FEED THE FUTURE

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

Peanut Innovation Lab

Annual Report
Fiscal Year 2021

Feed the Future
Innovation Lab for Peanut

(Peanut Innovation Lab)

Annual Report – Fiscal Year 2021

(1 October 2020 – 30 September 2021)

Peanut Innovation Lab Management Entity
University of Georgia, Athens, Georgia
December 2021

Table of Contents

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), Allen Stripling (business manager), Allison Floyd (communications coordinator), Kristen McHugh (operations specialist) and Jessica Marter-Kenyon (Gender and Youth specialist).

Daniel Fonceka in Senegal speaks with Dave Hoisington, the Peanut Innovation Lab director.

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. Samara Sterling, research director for The Peanut Institute, has agreed to serve on the EAP and provides expertise in the area of peanut nutrition.
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 (Shivaun Leonard, Daniel Bailey and 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 India, Kenya, Mali and Niger.

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
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 Regional 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
Uganda		
Makerere University	College of Agricultural and Environmental Sciences	Kampala

Institution	Department	City
	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: [afləˈtäksən] 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

All Peanut Innovation Lab projects made significant advances during FY21, despite the many limitations imposed by the COVID-19 pandemic. Strong partnerships with national program partners kept research moving forward, and virtual communication tools meant everyone stayed in touch.

Ten phenotyping trials were completed in seven countries, assessing 300 diverse lines in the African core set. Already, several lines have been found to have advantages over local varieties, including better resistance to fungal and viral diseases, more tolerance to water stress, and desirable seed traits. Breeders in each country are selecting these and, in some cases, moving them directly to variety trials for quick release to farmers. In other cases, the best lines are being crossed to local varieties to combine the best of both lines.

Further genotyping of over 4000 accessions in the USDA collection has identified around 50 lines that add missing diversity to the core set. Seed of these additional lines will be sent to the African programs to include in future field trials.

Over 300 lines containing wild species introgressions were tested in Senegal and Uganda and lines with nematode and leaf spot resistance and better seed size were identified. These lines are being further advanced and crossed to local varieties.

More efficient high-throughput phenotyping tools are now available for researchers to select the best lines in trials. Handheld RGB and infrared cameras were shown to be correlated with disease ratings and even plant vigor. UAV mounted cameras were equally correlated and offer even quicker data acquisition – only 10 minutes per field as opposed to an hour with handheld devices. Analysis of satellite images has also been shown to be able to identify groundnut fields and appear correlated to plant health and vigor.

An accession from the USDA genebank was found to be highly resistant to *Aspergillus flavus*, the fungus that produces aflatoxin, using the single-seed assay and two biochemicals identified to significantly inhibit *A. flavus* growth. Efforts are underway to introgress the resistance into African lines including high oleic varieties.

A simple set of molecular markers is now available to quickly determine the quality of hybrids in breeding programs. Molecular markers are also available to screen for groundnut rosette disease resistance and the actual genes involved are close to being identified. Four potential alternate hosts of the aphid transmitting rosette disease have been identified and confirmation is in progress.

Better agronomic packages involving optimal plant density, better weed, pest and disease management, and optimal harvest are in their second or third year of field trials in Ghana and Malawi. The results from these and other trials were used to produce the second edition of the Groundnut Production Guide for Malawi, two SAWBO animated videos, as input into the first versions of the Risk Index Tool for Ghana and Malawi, and to create an agronomy course for the online Groundnut Academy.

Farmers in Senegal were introduced to the use of indigenous shrubs interplanted in groundnut fields, a system that is showing promise in improved water availability and soil fertility after the first year of testing.

The second round of nearly 1100 household surveys in Senegal and almost 200 in Ghana have provided a better picture of the role of youth and gender in the ground value chain. In Senegal, researchers captured how youth out-migration is significant, but also how young people who return home provide much needed labor and financial resources. In Ghana, research showed that both genders deal with time poverty, but there are significant differences in the way men and women perceive each other's time use.

Surveys collected data about the impact of the COVID-19 pandemic on rural households, indicating that most escaped COVID-19 infection, but experienced significant impact on access to inputs and markets.

A time-use project in Senegal completed a pilot study in the USA to validate wrist-worn devices to monitor and record audio. Initial results suggest that this method is equal to or more accurate than traditional written instruments but may offer advantages of scaling and the ability to work with non-literate people.

Photos captured by youth in two villages in Uganda provide new insight into youth involvement along the groundnut value chain. The photovoice approach uses the photos to elicit discussion and engage with other stakeholders to address constraints and opportunities faced in their communities.

Finally, after several delays due to COVID-19, trails of ready-to-use school food got underway in northern Ghana with the enrollment of students and initial health surveys. Over the course of the trials, the students will be monitored for improved health and cognitive learning as they consume peanut-based foods.

A study looking at the effects of peanut consumption on the gut microbiome in school-aged children is about to start and will use locally sourced roasted peanuts.

Focus Country Key Accomplishments

Ghana

The Peanut Innovation Lab has five 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. A sixth project was launched during FY21 as a follow-up to the risk tool commissioned project to assess the economics of the variables in the tool. Fifteen graduate students (4 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 will be crossed to local varieties and advanced to large-scale field trials. 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 CSIR-SARI and CSIR-CRI groundnut breeding programs are being provided a groundnut sheller/aspirator and grading table developed by Frank's Designs for Peanuts to speed up seed processing.

The project evaluating new peanut-based ready-to-eat school foods on child cognitive learning received final approvals and began the trials near Tamale.

A project studying gender time poverty differences in northern Ghana completed its third round of household surveys has identified a number of key differences in male and female perspectives on time use. The latest survey included questions on the impacts of the COVID-19 pandemic. Interestingly, most mentioned few impacts on the household, although most indicated difficulties in access to inputs and markets.

Key accomplishments from FY2021 include:

- The second field trials of the African core set of 300 lines were completed, identifying several lines with higher levels of disease resistance than local checks.
- New MAGIC populations segregating for drought tolerance were advanced, and 92 lines evaluated in replicated field trials with several lines found to have higher yield, better disease resistance and earlier maturity than the local Chinese variety.
- Two populations containing the high oleic trait were evaluated for yield and leaf spot resistance with several lines having better resistance than the local varieties and similar yields.
- Determined that simple handheld RGB camera images can be used to select for early and late leaf spot diseases. UAV-based RGB camera images were also found to be highly correlated with disease ratings and can provide an inexpensive and rapid whole-plot assessment.
- About 0.6 tons of SARINUT 1 foundation seed produced and more than 2 hectares were planted for seed production in 2021.
- A second year of field trials were completed to evaluate planting dates, fertilizer application, improved production packages and crop rotations at SARI research stations in Kumasi, Tamale and Wa.

- Third Ghana Groundnut Working Group conference allowed over 50 stakeholders in the peanut value chain to exchange ideas and discuss strategies to improve the production and use of groundnuts.
- The first version of the Ghana Groundnut Risk Index Tool was completed and will be further tested and refined in 2021-22.
- An additional project to be led by a new PI at Alcorn State University in Mississippi, in collaboration with CSIR-SARI, will survey farmers in 5 regions assessing the variables determined in the risk tool. This data will develop a better baseline of productivity factors and offer further insight into the managerial efficiency of groundnut farmers and potential ROI of interventions.
- Trials of ready-to-use school foods were initiated at three elementary schools near Sang in northern Ghana.
- Linking farmers via aggregators to premium processors has been very difficult due to several dimensions of uncertainty, low liquidity and a lack of trust. Rather than continue to pursue this approach, focus shifted to the informal kuli-kuli value chain. Initial interviews determined that kuli-kuli is mostly sold out of the home, buyers are not loyal to a single producer nor do they differentiate based on taste. Buyers are interested in quality product.
- A second wave of household surveys (173 respondents) indicated variations in time poverty over seasons, with clear differences between men and women during the year.
- Weekly farmer field schools started in August 2021 introduced topics on gender roles, power inequalities, decision-making and time use to over 150 participants.
- A Fulbright researcher began her project on time use in Ghana in September 2021.

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 is being provided a groundnut sheller/aspirator and grading table developed by Frank's Designs for Peanuts to speed up seed processing.

Key Accomplishments in FY2021 include:

- Completed the first year of field trials with the African core set of 300 lines. Data of pest and disease, drought stress and yield were collected and will be analyzed jointly with the other regional breeders in late 2021.
- Results from field trials at DARS-Chitedze and Horizon Farming Ltd. near Lilongwe indicated that while inoculant increased the number of nodules, yields were not always improved. Fertilizer, pre-emergent herbicides, higher plant densities and one application of fungicide did increase yields.
- Results from other field trials at DARS-Chitedze and Horizon Farming Ltd. are evaluating use of boron and calcium, harvest date, and storage conditions on seed quality. Harvest is completed and seed is being tested for germination.
- Published the second edition of the Groundnut Production Guide for Malawi that includes updated tables on varieties and new photos of pests and diseases.
- 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, and can explain a significant portion of yield variation and plant stress.

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 FY2021 include:

- Seven of the 80 lines screened under well-watered and water-stress conditions were identified as drought tolerant, and 11 of the 80 lines were found resistant to *A. flavus* under single seed assays.

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 are being provided groundnut shellers/aspirators and grading tables developed by Frank's Designs for Peanuts to speed up seed processing.

An agronomic system that purposely plants native shrubs in crop fields and incorporates shredded shrub material into the soil is being 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.

The role of youth and youth migration as well as intersectional dimensions of time use and time poverty are being studied in two projects working in the groundnut basin. These projects aim to provide strategies to better target interventions that provide enhance gender and youth equality in the peanut value chain.

Key Accomplishments in FY2021 include:

- Currently 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.
- Identified several lines with greater leaf spot resistance, larger seed, more biomass and earlier maturity over the local variety through field trials of 250 lines of the variety Fleur 11, which contains various segments from wild species *A. ipaensis*/*A. correntina*.
- Determined that simple handheld RGB and UAV-based RGB camera images provide similar results in assessing crop health and vigor. UAV measurements take less than 10 minutes while handheld data requires an hour.
- Conducted workshops in Meckhe and Nioro with farmers to discuss the first-year trial results, which indicated that fields planted with the two native shrubs had higher groundnut yields.
- Conducted a baseline survey and piloted the use of watches as activity monitors in two villages outside Dakar, preparing the way for a time-use project to deploy in October 2021. Through a pilot study in the US, a new audio recording method was determined to be as accurate as the more traditional written method. A rapid ethnographic assessment was completed, and the data are being analyzed.

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 6 graduate students (4 female, 2 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 is being 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, is exploring 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 FY2021 include:

- The second 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.
- Seed of the African core set was sent to breeders in Malawi, Mozambique and Zambia for field evaluations next season.
- One line containing *A. batizacoi*/*A. stenosperma* germplasm was identified as having a higher level of resistance to GRD and LLS than the local resistant variety.
- Eighty-nine interspecific *A. diogoi* lines were evaluated in field trials and several lines found to have yield and resistance to GRD and LLS that are comparable or higher than local checks.
- Genes involved in GRD resistance have been located to two chromosomes (A04 and B04) and markers are being developed for use in selecting for resistance to this important disease.
- Indices derived using handheld sensors (RGB camera, GreenSeeker and a thermal camera) on 50 varieties in field trials in Nakabango and Serere indicated good correlations with late leaf spot and GRD ratings, indicating these high-throughput phenotyping tools as possible indirect selection methods.
- Four common weeds, sickle pod, black night shade, billy goat weed and coffee senna have been identified as the likely alternative hosts for groundnut rosette disease. *Aphis craccivora* has been found to be the only aphid type associated with GRD.
- Baseline surveys and information were collected for children from 120 households that consented to participate in the gut microbiome study. Packaged, locally-produced groundnuts were located, and the trials are expected to start in late 2021.
- Over 2100 photos have been taken by youth participating in the photovoice project and initial discussions. centered on general groundnut value chain activities, cost and revenue analyses, incentives for youth participation, food quality and safety, and gender.

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 country. 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, and pilot testing of time trackers. In addition, the Management Entity is coordinating several capacity-building activities.

Currently, the lab supports eight graduate students (5 female, 3 male) and three post-doctoral fellows (3 female) at US universities. One of the students (male) is from Ghana and two students (1 female, 1 male) are from Senegal.

