satellites or of unmanned drones may prove to be more suitable. Flying transects under the cloud cover would allow for more frequent data collection.

# Project B6. Peanut production packages for Malawi

## Research Locations

DARS-Chitedze Research Station, Chitedze, Malawi; LUANAR, Mitundu, Malawi; Horizon Farms, Mitundu, Malawi

## Description

This project develops profitable and sustainable peanut production practices that combine inputs and interventions to increase yield, quality and profitability for smallholder and more commercial farmers. This project will develop packages of proven technologies and evaluate them across recently released cultivars. Specific objectives of the project are to: 1) develop production packages that optimize smallholder farmer productivity, quality, and profitability; 2) publish and disseminate a production and management guide for peanut production in Malawi and surrounding countries; and 3) build capacity in Malawi through the training of MSc students and conducting training workshops in peanut production.

## Theory of Change/Impact Pathway(s)

Adoption of technologies that improve peanut production is limited because farmers lack access to inputs, such as improved varieties, but also are not aware of costs and benefits of technologies that are presented as a package. This research will generate and share knowledge related the package-based approach that may help improve productivity.

## Collaborators

Rick Brandenburg (PI), David Jordan and Dominic Reisig, North Carolina State University Raleigh, NC; Wezi Mhango, Lilongwe University of Agriculture and Natural Resources, Mitundu, Malawi; Jeremy Venable, Malawi Agricultural Diversification Activity, Lilongwe, Malawi; Andrew Goodman, Horizon Farms Ltd, Mitundu, Malawi; Justus Chintu, DARS, Malawi

## Achievements

This project is organized around two MS student projects conducting field trials at two locations.

The first project evaluating the use of fungicide and pre- and post-emergent herbicides on high- and low-density planting of both Chitala (Spanish type) and CG9 (Virginia type) has collected two seasons of data (2019/20 and 2020/21) and the thesis has been completed. The key findings include improved yield for all treatments, but specifically when used with high density plantings and were more impactful on Chitala. Return on investment for the added inputs requires higher density plantings (i.e. double rows).

The second project is evaluating inorganic fertilizer, inoculant, gypsum and boron and harvest timing and the impacts on yield and seed quality, also using Chitala and CG9. Field trials were completed in 2020/21 and 2021/22, though only data analysis from the first year has been completed. Key findings include increased germination and seedling vigor with gypsum and boron applications as well as yield increases. Rhizobia inoculants and inorganic fertilizer also showed increases in N fixation and yield, but with greater response from Chitala.

Overall, the results of both trials confirm other studies showing that higher planting densities are needed to optimize yields when input packages are used and to make them financially viable.

### Capacity Building

This project trained two MSc students who will be seeking employment in agricultural science fields in Malawi. Limited field and laboratory research supplies and equipment were purchased which will be used by current faculty and future students. The advisor, Wezi Mhango, gained additional field research insight which she is incorporating into her lectures for future classes. This experience will prove valuable for future students.

### Lessons Learned

It is critical to conduct replicated field research trials off-campus at Bunda in locations that have trained technicians. This practice promotes the development of high-quality research plots that provide valuable data. Using private commercial farms also permits the use of the research plots to train and educate farmers who work on the commercial farm to adopt specific practices on their own smallholder sites.

### Presentations and Publications


Brandenburg, R., et al. (July 2021). Enhancing the Peanut Value Chain through Peanut Innovation Lab Partnerships: Examples of a Production Guide in Malawi using Research Results from Ghana. Presentation at Annual Meeting American Peanut Research and Education Society, (Virtual).

Chintu, J., et al. (August 2021). Malawi Production Guide for Groundnut – Best Management Practices for a High-Quality Crop.

Mhango, W., et al. (July 2021). Effects of Fungicides application and Weed Management methods on performance of peanut (*Arachis hypogaea*). Presentation at 2021 American Peanut Research and Education Society (APRES), (Virtual).

Mkanda, B., et al. Effects of boron and calcium fertilizer application, harvesting dates and storage techniques on seed quality, yield and yield components of groundnut (*Arachis hypogaea* L). Presentation at 2021 Joe Sugg Graduate Student Competition, (Virtual).

Mkandawire, L., Mhango, W., Jordan, D. L., & Brandenburg, R. (September 2021). Influence of Plant Population and Harvest Date on Peanut (*Arachis hypogaea*) Yield and Aflatoxin Contamination(pp.33-39). Peanut Science, 48, Tifton, GA. doi:https://doi.org/10.3146/PS20-30.1

Mtengezo, P., et al. (July 2021). Response of Groundnuts (*Arachis hy*pogaea) to Rhizobia Seed Inoculation, Inorganic fertilizer application and plant density. Presentation at 2021 Joe Sugg Graduate Student Competition, (Virtual).


## Project B7. Modern peanut technology adoption and smallholder farmer welfare in northern Ghana

### Research Locations

Alcorn State University, Lorman, MS, USA; CSIR-SARI, Tamale, Ghana

### Description

This project will build on the work of the other Ghana projects to evaluate the adoption and impact of several technologies for peanut production. The Risk Index Tool is the foundation of the survey instrument, which will be administered in 32 communities across 16 districts of the four regions in northern Ghana. The survey will also assess the impact of technology adoption on household welfare. The findings will serve as an empirical grounding and baseline to verify the assumptions of the experts, improve the tool by adding economic data for estimating return on investment, and help prioritize interventions for development and extension partners.

## Theory of Change/Impact Pathway(s)

Through better understanding of the level of adoption and return on investment of various technologies, farmers, development professionals and extension partners can prioritize interventions and improve communication. Likewise, future research needs will also be better understood.

## Collaborators

Anthony Bonnie-Baffoe (PI) Alcorn State University; Iddrisa Yahaya, Jerry Nboyine, CSIR-SARI; David Jordan, North Carolina State University

## Achievements

The survey (n=800) was completed with 54% male and 46% female participation. There was a challenge to achieve near gender parity due to a stronger male dominance in production decision-making than anticipated, while women's roles in labor, post-harvest management and marketing remain dominant. The average age of respondents was 43 and a majority reported no education (58% for men, 78% for women). Male respondents reported double the average household income of women-headed household, with even higher disparity when comparing agricultural assets and non-agricultural assets (30x and 5x higher for men respectively) offering a clear indication for challenges to invest in greater productivity. Less than 20% of either gender had access to credit.

The survey also gathered important gender-disaggregated descriptive statistics specific to peanut production that point towards potential areas of intervention. On seed sourcing, 68% saved seed from the previous harvest and 23% bought seed from the market. Men saved the seed more frequently (77%) than women (58%), suggesting women may have a greater financial challenge to retain the crop at harvest for future planting. However, women were more aware of improved varieties (42%) than men (35%), which could be attributable to participation in Village Savings and Loan programs or other female-targeted interventions. Despite the difference, the overall availability and use of improved varieties was low in 2021 (9% for men, 13% for women), though slightly higher than 2020. Men reported cultivating ~3ac, whereas women just over 2ac. A slight majority of farmers reported planting in rows (51%) as opposed to broadcasting (25%) or some combination (24%) though a higher percentage of women reported planting in rows.

In general, the results showed a very limited use of inputs (<1% use of alata soap (GRD control), oyster shells (source of Ca) or fungicides, 11% use of insecticides), which challenges some analysis for the yield response to inputs and evaluation of the risk index tool. Yield analysis showed, unsurprisingly, men with higher reported yields than women, but generally very low average yields (300kg/ha). Some variables such as row planting and improved varieties surprisingly had negative to no effect on yield, with only pre-plant germination testing showing an increased yield and profitability from initial analysis.

Relative to aflatoxin, the survey yielded some surprising results. Many respondents were aware of aflatoxin (73%), presence of moldy nuts (84%) and practice of sorting moldy nuts (80%). However, practices to reduce aflatoxin, such as improved drying practices like tarpaulins or platforms, are not widely adopted; the majority of nuts are dried on the bare soil (77%), suggesting additional training and access to technology is needed.

Overall, the survey provides an excellent baseline and insights on current production practices and levels of awareness about technology.

### Capacity Building

The survey data was analyzed and presented and discussed at the GGWG meeting in July 2022.

### Lessons Learned

None reported.

### Presentations and Publications

None Reported.

# C. Nutrition Research Project Reports

## Project C1. Regulation of gut microbiome by peanut supplements in youth

### Research Locations

Makerere University, Kampala, Uganda; University of Georgia, Athens, GA, USA

### Description

This project studies the specific role peanuts play in improving nutrition and health in growing children by regulating their gut microbiota through a peanut snack provided to 6- to 9-year-old boarding-school children of both genders in Mukono district in Uganda. We will use the next-generation sequencing and high-throughput analytical techniques to perform metagenomics and metabolomics analysis to assess the regulatory effects of peanut consumption on the structure and function of gut microbiome in healthy children. Preliminary analysis of both urine and stool samples will be conducted in Makerere University's College of Health Sciences, while advanced genomic and metabolomics analysis will be done at the University of Georgia in the US.

A baseline cross-sectional survey will be conducted in two primary schools to assess the household characteristics as well as nutritional and health status of the children. One of the schools will be randomized as the control and the other as the intervention. Over 90 days, one group of 48 students will receive salted peanuts, while 48 students will not receive peanuts.

Growth parameters, such as weight and height, will be measured every 15 days. Fecal and urine samples will be collected at the same time for microbiome and metabolomics analysis. The research will explore the significant difference on growth parameters between children who regularly consume peanut snacks and those children who rarely consume peanut/peanut-based meals, as well as variations on peanut effects between males and females based on microbiome and metabolomics outcomes.

### Theory of Change/Impact Pathway(s)

Increased understanding of the impact of peanut consumption on growth parameters and the gut microbiome may increase peanut consumption.

### Collaborators

JS Wang (PI), Lili Tang and Kathy Xue, University of Georgia, Athens, GA; John Ssempembwa and Geofrey Musinguzi, Makerere University, Kampala, Uganda

### Achievements

A total of 115 children (59 females and 56 males) were recruited for the study, and baseline fecal sample collections were collected. The peanut supplement was distributed over the next 90 days and fecal samples collected at Day 0, Day 30, Day 60, Day 90, and Day 120 (30 days after the intervention ended). Anthropometric measurements of body weight and height were recorded, along with 24-hour diary of foods consumed by children and their households. Statistical analysis of results was conducted.

Of the 440 fecal samples collected during 120-day study period, 70 infected samples were excluded, and aliquots of the remaining 370 fecal samples shipped to UGA for microbiome and metabolomics analysis. We are waiting for the sequencing results for data analysis. Targeted metabolomics analysis using ultra-high-performance-liquid-chromatography (UHPLC) was initiated to check if peanut supplement can modify concentrations of short-chain fatty acids in children's fecal samples. Lab works for both targeted metabolomics analysis with UHPLC and UHPLC/mass spectrophotometry (MS) and nontargeted metabolomics analysis with gas chromatography-mass spectrophotometry (GC-MS) are on-going.

### Capacity Building

Via the collaboration with investigators at the School of Public Health, Makerere University, the project has enhanced the following capacities in Uganda: (1) assembled and trained an investigators' team, including faculty, staff, graduate and undergraduate students, and local community workers; (s) used locally produced peanuts as the study material and used a local vender to provide roasted peanuts for the intervention study; and (3) provided parents and study communities knowledge on basic nutrition, food safety and hygiene.

### Lessons Learned

The impact of the COVID pandemic delayed our planned study for almost two years and forced us to change the study design from school-based to community-based. The unexpected high infection rate with parasites in Ugandan children, required us to add a screening procedure every time there was a fecal sample collection.

### Presentations and Publications

Wangia, R. N., et al. (October 2020). Nutrition and growth outcomes are affected by aflatoxin exposure in Kenya children(pp.2123-2134). Food Additives & Contaminants: Part A, 37(No. 12), Taylor & Francis. doi:https://doi.org/10.1080/19440049.2020.1825825

Wangia, R. N., et al. (November 2019). Aflatoxin in household maize for human consumption in Kenya, East Africa (pp.1-8). Food Additives & Contaminants: Part B, Online, Taylor& Francis. doi:1939-3229

## Project C2. Integrating the power of peanuts into school feeding

### Research Locations

University of Ghana, Accra, Ghana; Project Peanut Butter, Kumasi, Ghana; Washington University in St. Louis School of Medicine, St. Louis, MO

### Description

School-aged children in Ghana receive largely starchy cereals for their sporadic school meals. A nutritious school meal would likely promote better growth and school performance. This project will develop a cost effective, peanut-based school food for distribution in Ghana and sub-Saharan Africa. Multiple food types, such as pastes, bars and whole peanut options will be considered in developing the final product. The project will then conduct clinical trials in Ghana to determine the effects of product consumption on growth and cognitive learning in young people. The results will help determine whether the power of the peanut, which has been such a game-changer in other food-aid products, can be channeled to school-age children as well.

## Theory of Change/Impact Pathway(s)

Evidence of positive impacts of consuming peanut-based foods may lead to additional markets and increased demand for locally sourced peanuts.

## Collaborators

Mark Manary (PI), Reginald Lee, and Donna Wegner, Washington University School of Medicine, St. Louis, MO; Matilda Steiner-Asiedu, University of Ghana, Accra, Ghana

## Achievements

Enrollment (initial) measurements of 875 school age children at six schools, mid-trial measurements of 304 school age children, and final measurements of 797 school age children were completed. In addition, 707 household surveys were conducted. Data cleaning has been conducted and analysis of results is in progress.

## Capacity Building

Mion District is a resource-poor location, and the schools do not have enough seating and workbooks for the children. As the participant gift we provided each student with a workbook that was recommended by the teachers. In addition, we also donated all tables and chairs that were purchased and utilized for neurocognitive testing.

## Lessons Learned

The lessons we have learned in the past year are that given the fact that many of the students have similar or identical names, a better method of identifying each child needed to be developed. To confirm that that correct child was measured at the start, mid, and end timepoints pictures of the child were taken with their study IDs. This allowed us to maintain accuracy when testing. Also we learned that attendance tracking is crucial and plays an important role in identifying the impact of the school feeding project on the schools. In addition, we learned that children are not only willing to eat the same food daily but enjoy it very much.

## Presentations and Publications

None reported.

# D. Gender and Youth Research Projects Reports

## Project D1. Retaining the next generation of Senegalese farmers

### Research Locations

Virginia Tech, Blacksburg, VA, USA; University of Georgia, Athens, GA, USA; University of Thiès/ENSA, Thiès, Senegal

### Description

This project explores climatic and land-tenure constraints to youth participation in the Senegalese groundnut sector. Despite the strong historic emphasis on groundnut production in central and western Senegal, the sector has been stagnant in recent years as climatic variability and uncertainty in policies have generated a risky production environment. This production environment has also reduced incentives for young adults to enter into groundnut production, leading to high levels of rural out-migration, and threatening the long-run viability of peanut production.

Secondary household survey data, historic climate data, and a primary survey of 1,125 households in the groundnut basin will be used to quantify the economic costs of highly variable production environments and uncertain land-tenure arrangements for young groundnut farmers. The results of these analyses, in conjunction with workshops held with local community groups and farmer organizations, will be used to evaluate the feasibility of technology and policy options to address constraints.

### Theory of Change/Impact Pathway(s)

Youth participation is a key to the future viability of the Senegalese groundnut sector. Young people will choose to enter (or remain in) groundnut farming if the sector contributes to a viable livelihood strategy. This project will provide insights regarding the best technical and policy options for reducing risks to production and land tenure, which if adopted by development actors, will improve the viability of groundnut production as a household livelihood strategy for the next generation of Senegalese farmers.

### Collaborators

Bradford Mills (PI), Virginia Tech, Blacksburg, VA; Genti Kostandini, University of Georgia, Griffin, GA; Pierre Maurice Diatta, Consultant, Senegal; Katim Toure, ENSA, Senegal; Tamsir Mbaye, ISRA, Senegal

### Achievements

*Panel Survey Analysis* – We have expanded analysis of the household survey beyond the initial analysis from the previous reporting period. PI Bradford Mills has completed a paper with former-VT PhD student Ange Kakpo, that examines the factors that determine which household members get access to groundnut fields and how constrained field access may be influencing observed groundnut field productivity. The paper served as one of three papers in Kakpo's PhD dissertation and has been submitted for publication at a referred journal.

As part of dissemination and outreach activities, project PIs produced five research briefs in French. These focus on 1) soil fertility management strategies employed on groundnut fields in

the Groundnut Basin; 2) comparison of GPS estimated field sizes with household head self-reported estimates of field size; 3) the determinants of household member access to groundnut fields and the implications of limited access for groundnut productivity of young adult and female producers; 4) farmer use of groundnut varieties; and 5) young adult use of social media and perceptions of climate change. As part of continuing research, PIs Kostandini, Toure, and Mills are examining the impacts of rainfall and temperature on household groundnut production. We have made initial estimates of the risk costs to groundnut farmers of exposure to weather variability and expect to complete this analysis by the end of the calendar year.

*Secondary Data Analysis* – The analysis of the secondary data with respect to young groundnut farmers (16 and 29 years old) in the Groundnut Basin of Senegal and the effects of climate shocks on groundnut production was compiled into a research brief. The research brief provides information on young women and men in rural areas with respect to agricultural land ownership, employment in agriculture, education and role within the household. In addition, we examine the effect of climate shocks such as drought and extreme temperatures on groundnut production.

### Capacity Building

The research findings in the briefs were presented at a one-day seminar at CIRAD in Thiès in July by PIs Toure, Mbaye, and Mills to 10 Senegalese researchers. Researchers were also made aware of the possibility of using the dataset for their own research.

### Lessons Learned

Differences in perspectives and methodologies between breeders and social scientists can lead to different opinions regarding the nature and extent of improved peanut variety adoption by farmers.

### Presentations and Publications


Diatta, P., et al. (February 2021). Retaining Next Generation Farmers in the Senegal Groundnut Basin. Presentation at National Coordination of Feed the Future Innovation Laboratories February 23-24, 2021., Senegal.

Mills, B., et al. (September 2021). Should I stay or should I go: Can youth migration be an asset, rather than a liability, in the Senegal Groundnut Basin? (Webinar).

Mills, B., et al. (2021). Generation and Gender Differences in Groundnut Productivity in the Senegalese Groundnut Basin.

Touré, K., et al. (2021). Groundnut Production Constraints and Opportunities for Young Adults in the Senegalese Groundnut Basin.

Touré, K. (July 2021). Retaining Next Generation Farmers in the Senegalese Groundnut Basin. Presentation at La journée des projets à l'ENSA – juillet 2021, Thiès, Senegal.


## Project D2. Farmer Incentives for quality Ghanaian peanuts

### Research Locations

University of Development Studies, Tamale, Ghana; Project Peanut Butter, Kumasi, Ghana; AMSIG, Tamale, Ghana; University of Georgia, Athens, GA

### Description

The original project aims were to strengthen value chain linkages by helping aggregators provide yield-enhancing and aflatoxin-reducing inputs to farmers. Given the difficulties in establishing contractual arrangements in the groundnut value chain in Ghana, the project team developed a

new research objective to investigate how incentives could improve the quality (food safety) of a groundnut-based product, kuli-kuli (a popular snack) almost entirely produced by women in northern Ghana. Kuli-kuli is produced as a by-product of peanut oil extraction which often involves very low quality peanuts as the source. Studies have shown that kuli-kuli can have very high levels of aflatoxin.

The project will enroll about 800 women processors and educate them200 about aflatoxin and good practices to reduce contamination. Those educated will be provided with a sign to place outside their shops informing customers of their training in aflatoxin management, and a changeable card displaying the safety rating of their products (the processors' kuli-kuli is tested for aflatoxin on a regular basis). The project will then evaluate the impact of the intervention on product quality and aflatoxin contamination, and its effect on consumer behavior. In addition, the project will evaluate the interest of the remaining 600 processors on their willingness to pay for the intervention (training, voluntary testing, and signage).

### Theory of Change/Impact Pathway(s)

By educating processors about the dangers of using poor quality peanuts to produce kuli-kuli, and indicating to consumers that the educated processor is producing a higher quality product, consumers will prefer to purchase the higher quality product, even if at a slightly higher price, and aflatoxin levels in the product will decrease, improving profit for the processor and reducing the health effects of aflatoxin to the consumer.

### Collaborators

Nicholas Magnan (PI) and Ellen McCullough, University of Georgia, Athens, GA; Vivian Hoffmann, International Food Policy Research Institute (IFPRI), Nairobi, Kenya; Nelson Opoku, University for Development Studies (UDS), Tamale, Ghana

### Achievements

We successfully conducted the-lab-in-the-field experiment that will serve as Ph.D. student Sean Posey's main dissertation chapter. We have just begun collecting baseline data and kuli-kuli samples for aflatoxin testing. We have purchased inputs and rented venues to conduct training on aflatoxin- safe kuli-kuli production for 225 producers.

### Capacity Building

None reported.

### Lessons Learned

None reported.

### Presentations and Publications

Hoffmann, V. (March 2021). Managing plant-associated hazards where regulatory capacity is weak. Presentation at CGIAR International Year of Plant Health Webinar Series, (Virtual).

Hoffman, V. (August 2021). Evidence on supply and demand for aflatoxin safety. Presentation at Market-Driven Strategies for Combating Aflatoxins in Rwanda, (Virtual).

Magnan, N., et al. (June 2021). Information, technology, and market rewards: Incentivizing aflatoxin control in Ghana(pp.102620). Journal of Development Economics, 151, Amsterdam, Netherlands. doi:https://doi.org/10.1016/j.jdeveco.2020.102620

# Project D3. Time poverty among women smallholders in Ghana: Implications for gender priorities in the peanut value chain

## Research Locations

CSIR-SARI, Tamale, Ghana; Pennsylvania State University, Reading and University Park, PA, USA

## Description

Groundnut is a labor-intensive crop, with time constraints at critical points in production. Women are the primary producers and processors of groundnut in Ghana, but their engagement and productivity are limited by traditionally gendered roles and responsibilities. This project investigates time poverty (defined as insufficient time to take on new tasks and responsibilities) and its influence on women's participation in the groundnut value chain. The project will survey men and women's time use at various stages of the production cycle to expand the understanding of time poverty in relation to the groundnut sector. After conducting an inventory of locally available time-saving and time-enhancing technologies, these technologies will be disseminated through gender-integrated farmer field schools and evaluated for their capacity to enhance women's participation in groundnut production.

## Theory of Change/Impact Pathway(s)

A better understanding of the differences between men's and women's roles in groundnut production is necessary to develop appropriate interventions. The study will inform efforts to improve technology adoption amongst smallholder groundnut farmers and assist practitioners in selecting interventions that reduce women's time poverty and enhance women's ability to engage in peanut production.