Key Accomplishments in FY2021 include:

- Over 4000 accessions of African origin from the USDA genebank were genotyped with the same SNP markers used for the previous Africa lines and results have identified several new lines that add additional diversity to the core set. These will be included in a new subset and provided to the breeding programs for phenotyping.
- Seed from new allotetraploids was produced from crosses of *A. magna* x *A. hoehnei*, *A. magna* x *A. cardenasii*, *A. magna* x *A. kuhlmanii*, and *A. valida* x *A. microsperma*. These will be increased and provided to breeders to enhance diversity.
- An accession from the USDA genebank was found to be highly resistant to *A. flavus* using the single-seed assay and two biochemicals identified to significantly inhibit *A. flavus* growth. Crosses were made to introgress the resistance into African lines including high oleic varieties.
- Five genome assemblies were completed from two lines – one GRD-resistant and another Senegalese – and will develop molecular markers for GRD resistance.
- A MAGIC population combining drought tolerant, early maturing, *A. flavus* resistance, and high oleic acid content was advanced to the next generation.
- Several SNPs were found to be associated with tolerance to water stress using GWAS analysis of the US minicore.
- Using data from georeferenced fields in Malawi, analysis of satellite images was able to distinguish between crop types (groundnut, maize and soy) from mid-season on and was able to make correlations with plant health and yield.
- A new audio recording method for survey work was found to be equal or better than the traditional written recording method, confirming the use of the audio time-tracking devices in Senegal.
- Two SAWBO videos were produced, one on agronomic practices and a second on harvesting, drying and storage. These are narrated in English and Chichewa in both female and male voices, and Malawian and American accents. Groundnut Academy, an platform for virtual courses, was launched with the first course on agronomy.
- 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 more rapidly identify 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.

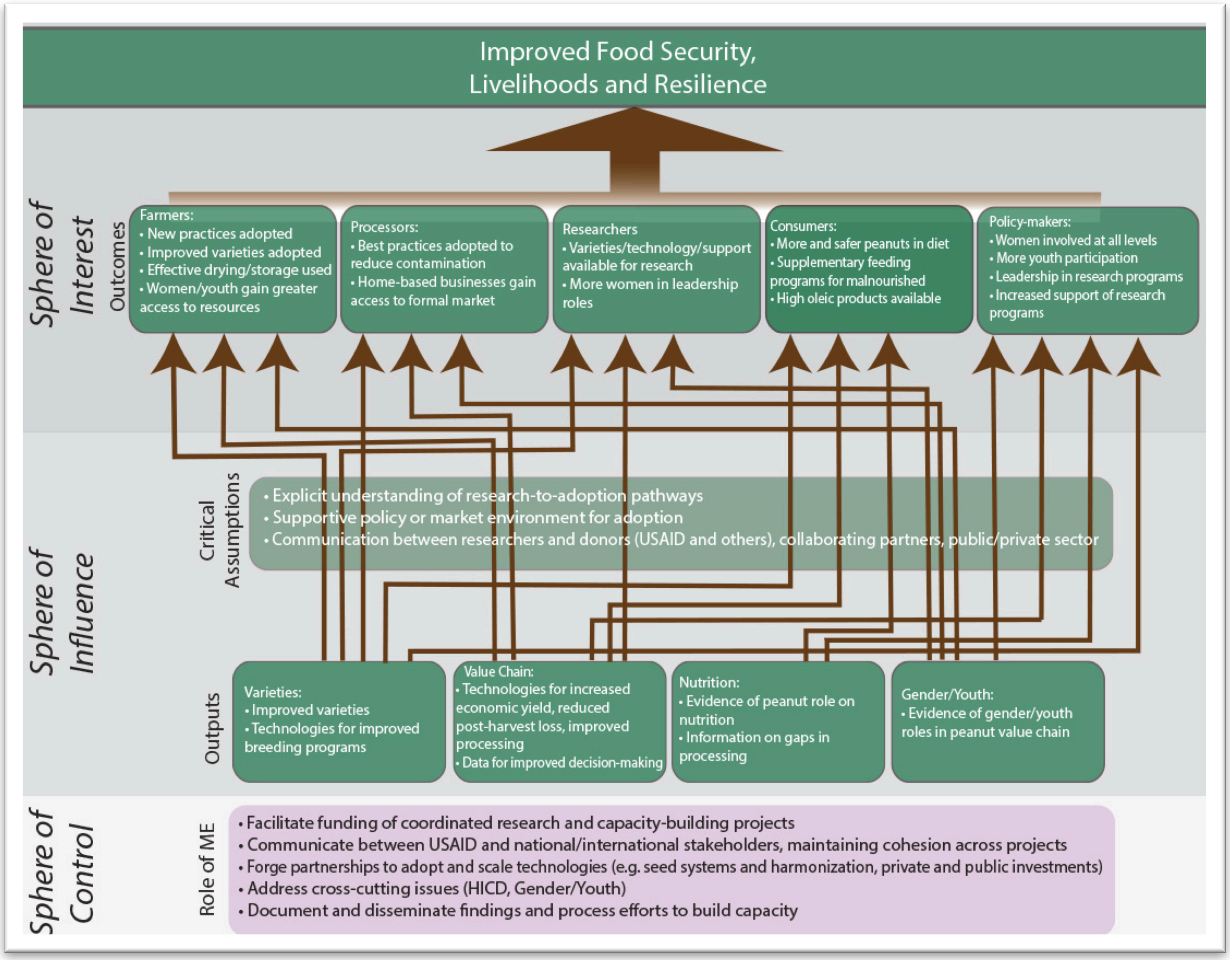
These outputs are developed in collaboration with the intended users (national program scientists), increasing the chance they will be adopted rapidly. The Peanut Innovation Lab is training researchers in partner countries to use molecular technologies and providing guidance in crossing new germplasm, 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 has been genotyped using the SNP chip, and a set of 300 lines identified to represent the diversity of the entire set. Seed is being increased for distribution 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. Once scientists in the US complete that genotyping work – assessing both the core set and US materials of African origin (see Project A4) – analyzed data will be shared with breeders.

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. Data analysis showed 14,504 markers that correspond to the most recent version of the Tifrunner genome updated in a new database file that was provided to ThermoFisher (Affymetrix). The SNP genotypes were also provided to PeanutBase for public release. Reseachers are reanalyzing the genetic similarity of the lines in the African core set to select a subset of lines that are representative of the total diversity in the larger group. The 300 core lines and the additional lines from this subset will be sent for Khufu sequencing at HudsonAlpha Institute for Biotechnology using co-funding from the Peanut Research Foundation.

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

Ivan Chapu in Uganda (left) and Emmanuel Sie in Ghana are two graduate students working to evaluate the use of handheld and arial devices as tools for high throughput phenotyping.

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

Senegal - The work in Senegal was performed at two sites, Bambay and Nioro, with the objective to compare two high throughput field phenotyping methods, one using an onboard multispectral camera on an unmanned aerial vehicle (UAV) and second one using handheld equipment at the ground level. The handheld sensors, GreenSeeker crop sensor and SPAD-502, are affordable, easy-to-use and quick measurement devices to assess the health and vigor of a crop (biomass, chlorophyll content). UAV flights were performed with a hexacopter UAV equipped with an onboard multispectral Airphen camera. The results showed a significant association between the two methods. The normalized difference vegetation index (NDVI) measured by the GreenSeeker and the NDVI from the UAV camera presented an average correlation coefficient around 0.8. Similar strong relationships were also observed between the SPAD relative chlorophyll content and green normalized difference vegetation index (GNDVI). Differences were observed in the time required to use these methods. For the handheld sensors, one hour was necessary to phenotype the whole experiment, while with the UAV a complete overview of the experiment took 10 minutes. Since the different methods largely are comparable, which to use depends only on the objectives and the investment desired by the research teams.

Ghana - A replicated experiment arranged in a lattice design was conducted during the rainy 2020 season using a set of 60 genotypes as the training population and 192 genotypes as the validation population for the development of indirect selection models for leaf spot tolerance using red-green-blue (RGB) color space indices. Early and late leaf spot were assessed at 70, 80, 85 and 95 days after planting (DAP) using 1 to 10 visual rating scale. A Samsung Galaxy NX300 RGB camera that captures 20.3 megapixel was used to take plot pictures at the same time with the visual disease evaluations. The indices derived from the RGB image were green area (GA), greener area (GGA), hue angle and crop senescence index (CSI). GA, GGA, and hue exhibited negative significant associations with both ELS and LLS. CSI, on the other hand, showed significant positive associations with both ELS and LLS. Eleven physiological and agronomic traits were separated into two principal components and explained 73.7% of the total variation. Results showed that GA, GGA, hue angle, number of pods per plant and pod weight per plant were important characteristics for use to improve groundnut yield in Ghana. The RGB indices exhibited comparable or better broad sense heritability to the disease visual scores indicating that they can be successfully used in the breeding programs to increase peanut genetic gain for leaf-spot tolerance.

In a preliminary study, an UAV carrying an RGB camera was used to estimate biomass yield and foliar diseases. Open-source software, WebODM and FieldImageR, were used to generate orthomosaics, point clouds, elevation models, 3D models, and plant traits including canopy area (CanArea), variable atmospheric resistance index (VARI), and normalized green red difference index (NGRDI). Results showed a strong relationship between digitally estimated CanArea, VARI, NGRDI, and ELS and LLS AUDPC. While VARI and NGRDI had a consistently negative relationship with ELS and LLS throughout the study period from growth staged R1 (beginning flowering) to R7 (physiological maturity), CanArea had a positive relationship with ELS and LLS at R1 although not statistically significant. CanArea had positive correlation with biomass yield at R7. The UAV estimated parameters could provide inexpensive whole-plot data for selection for ELS and LLS tolerance and higher biomass in peanut.

Uganda - Fifty genotypes, including Spanish, Valencia, and Virginia market types, were planted in Nakabango and NaSARRI (GRD and LLS hotspots) under rain-fed conditions. Three handheld sensors (RGB camera, GreenSeeker, and thermal camera) were used to collect HTP data on the dates visual scores were taken, at 5, 8, 12, and 16 weeks after planting. Correlation analysis revealed that NDVI and RGB indices were highly correlated with LLS visual scores. NDVI and GA were best related to the GRD visual symptoms. NDVI, GA, GGA and hue angle had the highest heritability. Logistic models developed using indices were 68% accurate for LLS and 45% accurate for GRD. Results presented in this study indicated that HTP tools can be used for screening for GRD and LLS resistance, and highly associated indices used for indirect selection for resistance in groundnut breeding.

Capacity Building

Training in the use and application of the HTP tools, including the use of UAVs, continued with all partners. One graduate student completed his research in Uganda.

Lessons Learned

Travel restrictions due to COVID-19 made it difficult for project leaders to see field work and provide efficient training. The major lesson learned is that effective collaborations are very important for project success.

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

Peanut breeders from across East and Southen Africa (including Lutangu Makweti of Zambia, David Okello Kalule of Uganda, Justus Chintu of Malawi and Amade Muitia of Mozambique are using trait-linked genetic markers to create resilient varieties.

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

Uganda - Researchers completed a second year of two seasons of field trials at two disease hotspots (Serere and Nakabango), assessing the entire 1250 lines compiled across the continent. Several lines have high resistance to LLS and GRD and are being used as parents in crosses to increase the resistance to these important diseases. Several other lines are being evaluated in multilocation trials for release as possible varieties.

Malawi, Mozambique and Zambia – Researchers completed the first year of field trials on the core set of 300 lines. Data collected from the trials is being analyzed and will be discussed in a joint meeting of all partners later in 2021. New seed of the 300 core lines was supplied by the Ugandan programs to partners in Malawi, Mozambique and Zambia for planting next crop cycle.

Capacity Building

One graduate student successfully defended her thesis in May and a second student will defend in October 2021.

Lessons Learned

Some delays were experienced due to the COVID-19 restrictions, especially the planned field days. Communications using social media and virtual technologies helped to maintain progress but does require a lot of data usage and appropriate hardware.

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

Senegal – All breeders that contributed genetic materials to the African collection (1049 accessions) received seeds of the core-collection (300 fully genotyped accessions). This represents a huge investment for the breeders, particularly the ones running young programs such as the ones in Burkina Faso and Togo. The breeders now hold much more diversity as the core-collection gathered genetic materials from 10 breeding programs in Sub-Saharan Africa. This resource also represents a reservoir of traits that they can tap to breed for new varieties. Because of the importance of the core-collection, several seed requests have been received from breeders from the region who were not initially part of the project. These requests will be met once sufficient seed is produced.