## Collaborators

Leland Glenna (PI), Paige Castellanos and Leif Jensen, Pennsylvania State University, University Park, PA; Janelle B. Larson, Pennsylvania State University Berks, Reading, PA; Edward Martey, Doris Kavenaa Puozaa and Richard Oteng-Frimpong, CSIR-Savanna Agricultural Research Institute, Nyankpala, Ghana

## Achievements

Farmer field schools focused on peanut agronomy and gender empowerment were completed in two communities in northern Ghana, resulting in knowledge gains for the participants. Two waves of the household survey on time-use were completed and data from these efforts is now being analyzed. Four mechanical peanut planters were purchased and delivered to the two study communities (two to each) and farmers were trained in how to use them.

## Capacity Building

The two Ghanaian students are continuing their education, which they are extending to their jobs at SARI. Three graduate students, one at Penn State and two in Ghana continue on the project. The Penn State student secured a Fulbright scholarship to spend nine months in Ghana working on the project.

### Lessons Learned

None reported.

### Presentations and Publications

Castellanos, P. & Jensen, L. (January 2021). Gender 101: What is Gender and Why Does It Matter?. Presentation at Gender and Agriculture Workshop, (Virtual).
Castellanos, P. (January 2021). Gender, Monitoring, and Evaluation. Presentation at Gender and Agriculture Workshop, (Virtual).
Fischer, K. (January 2021). Gendered Time Poverty and Empowerment among Peanut Producers in Northern Ghana: Baseline Findings. Presentation at Gender and Agriculture Workshop, (Virtual).
Glenna, L. & Martey, E. (January 2021). Project Overview: Time Poverty Among Women Smallholders in Ghana. Presentation at Gender and Agriculture Workshop, (Virtual).
Jensen, L. (January 2021). Incorporating Gender into Outreach: Lessons from a Farmer Field School in Honduras. Presentation at Gender and Agriculture Workshop, (Virtual).
Larson, J. (January 2021). One Big Happy Family. Presentation at Gender and Agriculture Workshop, (Virtual).
Larson, J. & Martey, E. (January 2021). Using Survey Tools / Women's Empowerment in Agriculture Index. Presentation at Gender and Agriculture Workshop, (Virtual).
Sachs, C. (January 2021). Feminist Research Methods. Presentation at Gender and Agriculture Workshop, (Virtual).
Sachs, C. (January 2021). Gender Theories and Epistemology. Presentation at Gender and Agriculture Workshop, (Virtual).

## Project D4. Photovoice for Ugandan youth empowerment

### Research Locations

Makerere University, Kampala, Uganda; NARO-NaSARRI, Soroti, Uganda; University of Tennessee, Knoxville, TN, USA

### Description

Youth participation in farming is critical for the future of Ugandan groundnut production, yet avenues for fostering youth engagement remain unclear. This project uses photovoice – a participatory visual research methodology – to compare the experiences of young men and women living in rural, groundnut-producing communities of Northern and Eastern Uganda, and to investigate the factors that empower and enable youth to be active stakeholders in the groundnut value chain. The study will also evaluate the use of photovoice itself as a tool for empowerment. Thirty youth will be trained in photovoice and will subsequently collect photos using smartphones over the course of two groundnut production seasons, select photos, explain their photo-stories, and then participate in focus group discussions to further articulate their actual and ideal engagement in groundnut value chains. The findings will be disseminated through community festivals, oral presentations, written reports, workshops, and a digital platform to host a repository of visuals of youth empowerment in peanut value chains.

### Theory of Change/Impact Pathway(s)

The results of this study will help practitioners to design agricultural policies and interventions that reflect youth aspirations and reduce the barriers to their engagement in Ugandan groundnut production. The project will also produce best practices for using photovoice as a method for

understanding and empowering rural, Ugandan youth, which can be adopted by practitioners in their own future work.

### Collaborators

Carrie Ann Stephens (PI), Dave Ader, Tom Gill and Jennifer Richards, University of Tennessee, Knoxville, TN; Archileo Kaaya, May Sengendo and Stephen Lwasa, Makerere University, Uganda; David Okello Kalule, NARO-NaSARRI, Uganda

### Achievements

The final photos from Nwoya and Tororo were selected; 15 were chosen out of an original 1,200 photos taken by the participants. The selected photos are those that participants felt best represented the food safety, gender, and youth opportunities and challenges of peanut agriculture in the study communities. The UT team traveled to Uganda in July 2022 to conduct interviews with 30 youth participants engaged in the project. The focus of the interviews was on peanut value chains and gender representation in peanut production. The data is being utilized for a student thesis, in publications related to utilizing photovoice in value chains, and will add to the body of literature in gender roles in peanut production. Photovoice participants in Nwoya and Tororo were trained on food safety and groundnut participation. The Makerere team traveled to Georgia for the Peanut Tour and learned more about the US peanut value chain approach, and then to Tennessee to visit the University of Tennessee where preparations were made for the community fairs, which were scheduled to take place in late October 2022.

### Capacity Building

None reported.

### Lessons Learned

Weekly communication between the UT and Makerere researchers helped foster positive team dynamics and ensured project activities continued successfully despite COVID-19 related difficulties with international travel.

### Presentations and Publications


Chandler, A. & Stephens, C. A. (2021). Photovoice, a visual research methodology: A review of literature across various fields.

Kemigisha, D. (July 2021). Drivers of Youth Participation in Groundnut Value Chains in Tororo and Nwoya districts, Uganda. 53rd American Peanut Research and Education Society, (Virtual).

Mirembe, R. (July 2021). Use of Photovoice to Assess Quality and Safety of Peanuts along the Value Chain: A case of Youth in Nwoya and Tororo districts, Uganda. Presentation at 53rd American Peanut Research and Education Society, (Virtual).


## Project D5. Gender dynamics in Senegalese peanut production

### Research Locations

University of California, Santa Barbara, CA, USA; Université de Gaston Berger, Saint-Louis, Senegal; CRDES, Dakar, Senegal

## Description

Achieving gender equality in agricultural development is fundamental to reduce global poverty, hunger, and malnutrition. Women's participation in Senegalese groundnut farming is embedded in social context and linked to the work and needs of others in the household and community. Although women play a critical role in groundnut production, their efforts may be impacted by inefficient and inequitable allocations of labor and resources with respect to complex household structures and concomitant intra- and inter-household gendered power dynamics. Existing research is lacking in terms of providing an adequate description of these interconnections, as well as the ways in which they mediate the impacts of stressful events.

This project is studying how men and women's engagement in various aspects of groundnut production in Senegal is influenced by intra-household structure and gendered power dynamics, and how those relationships are further impacted by stressors including 1) the initiation, timing, and spacing of births; and 2) concurrent climate shocks (precipitation and temperature). Traditional time-use study methods have significant limitations in low-literacy, low-resource populations like those of rural farmers in Senegal. The project is developing an innovative method for measuring time use employing wrist-worn technologies (activity monitors and recorders) to periodically signal participants to record audio clips of their activities. This method has several potential advantages over traditional approaches including minimized participant burden, increased granularity, decreased seasonality effects, more specific coding and analysis, and less required resources.

## Theory of Change/Impact Pathway(s)

A better understanding of the differences between men's and women's roles in groundnut production is necessary to develop appropriate interventions. The research takes a complex systems approach to understanding the lives and livelihoods of male and female groundnut farmers. The results will inform the development of multi-sectoral strategies (involving e.g. agriculture, health, environment and education) to improve the resilience and gender inclusivity of groundnut production in rural Senegal. While time-saving technologies have been proposed as a solution to time poverty in this region, they may be ineffectual if implemented without an understanding of the power dynamics that keep women working in limited roles and for many hours. Analyses of farmer responses to weather shocks can be used to understand resilience, and model production outcomes under future climate scenarios. Monitoring time use during both the dry and rainy season will provide a more detailed understanding of how men and women's time-use varies at different times of the year, which practitioners can use to refine the timing of their interventions.

Finally, the innovative wrist-worn technology and associated protocols developed through the project will be of significant benefit to other researchers seeking to understand time use and activities in similar contexts.

## Collaborators

Stuart Sweeney (PI), Kathy Baylis, and Sari Blakeley, University of California, Santa Barbara, CA; Jacqueline Banks, University of Minnesota, Minneapolis, MN; Samba Mbaye and Mamadou Ba, CRDES, Senegal

## Achievements

*Pilot with UCSB undergraduates* – Audio clips were transcribed, and qualitative analysis of the dataset completed. Analysis of the heart rate data is ongoing, using statistical analysis and machine learning. This analysis is important for the Senegal datasets, as algorithms are being created to detect work and sleep patterns from the heart rate data.

*Research in Senegal* – The research in Senegal has focused on capacity building and development of monitoring structures for the baseline survey and the three phases of time-use data collection. An extensive baseline survey and methodology was developed and fielded to understand the context the farmers find themselves in, their best practices around peanut farming, how they view their own time and activities, and their family structure. Additionally, a framework for collecting heart rate monitoring data, time-use activities, and a post-activity monitoring survey were created, and also a statistical methodology for analyzing the voice recorded activities, which has been presented and published at the Joint Statistical Meeting 2022. Phase 1 time-use data was collected and phase 2 is undergoing collection. The oral activity data from phase 1 was translated into an activity dataset.

The data collected from the baseline survey, phase 1 and 2 (and expected phase 3), along with the ethnographic study are being shared with the group. The team is developing methods for analyzing this data for scholarly papers.

## Capacity Building

Surveyors at CRDES trained in new fieldwork methods for time-use data collection.

## Lessons Learned

After one round of data collection, two issues emerged. Firstly, farmers, despite stating that they would be open to wearing watches and recording their activities, were in fact rather reticent about doing so, with one entire village refusing to continue to participate (this village has since been replaced). The compensation for the farmers has been increased to motivate further involvement as well as relying on the continued presence of research team members to reinforce trust amongst the participants. Secondly, the first phase of data collection saw heavy involvement of researchers in the field to ensure regular recordings. Although the dataset is complete, this will not be sustainable, as it is too involved to be replicable elsewhere. Therefore, in the second phase of data collection, targeted phone calls will remind households to participate, including the fact that their compensation is tied to their participation, in order to motivate their involvement.

## Presentations and Publications

Gender and Time Poverty in Rural Senegal: Effects of Intrahousehold Structure and Composition, Physical Landscape, and Seasonality. Presentation by Jessica Marter-Kenyon. Association of American Geographers (AAG) Annual Meeting. Virtual. April 7-11, 2021.

# Associate Award Research Project Reports

While technically not an associate award, the Peanut Innovation Lab has received funding from the following two implementing partners of USAID mission projects.

## AA1. Malawi Agricultural Diversification Activity, Palladium International, LLC (IP)

### Project Description

The Malawi Agricultural Diversification Activity (AgDiv) contracted with the Peanut Innovation Lab to recommend best management practices to increase groundnut productivity, evaluate potential improved groundnut varieties, enhance seed production of released varieties, conduct household surveys to identify constraints to improved groundnut production, provide training on groundnut production, and conduct cost-benefit analyses of AgDiv-promoted technologies. Additional projects were developed during this fiscal year to evaluate the use of Aflasafe, improve grading and aflatoxin testing capacity, and to develop recipes and strategies to include peanuts in a pre-existing soymilk project.

### Collaborators

Dave Hoisington and Jamie Rhoads, University of Georgia; Rick Brandenburg and David Jordan, North Carolina State University; Boris Bravo-Ureta, University of Connecticut; Frank Nolin, Frank's Designs for Peanuts; Greg MacDonald, University of Florida; Justus Chintu, DARS Chitedze Research Station; Limbikani Matumba, Aggrey Gama and Wezi Mhango, LUANAR; Andrew Goodman, Horizon Farms; Tadala Rambiki, Pyxus

### Achievements

Despite the challenges of COVID-19 several initiatives under the AgDiv project continued with either virtual connections or local leadership. During the 2020-21 cropping season, seed of recently released lines was multiplied by DARS and through collaborations with private sector partners. The ME and an EAP member reviewed the seed system through a collaboration with private-sector partners for the Innovations to Impact (i2i) project managed by the Soybean Innovation Lab. The report found that unique biophysical aspects of groundnut, such as multiplication rates and fragility, require special considerations for seed system policy and have implications for sustainably scaling seed with public and private partners. Private sector investment in Malawi with technical assistance from the IL has led to rapid scaling of high quality, certified seed and could be used as a model.

A collaboration between LUANAR and private sector partner Pyxus assessed the effectiveness of the aflatoxin biocontrol product Aflasafe under farmer management, collecting samples from more than 800 fields in multiple locations.

LUANAR scientists were able to adapt and improve upon a kit developed by partners of the Soybean IL to produce soy milk at the household scale to sell locally. The objective was to incorporate peanuts and adjust the recipes for optimal consumer preference, nutrition, and value. The researchers shared these recipes, incorporated additional training on food safety, and recommended improvements on the equipment used in the kit, which resulted in higher protein

levels and reduced sugar and artificial flavorings. This project has resulted in additional funds for research on options to improve the shelf life of the products, which could greatly improve commercialization opportunities for larger scale production. A complimentary project was also awarded to this team by the UGA CAES to assist in commercialization through a competitive process.

A training and technical support program that was launched in the previous year was continued through virtual workshops with two private sector partners. These meetings involved comprehensive training on aspects of production during the appropriate times of the season for field technicians who then extended this knowledge to the outgrower networks. These trainers would bring questions, as well, which helped prioritize future training and research, including a significant update to the Malawi Groundnut Production Guide. This "living" document, completed during the previous year, established a foundation based on previous research and continues to be updated from year to year. This was completed in coordination with DARS and was released by the government as approved technology.

### Capacity Building

The ongoing Aflasafe evaluation and peanut drink projects have involved two graduate students at LUANAR. Soymilk processors were trained on the adapted peanut-based recipes. The technicians and commercial farm managers from the two private sector companies have received updated training and technical feedback.

### Lessons Learned

The complexity of the Aflasafe field trials in the previous year resulted in limited useful data collected. Coordination between the university, the private sector partner and collaborating farmers on financial and technical responsibilities needs to be clearer and better documented to avoid assumptions and frustration.

Virtual training has been possible and mutually useful, but the lack of face-to-face and in-person field visits results in lower quality support and learning.

Public sector researchers can greatly contribute to commercialization and development activities, such as the peanut drink, but additional funds and skillsets are needed to avoid technologies being left on the shelf.

## AA2. Bangladesh Rice and Diversified Crops Activity, ACDI/VOCA (IP)

### Project Description

Bangladesh produces approximately 66,000 MT of peanuts (groundnuts) with yields averaging around 1.5 kg/ha. Peanuts are grown primarily by smallholder farmers, although there are some farmers cultivating larger acreage and/or assembled into cooperatives. The majority of peanut produced is used for internal processing and consumption. It is estimated that farmers are able to meet only 50% of the internal demand for quality peanuts. Given expected trends in the marketing and consumption of peanuts and peanut products, the demand is expected to rise, further reducing the ability of local farmers to meet the requirements. With the lack of additional land for cultivation, increases in peanut production will need to come from improved varieties

and agronomic practices, while also working to reduce losses and preserve quality during post-harvest handling and storage.

The predominant variety, Dhaka-1, is a small-seeded, red-skinned Spanish peanut that was released many years ago. A few newer varieties (e.g., Chinabadam 8) are available that are larger seeded, possess resistance to the major diseases and are potentially higher yielding. Adoption of these varieties is limited, partly due to a lack of quality seed and a formal seed system for scaling. There is a desire to have a large-seeded, but early maturing (<120 days) variety that would be more adaptable to the current short growing season and meet market demands.

The ultimate goal is to enhance the production and processing of quality peanuts that meet the market demands in Bangladesh. The initial objective will be to increase the availability of improved varieties (short season, high oleic, large seed size) that meet market demands and increase productivity on-farm.

To accomplish this objective, new peanut varieties developed in the USA and potentially suitable for Bangladesh will be sent to the Bangladesh Agriculture Research Institute (BARI) and the private sector to conduct variety trials of these and improved locally-bred varieties. The varieties will be provided by Naveen Puppala, peanut breeder at New Mexico State University and Peanut Innovation Lab collaborator. Puppala's breeding program focuses on short duration Valencia, Virginia and Spanish market types, including high-oleic varieties, that are most likely to fit the local agronomic and market requirements. Puppala also has a long-term relationship with ICRISAT scientists currently working in Bangladesh and can help strengthen the linkages between the US and ongoing variety evaluation and development efforts.

### Collaborators

Dave Hoisington and Jamie Rhoads, University of Georgia; Frank Nolin, Frank's Designs for Peanuts; Naveen Puppala, New Mexico State University, BARI Groundnut Program, Partex Ltd.

### Achievements

Due to COVID-19 restrictions, no activities occurred during FY22.

### Capacity Building

None.

### Lessons Learned

COVID-19 has made it difficult to continue the activities planned, especially the site visits in-country.

# Human and Institutional Capacity Development

## Short-term Training (Workshops/Courses)

| Date of Training | Country of Training | Brief Purpose of Training | Number Trained | | |
|---|---|---|---|---|---|
| | | | M | F | Total |
| **7/25/2022** | Ghana | GGWG & Ghana Projects Meeting-The Peanut Innovation Lab and the Ghana Groundnut Working Group held a meeting on July 25-29, 2022, in Tamale, Ghana at the Mariam Hotel. The GGWG met July 25-27, and the annual projects meeting then began on July 27-29, 2022. THE GGWG discussed topics such as the importance of groundnut, food safety, production, and market chains. Field visits occurred during both the GGWG and the projects meeting. | 67 | 23 | 90 |
| **2/15/2022** | Ghana | Ghana Groundnut Working Group (GGWG) Planning Meeting- Reviewed the 2021 GGWG meeting and planned for the 2022 GGWG meeting. Also, drafted a manuscript on peanut risk management tools for Ghana | 18 | 2 | 20 |
| **3/4/2022** | Ghana | Enumerator training on data collection- The objective was to train the enumerators on the data tool to be used for data collection. The purpose was for them to have hands-on experience and have a common understanding of the type of data to be collected and how to collect the data sets. | 25 | 15 | 40 |
| **4/5/2022** | Malawi | Malawi Projects Meeting- The Malawi Projects Meeting was held April 5-7, 2022, in Lilongwe, Malawi at Ufulu Gardens. The meeting was hosted by the Peanut Innovation Lab. The Management Entity along with External Advisory Panel members, project leads, collaborators, students, and partners all came together for three days to discuss projects, have student presentations, field/site visits, and discussions on future priorities. | 36 | 11 | 47 |
| **9/6/2022** | Senegal | Senegal Projects Meeting- The Senegal Projects Meeting was held September 6-8, 2022, in Saly, Senegal at the Lamantin Hotel. The meeting was hosted by the Peanut Innovation Lab. The Management Entity along with External Advisory Panel members, project leads, collaborators, students, and partners all came together for three days to discuss projects, have student presentations, field/site visits, and discussions on future priorities. | 32 | 16 | 67 |

| Date of Training | Country of Training | Brief Purpose of Training | Number Trained | | |
|---|---|---|---|---|---|
| | | | M | F | Total |
| **10/7/2021** | Senegal | Optimized Shrub System (OSS) Inaugural Field Day-The objective of the OSS Field Day was to showcase the Optimized Shrub System (OSS) through a site visit to the long-term research plots. The day included presentations on the results of OSS research that has shown a dramatic yield response, improved soil quality, nutrient and water availability, and reduced days to harvest. Importantly, OSS can support crops through in-season drought via hydraulic lift. Further, the impacts on peanut and cowpea varieties were discussed as well as a demonstration of a shrub shredder to assist with the labor of chopping shrub residue for incorporation into the soil. Participants represented the majority of stakeholder groups including farmers, farmer cooperatives, research and extension professionals, students, and NGOs. The day ended with an engaging discussion where there was shared excitement over the next steps for the OSS innovation. | 36 | 10 | 46 |
| **7/25/2022** | Senegal | ENSA One-Day Seminar on Project Research Results- One-day seminar provided key research results on groundnut production in the Senegal Groundnut Basin from a panel survey of 1,123 households. Participants were also introduced to the survey dataset and how to access the dataset. | 7 | 3 | 10 |
| **11/8/2021** | Senegal | Fieldwork Training- Train the research assistants on how to conduct the baseline survey. | 3 | 5 | 8 |
| **6/14/2022** | Uganda | Uganda Projects Meeting- The Uganda Projects Meeting was held June 14-17, 2022, in Kampala, Uganda at the Royal Suites Hotel. The meeting was hosted by the Peanut Innovation Lab. The Management Entity along with External Advisory Panel members, project leads, collaborators, students, and partners all came together for three days to discuss projects, have student presentations, field/site visits, and discussions on future priorities. | 33 | 12 | 45 |
| **11/22/2021** | Uganda | Groundnut Value Chain Development and Farmer Participatory Variety Selection (FPVS) Training- We conducted training on the entire Groundnut Value Chain Development, associated actors and ways to make it sustainable. Another topic covered was Farmer Participatory Variety Selection (FPVS). Here we discussed the modalities of the FPVS, the planning, the hosts farmers, the contributions of each actor and joint monitoring of trials, data collection and valuable feedback to research. | 13 | 13 | 26 |
| **11/23/2021** | Uganda | To train participants on groundnut value chain developments, associated actors and modes of operations. We also train the participants on Farmer Participatory Variety Selection (FPVS), how it's organized, what it takes to happen, hosting trials, data collection and feedback loop | 14 | 9 | 23 |
| **1/17/2022** | Uganda | Groundnut Value Chain Development and Farmer Participatory Variety Selection (FPVS) Training- Participants were taught on Quality Groundnut Seed Production. The aspects of keeping seeds pure and alive was stressed. Having a clean, pure, and uniform start up planting materials, planting on a fine seedbed, following recommended phyto-hygiene, rogueing, crop protection, timely harvesting, drying, sorting and storage | 10 | 6 | 16 |

| Date of Training | Country of Training | Brief Purpose of Training | Number Trained | | |
|---|---|---|---|---|---|
| | | | M | F | Total |
| **1/25/2022** | Uganda | Agronomy of Groundnut- The training centered on recommended good agronomic practices for a higher yield. Participants appreciated row planting, planting according to the recommended plant density, timely weeding, spraying, harvesting, drying and storage | 3 | 1 | 4 |
| **5/12/2022** | Uganda | Seeds systems and Local Seed Business Implementation- To train the local seed business farmers in best practices for quality and higher yields of groundnuts and groundnuts-based products. The LSBs were also trained in the pre-booking seeds model | 36 | 20 | 56 |
| **9/16/2022** | Uganda | Quality Seed Production- Training of Local Seeds Business Farmers and Extension agents in quality groundnut seeds production | 64 | 32 | 96 |
| **12/13/2021** | Uganda | Agribusiness aspects of Groundnut production and processing- Stephen Lwasa and Makerere University team of staff and Students, and Okello Kalule David conducted an Agribusiness training to improve value for money in Nwoya and Tororo for Photovoice participants. | 30 | 30 | 60 |
| **11/15/2021** | Uganda | Training of Research Assistants for Intervention phase data collection for the Peanut project- Training of Research Assistants for the intervention phase data collection. Sampling, identifying households and selection of respondents. Taking anthropometric measurements - weight and height. Food diary filling. | 9 | 6 | 15 |
| **11/17/2021** | Uganda | Training of Village Health Team members for Intervention phase data collection for the Peanut project- Training of the Village Health Team members on the intervention phase procedures. Procedures included to assist the Research Assistant to collect anthropometric measurement (weight and height) information from participating children. Assisting in compilation of the food diaries, sensory evaluation, health status and physical activity, peanut consumption. Distribution of peanuts among the participants in the intervention arm of the study. | 6 | 7 | 13 |
| **10/8/2021** | United States | Training and Feedback on Baseline Survey Implementation- This training covered the questions that would be asked in the field survey and discussed the objectives of the project with the field leaders, Codou Ndiaye and Maimouna Diop (our Senegalese students). | 0 | 4 | 4 |
| **7/1/2022** | United States | Statistical and Survey Methodologies at UCSB- Training on survey methodologies, conducting statistical methods in Research, and analysis of collected data. | 0 | 2 | 2 |
| **5/3/2022** | United States | Training for Phase 1 of Research - To train grad students Codou Ndiaye and Maimouna Diop for preparation to go to the field for Phase 1 data collection. | 0 | 2 | 2 |
| **8/30/2022** | United States | Training for Fieldwork- To train graduate students Codou Ndiaye and Maimouna Diop on Phase 2 data collection | 0 | 2 | 2 |