A comprehensive phenotyping dataset was compiled across five environments: the rainy and dry seasons in Senegal, and the rainy season in Ghana, Mali, and Niger. Some inconsistencies in the data coming from Mali and Ghana were noted. The reasons for such inconsistencies are not clear and those traits were discarded from the analysis. All the participating breeders were involved in discussions to better prepare the data capture for the 2021 trials. New trials were planned in Ghana, Togo and Burkina Faso for 2020-21, but these were postponed to next year (2022) because of the delays in arranging the trials.

Capacity Building

The PhD student is continuing her research on the genetic and phenotypic diversity of these materials. All breeders are being trained in the phenotypic methods being used.

Lessons Learned

Multi-environmental trials are challenging and there is a need for more concerted efforts to be able to capture traits in the same way. The core-collection is a unique genetic resource which is of interest to many scientists in the region and globally. Thus, a clear strategy is needed for conserving, multiplying and distributing seeds.

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 they will also 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

Uganda – Five advanced lines with BatSten1 alleles on chromosomes 2 and 9 that confer root knot nematode resistance were transferred to Uganda. The lines were field evaluated to observe the general adaptability to Ugandan conditions, in Serere season 2021A. NARONUT 1R, NARONUT 1T and Serenut 11T were used as controls. Most lines succumbed to GRD and barely produced any seed for the next season. However, one line had a final stand count higher than all controls. It also had the lowest incidence of LLS and offers great promise as an extra source of wild alleles for disease resistance. Final yield is still being evaluated and results will be out soon. Eighty-nine interspecific *A. diogoi* lines (ILs) plus SPT-06-06, Bailey and IAC-321 (*A. cardenasii*-derived) were evaluated in Serere and Nakabango in the 2021A season. Controls were Ser 4, Ser 6, Ser 11, DOK 1T, DOK 1R, Acholi white and red beauty. Six lines had pod numbers between those of Ser 6 and Ser 11. Five lines had GRD incidence comparable to that of Ser 11 and DOK 1R. Finally, 17 lines had higher resistance to LLS than that of all local checks. These lines have potential for introgression and can be used for crosses with local elite lines.

Capacity Building

Three graduate students at Makerere University continue their research to evaluate these materials under field conditions.

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

US – The following allotetraploids were successfully produced after colchicine treatment of diploid hybrids: *A. magna* x *A. hoehnei*, *A. magna* x *A. cardenasii*, *A. magna* x *A. kuhlmanii* and *A. valida* x *A. microsperma*. Seedlings are being kept for seed production in the greenhouse at UGA.

Senegal – The Fleur 11 x IpaCor AB-QTL population of 250 lines was phenotyped in the field at Nioro. Several lines were more resistant to leaf spot than the resistant check (CS 16), had larger biomass and larger seed than Fleur 11, and were also early maturing. The population has been genotyped using the Affymetrix SNP chip at UGA. The date will be used to identify molecular markers linked to the traits. The first crosses were completed to develop a new population using IL 20 (*A. diogoi* derived) and 55-437 as parents.

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

US – The *A. flavus* resistant line, 55- 437, was crossed with TMV-2 (a susceptible line) to develop a new mapping population. Of the 30 crosses, two F1 hybrids were confirmed using SSR markers, and 10 F2 seeds obtain and are currently growing in the field. Screening of lines resulted in the identification of PI 544346 as a very resistant line. To introgress the *A. flavus* resistance, PI 544346 was crossed with a Schubert line (high oleic line but susceptible to *A. flavus*) to produce a novel high oleic and *A. flavus* resistant variety. Four F1 hybrids were identified using KASP markers, hybrid seed obtained and are currently growing in the field to advance to the next generation. Similarly, to introgress the A. flavus resistance from PI 544346 line to an African line, the PI 544346 was crossed with Nkatiesari (Ghanaian variety with leaf spot resistant) and 6 putative hybrids have been produced (plants that make pegs) from 20 crosses.

Fifty-eight lines have been obtained from USDA based on the resistant line (PI 544346) seed coat color and sister lines. These lines are currently growing under well-irrigated and drought fields for testing for *A. flavus* resistance.

The newly identified PI 544346 line together with TMV-2 and 55-437 were evaluated to determine the role of seed coat biochemicals in reducing the *A. flavus* growth. HPLC was used as an analytical tool to identify these biochemicals from the seed coat. Ten different biochemicals were identified to be present in the seed coat. Also, the amount of biochemicals deposited in seed coat was significantly higher in 55-437 than TMV-2. Six out of the 10 biochemicals identified were tested for their antifungal properties on *A. flavus* using radial growth bioassay. The radial growth bioassay revealed that phenolic acid significantly inhibits *A. flavus*; however, ferulic acid showed the highest percentage of inhibition.

Niger – 80 ICRISAT lines were grown under well-watered and water-stressed conditions to identify drought-sensitive and tolerant lines. Seven lines were identified as drought tolerant. The seeds obtained from the 80 lines under well-watered conditions were screened for *A. flavus* resistance using the IVSC assay. Eleven lines were found to be resistant.

Capacity Building

The master's student at TAMU successfully completed his degree and will continue at TAMU towards a PhD.

Lessons Learned

None reported.

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

US – The final genome assemblies of GRV resistant line ICGV91707 and West Africa variety Fleur 11 were completed. The ICGV91707 assembly is highly contiguous with the whole assembly being within 160 contigs with an N50 of 41 Mb.

Zambia and Kenya – A PhD student working with ICRISAT-Kenya is using the assembly to develop markers for use in breeding programs. A total of 343 DNA samples from the ICG91707 x Serenut 1 population were isolated and sent to HudsonAlpha for sequencing and analysis using Khufu, a HudsonAlpha genotyping platform that utilizes low pass whole genome sequence data to generate de novo genotyping data.

Uganda – F3 seeds were phenotyped in the fall for GRV resistance. Those phenotypes combined with the genotyping data will be used to map GRV resistance. This was necessary because the population we were working with had too much structure to map resistance properly. The PhD student at Makerere University has mapped GRV resistance in the core set of 300 lines with very good results, and DNA is ready from this set for Khufu sequencing. These data will allow us to have a higher resolution view of the GWAS analysis.

Capacity Building

Training in sequence analysis and GWAS is being provided to the 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

Teams in Ghana, Senegal and the US (here, Ghanaian grad student Leslie Commey working in Lubbock, Texas) are evaluating crosses for resilience traits.

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

Developing peanut accessions with tolerance to water deficit stress

Ghana – To produce MAGIC populations segregating for drought tolerance and other traits, eight parents were combined in a two-way cross and progeny from each cross have been validated via SSR markers in Ghana. The four-way cross is underway. The rest of the true hybrids from the two-way crosses have been advanced to the F2 generation.

Ninety-two lines were received in the summer of 2020 and planted for increase as unreplicated plots during the 2020 rainy season. Field data were taken using HTP equipment. Measurements included days to emergence, first flowering, and 50% of plants flowering, plant height, SPAD chlorophyll, NDVI, canopy temperature, early and late leafspot, days to maturity, haulm yield, and pod yield. Two entries had pod yields numerically greater than or equal to Chinese, 14 entries had early leaf spot scores <4.0, compared to Chinese with a score of 5.0, and 5 had late leafspot scores <3.1, compared to Chinese with a rating of 4.8. Fifteen had a time to maturity of <124 days, compared to Chinese (129 days). Three entries combined high yield, early maturity, and less leaf spot. Materials were planted in the dry season for further evaluation.

Dry season evaluation of 60 lines was completed in two-row plots with three. In addition, 94 genotypes that were increased last year have been planted under the rain-fed conditions for evaluation of yield potential and reaction to foliar diseases. After harvest, the fatty acid composition will be evaluated using the NIRS facility at ICRISAT WCA in Bamako, Mali.

Senegal – Materials from TAMU were planted for increase in July 2020 and harvested in December at the Nioro research station in Senegal. Almost all entries germinated well except a few for which the seeds were not so mature. For 2021, 38 lines were selected and planted in a field trial under fully irrigated and drought-stressed conditions. Due to poor vegetative development likely due to low soil fertility, physiological and agronomic measurement were not done. The trial will be repeated during the 2022 off-season.

US – Efforts continue to double the chromosome number of the *A. dardani*-derived hybrid with *A. vallsii*. Several pollinations were made on a healthy *A. vallsii* in the fall 2020 crossing program. The seeds from these crosses will be planted in the greenhouse and the plants treated with colchicine to get the complex hybrid that will cross with cultivated peanut lines, transferring drought tolerance from wild peanuts to the cultivated line. In addition, a previously doubled introgression line involving *A. pflugeae*, *A. paraguariensis* and *A. vallsii* as parents has been successfully crossed with Tamrun OL11 and is currently being backcrossed a third time to produce a more agronomically acceptable cultivated introgression line.

Eight parental lines are being used to produce to MAGIC populations. One set combines drought tolerance, early maturity, resistance to aflatoxin contamination, and high oleic. The second set is to combine high harvest index, salinity tolerance, resistance to leafspots, and high oleic oil. Crosses were made in December 2020, but were not successful because COVID-19 closures forced planting to happen too late. The population was replanted in the spring of 2021, and 20 pegs from four two-way crosses were obtained. Pods will be tested with markers to validate true hybrids.

GWAS analysis of the US minicore collection for tolerance to water deficit was performed using 8,189 SNPs and phenotypic data from Texas, Oklahoma and Virginia in 2017. Using Tassel, 120 SNPs (P-value $< 10^{-4}$) and 558 SNPs (P-value $< 10^{-3}$) were significantly associated with the phenotypic data. Of these, 71 SNPs were significantly associated with more than one trait. Overall, 163 SNPs are considered the most reliable because they were significantly associated with either different locations, multiple traits, or both.

Developing peanut accessions with tolerance to leaf spots

Ghana – Two LS resistant populations (BC3 x Schubert, BC3 x TS32-1) were evaluated in the field in Ghana for yield and resistance to leaf spots. Several breeding lines had yield as good as Chinese or NkatieSARI, but resistance similar to NkatieSARI and better than Chinese. The materials will be further evaluated with the goal of releasing a leafspot-resistant high oleic Spanish cultivar earlier in maturity than NkatieSARI.

Forty-four individual plants were selected from the F7 population based on their pod yield and tolerance to LLS in the major season of 2020. A preliminary yield trial was established during the minor season (September to December 2020) in Kumasi. There were 44 entries and a check. Plots were single rows 4 meters long, spaced 40 centimeters between rows with 3 replications. Mean days to first flowering and 50% flowering were 27 and 31 days respectively. Days to maturity ranged from 91 to 101 days. Pod yield ranged from 665 to 1443 kg/ha. The trial is being repeated in Kumasi during the major season in 2021. Quantifying the percentage oleic acid in the seeds will be done in 2021. Replicated trials of the 10 selected lines have been planted at Nyankpala in 2021 for evaluation under rainfed conditions.

Senegal – Eight recombinant lines (4 lines from each population) that were derived from the crosses Fleur 11 × 73-30 and ICGV 96894 × 73-30 were tested along with the 300 core accessions. Most accessions lacked fresh seed dormancy and had a high percentage of seeds that sprouted at maturity. Four entries from the cross ICGV 86904 x 73-30 had good dormancy, with between 0.9% and 2.9% germination. Among 100 late maturing accessions, forty-five were identified as dormant, having <10% germination at maturity. For many of the early-maturing entries, over 60% of the seeds germinated at maturity. Four entries from the cross between Fleur 11 and 73-30 had good fresh seed dormancy between 1.0% and 3.5% germination. Among the remaining 189 entries, only 17 had <10% germination at maturity. GWAS analysis will be carried out using that dataset for identifying markers linked to fresh seed dormancy in peanut.

US – Eighty-four breeding lines and checks of BC3-60-02-03-02 x Schubert selected for the Spanish market type were planted as single plants in June at the Yoakum disease nursery in South Texas. Disease ratings will be taken in October when disease pressure is sufficient. Remnant seed have been retained for DNA extraction and marker analysis.

Seed from 185 breeding lines were increased in Texas in 2020 to allow field evaluation in 2021. One plant per breeding line will undergo marker analysis. Based on seed availability, 150 breeding lines of the NkatieSARI x Schubert cross were also planted at Yoakum in 2021 for leafspot evaluation. These also were planted as single plants for each breeding lines. As with the BC3 x Schubert cross, remnant seed have been retained for DNA extraction and marker analysis.

Introducing high oleic oil composition

US – While the FAD2B marker is routinely used to screen runner materials, neither the FAD2A or FAD2B markers have been tested on a Spanish population. Several hundred seeds from runner x runner and Spanish x Spanish crosses supplied by J. Cason in Stephenville were evaluated using NIR and seed chips sampled for DNA extraction to validate the FAD2A and FAD2B markers.

Increasing the use of genomics

US - A resequencing system for genotyping is being tested based on a kit from Tecan Allegro GBS for the smallest scale for up to 2,500 targets by 192 peanut samples. So far, 1,700 targets have been identified with few paralogs in collaboration with colleagues and expect to add several hundred more highly-polymorphic targets. If successful, we would be able to genotype a population with this number of markers, selected for high polymorphism across multiple genotypes, for about half the cost of the SNP chip.

Conducting regional trials and varietal increase

Ghana – About 0.6 tons of SARINUT 1 foundation seed was produced in the 2020 planting season. In 2021, more than 2 hectares will be planted to SARINUT 1. However, the adoption is not going as we expected due to concerns about the deep pod constriction which makes shelling difficult as it is mostly done manually. We also have received reports on problems with germination this year from our demonstration plots.

Capacity Building

Two graduate students are continuing their work towards their degrees in Ghana. Both are expected to complete their degrees by the end of 2021.

A PhD student from Ghana at TAMU was trained in the use of the KASP FAD2A and FAD2B markers for hybrid determination and ultimately high oleic composition.

Lessons Learned

We will need to investigate how we can screen better for the high oleic trait – either find methods for single seeds or devise metrics for screening bulks by refractive index measurement. The latter requires the least-expensive equipment, and this has already been purchased and delivered. The external review panel has also requested that we devise a protocol for testing the purity of high oleic varieties and breeding lines to guarantee their purity for this trait.

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

Uganda – The following common weeds– *Senna obtusifolia* (sickle pod), *Solanum nigrum* (black night shade), *Ageratum convzoides* (billy goat weed) and *Senna occidentalis* (coffee senna) – continue to be surveyed as putative alternative hosts for GRD from widespread areas of Uganda. Morphological identification and genetic screening of aphids from multiple survey sites from multiple hosts have identified *Aphis craccivora* as the only aphid type detected in the fields. Screen house experiments monitoring GRD transmission to and from alternative hosts and groundnut are ongoing.

Capacity Building

A graduate student at Makerere Universities continues his studies on the project and is expected to finish in 2022.

Lessons Learned

None reported.

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

The Optimized Shrub System project is working with farmer groups to pilot the use of native shrubs in groundnut fields to increase moisture and biomass in the soil.

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, 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 on-going engagement with farmers, monitoring, and data collection. Workshops were held in April at both sets of pilot farmer locations (Meckhe and Nioro) to review the 2020 cropping season and prepare for the upcoming season of peanut rotation. In keeping with the millet/peanut rotation, this year the long-term plots were planted with millet. There were eight treatments repeated four times, i.e. four complete randomized blocks. The shrubs were cut twice (during clearing and in August) and the resulting residues were cut into small twigs and incorporated into the soil using a horse-drawn sine hoe. Sowing took place on August 6 in Keur Matar Aram and on August 15 in Nioro. The maintenance of the trials was done according to the research recommendations. Measurements will be made only on the yield of millet and its components.

Capacity Building

The existing partnerships continue with ISRA/CNRA, Bambey; University of Thiès; NGO Symbiose, Nioro; FAO-Makhfousse Sarr Farmers' Cooperative, Meckhe; and Trees for the Future, a U.S.-based NGO with projects across Sub-Saharan Africa, and a large footprint in Senegal that includes 250 technicians, motor bikes, and 3,000-5,000 participating farmers. We are coordinating with TREES on a large proposal that would combine their Forest Garden Approach for irrigated fruits and vegetables with OSS for rain-fed crops (millet, groundnut, cowpea, cassava). We have received a small grant from the Food, Conservation, & Health Foundation to establish an Agro-Shrub Farm Network as demonstration and training sites for OSS. GreenAgro Consulting is a new partner that will be establishing one of the farms at their existing location near Saly.

In a new partnership, we will collaborate with the Ecole Polytechnique de Thiès (EPT) to manufacture and test the machine intended to cut the shrubs' biomass.

Lessons Learned

Conducting participatory technology transfer trials in the field requires patience, awareness-raising and constant presence in the field until the farmers start to notice the positive results of the technology; as a result, this type of research requires a longer period of time to have the expected impacts.

Protecting land has been a long-time problem across the Sahel with the patchwork of land tenure rules. We have learned that an effective way to protect land and the investment made in OSS is through local convention where an agreement is made with a local administrator that if someone's animal eats the shrubs or crops, the owner of the animal must pay for the damage. These local conventions are currently working in Nioro.

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

Two PhD students completed a third year of research on the project. Stakeholders gathered for the third meeting of the Ghana Groundnut Working Group in Tamale, and researchers and graduate students from Ghana participated in the annual meeting of the American Peanut Research and Education Society (APRES) which was held online. A project was initiated with Alcorn State University to survey farmers to improve the economic component of the peanut risk tool for Ghana. The first version of the Ghana Peanut Risk Tool soon will be released for public use.

Capacity Building

Workshops were held in November 2020 and August 2021 to develop risk tools for northern Ghana and southern Ghana. Participants represented SARI, CRI, and KNUST.

Lessons Learned

None reported.

Presentations and Publications

Abayiza, B. & Opoku, N. (July 2021). Detoxification of aflatoxin contaminated groundnut using natural alkaline sources. 3rd Ghana Groundnut Working Group Meeting, Tamale, Ghana.

Abogoom, J., et al. (July 2021). Assessment of genetic purity of commercially cultivated peanut varieties in Ghana. Proceedings 53nd Annual Meeting American Peanut Research and Education Society, (Virtual).

Abogoom, J., et al. (July 2021). Genetic Purity of Two Commercially Cultivated Groundnut Varieties in Ghana. Presentation at 3rd Ghana Groundnut Working Group (GGWG) Conference, Tamale, Ghana (Virtual).

Abogoom, J., et al. (July 2021). Seed Quality of Groundnut Seeds in Ghana. Presentation at 3rd Ghana Groundnut Working Group (GGWG) Conference, Tamale, Ghana.

Abubakari, M. (July 2021). Targeting critical control points with appropriate interventions to reduce the risk of aflatoxin contamination. 3rd Ghana Groundnut Working Group Meeting, Tamale, Ghana.

Abudulai M., et al. 2021. (July 2021). Developing risk management tools to help farmers minimize risk in peanut production in two agro-ecologies in Ghana. American Peanut Research and Education Society, (Virtual).

Abudulai, M., et al. (July 2021). Impact of adoption of improved varieties on household share of peanut income in northern Ghana. American Peanut Research and Education Society, (Virtual).

Abudulai, M., et al. (July 2021). Influence of geographical location and time of planting on pest densities and yield of peanut varieties in Ghana. American Peanut Research and Education Society, (Virtual).

Abudulai, M., et al. (July 2021). Influence of geographical location and time of planting on pest dynamics, yield and quality of groundnut (Arachis hypogaea L.). Presentation at APRES and GGWG, Tamale, Ghana.

Akpogo, D., et al. (July 2021). Developing new groundnut varieties to meet market demands. Proceedings 3rd Annual Meeting of the Ghana Groundnut Working Group, Tamale, Ghana.

Akromah, 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. American Peanut Research and Education Society, (Virtual).

Akromah, R., et al. (July 2021). Growth and yield response of peanut to pest and crop management packages in Ghana. American Peanut Research and Education Society, (Virtual).

Appiah-Kubi, Z., et al. (July 2021). Response of peanut genotypes to pre-harvest aflatoxin contamination in Ghana. American Peanut Research and Education Society, (Virtual).

Arthur, S. (July 2021). Effect of Pest and Crop Management Packages in Groundnut - Based Cropping Systems on Agricultural Productivity: updates. Presentation at 3rd Ghana Groundnut Working Group, Tamale, Ghana.

Arthur, S., et al. (July 2021). Benefits of peanut–cereal rotation and inputs systems on maize growth and yield in northern part of Ghana. American Peanut Research and Education Society, (Virtual).

Arthur, S., et al. (July 2021). Effect of pest and crop management packages in groundnut-based cropping systems on agricultural productivity. 3rd Ghana Groundnut Working Group Meeting, Tamale, Ghana.

Asibuo, J., et al. (July 2021). Validation and Utilization of SNP markers for introgression of late leaf spots resistance genes in peanut. American Peanut Research and Education Society, (Virtual).

Brandenburg, R., et al. (July 2021). Enhancing the groundnut value chain through Peanut Innovation Laboratory partnerships: examples of a production guide in Malawi using research results from Ghana. 3rd Ghana Groundnut Working Group Meeting, Tamale, Ghana.

Buol, G., et al. (July 2021). Contrasts of peanut risk management tools for peanuts in Argentina, Ghana, India, Malawi, and North Carolina. American Peanut Research and Education Society, (Virtual).

Cahoon, C., et al. (July 2021). Developing weed management risk tools for crops in North Carolina. American Peanut Research and Education Society, (Virtual).

Danso, B., et al. (July 2021). Validation and utilization of SNP markers for introgression of late leafspots resistance genes in groundnut. 3rd Groundnut Working Group Meeting, Tamale, Ghana.

Dzomeku, I.,et al. (July 2021). Research outlook for groundnut in Ghana.. 3rd Ghana Groundnut Working Group Meeting, Tamale, Ghana.

Etwire, P. M. & Martey, E. (July 2021). Covid-19 pandemic and its effect on food systems. Proceedings. 3rd Ghana Groundnut Working Group Meeting, Tamale, Ghana.

Financial return from weed and disease management practices in peanut (Arachis hypogaea L.) in southern Ghana. International J. Pest Management.

Foote, D. (July 2021). Overview of groundnut seed chain: example of a model used in the USA. 3rd Ghana Groundnut Working Group, Tamale, Ghana.

Jordan, D. L. & Brandenburg, R. (July 2019). Value of International Projects to Faculty in the United States: Examples of Participation by Individuals at North Carolina State University with the Peanut Innovation Lab. APRES, Auburn, AL.

Jordan, D. L.,et al. (July 2021). Validating risk tool developed to help farmers minimize risk. 3rd Ghana Groundnut Working Group, Tamale, Ghana.

Koomson, I., et al. (July 2021). Quality of groundnut seed in the public domain in Ghana. Proceedings 3rd Annual Meeting of the Ghana Groundnut Working Group (in press). 3rd Ghana Groundnut Working Group, Tamale, Ghana.

Martey, E. & ETWIRE, P. M. (July 2021). Gender and youth issues in peanut value chain in northern Ghana. 3rd Ghana Groundnut Working Group, Tamale, Ghana.

Mochiah, B. (July 2019). Summary of Interventions to Minimize Aflatoxin Contamination in Ghana at Pre- Harvest and Post-Harvest Steps in the Supply Chain. APRES, Auburn, AL.

Musah, F. (September 2021). Role of nutrition in boosting immune system against Covid-19 infection: the case for groundnut. 3rd Ghana Groundnut Working Group, Tamale, Ghana.

Ndela, D., et al. (July 2021). Evaluation of advanced groundnut (Arachis hypogaeae) breeding lines for resistance to Aspergillus flavus infection and aflatoxin accumulation. 3rd Ghana Groundnut Working Group, Tamale, Ghana.

Opoku, N. (July 2021). Standards and food safety concerns associated with groundnut in Ghana. 3rd Ghana Groundnut Working Group, Tamale, Ghana.

Omari, R. (July 2021). Aflatoxin contamination and policy issues in Ghana. 3rd Ghana Groundnut Working Group, Tamale, Ghana.

Parwar, B. (September 2021). Economic activities along the peanut value chain and their profitability. 3rd Ghana Groundnut Working Group, Tamale, Ghana.

Puozaa, D. K. & Oteng-Frimpong, R. (July 2021). The groundnut seed sector in northern Ghana: challenges and opportunities. 3rd Ghana Groundnut Working Group, Tamale, Ghana.

Seidu, A., et al. (July 2021). Influence of geographical location and time of planting on pest dynamics, yield and quality of groundnut (Arachis hypogaea L.). 3rd Ghana Groundnut Working Group, Tamale, Ghana.

Sie, E. K., et al. (July 2021). Photogrammetry enables indirect selection and increase genetic gains for leafspot tolerance in peanut breeding program in Ghana. 3rd Ghana Groundnut Working Group, Tamale, Ghana.

Sugri, I. (July 2021). Mapping opportunities to increase efficiency at groundnut harvesting, drying and shelling operations. 3rd Ghana Groundnut Working Group, Tamale, Ghana.