## Long-term Training (sorted by Home Country)

| USAID ID | Gender | Institution | Training Type | Degree for Students | End Date | Degree Granted | Home Country |
|---|---|---|---|---|---|---|---|
| **1** | F | Makerere Regional Center for Crop Improvement (MaRCCI), Makerere University | Master's | Plant Breeding & Genetics | May-21 | Y | Ghana |
| **6** | M | University for Development Studies (UDS) | Master's | Biotechnology | Sep-20 | N | Ghana |
| **8** | M | Texas Tech University | Ph.D. | Plant and Soil Science | Aug-24 | N | Ghana |
| **24** | M | CSIR-College of Science and Technology | Master's | MPhil, Plant Breeding and Biotechnology | Jul-23 | N | Ghana |
| **26** | F | Kwame Nkrumah University of Science and Technology (KNUST) | Master's | Agronomy | Nov-21 | Y | Ghana |
| **27** | M | University for Development Studies | Master's | Biotechnology | Nov-22 | N | Ghana |
| **28** | M | Kwame Nkumah University of Science and Technology (KNUST) | Ph.D. | Agronomy and Pest Management | Dec-22 | N | Ghana |
| **33** | M | University of Ghana | Master's | Plant Breeding | Jul-22 | Y | Ghana |
| **40** | F | Makerere Regional Center for Crop Improvement (MaRCCI), Makerere University | Master's | Plant Breeding & Genetics | Jan-23 | N | Ghana |
| **43** | M | Kwame Nkrumah University of Science and Technology (KNUST) | Master's | Plant Breeding | Nov-22 | N | Ghana |
| **48** | M | SARI-UDS | Ph.D. | Agronomy and Pest Management | Dec-22 | N | Ghana |
| **56** | M | University of Ghana | Ph.D. | Agricultural Extension | Dec-24 | N | Ghana |
| **57** | F | Kwame Nkrumah University of Science and Technology | Ph.D. | Horticulture and Seed Science and Technology | Nov-24 | N | Ghana |
| **60** | M | University for Development Studies | Master's | M.Phil. in Biotechnology | Apr-23 | N | Ghana |
| **61** | M | West Africa Centre for Crop Improvement, University of Ghana | Ph.D. | Plant Breeding | Dec-19 | Y | Ghana |
| **62** | M | University of Ghana | Ph.D. | Plant breeding | Dec-22 | N | Ghana |
| **65** | M | University for Development Studies | Master's | Crop Science | May-22 | Y | Ghana |
| **49** | M | ICRISAT | Master's | Genetics and Plant Breeding | Aug-20 | Y | India |
| **7** | F | Makerere Regional Center for Crop Improvement (MaRCCI), Makerere University | Master's | Plant Breeding & Genetics | Jan-23 | N | Kenya |
| **31** | F | Mekerere University | Ph.D. | Agronomy | Dec-22 | N | Kenya |
| **3** | M | LUANAR | Master's | Crop production | Jan-23 | N | Malawi |

| USAID ID | Gender | Institution | Training Type | Degree for Students | End Date | Degree Granted | Home Country |
|---|---|---|---|---|---|---|---|
| **25** | M | Lilongwe University of Agriculture and Natural Resources, Bunda College | Master's | Master of Science in Agronomy | Dec-22 | N | Malawi |
| **36** | F | LUANAR | Master's | Agronomy | Jan-23 | N | Malawi |
| **54** | M | Lilongwe University of Agriculture and Natural Resources | Master's | Impact of agronomic practices on groundnut seed quality | Mar-23 | N | Malawi |
| **71** | M | LUANAR | Master's | Food Science and Technology | Oct-22 | N | Malawi |
| **72** | M | LUANAR | Master's | Food Science and Technology | Apr-23 | N | Malawi |
| **10** | M | ICRISAT | Ph.D. | Agrophysiology | Feb-23 | N | Niger |
| **15** | F | ICRISAT | Ph.D. | Agronomy | Dec-22 | N | Niger |
| **5** | M | High School for Agricultural Engineering, Thiès University/ENSA | Master's | Agricultural Engineering | Sep-21 | Y | Senegal |
| **9** | M | National Superior School of Agriculture (ENSA), University of Thiès | Master's | Agricultural Engineering | Dec-20 | Y | Senegal |
| **16** | F | National Superior School of Agriculture (ENSA), University of Thiès | Master's | Agricultural Engineering | Mar-21 | Y | Senegal |
| **17** | M | National Superior School of Agriculture (ENSA), University of Thiès | Master's | Agricultural Economics | Sep-22 | Y | Senegal |
| **19** | M | National Superior School of Agriculture (ENSA), University of Thiès | Ph.D. | Agronomic Sciences | Dec-19 | N | Senegal |
| **20** | M | National Superior School of Agriculture (ENSA), University of Thiès | Master's | Agronomy with Rural Economics specialization | Dec-20 | Y | Senegal |
| **21** | M | National Superior School of Agriculture (ENSA), University of Thiès | Master's | Agronomy with Rural Economics specialization | Jan-21 | Y | Senegal |
| **22** | M | ISRA-CERAAS | Ph.D. | Molecular Genetics | Mar-23 | N | Senegal |
| **23** | F | ISRA/CERAAS | Ph.D. | Molecular Genetics | Mar-23 | N | Senegal |
| **32** | F | National Superior School of Agriculture (ENSA), University of Thiès | Ph.D. | Agronomy with Rural Economics specialization | Sep-22 | N | Senegal |
| **38** | F | Centre de Recherche pour le Dévelopement Economique et Sociale | Ph.D. | Agricultural Economics | Jun-23 | N | Senegal |
| **39** | F | National Superior School of Agriculture (ENSA), University of Thiès | Master's | Agricultural Engineering | Jul-20 | Y | Senegal |
| **42** | M | National Superior School of Agriculture (ENSA), University of Thiès | Master's | Agricultural Economics | Nov-21 | Y | Senegal |

| USAID ID | Gender | Institution | Training Type | Degree for Students | End Date | Degree Granted | Home Country |
|---|---|---|---|---|---|---|---|
| **45** | M | High School for Agricultural Engineering, Thiès University/ENSA | Master's | Agricultural Engineering | Oct-21 | Y | Senegal |
| **47** | F | National Superior School of Agriculture (ENSA), University of Thiès | Master's | Agricultural Economics | Aug-22 | Y | Senegal |
| **51** | F | Centre de Recherche pour le Dévelopement Economique et Sociale | Ph.D. | Agricultural Economics | Jun-24 | N | Senegal |
| **52** | M | National Superior School of Agriculture (ENSA), University of Thiès | Master's | Agricultural Engineering | Mar-21 | Y | Senegal |
| **63** | F | University of Dakar | Master's | Breeding/physiology | Dec-22 | N | Senegal |
| **64** | M | University of Georgia | Ph.D. | PhD in Agricultural and Applied Economics | May-24 | N | Senegal |
| **66** | F | ENSA | Master's | Agricultural Engineering | Dec-22 | N | Senegal |
| **67** | F | National Superior School of Agriculture (ENSA), University of Thiès | Master's | Agricultural Engineering - Value Chain | Dec-22 | N | Senegal |
| **69** | M | National Superior School of Agriculture (ENSA), University of Thiès | Master's | Agricultural Economics | Nov-22 | N | Senegal |
| **70** | F | National Superior School of Agriculture (ENSA), University of Thiès | Master's | Agricultural Economics | Nov-22 | N | Senegal |
| **73** | F | National Superior School of Agriculture (ENSA), University of Thiès | Master's | Agricultural Engineer with specialty in economics | Nov-22 | N | Senegal |
| **34** | F | Makerere University | Master's | Plant Breeding and Seed Systems | Jan-23 | N | Tanzania |
| **12** | F | Makerere Regional Center for Crop Improvement (MaRCCI), Makerere University | Ph.D. | Plant Breeding & Genetics | Mar-23 | N | Uganda |
| **13** | M | Makerere Regional Center for Crop Improvement (MaRCCI), Makerere University | Master's | Crop Science (Crop Protection) | Jan-23 | N | Uganda |
| **35** | M | Makerere Regional Center for Crop Improvement (MaRCCI), Makerere University | Master's | Crop Science | Sep-21 | Y | Uganda |
| **41** | F | Makerere University | Master's | Food Science and Technology | Sep-22 | Y | Uganda |
| **46** | F | Makerere University | Master's | Agricultural and Applied Economics | Dec-22 | N | Uganda |
| **50** | F | Makerere University, School of Women and Gender Studies | Post-doctoral Studies | Post-Doctoral on Gender Studies and Development including Agriculture | Dec-20 | N | Uganda |

| USAID ID | Gender | Institution | Training Type | Degree for Students | End Date | Degree Granted | Home Country |
|---|---|---|---|---|---|---|---|
| **2** | F | The University of Georgia | Post-doctoral Studies | Nutrition and Health | May-22 | Y | United States |
| **4** | F | The University of Georgia | Post-doctoral Studies | Gender and Youth | Sep-21 | Y | United States |
| **11** | M | University of Georgia | Ph.D. | Agricultural and Applied Economics | May-23 | N | United States |
| **14** | F | University of California at Santa Barbara | Ph.D. | Geography | Jun-23 | N | United States |
| **18** | F | University of Tennessee | Master's | Agricultural Leadership, Education and Communications | Dec-20 | Y | United States |
| **29** | F | University of Minnesota | Post-doctoral Studies | Demography | Dec-21 | Y | United States |
| **30** | F | University of California, Santa Barbara | Post-doctoral Studies | Demography | Dec-22 | N | United States |
| **37** | F | Pennsylvania State University | Ph.D. | Rural Sociology | May-23 | N | United States |
| **44** | M | University of Georgia | Ph.D. | Agricultural and Applied Economics | Dec-20 | Y | United States |
| **47** | F | Virginia Tech | Master's | Agricultural and Applied Economics | Jul-23 | N | United States |
| **53** | M | University of California, Santa Barbara | Bachelor's | Anthropology | Jun-22 | Y | United States |
| **55** | F | University of California, Santa Barbara | Bachelor's | Statistics and Geography | Jun-23 | N | United States |
| **59** | F | University of Tennessee | Master's | Department of Agricultural Leadership, Education and Communications | May-23 | N | United States |
| **58** | M | African Center for Crop Improvement | Ph.D. | Plant Breeding | Oct-23 | N | Zambia |

# Innovation Transfer and Scaling Partnerships

## Steps Taken

We continue to encourage partnerships between the public and private sector to effectively move innovations forward. These have focused on decreasing the time required to release new varieties and the development of optimized equipment for shelling and sizing peanuts in the target countries.