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

Malawi – Completed data sets (approximately 800 peanut, maize, and soybean fields) from five districts have been submitted to collaborators at Stanford University. The survey of these field sites and the GPS referencing also included the collection and analysis of soil pH provides additional insight into yields. Another data set of approximately 300 fields from Horizon Farming Ltd is being prepared to transfer to the collaborators at Stanford to further build this data base and strengthen the analysis.

US – Preliminary analysis indicated that satellite imagery is able to determine crop species accurately from midseason onwards until harvest. Their analysis also indicates they can explain a significant percentage of the yield variability (and plant stress) through the satellite imagery. We have also initiated the analysis of peanut and millet fields in Senegal with our collaborators at Stanford.

Capacity Building

We are building institutional capacity through creating a familiarity with new technology and potential collaborations for scientists, private entities, and agriculturalists in Malawi. These technologies will help address climate change and offer insight into the necessary transformation needed to address this threat to sustainable agriculture in Malawi. Increased exposure to these technologies will create new ways of thinking and creativity in the institutions assigned the task of addressing climate change in agriculture.

Lessons Learned

The challenges of obtaining quality data over a large geographic area in a pandemic were addressed by contracting out data collection to a private entity. The ability of staff and students to complete such an arduous task this past year was daunting. The use of a private agricultural service produced a high-quality data set in a timely manner at a very reasonable cost.

Presentations and Publications

None reported.

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

Malawi – The field trials located at the DARS-Chitedze location and Horizon Farming Ltd near Bunda were completed during the cropping season of 2020-2021. In a second year, one set of trials is testing the yield impact of various inputs including inorganic fertilizers, inoculant, plant density, varieties, pre- and post-emergence herbicides, and fungicides. Results indicate that the use of inoculant did increase the number of nodules on plant roots, but this did not always result in higher yields. Inorganic fertilizer always increased yield but did not significantly affect nodulation. The effect of gypsum was quite variable and under low soil pH conditions sometimes reduced yield. Herbicides increased yield while reducing the labor required to grow the crop and pre-emergence herbicides provided the most significant impact on yield and labor costs. Higher plant densities resulted in higher yields and better weed management. The use of one application of the fungicide chlorthalonil at 40 days after planting significantly increased yields. These results indicate that yield can be increased with the use of inoculants, inorganic fertilizers, increased plant density, herbicide use, and fungicide applications. However, the results of these trials were not consistent across the varieties used, CG9 and Chitala. More research is needed to further document the plant response to these inputs across more varieties and to determine the optimal package of multiple inputs in combination.

Another set of trials were in their first year and focus on the impact of specific inputs, harvest dates, and storage techniques on seed quality. Treatments included applying boron and calcium, planting two varieties (Chitala and CG9), and following two harvest dates (early and late). There were also two drying and storage programs (optimal and suboptimal) for pods collected from each plot. These seeds will be subjected to germination trials to detect differences in viability. Results from the trial indicate some plant health benefit from boron and calcium. Harvest date significantly affected yield (as observed in previous PIL research) and kernels will be evaluated for viability. A second year of this research will take place at the beginning of the rainy season in 2021-2022 at the same research locations.

A survey was conducted to evaluate the presence of the peanut pod nematode *Ditylenchus africanus*, a serious pest which reduces seed viability in South Africa. Pods from more than 300 fields across Lilongwe, Ntchisi, Salima, Mzimba and Kasungu districts were collected prior to harvest. Scientists at LUANAR in collaboration with Agriculture Research Council (ARC), Potchestroom, South Africa experts are working to determine if this nematode is present in Malawi. Such information may explain poor seed quality in some areas.

Capacity Building

Our collaborations with LUANAR result in additional research experience and funding for faculty, and we provide support and guidance for the training of two MSc students. Our collaboration with staff at DARS-Chitedeze also provides research funding, additional insight into the performance of new varieties, and research guidance.

Lessons Learned

During the pandemic, transportation for students became problematic as the use of public transportation was discouraged. The use of private transportation increases the cost of the projects for students and staff.

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 contract and subawards have been approved. The survey plan and draft instrument have been developed.

Capacity Building

This project has been the first direct subaward to a Minority Serving Institution (MSI) by the Peanut Innovation Lab. The ME has worked with the PI and team at Alcorn State to streamline orientation to the IL given the late starting date within the overall project.

Lessons Learned

USAID has prioritized partnerships with MSIs. Due to the project initiation being so late in the current phase, the IL used existing relationships to find an excellent research partner to assist with a previously identified research priority. Given the added time required for competitive calls, this jumpstart has made this project possible in the remaining timeframe and helped establish relationships for potential future collaborations.

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 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

Uganda – Baseline surveys were conducted with families of children 6 to 9 years of age. A total of 120 households participated; parents and children learned the study goals and protocols. Twenty fecal samples were collected and frozen for future shipment to the University of Georgia laboratory for baseline microbiome analyses. A vendor was identified to produce roasted peanut packets for the three-month supplement study. The COVID-19 pandemic remained severe in Uganda and schools remain closed. The project will continue as a community-based supplement study in November 2021 and complete all data collection by March 2022.

US – A detailed study procedure was developed and will be moved forward once samples are received from Uganda.

Capacity Building

None reported.

Lessons Learned

The COVID-19 pandemic remains severe in Uganda, keeping schools closes and restricting travel. We plan to conduct the community-based supplement study in November 2021 and to complete all data collection by March 2022.

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

Children seem to really enjoy a peanut-based food distributed in Ghanaian schools. Attendance even improved. Upcoming tests will show if the children perform better on cognitive tests after a steady supply of the food.

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 in St Louis School of Medicine, St. Louis, MO; Matilda Steiner-Asiedu, University of Ghana, Accra, Ghana

Achievements

Ghana –All IRB approvals, including Ghana Health Services IRB as well as approvals from the local, district and national level of Ghana School System were received. All standard operating procedures have been created to handle Bio-Impedance Analysis (BIA) and anthropometrics, cognition measurements, food preparation and distribution. All protocols address COVID-19 and general food safety. Project staff were trained in Good Clinical Practices, protocols, anthropometric measurements, body composition measurements, neurocognitive measurements and data entry. Participants began to be enrolled the first week of September. During parent information meetings, a brief nutritional training was conducted. Feeding was initiated at all schools, and attendance quickly improved. At one school, over 100 participants completed initial measurements (anthropometrics, body composition and cognitive) and were scheduled to begin receiving school food the last week of September. One additional school was expected to complete measurements by end of September and start trials shortly thereafter.

Capacity Building

WUSTL continues to collaborate with the University of Ghana and Project Peanut Butter in this work. Issah Shani of Tamale, student at University of Ghana, continues to work with the team and develop research-related skills.

Lessons Learned

We knew that IRB approval was required prior to the trials, but were unaware of approval necessary from Ghana Educational Services (GES). In a previous study conducted by this group, only district approval was necessary. In this case, district approval is contingent on GES approval. This has been successfully resolved.

Although a previous employee tested the chosen cognitive assessment, NIH Toolbox, with some Ghanaian children, it became apparent when we implemented the assessment that the children did not have necessary knowledge of the animals/foods displayed. The team, under the guidance of a professor of psychiatry at WUSTL, worked quickly to identify a solution. An interactive keynote presentation using the same logic as NIH Toolbox was created using more commonly identifiable animals/foods for the participants. These tests will be individually scored.

The age population at the school is also different than we original identified in prior visits to the school. Therefore, there is a larger percentage of children that do not meet the criteria. This is an ongoing concern we are in the process of addressing. In addition, COVID-19 still is an unknown and could close schools if infections rise in Ghana. However, the availability of the vaccination should allow for schools to remain.

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

Senegal – Data from the first-year survey of 1123 households were distilled into research and policy briefs. The research brief focuses on groundnut production practices and outcomes from our sample of over 2,500 groundnut fields associated with the household survey. Significant findings include the fact that few young adults and women have the opportunity to grow groundnuts for their own income. While groundnuts are still the predominant crop, with 93% of household heads managing a groundnut field and 83% of young adults working on groundnut fields, only 18% of young adults and 10% of women manage a field where they retain the income. We also found that young adult groundnut production occurs as low input-low output production systems with modest returns. Some 43% of young adults do not apply any soil fertility amendments, 38% use inorganic fertilizer, and 10% use manure. Female farmers show particularly low input use, along with significantly smaller fields. Findings indicate that when soil fertility amendments are used, they have high returns. For example, the rate of return from inorganic fertilizer use is calculated to be 50% and use of organic manure and fallowing 13% and 27%, respectively.

The policy brief focuses on how out-migration of young adults influences rural households in the Groundnut Basin, as well as the role of groundnut cultivation in young people’s livelihoods. Results show that migration is an important livelihood option for young adults (16-29 years) in the Groundnut Basin, with 25% of young adults having migrated temporarily or permanently in last 5 years. Young men are far more likely to have recently out-migrated (38%) than women (10%). Almost all (98%) of young adults migrating out of rural villages in the Groundnut Basin stay in and remain actively engaged in rural communities. Around 18% of young adult migrants send back remittances (USD $195 on average) and 94% return during cropping season to assist the household. These results suggest a need to re-think the role of migration in rural community development. Development programs need to think of innovative ways that migrants’ assets can be more efficiently employed to help their villages.

The second-year panel survey of 1,098 (98% of the first year) households included a module of COVID-19 impacts in the rural Groundnut Basin; results are included in a research brief that is ready for dissemination. The health impacts of COVID-19 in rural areas of the Groundnut Basin are hard to quantify, given the lack of COVID-19 testing and limited use of rural healthcare infrastructure. With those qualifications, the data suggests the initial wave of COVID-19 did not result in widespread severe illness and death in rural areas between March 2020 and May 2021. Further, Senegal instituted strong lockdown measures that likely reduced the spread of COVID-19 into rural areas. However, lockdown measures had strong negative impacts on household well-being, through reductions in work and earnings, as well as disruptions in important food markets. Earnings, market, and schooling impacts were mainly temporary, with the majority of household members returning to pre-COVID-19 activities by May 2021. Survey results also indicate that the government of Senegal was able to muster an effective response to COVID-19 impacts in rural areas of the Groundnut Basin through widespread and timely provision of basic food and health-sanitation supplies.

Capacity Building

Three Senegalese graduate students supported by the project completed or are near completion of their thesis research in the reporting year. A UGA PhD student worked for a period of 16 months for the project (August 2019 to December 2020) on secondary data analysis and also travelled to Senegal during the first-year survey. Funding was secured to support another PhD student in Agricultural Economics at UGA starting in the fall semester of 2021.

Lessons Learned

After COVID-19 delays in survey data verification and in MS student enrollment at VT, project activities are again running smoothly. However, the limited travel by project PIs has slowed activities focused on dissemination of results and establishment of research collaborations for data analysis within Senegal. One lesson learned, is that remote teleconferencing is not a substitute for in-country visits for these types of activities.

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

Groundnut value chains in Ghana are long and fragmented, consisting of many smallholder producers and intermediate traders. In this market environment, the farmer may not receive incentives to grow high quality and safe food, and the produce available at the market is generally low quality and at risk of aflatoxin contamination. Consequently, demand for aflatoxin-safe groundnuts is mostly fulfilled by imports even though Ghana is the 10th largest groundnut producing country in the world. Efforts to link smallholder groundnut farmers to high value markets in Ghana rely on an aggregator model, wherein aggregators provide services or inputs to farmers at the beginning of a season, and subsequently purchase their production to sell to downstream buyers. This model has potential but, for a number of reasons, aggregators are challenged in their ability to accumulate safe, adequate groundnut supplies.

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 the quality (food safety) in groundnut-based products, kuli-kuli (a popular snack) and groundnut oil.

Theory of Change/Impact Pathway(s)

By gauging how farmers accept inputs on credit, how much they sell to the aggregator, how much they keep for home consumption, and groundnut aflatoxin levels, the study will serve as a proof of concept to downstream premium buyers, NGOs, or government agencies seeking to enhance smallholders' participation in premium value chains. The study will also provide insights about ways to improve gender inclusivity in groundnut market and value chain interventions.

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

Ghana – Given the difficulties in establishing contractual arrangements in the groundnut value chain in Ghana, we developed a new research objective to investigate the quality (food safety) in groundnut-based products, kuli-kuli (a popular snack) and groundnut oil. Initial surveys have indicated high levels of aflatoxin in locally marketed kuli-kuli. Interviews with kuli-kuli processors were conducted to learn details about kuli-kuli and oil production and marketing in the greater Tamale region. Producers indicated that they use good quality whole groundnuts to produce kuli-kuli, although there appears to be no evidence of the quality. It was also learned that most kuli-kuli is sold out of the home, and that consumers are not loyal to one particular producer and do not differentiate much based on taste. Consumers do prefer to purchase kuli-kuli from producers who have the appearance of doing it "cleanly."

Capacity Building

Working with Farmer Pride, we trained 800 farmers and provided them with drying tarps. Since July 2021 we have been working with University of Development Studies to investigate kuli-kuli markets and production in and around Tamale.

Lessons Learned

Making contractual arrangements in the groundnut value chain in Ghana is made very difficult by several dimensions of uncertainty, low liquidity, and a lack of trust. We have written up our experiences trying to connect farmers to a premium processor, highlighting these issues.

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

Research into time poverty in Ghana shows that women have less time than men, but how stretched they are depends on the agricultural cycle. Some seasons are busier than others.

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

Ghana – Enumerators completed the second wave of the first round of the survey in December 2020 and the third wave in June 2021 with 173 respondents. The team initiated weekly farmer field schools in late August 2021 with attendance ranging from 56 to 100 participants (both men and women). Topics included gender roles and relations; power inequalities and household decision-making; crop preferences by gender; conflict and conflict resolution; and time use by men, women, and young people in the household.

Capacity Building

The SARI team is working with the Penn State team to develop gender-intensive interventions in the farmer field schools. The two Ghanaian students are continuing their educations, which they are extending to their jobs at SARI. Penn State had a virtual workshop in January 2021 focused on gender and agriculture for the time poverty research team with 16 people attending over 3 days. 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

Patterns are beginning to emerge from the analysis of the first three waves of the data. There are clear variations in time poverty during the seasons of the year. There are clear differences between men and women in terms of when time poverty is highest. If we see changes in those time differences after the introduction of new technologies and gender-intensive interventions, we will be able to make recommendations about how to reduce time poverty for both men and women.

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

Uganda – The Makerere University partners conducted photovoice trainings in both Nwoya and Tororo and administered two surveys (one in February and September 2021). The objectives of the surveys were to find out the incentives and disincentives for youth to participate in the peanut value chain and the extent to which these factors affect their willingness to invest time and money. The Positive Youth Indicators survey was also administered to all participants in

February. Approximately 2,179 photos were collected in February, April, and September, and analysis is underway. Photos continue to be taken. Focus group interviews with participants were conducted in February, April, and September centered on four themes: general activities relating to the peanut value chain, cost and revenue analysis as well as incentives and disincentives of youth participation along the value chain, food quality and safety, and gender issues along the value chain.

Capacity Building

Existing partnerships continue between Makerere University, University of Tennessee and NARO. Two graduate students at Makerere completed their data collection and are writing their theses. A graduate student at the University of Tennessee completed her master's degree and a second graduate student from the University of Tennessee was added to the project.

Lessons Learned

It is possible to work collaboratively even during a pandemic, but physical distance does make it difficult when a project is designed to be team based. Graduate students being involved in the distribution of the surveys, collecting photos, and conducting focus groups is essential.

Weekly meetings are essential to make long-term progress when communication is virtual and including graduate students in those calls is beneficial.

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

Senegal – A baseline intrahousehold survey was developed and then, in September, pilot tested in two villages outside of Dakar. Prior to piloting the survey, local scientists received training in both required COVID-19 precautions as well as extensive training on survey administration. The baseline pilot included testing the baseline survey as well as collecting watch data (to further test the watches *in situ*.) Subsequently, using the results of the pilot field test and feedback from the CRDES team, modifications and updates were made to the survey instrument, which is slated to be deployed at the end of November/beginning of December.

Initial results from the UCSB pilot test of the wrist-worn tracking devices and audio recording system suggest that the percent of activities captured by the audio method is not significantly different from the percent of activities captured by the written method (both around 80% for this population.) In terms of the broader aims of the project, this result is exciting and re-assuring, as it suggests that audio capture methods for time use are a reasonable substitute for traditional written methods. In fact, if we exclude three individuals with particularly low audio activity scores (bottom 12% of scores), then the audio logs slightly, but significantly out-perform the written logs in terms of number of activities captured (81% versus 80%). This indicates that while there may be some individual level variation that contributes to method performance, in our small sample, the audio logs appear to be a viable, if not slightly superior method to activity capture.

USA – Preliminary analyses of the local student pilot project (which tested the validity of the wrist-worn time tracking device and associated protocols using graduate and undergraduate student volunteers) conducted at UCSB in 2020 are underway. Student researchers have focused on proving the efficacy of the new audio recording method, i.e., assessing if the audio recording method performs as well as the traditional written method. We are now in the process of investigating individual level variation that might contribute to better or worse audio log performance. The UCSB Geography student researchers, along with project collaborators, are also drafting two related manuscripts for publication.

Capacity Building

The UCSB team continues to work closely with the Centre de Recherche pour le Développement Economique et Sociale (Research Center for Economic and Social Development) – CRDES. Through the collaboration with UCSB, CRDES has received a telecom device and four new computers to aid in analysis and data collection. Additionally, the team has received two installations of Withings Pulse HR smart watches (6 test watches and 100 new watches for the data collection period), two field-ready battery blocks for recharging, and a heart rate chest-strap.

Training was provided to project staff on the steps in administration of the baseline survey in the pilot phase. The baseline survey is comprised of three general parts: watch instrumenting, a household focus group on collective time use, and a traditional survey with various topic modules. The materials covered in the training largely focused on how to administer the focus group (and best practices), as well as specific instructions and troubleshooting with the survey administration.

In addition to the technological capacity-building, the UCSB team has provided several specific trainings for the two graduate students at CRDES including how to work with the watches and best practices and necessary precautions for dealing with COVID-19.

The post-doctoral researcher who completed her training at the University of Minnesota Population Center is now an employee of the U.S. Census Bureau.

Lessons Learned

From the baseline survey pilot, we have some key learnings related specific activities and question modules, as well as general lessons.

In order to secure the participation of the *chef du ménage* (household head) we found we need to schedule a time to return to each household when the *chefs* will be there. Hence, for rolling out the baseline survey for data collection we plan the first field day to be a "scheduling day" for our interviewers.

The purpose of the focus group is to prime participants into focusing on their activities from the day before, both as a household and individuals. The focus group uses a “gameboard” for types of activities, and has individuals place beads in each category to capture hours. We are rethinking how effective this focus group approach is for priming purposes, and if it is worth the time it takes to administer.

In our initial baseline survey, we have some modules for some household members, but generally everyone in a household receives similar questions. This was intentional so that we could verify different aspects of household function across individuals, but partners at CRDES suggest that in the field, the repetition is taking too long, and that some participants are uncomfortable with some questions (and some interviewers are uncomfortable asking those questions.)

COVID-19 and human subjects research requires significant schedule flexibility. In addition to taking precautions in research collection (both for participants and research team members), it can be helpful to take advantage of relatively low transmission rates/areas in planning fieldwork. This requires greater flexibility for both on-the-ground research team members and distant collaborators to be ready to go quickly, effectively, and safely. Requesting IRB protocols to be approved with other institutions takes time- on the order of a month if pushed to be done quickly. Requesting IRB protocols to be approved with international institutions takes much longer. Knowing the lengths on these approval times helps us to better plan future data collection timelines.

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 over 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 FY21.

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	Country of Training	Brief Purpose of Training	Number Trained		
			M	F	Total
1-15 Oct 2020	Ghana	Training for 800 female farmers working under the Farmer Pride aggregator on how to use tarpaulins to dry their groundnuts and reduce aflatoxin risk in marketed groundnuts.	0	800	800
10 Sep 2021	Ghana	Nutritional training to inform parents of healthy food choices and best practices	18	2	20
10 Sep 2021	Ghana	Nutritional training to inform parents of healthy food choices and best practices	36	36	72
17 Sep 2021	Ghana	Nutritional training to inform parents of healthy food choices and best practices	50	32	82
27 Jul 2021	Ghana	Day 1 – Ghana Groundnut Working Group: Annual meeting of stakeholders along the Ghana groundnut value chain in Tamale	49	9	58
28 July 2021	Ghana	Day 2 – Ghana Groundnut Working Group: Annual meeting of stakeholders along the Ghana groundnut value chain in Tamale	50	7	57
30 Aug 2021	Ghana	Training of testers on NIH Toolbox Neurocognitive testing and Keynote testing module for School Feeding in Ghana project	3	2	5
23 Nov 2020	Ghana	Workshop to train scientists on a risk management tool developed for farmers and advisors in USA and Malawi, as well as to develop a similar tool for peanut farmers in Ghana. Participating institutions were CSIR-Savanna Agricultural Research Institute, CSIR-Crops Research Institute, Kwame Nkrumah University of Science and Technology and University for Development Studies.	17	1	18
2 Oct 2020	Senegal	Workshop to provide information on the Optimized Shrub System in Senegal, share the experience that this project’s first year, and discuss soil degradation, means of maintaining soil fertility, the role of shrubs, as well as to collect information to better conduct the OSS	21	11	32
22 Apr 2021	Senegal	Workshop aimed to evaluate the 2020 Optimized Shrub System campaign on the basis of results obtained and involvement of each actor, and to prepare and plan the next agricultural campaign for the 2021 winter season.	16	1	17
10 Apr 2021	Senegal	Review the progress of Optimized Shrub System implementation and strengthen synergy among pilot farmers and beneficiaries.	28	22	50
28 Oct 2020	Uganda	Training to showcase improved varieties and products, train farmers on basic agronomic practices, provide market/product related information and disseminate printed materials	40	12	52

20 Nov 2020	Uganda	Training on improved groundnut varieties and recommended agronomic practices in groundnut production	17	10	27
30 Nov 2020	Uganda	Showcase improved varieties and allow farmers to choose based on traits of individual interest, train farmers in pest and disease identification and give them sustainable control measures, and discuss good agricultural practices along the entire groundnut value chain	35	31	66
16 Feb 2021	Uganda	Introduce Seed Quality project to enumerators, train on data collection tools	12	6	18
23 Feb 2021	Uganda	Session to teach technicians about various educational tools	9	2	11
26 Feb 2021	Uganda	Training to introduce participants to Breeding Management System (BMS), generate trials for MLT project in the BMS, design planting labels with barcodes, export designed fields from the BMS and upload in the tablets for practical data capture	11	3	14
31 Aug 2021	Uganda	Training for journalists on good agricultural practices and groundnut	2	1	3
11 Dec 2020	Uganda	Training for youth on participatory mapping and utilizing smartphones to take photos of the peanut value chain for a photovoice project.	31	29	60
29 Jan 2021	Uganda	Focus group interviews with photovoice participants	15	15	30
29 Apr 2021	Uganda	Discussion of photovoice participants' photos and focus groups	--	--	30
29 Apr 2021	Uganda	Training for youth participants in photovoice on better agricultural practices	15	15	30
7 Sep 2021	Uganda	Training of research assistants in the collection of baseline data for the project Regulation of Gut Microbiome in 6- to 9-year-old school children in Mukono district, Uganda. Training content included research ethics, consent process and review of consent forms; introduction to KoBo tool box; sampling, identifying households and selection of respondents; taking anthropometric measurements (height and weight); interviewing and translating; COVID-19 SOPs; pre-testing study tools	9	6	15
8 Sep 2021	Uganda	Training of Village Health Team members on the nutritional importance of peanuts and how they would assist research assistants to collect data in their respective village communities for the Gut Microbiome project	6	7	13
22-24 Jun 2021	United States	Annual Research Meeting for the Feed the Future Innovation Lab for Peanut, held virtually three hours a day over three days). The program consisted of 3 invited lectures on nutrition, remote sensing and partnerships, 3 graduate student presentations, 1 panel discussion on gender, 3 presentations on product life cycles and product profiles, and 7 breakout rooms on important issues.	76	40	116
10-17 Feb 2021	United States	Students were trained on how to wear activity monitors as part of the time-tracker project in Senegal – how to place the monitor on other people, and how to sync and collect the data.	0	4	4
1 Sep 2021	United States	This training was intended to instruct research assistants going out into the field on how to conduct the baseline survey, along with instructions for reporting difficulties/problems with the survey itself.	0	5	5
1 Sep 2021	United States	For those going into the field, to train on proper preventative measures to take for COVID-19 according to Senegalese, CRDES, and UCSB safety regulations.	0	5	5

	United States	Present peanut breeding program (including USAID / FtF links) to visiting US Congressional delegation visiting Texas A&M AgriLife Research and Education Center	12	8	20
22 Sep 2021	United States	To discuss recent data from a panel survey of 1,100+ households in rural Senegal about constraints to youth involvement in peanut cultivation	18	23	41