## Partnerships Made

A partnership with Frank's Designs for Peanuts in the USA has produced several models of hand-cranked and motorized groundnut shellers, aspirators and grading tables.

## Technologies Ready to Scale

Hand-cranked and motorized groundnut shellers, aspirators and grading tables were based on the design of industrial equipment used by the US peanut industry, but provide capacities similar to those found in breeding programs and village-based shellers. In addition, the equipment is flexible to handle the various sizes of groundnut found in many countries.

## Technologies Transferred

Both hand-cranked and motorized units have been shipped to the national program breeders in Ghana, Malawi, Mozambique, Senegal and Uganda. These will be first tested with local varieties and then used by the breeding programs to process seed from field trials and seed production nurseries.

## Technologies Scaled

The units are ready to be scaled and some units have been provided to private companies in Malawi, and NGOs in Ghana.

# Environmental Management and Mitigation Plan (EMMP)

All approvals are in place and scientists and staff are trained in the proper handling of all herbicides and pesticides.

# Open Data Management Plan

No data is ready for submission during this period.

# Governance and Management Entity Activity

## Research sharing

### Meetings

With the lifting of many Covid-19 travel restrictions, the management entity held research meetings in each of the four main focus countries, allowing participants to share research findings from projects nearing their completion, visit research sites and set research priorities for the future. From March to September, the Peanut Innovation Lab conducted four country-focused meetings in Ghana, Malawi, Senegal and Uganda.

### Presentations

In addition to presenting at those meetings, ME representatives shared information about the Innovation Lab and their particular areas of expertise in numerous seminars, workshops and meetings, including:

Director Dave Hoisington:

- US Peanut Quality Workshop, 29-30 Nov 2021, Tifton, GA - "A Global Perspective of the Impact of Aflatoxin"
- APC Webinar, 3 Nov 2021 - "Working to feed a hungry world: How the Feed the Future Innovation Lab for Peanut works to alleviate hunger and poverty through peanuts"
- USAID Research Community of Practice Webinar, 9 Mar 2022 - "Driving innovation to impact: How the Feed the Future Innovation Lab for Peanut works to alleviate hunger and poverty through peanut research"
- USAID Innovation Lab Council Business Meeting, 20 Sep 2022, Washington, DC - "Innovation Lab - CGIAR - NARS Collaboration"

Gender and Youth Specialist Jessica Marter-Kenyon:

- Athens, Georgia (virtual): "Exploring Social Dynamics to Better Understand a "Women's Crop": Gender+ and Groundnut in Africa", Cultivating Equality Conference, 10/13/2021

- Athens, Georgia (virtual): "Reflections on Gender Integration Strategy: Elevating Gender+ to a Stand-Alone Research Area" Participatory Workshop on Integrating Gender throughout the Project Life Cycle of Innovation Labs, 3/2/2022
- Athens, Georgia (virtual): "Gender and the Transition from Tobacco to Groundnut in Malawi", Gender IL CoP April Meeting, 4/14/2022
- Athens, Georgia (virtual): "Career Panel for International / "Majority World" Students: Navigating the Post-Graduate School Job Search", AFVHS Conference, 5/18/2022
- Washington, DC (virtual): "Gender & Youth as a Stand-Alone Research Area", IL Director's Meeting, 9/21/2022
- Tororo, Uganda: "Photovoice, Youth Empowerment and the Peanut Innovation Lab", Tororo Photovoice Community Sharing Festival, 10/26/2022
- Nwoya, Uganda: "Photovoice, Youth Empowerment and the Peanut Innovation Lab", Nwoya Photovoice Community Sharing Festival, 10/28/2022

### American Peanut Research and Education Society

The Management Entity has made a particular effort to give graduate students support and opportunity to present their research in professional settings.

In FY 2022, 10 African students presented virtually at the premier US-based conference for peanut research. One of those students -- Esther Achola of Makerere University – won the main prize for graduate student presentations, the first time an international student or a virtual presenter has won the award.

## Learning and communications

### Scholarly exchange

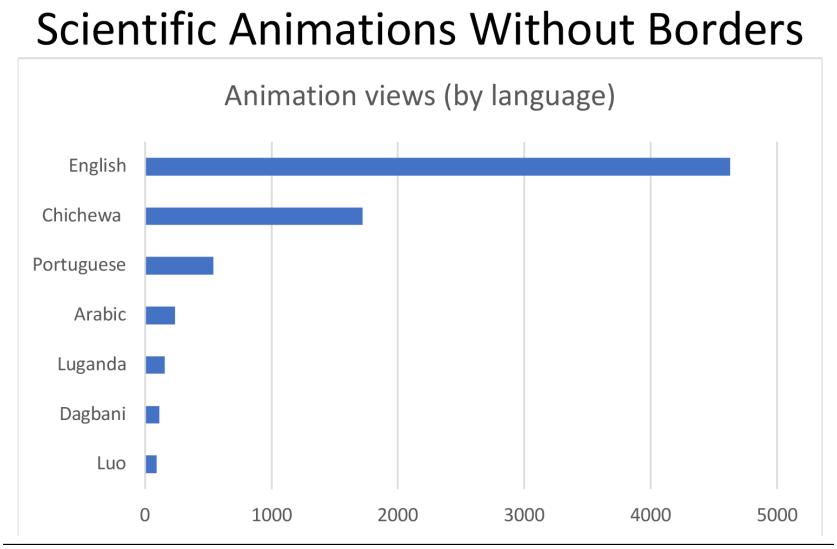
Started in 2020, the Peanut Lab Graduate Scholarly Exchange Seminar is an online gathering of graduate students from across the world that meets regularly to strengthen the connection among our students, promote interdisciplinary and international thinking in agricultural development research, and support their professional development. Expert speakers working in peanut and agricultural research, education and business are invited to present on professional and technical topics to African and US graduate students supported by the Lab; presentations are followed by Q&A and discussion.

Seven Scholarly Exchange Seminars were held this year. In one seminar, a graduate student working in Ghana solicited feedback from the group for a conference panel she was organizing, which improved the panel's relevance to international students and led to the Peanut Lab's support for Africa-based students to attend the conference virtually. Other seminars broadened students' understanding of social science approaches to variety development; food systems thinking; the challenges of peanut butter production in Uganda; and careers in national research organizations, academia, and the private sector.

Students feel more connected with the Innovation Lab and have learned from each other and guest speakers. At least one student started a similar mentoring and sharing seminar at his home university.

## Scientific Animations Without Borders

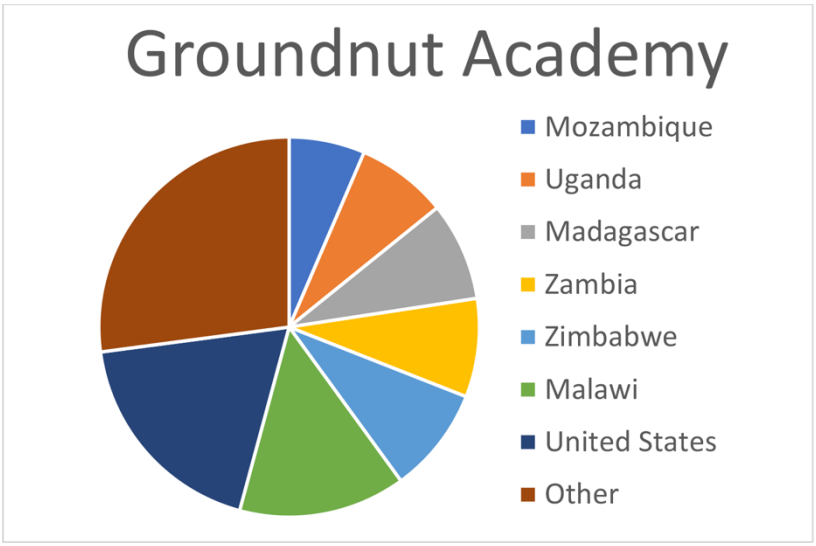
In 2021, the management entity, working with AgDiv in Malawi, created the first in a series of animations covering basic agronomy of groundnut. In 2022, the Innovation Lab added to this series and translated the English-language animations into six additional languages – Arabic, Chichewa, Dagbani, Luganda, Luo and Portuguese. A Swahili translation was in process.




The animations proved popular with farmers, particularly those versions in local languages, and are used in training programs to reinforce best practices. Of the 27 distinct version of the three videos (some recorded in male and female voices for training) some have been viewed a few dozen times.

## Groundnut Academy

A platform of online digital courses created and promoted by the management entity grew in FY2022 to reach students in 34 countries around the world.




Groundnut Academy (https://groundnut-academy.uga.edu) launched in FY2021 with a course on Groundnut Agronomy. A second course on Aflatoxin launched in FY2022, and both courses were translated into Portuguese to facilitate learning, particularly in Mozambique.

Allows students around the world to register and take courses at their own pace, return to review previous lessons, pass quizzes to check their retention and receive a certificate upon completing the course.

While individuals in more than two dozen countries have taken Groundnut Academy courses on their own, groups such as Farmer 2 Farmer have found the courses useful in group training (see Success Story).

### Farmer to Farmer

A partnership between the Feed the Future Innovation Lab for Peanut and Southern African Farmer-to-Farmer (F2F) program brought innovation and capacity-building to scale, training 3,636 farmers in groundnut production and aflatoxin control, including 2,245 women and 363 youth. Through the collaboration – which was built on the strengths of both parties – thousands of smallholder farmers received training in Malawi (669 farmers), Mozambique (381 farmers), Zambia (1,254 farmers) and Zimbabwe (1,322 farmers).

### Webinars

A series of webinars highlighting research findings drew viewers from around the globe. The sessions each attracted dozens of researchers, policy-makers, students and others to listen and ask questions live, and were recorded for on-demand watching later.

Stronger together: How a network of African national programs is creating continent-wide resiliency in groundnut, Nov. 2, 2021

Finding enough hours in the day: Can agricultural innovation help alleviate women's time poverty?, Nov. 11, 2021

Managing risk: How a web-based tool can help smallholder farmers know when to invest, Nov. 16, 2021

Speed matters: How digital imaging can create a more resilient crop in a changing climate, March 2, 2022

Nature Knows: How Indigenous Shrubs' survival techniques can help rain-fed crops thrive in the Sahel, April 14, 2022

## Program management

The Piestar DPx project management software was used to request and receive progress reports for this report. The ME has worked with Piestar to develop the modules for the project PIs and other scientists to report progress, request approvals to travel, purchase supplies, train students and register for events. Modules also have been implemented to collect information on project progress, degree training, short-term training events, data management, EMMP activities and technology pipelines, as well as for PIs to submit annual work plans and budgets.

## Publications

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Commey, L., et al. Peanut seed coat acts as a physical and biochemical barrier against Aspergillus flavus infection. Journal of fungi.