Long-term Training (sorted by Home Country)

Home Country	Trainee Number	Sex	University	Degree	Major	Program End Date	Degree Granted
Ghana	1	Female	Makerere Regional Center for Crop Improvement (MaRCCI), Makerere University	Master's	Plant Breeding & Genetics	Mar-22	N
Ghana	6	Male	University for Development Studies (UDS)	Master's	Biotechnology	Sep-20	N
Ghana	8	Male	Texas Tech University	Ph.D.	Plant and Soil Science	Aug-23	N
Ghana	24	Male	CSIR-College of Science and Technology	Master's	MPhil, Plant Breeding and Biotechnology	Dec-21	N
Ghana	26	Female	Kwame Nkrumah University of Science and Technology (KNUST)	Master's	Agronomy	May-21	N
Ghana	27	Male	University for Development Studies	Master's	Biotechnology	Apr-22	N
Ghana	28	Male	Kwame Nkumah University of Science and Technology (KNUST)	Ph.D.	Agronomy and Pest Management	Nov-22	N
Ghana	33	Male	University of Ghana	Master's	Plant Breeding	Aug-22	N
Ghana	40	Female	Makerere Regional Center for Crop Improvement (MaRCCI), Makerere University	Master's	Plant Breeding & Genetics	Jan-22	N

Home Country	Trainee Number	Sex	University	Degree	Major	Program End Date	Degree Granted
Ghana	43	Male	Kwame Nkrumah University of Science and Technology (KNUST)	Master's	Plant Breeding	Dec-21	N
Ghana	48	Male	SARI-UDS	Ph.D.	Agronomy and Pest Management	Sep-22	N
Ghana	56	Male	University of Ghana	Ph.D.	Agricultural Extension	Dec-24	N
Ghana	57	Female	Kwame Nkrumah University of Science and Technology	Ph.D.	Horticulture and Seed Science and Technology	Nov-24	N
Ghana	60	Male	University for Development Studies	Master's	M.Phil. in Biotechnology	Nov-22	N
Ghana	61	Male	West Africa Centre for Crop Improvement, University of Ghana	Ph.D.	Plant Breeding	Dec-19	Y
Ghana	62	Male	University of Ghana	Ph.D.	Plant breeding	Dec-21	N
Ghana	65	Male	University for Development Studies	Master's	Crop Science	Dec-21	N
India	49	Male	ICRISAT	Master's	Genetics and Plant Breeding	Aug-20	Y
Kenya	7	Female	Makerere Regional Center for Crop Improvement (MaRCCI), Makerere University	Master's	Plant Breeding & Genetics	Jan-22	N
Kenya	31	Female	Mekerere University	Ph.D.	Agronomy	Oct-22	N
Malawi	3	Male	LUANAR	Master's	Crop production	Jan-23	N
Malawi	25	Male	Lilongwe University of Agriculture and Natural Resources, Bunda College	Master's	Master of Science in Agronomy	Dec-21	N

Home Country	Trainee Number	Sex	University	Degree	Major	Program End Date	Degree Granted
Malawi	36	Female	LUANAR	Master's	Agronomy	Jan-23	N
Malawi	54	Male	Lilongwe University of Agriculture and Natural Resources	Master's	Impact of agronomic practices on groundnut seed quality	Sep-22	N
Niger	10	Male	ICRISAT	Ph.D.	Agrophysiology	Dec-22	N
Niger	15	Female	ICRISAT	Ph.D.	Agronomy	Dec-22	N
Senegal	5	Male	High School for Agricultural Engineering, Thies University/ENSA	Master's	Agricultural Engineering	Oct-21	N
Senegal	9	Male	National Superior School of Agriculture (ENSA), University of Thies	Master's	Agricultural Engineering	Oct-21	Y
Senegal	16	Female	National Superior School of Agriculture (ENSA), University of Thies	Master's	Agricultural Engineering	Jul-21	N
Senegal	17	Male	Ecole Nationale Superieure d'Agriculture de Thies	Master's	Agricultural Economics	Oct-21	N
Senegal	19	Male	University of Thies, National Superior School of Agriculture (ENSA)	Ph.D.	Agronomic Sciences	Jun-23	N
Senegal	20	Male	National Superior School of Agriculture (ENSA), University of Thies	Master's	Agronomy with Rural Economics specialization	Dec-20	Y
Senegal	21	Male	National Superior School of Agriculture (ENSA), University of Thies	Master's	Agronomy with Rural Economics specialization	Dec-20	Y
Senegal	22	Male	ISRA-CERAAS	Ph.D.	Molecular Genetics	Dec-22	N

Home Country	Trainee Number	Sex	University	Degree	Major	Program End Date	Degree Granted
Senegal	23	Female	ISRA/CERAAS	Ph.D.	Molecular Genetics	Jun-23	N
Senegal	32	Female	Ecole Nationale Supérieur Agricole, University of Thies	Ph.D.	Agronomy with Rural Economics specialization	Nov-21	N
Senegal	38	Female	Centre de Recherche pour le Dévelopement Economique et Sociale	Ph.D.	Agricultural Economics	Jun-24	N
Senegal	39	Female	National Superior School of Agriculture (ENSA), University of Thies	Master's	Agricultural Engineering	Jul-20	Y
Senegal	42	Male	Ecole Nationale Superieure d'Agriculture de Thies	Master's	Agricultural Economics	Oct-21	N
Senegal	45	Male	High School for Agricultural Engineering, Thies University/ENSA	Master's	Agricultural Engineering	Oct-21	N
Senegal	47	Female	Ecole Nationale Superieure d'Agriculture de Thies	Master's	Agricultural Economics	Oct-21	N
Senegal	51	Female	Centre de Recherche pour le Dévelopement Economique et Sociale	Ph.D.	Agricultural Economics	Jun-24	N
Senegal	52	Male	National Superior School of Agriculture (ENSA), University of Thies	Master's	Agricultural Engineering	Jun-21	Y
Senegal	63	Female	University of Dakar	Master's	Breeding/physiology	Mar-22	N
Senegal	64	Male	University of Georgia	Ph.D.	PhD in Agricultural and Applied Economics	Jun-25	N
Senegal	66	Female	ENSA	Master's	Agricultural Engineering	May-22	N
Tanzania	34	Female	Makerere University	Master's	Plant Breeding and Seed Systems	Jan-22	N

Home Country	Trainee Number	Sex	University	Degree	Major	Program End Date	Degree Granted
Uganda	12	Female	Makerere Regional Center for Crop Improvement (MaRCCI), Makerere University	Ph.D.	Plant Breeding & Genetics	Aug-22	N
Uganda	13	Male	Makerere Regional Center for Crop Improvement (MaRCCI), Makerere University	Master's	Crop Science (Crop Protection)	May-22	N
Uganda	35	Male	Makerere Regional Center for Crop Improvement (MaRCCI), Makerere University	Master's	Crop Science	Sep-22	N
Uganda	41	Female	Makerere University	Master's	Food Science and Technology	Jul-22	N
Uganda	46	Female	Makerere University	Master's	Agricultural and Applied Economics	Jul-22	N
Uganda	50	Female	Makerere University, School of Women and Gender Studies	Post-doctoral Studies	Post-Doctoral on Gender Studies and Development including Agriculture	Sep-22	N
United States	2	Female	The University of Georgia	Post-doctoral Studies	Nutrition and Health	Jun-22	N
United States	4	Female	The University of Georgia	Post-doctoral Studies	Gender and Youth	Sep-21	N
United States	11	Male	University of Georgia	Ph.D.	Agricultural and Applied Economics	May-23	N
United States	14	Female	University of California at Santa Barbara	Ph.D.	Geography	Jun-23	N
United States	18	Female	University of Tennessee	Master's	Agricultural Leadership, Education and Communications	Dec-20	Y

Home Country	Trainee Number	Sex	University	Degree	Major	Program End Date	Degree Granted
United States	29	Female	University of Minnesota	Post-doctoral Studies	Demography	Dec-21	Y
United States	30	Female	University of California, Santa Barbara	Post-doctoral Studies	Demography	Dec-21	N
United States	37	Female	Pennsylvania State University	Ph.D.	Rural Sociology	May-22	N
United States	44	Male	University of Georgia	Ph.D.	Agricultural and Applied Economics	Dec-20	Y
United States	53	Male	University of California, Santa Barbara	Bachelor's	Anthropology	Jun-24	N
United States	55	Female	University of California, Santa Barbara	Bachelor's	Statistics and Geography	Jun-22	N
United States	59	Female	University of Tennessee	Master's	Department of Agricultural Leadership, Education and Communications	Sep-22	N
Zambia	58	Male	African Center for Crop Improvement	Ph.D.	Plant Breeding	Oct-23	N

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

Project, program and student events

Quarterly meetings with each project PI were conducted to discuss progress and plans for the next quarter. Impacts of COVID-19 were also discussed and each project is considering the need for an extension to complete the original objectives.

Learning and communications

In the first half of the year, the communications department of the ME, working with SAWBO, completed two short animations explaining proper early-season and late-season production practices in Malawi. Communications published 20 original articles about innovation lab activities and findings through the lab's website and at Agrilinks. Two additional articles were distributed through the University of Georgia news service and were circulated widely in general interest media. A student worker was hired to write, while learning about USAID and global food security. In spring, the lab launched a digital learning platform called Groundnut Academy, https://groundnut-academy.uga.edu/ In the first three months, 40 students from 18 countries completed a basic course in Groundnut Agronomy. In fall, the ME produced the first of several webinars to disseminate research findings and stoke interest in the global community about the latest research into groundnut and social science surrounding its production. Forty people attended live an another 37 registered to watch a later recording.

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.

Presentations and Publications

Butts, C. (February 2021). Hermetic Storage of Shelled Peanut Using the Purdue Improved Crop Storage Bags(pp.1-36). Peanut Science, 1, United States. doi:Peanut Science.

Chintu, J. M. M.. A Proposal to Release Two Spanish Groundnut Genotypes ICGV-SM 08528 and ICGV-SM 03530 for Cultivation in Malawi.

Hoisington, D. (July 2021). Feed the Future Innovation Lab for Peanut Employs Novel Approach to Research During Pandemic Travel Restrictions. American Peanut Research and Education Society, online. https://apresinc.com/wp-content/uploads/2021/07/Hoisington-Poster-2021-PDF-2.pdf.

Hoisington, D. National Coordination Workshop of Feed the Future Innovation Laboratories.

Marter-Kenyon, J. (November 2020). Reflections on Gender Integration at the Feed the Future Innovation Lab for Peanut. Presentation at GREAT Symposium on Gender Responsive Crop Breeding, (Virtual).

Marter-Kenyon, J. (April 2021). Gender and Time Poverty in Rural Senegal: Effects of Seasonality and Intrahousehold Structure. Presentation at Association of American Geographers (AAG) Annual Meeting, (Virtual).

Matumba, L., et al. (October 1, 2020). Estimating Aflatoxin B1 (AFB1) In Farmers In-shell Groundnuts by Testing Various Groundnuts-Grade Components in Malawi. Lilongwe University of Agriculture and Natural Resources.

Meya, M., et al. (September 30, 2021). Evaluating the Effectiveness of Aflasafe and Agronomic Practices on Aflatoxin Practices on Aflatoxin Contamination and Productivity in Groundnut Production in Malawi. Lilongwe University of Agriculture and Natural Resources.

Other Topics

None to report.

Issues

None to report.

Future Directions

The USDA collection will send seed of lines that enhance the existing 300-line core set to Senegal and Uganda to be multiplied and distributed to African national programs for phenotyping. The core 300 lines representing the diversity of African peanut varieties will be evaluated further for disease resistance and drought tolerance in trials conducted by the national programs in Senegal, Ghana, Uganda, Malawi, Zambia and Mozambique and for the first season in Burkina Faso, Togo and a second location in Ghana. Other countries in Africa have expressed interest in evaluating the lines and an effort will be made to provide seed to these programs.

The nutritional composition of the 300 lines will be analyzed by the USDA quality lab in Raleigh, NC using seed samples provided from Senegal and Uganda. Full genome sequences will also be completed by HudsonAlpha on the 300 lines and all data made available in the public domain.

Lines derived from wild relatives will be evaluated for a third season in Senegal and Uganda under leaf disease pressure to confirm the high level of resistance identified in the first season. Molecular markers for groundnut rosette resistance will be confirmed in field trials and made available to breeding programs to add resistance into new varieties. Sequencing of the resistant and susceptible parental lines will be completed and used to identify the specific genes involved in resistance. A new population segregating for rosette resistance will be genotyped by HudsonAlpha and phenotyped under field conditions in Uganda. The data will be used to confirm the genetic locations of resistance.