Denwar, N., Simpson, C. E., Starr, J. L., Wheeler, T. A., & Burow, M. (April 2021). Evaluation and selection of interspecific lines of groundnut (Arachis hypogaea L). for resistance to leaf spot disease and for yield improvement(pp.873). Plants, 10, Basel, Switzerland. doi:doi:10.3390/plants10050873

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Jordan, D.L., et al. 2022. Examples of Risk Tools for Pests in Peanut (Arachis hypogaea) Developed for Five Countries Using Microsoft Excel. Journal of Integrated Pest Management, 13(1), p.20.

Magnan, N., et al. (June 2021). Information, technology, and market rewards: Incentivizing aflatoxin control in Ghana(pp.102620). Journal of Development Economics, 151, Amsterdam, Netherlands. doi:https://doi.org/10.1016/j.jdeveco.2020.102620

Mkandawire, L., Mhango, W., Jordan, D. L., & Brandenburg, R. (September 2021). Influence of Plant Population and Harvest Date on Peanut (Arachis hypogaea) Yield and Aflatoxin Contamination(pp.33-39). Peanut Science, 48, Tifton, GA. doi:https://doi.org/10.3146/PS20-30.1

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Wangia, R. N. & Wang, J. (November 2020). Determinants of aflatoxin exposures in Kenya school-aged children(pp.1183-1191). International Journal of Environmental Health Research, 32(6), Taylor & Francis, Philadelphia, USA.. 1944-0049

Wangia, R. N., et al. (November 2019). Aflatoxin in household maize for human consumption in Kenya, East Africa(pp.1-8). Food Additives & Contaminants: Part B, Online, Taylor& Francis. doi:1939-3229

Wangia, R. N., et al. (October 2020). Nutrition and growth outcomes are affected by aflatoxin exposure in Kenya children(pp.2123-2134). Food Additives & Contaminants: Part A, 37(No. 12), Taylor & Francis. doi:https://doi.org/10.1080/19440049.2020.1825825

Zhou, J., et al. (October 2021). Aflatoxin B1 induces gut-inflammation-associated fecal lipidome changes in F344 rats(pp.363-377). Toxicological Sciences, 183(2), Oxford University Press, UK. Society of Toxicology.

## Other Topics

None to report.

## Issues

None to report.

# Appendix A. List of Awards to U.S. Partners

| Institution | | Project Name | Start Date (mm/dd/yy) | End Date (mm/dd/yy) | FY 2022 Budget | Total Budget |
|---|---|---|---|---|---|---|
| **California** | | | | | **$145,617** | **$561,337** |
| **Stanford University** | VAG | Examining the Utility of Satellite-based Assessment in a Maize/Peanut Agroecosystem for Estimated Crop Response in Malawi *(sub-award from NCSU)* | 10/1/2018 | 9/30/2022 | $6,000 | $71,000 |
| **University of California, Santa Barbara (UCSB)** | GEN | Gender, Fertility, and Intra-household Dynamics and resilience in the Senegalese Peanut Farmers in Ghana | 7/1/2019 | 11/30/2022 | $139,617 | $490,337 |
| **District of Columbia** | | | | | **$20,350** | **$108,176** |
| **International Food Policy Research Institute (IFPRI)** | GEN | Connecting Male and Female Smallholder Farmers to Premium Groundnut Markets and Aflatoxin-mitigating Technologies through Innovation Aggregator Contracts *(sub-award from UGA)* | 8/1/2018 | 9/30/2022 | $20,350 | $108,176 |
| **Florida** | | | | | **$0** | **$4,000** |
| **University of Florida (UFL)** | VAG | Development and Delivery of Improved Production and Pest Management Packages to Peanut Farmers in Ghana *(sub-award from NCSU)* | 10/1/2018 | 9/30/2022 | $0 | $4,000 |
| **Georgia** | | | | | **$142,141** | **$1,382,502** |
| **University of Georgia (UGA)** | VAR | Leveraging Genetics Resources to Enhance Peanut/Groundnut Breeding in Africa and the United States | 10/1/2018 | 1/10/2023 | $0 | $21,700 |
| | VAR | Use if Novel Genetic Diversity for Peanut Varietal Development in East Africa | 9/1/2018 | 1/10/2023 | $0 | $110,000 |
| | VAR | Incorporating New Wild Alleles to Improve Elite African Peanut Cultivars | 10/1/2018 | 1/10/2023 | $0 | $110,000 |
| | VAR | Mapping Groundnut Rosette Virus (GRV) Resistance to Marker-assisted Selection | 10/1/2018 | 1/10/2023 | $0 | $93,080 |
| | GEN | Connecting Male and Female Smallholder Farmers to Premium Groundnut Markets and Aflatoxin-Mitigating Technologies through innovation Aggregator Contracts | 8/1/2018 | 1/10/2023 | $28,842 | $244,173 |
| | VAG | Identifying the Alternative Host for Groundnut Rosette Disease Virus Complex | 8/1/2018 | 1/10/2023 | $0 | $47,800 |
| | NUT | Regulation of Gut Microbiome by Peanut Supplement in Youth with both Genders | 4/1/2019 | 1/10/2023 | $92,864 | $446.783 |
| | VAR | Enhancing the Genetics Potential of Peanut Production in Eastern/Southern Africa *(sub-award from NASARRI)* | 2/1/2019 | 7/31/2022 | $0 | $15,400 |
| | VAR | Enhancing the Genetics Potential of Peanut Production in West Africa *(sub-award from ISRA)* | 2/1/2019 | 7/31/2022 | $0 | $15,400 |

| Institution | Project Name | Start Date (mm/dd/yy) | End Date (mm/dd/yy) | FY 2022 Budget | Total Budget |
|---|---|---|---|---|---|
| | COM Genotypic Analysis of Peanut using Axiom_Arachis2 SNP Array | 5/1/2018 | 4/30/2019 | $0 | $123,775 |
| | GEN Retaining Next Generation Farmers in the Senegalese Groundnut Basin *(sub-award from Virginia Tech)* | 3/1/2019 | 11/30/2022 | $49,277 | $154,391 |
| **USDA-ARS National Peanut Research Laboratory (NPRL)** | COM Technical Evaluation of PICs Bags for use with Shelled Peanuts | 5/1/2018 | 4/30/2019 | $0 | $0 |
| **Mississippi** | | | | **$86,711** | **$86,711** |
| **Alcorn State University** | VAG Modern Peanut Technology Adoption and smallholder Farmers Welfare | 9/01/2021 | 11/30/2022 | $86,711 | $86,711 |
| **Missouri** | | | | **$213,512** | **$531,193** |
| **Washington University (WU)** | NUT Integrating the Power of Peanuts into School Feeding | 1/1/2019 | 12/31/2022 | $213,512 | $531,193 |
| **North Carolina** | | | | **$149,458** | **$37** |
| **USDA-ARS** | VAG Nutritional Phenotyping of Peanut Seed | 8/01/2022 | 1/10/2023 | $94,200 | $94,200 |
| **North Carolina State University (NCSU)** | VAG Examining the Utility of Satellite-based Assessment in a Maize/Peanut Agroecosystem for Estimated Crop response in Malawi | 10/1/2018 | 9/30/2022 | $0 | $86,604 |
| | VAG Development of Efficient Agronomic Peanut Production Packages for Malawian Farmers | 10/1/2019 | 11/30/2022 | $32,256 | $113,811 |
| | VAG Development and Delivery of Improved Production and Pest Management Packages to Peanut Farmers in Ghana | 10/1/2018 | 11/30/2022 | $23,002 | $92,976 |
| | COM Modification of NCSU Risk Index Tool for North Carolina and Developing a Risk Tool for Peanut Innovation Lab Target Countries | 5/01/2018 | 4/30/2019 | $0 | $79.190 |
| **Ohio** | | | | **$17,548** | **$203,979** |
| **Ohio State University (OSU)** | VAG Optimized Shrub System (OSS): an Innovation for Landscape Regeneration and Improved Resilience for the Peanut-Basin on Senegal | 9/1/2018 | 12/31/2022 | $17,548 | $203,979 |
| **Pennsylvania** | | | | **$77,027** | **$371,329** |
| **Pennsylvania State University (Penn State)** | GEN Time Poverty among Women Smallholder in Ghana: implications for Gender Priorities in the Peanut Value Chain | 3/1/2019 | 10/31/2022 | $77,027 | $371,329 |
| **Tennessee** | | | | **$15,481** | **$184,228** |
| **University of Tennessee (UT)** | GEN Photovoice for Youth Empowerment in Peanut Value Chain | 3/1/2019 | 12/31/2022 | $15,481 | $184,228 |
| **Texas** | | | | **$84,787** | **$384,704** |
| **Texas Agriculture and Mechanical College (Texas A&M)** | VAR Breeding and Enhancement of Tolerance to Water Deficit, Resistance to Leafleaf Spot and Improved Oil Composition on Peanut | 10/1/2018 | 11/30/2022 | $10,667 | $86,431 |

| Institution | Project Name | Start Date (mm/dd/yy) | End Date (mm/dd/yy) | FY 2022 Budget | Total Budget |
|---|---|---|---|---|---|
| **Texas Tech University (TTU)** | VAR Developing Aspergillus flavus Resistance Peanut using Seed Coat biochemical marker(s) | 10/1/2018 | 11/30/2022 | $74,120 | $299,273 |
| **Virginia** | | | | **$37,284** | **$317,499** |
| **Virginia Tech (VT)** | VAR Integration of High Throughput Phenotyping (HTP) for Enhancing Breeding Programs in Senegal, Ghana, Uganda, and Regional Cooperation | 9/1/2018 | 11/30/2022 | $6,300 | $129,080 |
| | VAG Development and Delivery of improved Production and Pest Management Packages to Peanut Farmers in Ghana *(sub-award from NCSU)* | 10/1/2018 | 9/30/2022 | $0 | $15,120 |
| | GEN Retaining Next Generation Farmers in the Senegalese Groundnut Basin | 3/1/2019 | 11/30/2022 | $30,984 | $173,499 |

# Appendix B. Success Stories

## Collaboration gets practical advice to more than 3,600 farmers

A partnership between the Feed the Future Innovation Lab for Peanut and Southern African Farmer-to-Farmer (F2F) program brought innovation and capacity-building to scale, training 3,636 farmers in groundnut production and aflatoxin control, including 2,245 women and 363 youth. Through the collaboration – which was built on the strengths of both parties – thousands of smallholder farmers received training in Malawi (669 farmers), Mozambique (381 farmers), Zambia (1,254 farmers) and Zimbabwe (1,322 farmers).

The Peanut Innovation Lab has worked in Southern Africa for years, finding practical solutions to production problems that limit groundnut farmers – whether the solution is a physical technology, such as a new variety, or a knowledge-based technology, such as production practices to adapt to disease and drought. The lab promotes these technologies in various ways, but also has an increasing number of digital training tools. In early 2021, the lab launched the Groundnut Academy, a platform of online courses that is free and accessible.

The F2F program has field offices in each of the four countries, where it has a large network of development partners, including USAID Mission-funded projects and the experience to organize trainings. As pandemic-era adaptation, the program started in 2021 to recruit in-country, local volunteers and connect them with U.S. experts to work together virtually.

The Peanut Innovation Lab's expertise and Farmer-to-Farmer's volunteer network allowed the two programs to work together for real impact. Here's how it works: F2F recruits local volunteers, who take Groundnut Academy courses online, and then train farmers, in part using Innovation Lab digital and print products.

The Innovation Lab then makes experts (often Deputy Director Jamie Rhoads) available to conduct Q&A sessions with volunteers, who ask for clarity on what they learned in Groundnut Academy courses and bring forward farmer questions and experiences. While these Q&A sessions provide clarity to the trainers, they also give the Innovation Lab anecdotal information about problems in the field or confusion over best management practices. This feedback helps the Peanut Innovation Lab to shape future research and outreach.

Early in the season in October and November 2021, F2F conducted 18 farmer trainings in the four countries – Malawi, Mozambique, Zambia, and Zimbabwe – covering all aspects of groundnut production, from planting to crop management to harvest. A second round of trainings were held in May and June 2022, just before groundnut harvest, so that farmers could learn about ways to reduce aflatoxin during the upcoming harvest and storage. Those 39 sessions were held in the same four countries.

Farmers showed up at the trainings with great enthusiasm, in numbers beyond expectations, and were quick to adopt new practices.

"What was so far adopted was early ploughing and purchase of seed dressing. The farmers learnt about seed dressing during the trainings; 150 of the farmers from the two wards purchased seed dressing and are going to seed dress their seed for the first (time) in life," said Rudo Mushangwe,

F2F partner in Zimbabwe and field officer for USAID's Fostering Agribusiness for Resilient Markets (FARM) project.

While increasing production was important to farmers, they also appreciated learning about aflatoxin.

"One thing I did not know that I learned was causes of aflatoxin and the long-term effect on human health if consumed," said Leya Lungu, 34, a farmer and training participant from Nyachilala Cooperative in Zambia's Petauke district. "As a family, we always selected the bad groundnuts for consumption and sold the good ones. It is interesting that as producers, we chose to poison ourselves and sell the good quality groundnuts to people who do not even produce them."

In all, 30 local volunteers took the Groundnut Academy's Production and/or Aflatoxin courses (some volunteers taught in multiple trainings) and received a certificate as acknowledgement.

With the support of the Peanut Innovation Lab and Farmer2Farmer, the volunteers felt prepared to conduct training.

"I enjoyed the whole process, the training, the Q&A with Jamie and the interaction with volunteers from Zambia and Malawi. It showed that the challenges we face with the farmers were similar so sharing experiences was good," said Inonge Simalumba, 33, a local volunteer and a Camp Extension Officer at Zambia's Ministry of Agriculture. "With the information we got from the Peanut Innovation Lab, it was very easy to train, and we were confident that whatever issues the farmers would bring up, we would get a response. My biggest take away was that I could access all the materials I needed for future trainings from the Groundnut Academy website."

Collaboration between the Southern Africa F2F and the Peanut Innovation Lab will continue during the 2022-2023 rainy season, increasing scale and impact of both programs.

## School meals increase school attendance … especially among girls

A few years ago, Bibi struggled to get her kids to go to school. Even when the mother of four could get them to class, they would leave early. They were hungry.

"Before the inception of the school feeding project, I used to be the one putting pressure on the children before they go to school. Sometimes they leave the house under the guise of going to school but rather, they will be loitering in the community. Even when they accept to go to school, they return back home before the school officially closes for the day," she said.

In 2021, a research project started in their village in Northern Ghana, a study to evaluate the effectiveness of a peanut-based school meal. With more structure to the school day and a guaranteed meal on the way, the kids' attitude changed.

"Now, because of the feeding project, no one tells the children to go to school in the morning. When they wake up in the morning, they will be shouting "mama hurry up, I want to go to school. It will soon be time for us to take our meals."

Bibi isn't alone. In schools participating in the project, attendance increased 70 percent over the previous year, and the change was even more pronounced for girls.

The improvement in attendance was a tangential benefit of the research project, which provided a daily meal to around 800 kids for a full school year to see how the nutritional content of the meal affects their learning. Some kids received a peanut-based meal, some received a soy-blend and some received traditional porridge (though the project did add micro- nutrients even to this control-group food).

The work was funded through a unique collaboration between USAID, a private company and a national commodity board which came together to provide research dollars for Project Peanut Butter to develop, produce and test the peanut meals. (The Peanut Innovation Lab contributed

$500,000, Birdsong Peanuts spent $100,000 and another $100,000 came from the National (U.S.) Peanut Board, a research, marketing and promotion organization supported by the 7,000 American peanut farmers.)

To create and test the peanut-based product, Project Peanut Butter worked closely with Ghanaian partners – the Department of Human Nutrition and University of Ghana.

In September 2021, the project started in six primary schools in the Mion District. At the time, the schools were not providing any sort of meal to the students.

While early results show that kids who received a daily peanut-based meal processed information more quickly and accurately than kids who ate a traditional porridge, headmasters, teachers and community members anecdotally said the meal gave structure to the day, making overall learning more productive.

During the months of the school feeding program, attendance soared by 70 percent, but the impact was greater among girls. While school rolls swelled with both boys and girls, enrollment among girls grew faster and girls attended more days.

For example, the average boy attended school 5.6 additional days during the year of the project, while the average girl was in class 9.3 more days than the year before.

Overall, attendance improved from 76% to 85%.

Bibi saw this with her own children, who were more likely to stay and learn all day.

“They stay at school until it is time for them to close for the day before they return home. This makes me happy as a parent,” she said.

# Remote sensors make plant breeding quicker, more accurate than the naked eye

By building a strong network of national programs across Africa and using cutting edge genomics technology, Peanut Innovation Lab researchers have uncovered a treasure of genetic diversity to empower plant breeders to solve real world problems.

But accurate phenotyping is a bottleneck for getting these genetic discoveries into new varieties. A project across three countries in Africa showed how high throughput phenotyping can open that bottleneck and give plant breeders more accurate and speedy ways to evaluate crosses in the field.

In Uganda, Ghana and Senegal, Virginia Tech plant physiologist Maria Balota supervised a team of researchers who used handheld devices and drones to evaluate plants' resiliency traits. By using remote sensors to gauge color and other attributes, the researchers could evaluate the health of stressed plants quicker and more accurately then with the naked eye.

The work helped to define which qualities correlate with which traits and at what stage of plant development those indices are most accurate. For example, does changing leaf color indicate foliar disease and when in the growing season is the result the most pronounced?

Working with NaSARRI in Uganda, student researcher Ivan Chapu analyzed plants in the field and greenhouse over two locations and two years to evaluate the difference between traditional phenotyping methods and high-throughput methods using handheld sensors.

He found that he could predict disease resistance more quickly and accurately using red-green-blue (RGB) imagery and red/near infra-red reflectance than he could using traditional visual scoring.

While evaluating 200 genotypes he identified several image- and reflectance-based methods that can be used to screen more accurately for two devastating diseases.

The research has immediate, real-world application as plant breeders in Uganda now have recently discovered genetic diversity to respond to groundnut rosette disease (GRD) and late leaf spot (LLS), plant diseases that can cause 100% yield loss in groundnut in Sub-Saharan Africa. Advancements in molecular breeding techniques have provided opportunities to understand the genetic components that control GRD resistance variation.

Accurately phenotyping large breeding populations for GRD & LLS resistance has remained a challenge, but the indices created by this research will improve that.

A genome wide association study found markers associated with the color and resistance differences in peanut plants – differences that were captured by the equipment and visual scores described by the research. The markers, located on two different chromosomes, were associated with disease resistance genes and other photosynthesis-related genes. These tools and associated genes present an opportunity to improve GRD resistance of future groundnut varieties.

In Ghana, student researcher Emmanuel Sie developed approaches using photogrammetry to evaluate drought- and disease-resistance traits. Planting two sets of 60 genotypes in water limited conditions, Sie found a strong correlation between early plant vigor, therefore better early plant growth under water stress, and photogrammetry indices.

In addition, the project Co-PI and groundnut breeder, Richard Oteng-Frimpong conducted a preliminary study with a drone carrying an RGB camera to develop vegetation indices that provided accurate estimates for crop damage by two common foliar diseases.

In Senegal, two agro-engineering students, Assane Diop and Moustapha Sakho worked in Bambey and Nioro to compare two HTFP methods to assess the health and vigor of a groundnut crop, one using a multispectral camera on a drone flown at 10 m above the crop and the second using handheld sensors close to the plants. The results showed a significant association between the two methods, and both were able to estimate the yield and biomass of the groundnut varieties.

The sensors used in this research are now used for breeding selection in peanut breeding programs in each of the countries – Ghana, Senegal, and Uganda.

The researchers presented their work at the American Peanut Research and Education Society, and published in high-impact factor journals including the Frontiers in Plant Science and Agronomy MDPI.

## Annual tour sparks innovation around the world

For years, the Feed the Future Innovation Lab has invited collaborators from around the world to visit Georgia during the annual Georgia Peanut Tour for a chance to see how the largest peanut-producing state in the U.S. gets a safe and bountiful crop from the field to the storage to market.

The tour is organized by the Georgia Peanut Commission, University of Georgia College of Agricultural and Environmental Sciences and the USDA-ARS National Peanut Laboratory and attracts around 200 people for three-days of tours and activities at peanut-related sites in different parts of the state's peanut-growing region. The 2022, 34th Annual Georgia Peanut Tour included stops at research farms to learn about trials into new varieties, water-use efficiency, disease control and precision ag; production farms to see large-scale harvest and transportation of the crop; specialty farms to explore organic production and seed replication; government inspection sites to learn how seeds are inspected and graded; warehouses to learn about storage; and equipment manufacturers to consider the many related fields connected to peanut production in the state. "This is one of the most successful capacity-building activities we do as a management entity. The Georgia Peanut Tour allows us chance to show partners the peanut supply chain on large scale – from harvesting to drying to testing – and discuss how these concepts might be applied in the partners' home countries.

"This scale of Georgia production obviously doesn't fit in the context of a rural part of Malawi, for example, but colleagues from across the world say that taking the time to see how it's done here and ask questions has help them to build appropriately-scaled systems where they live."

A delegation from Malawi first came to the peanut tour about 10 years ago, and different people from the private sector, government agencies and USAID activities continue to visit year after year.

"I participated in the tour in 2019 and enjoyed all the sites," said Tadala Rambiki, the Groundnuts Production Manager at Pyxus International, an agriculture company in Malawi. He particularly enjoyed seeing Birdsong Peanut and Sasser 520 buying points, as well as JLA, an international lab testing company that evaluates peanuts for aflatoxin and Salmonella, among other safety factors.

"The visit was indeed helpful in envisaging how we can scale up production and processing.

For instance, from the tour we embarked on a research project to determine risky components for aflatoxin in groundnuts in partnership with the Peanut Innovation Lab and LUANAR (Lilongwe University of Agriculture and Natural Resources).

"This was after the brief and discussion from the JLA peanut lab. Having understood the various test procedures and methodologies, we also sought to develop and validate a testing procedure for peanuts at Pyxus."

With the knowledge Rambiki and others took away from the 2019 tour, Pyxus began to explore ways to reward farmers for safe high-quality nuts, a challenge that would require a new structure at the buying point.

"With lessons learnt we are also continuing to develop a tailor-made grade-based pricing system that works in Malawi considering the difference in the buying models which also results in differences of the buying point set up especially in working with smallholder farmers," he said.

"We are also lobbying with government to recognize the grade based pricing system as opposed to a fixed pricing model that is currently in place."

To make the trip as valuable as possible for the overseas visitors, the Peanut Innovation Lab coordinates additional visits for the partners, including research partners, testing labs and equipment manufacturers that might become helpful connections in future endeavors.

In recent years, the management entity has coordinated visits for delegations from Malawi, Bangladesh, Sudan, Uganda and elsewhere.

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