Laboratory tests will confirm that a line identified as highly resistant to *Aspergillus flavus* is, in fact, resistant to the fungus that causes aflatoxin contamination. Other lines also will be screened for resistance, and crosses will be advanced to introduce the resistance into susceptible varieties, particularly high oleic varieties.

A third season of field trials will be conducted in Ghana and Malawi to evaluate production packages consisting of quality seed, inoculants, fertilizers and weed control to find optimal packages for farmers. Cultivated crop and yield estimates, along with GPS data, for farms in Malawi and Senegal will be used to confirm that satellite images can be used to identify peanut fields and estimate yields and plant health. The Risk Index Tool will be further enhanced with additional input from local experts in Ghana and Malawi.

A third year of field trials to determine the impact of the optimize shrubs system on groundnut production in Senegal will be conducted, including training for farmers.

Courses on IPM and food safety will be added to the Groundnut Academy. The courses will be translated to French, Portuguese and Spanish. A new version of the Production Guide for Malawi will be produced and options to use the manual as a template for other countries explored.

Motorized sheller/aspirator and grading equipment will be tested by the national programs in Senegal, Ghana, Uganda, Malawi, Zambia and Mozambique to optimize the equipment for use with local varieties. Breeding and seed production programs will use the equipment to more efficiently shell peanuts in variety trials and seed production nurseries increasing the amount of seed and decreasing the time spent shelling.

School feeding trials will continue in northern Ghana to assess the impact of the novel peanut-based school foods on cognitive learning and health. The trials are expected to end by mid-2022 with results available by the end of November 2022.

Feeding trials using locally produced peanuts will be conducted in Uganda to evaluate the effect of peanuts on the gut microbiome in school children. The samples collected will be sent to the US for evaluation.

Youth in Uganda will continue to take photos as part of the photovoice project. Visits by the project team will occur during FY22. Time-monitoring devices will be deployed in the Kaolack area of Senegal and monitored during FY22. Analysis of the household surveys on time-use in northern Ghana will be finalized. Farmer field schools will introduce innovations (planters and tarps for drying) that will be evaluated for impacts on time use.

Plans are underway to hold a final research meeting in each of the major target countries, Ghana, Malawi, Senegal and Uganda, during FY22. These meetings will be attended by all local partners, PIs with projects in the respective country, and EAP and ME staff able to travel. Discussions on the results and potential future activities as well as site visits are planned.

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

Institution	Project Name	Start Date (mm/dd/yy)	End Date (mm/dd/yy)	FY 2021 Budget	Total Budget
California				**$131,622**	**$561,337**
Stanford University	B5: 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	$12,000	$71,000
University of California, Santa Barbara (UCSB)	D5: Gender, Fertility, and Intra-household Dynamics and resilience in the Senegalese Peanut Farmers in Ghana	7/1/2019	11/30/2022	$119,622	$490,337
District of Columbia				**$56,888**	**$108,176**
International Food Policy Research Institute (IFPRI)	D2: 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	$56,888	$108,176
Florida				**$5,040**	**$15,120**
University of Florida (UFL)	B4: 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	$5,040	$15,120
Georgia				**$326,345**	**$1,325,822**
University of Georgia (UGA)	A3: Leveraging Genetics Resources to Enhance Peanut/Groundnut Breeding in Africa and the United States	10/1/2018	9/30/2022	$0	$21,700
	A8: Use if Novel Genetic Diversity for Peanut Varietal Development in East Africa	9/1/2018	9/30/2022	$43,234	$110,000
	A9: Incorporating New Wild Alleles to Improve Elite African Peanut Cultivars	10/1/2018	9/30/2022	$26,527	$110,000
	A11: Mapping Groundnut Rosette Virus (GRV) Resistance to Marker-assisted Selection	10/1/2018	9/30/2022	$7,000	$93,080
	D2: Connecting Male and Female Smallholder Farmers to Premium Groundnut Markets and Aflatoxin-Mitigating Technologies through innovation Aggregator Contracts	8/1/2018	9/30/2022	$78,079	$215,331
	B2: Identifying the Alternative Host for Groundnut Rosette Disease Virus Complex	8/1/2018	9/30/2022	$7,601	$32,800
	C1: Regulation of Gut Microbiome by Peanut Supplement in Youth with both Genders	4/1/2019	9/30/2022	$116,804	$453,555
	A6: Enhancing the Genetics Potential of Peanut Production in Eastern/Southern Africa *(sub-award from NASARRI)*	2/1/2019	7/31/2022	$0	$15,400
	A7: Enhancing the Genetics Potential of Peanut Production in West Africa *(sub-award from ISRA)*	2/1/2019	7/31/2022	$0	$15,400
	A3: Genotypic Analysis of Peanut using Axiom_Arachis2 SNP Array	5/1/2018	4/30/2019	$17,105	$123,775

Institution	Project Name	Start Date (mm/dd/yy)	End Date (mm/dd/yy)	FY 2021 Budget	Total Budget
	D1: Retaining Next Generation Farmers in the Senegalese Groundnut Basin *(sub-award from Virginia Tech)*	3/1/2019	11/31/2022	$29,995	$139,871
USDA-ARS National Peanut Research Laboratory (NPRL)	Technical Evaluation of PICs Bags for use with Shelled Peanuts	5/1/2018	4/30/2019	$0	$0
Mississippi				**$0**	**$86,711**
Alcorn State University	B7: Modern Peanut Technology Adoption and Smallholder Farmers Welfare	9/1/2021	11/30/2022	$0	$86,711
Missouri				**$202,841**	**$531,193**
Washington University (WU)	C2: Integrating the Power of Peanuts into School Feeding	1/1/2019	9/30/2022	$202,841	$531,193
North Carolina				**$86,407**	**$409,330**
North Carolina State University (NCSU)	B5: Examining the Utility of Satellite-based Assessment in a Maize/Peanut Agroecosystem for Estimated Crop response in Malawi	10/1/2018	9/30/2022	$26,730	$86,604
	B6: Development of Efficient Agronomic Peanut Production Packages for Malawian Farmers	10/1/2019	9/30/2022	$31,437	$113,811
	B4: Development and Delivery of Improved Production and Pest Management Packages to Peanut Farmers in Ghana	10/1/2018	9/30/2022	$28,240	$129,725
	B1: 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				**$34,286**	**$203,979**
The Ohio State University (OSU)	B3: Optimized Shrub System (OSS): an Innovation for Landscape Regeneration and Improved Resilience for the Peanut-Basin on Senegal	9/1/2018	8/31/2022	$34,283	$203,979
Pennsylvania				**$98,146**	**$371,329**
Pennsylvania State University (Penn State)	D3: Time Poverty among Women Smallholder in Ghana: implications for Gender Priorities in the Peanut Value Chain	3/1/2019	10/31/2022	$98,146	$371,329
Tennessee				**$33,417**	**$184,228**
University of Tennessee (UT)	D4: Photovoice for Youth Empowerment in Peanut Value Chain	3/1/2019	2/28/2022	$33,417	$184,228
Texas				**$88,608**	**$384,704**
Texas Agriculture and Mechanical College (Texas A&M)	A12: Breeding and Enhancement of Tolerance to Water Deficit, Resistance to leaf Spot and Improved Oil Composition on Peanut	10/1/2018	9/30/2022	$23,411	$86,431
Texas Tech University (TTU)	A10: Developing Aspergillus flavus Resistance Peanut using Seed Coat biochemical marker(s)	10/1/2018	11/30/2022	$65,197	$299,273
Virginia				**$102,790**	**$317,499**
Virginia Tech (VT)	A5: Integration of High Throughput Phenotyping(HTP) for Enhancing Breeding Programs in Senegal, Ghana, Uganda, and Regional Cooperation	9/1/2018	11/30/2022	$41,000	$129,080

Institution	Project Name	Start Date (mm/dd/yy)	End Date (mm/dd/yy)	FY 2021 Budget	Total Budget
	B4: 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	$5,040	$15,120
	D1: Retaining Next Generation Farmers in the Senegalese Groundnut Basin	3/1/2019	11/30/2022	$56,750	$173,499

Appendix B. Success Stories

Wild relatives offer genetic diversity to African breeders

David Bertioli and Soraya Leal-Bertioli introduced new synthetic allotetraploids and tracked peanut diversity around the globe.

Working with wild species related to peanut, scientists working with the Peanut Innovation Lab have located regions in the DNA where resiliency traits lie, giving breeders new genetic resources to use in developing improved varieties.

Peanut has an exceptionally narrow genetic base and very low DNA polymorphism, challenging breeders as they look to incorporate resilience to drought, heat, pests and disease. Wild relatives offer untapped genetic diversity – which has been used to create some modern improved varieties – but are difficult to work with because peanut's diploid relatives are not sexually compatible with cultivated tetraploid peanut.

Peanut Innovation Lab scientists David and Soraya Bertioli (who serve as PIs on two separate projects within the lab) recently published a paper in the US Proceedings of the National Academy of Science on the strength of the genes in the wild species and how their contributions became lost in the pedigree of some modern varieties (https://www.pnas.org/content/118/38/e2104899118/tab-article-info).

Through their work in their University of Georgia Wild Peanut Lab, the Bertiolis have produced synthetic allotetraploids (lines that behave like cultivated peanut but are derived from wild relatives) from several of these untapped wild relatives, lines that the Peanut Innovation Lab partners tested in Africa this year.

For example, five advanced lines of synthetic allotetraploids were transferred from Georgia to Uganda, where they were field tested for resistance to root knot nematode.

In real world conditions and compared to improved varieties currently in use in the country, four of the lines were destroyed by nematodes. But one line had more resistance and a higher stand count than the other wild relatives and the improved varieties.

"Thus, this line presents great promise as a new source of genes for resistance to nematodes," Soraya Leal-Bertioli said. Nematodes are microscopic worms that invade the roots of plants, including peanut. They can devastate a crop resulting in little to no yield. Since chemical nematicides are not a general option in much of the developing countries, finding genetic resistance that can be bred into varieties is about the only option.

"Finding such a resistant source is a great first step in developing varieties that will resist the pest in farmers' fields," said David Okello Kalule, groundnut breeder with the Ugandan national program.

Similar work that David Bertioli is conducting with partners in Senegal identified lines that were more resistant to leaf spots than a widely grown improved local variety. These wild relative derivatives also had larger biomass (an important trait given the value of the haulms as animal feed), larger seed size (preferred by local farmers) and flowered earlier (an important trait to avoid late season drought).

By working with partners in two countries, the Bertiolis are able to screen more materials for a larger number of contrasting traits. Thus, increasing the likelihood to finding the best sources of resistance to build broad resilience into African peanut varieties.

Homing in on destructive rosette disease through genomics

A group of researchers identified where within peanut's genome the resistance to Groundnut Rosette Disease (GRD) lies, which will enable targeted plant breeding to give farmers a variety that can withstand the disease. By finding the major locus controlling GRD resistance and validating that locus as suitable for marker-assisted selection, the team achieved a historic accomplishment in the fight against the most destructive peanut disease in Africa.

The Peanut Innovation Lab is working on several fronts to fight GRD, a disease that is caused by a complex of viruses spread by aphids in sub-Saharan Africa. The disease is worst in tropical climates and can cause 40-100% yield reduction; there are no effective treatments for the disease and spraying to control the aphids that transmit the disease involves pesticides that are costly and toxic to the environment. Knowing the genes and having markers for these will help breeders more easily incorporate resistance into new varieties and provide farmers protection in the best way possible – in the seed.

Esther Achola, a PhD student at Makerere University, has worked to find resistance to groundnut rosette disease in the peanut gene.

To locate the resistance genes, the Innovation Lab project Mapping Groundnut Rosette Disease (GRD) resistance for marker-assisted selection https://ftfpeanutlab.caes.uga.edu/Research/variety-development/mapping-grv-resistance.html was able to benefit from other Innovation Lab projects that had collected hundreds of peanut lines from across the continent and genotyped using modern molecular tools to assess the genetic diversity of the collection. The results were used to identify a core set of 300 lines that seem the most valuable for breeding and research.

By determining which of the 300 lines were resistance to GRD, scientists were able to quickly identify where the genes for resistance were located. Breeders have already started to cross the GRD-resistant varieties with other varieties that are high oleic, high yielding and have other desirable qualities.

Since the identification of the disease more than 100 years ago and the identification of resistant germplasm in the 1980s, this is the very first time there have been a genetic locus identified to be used for breeding.

With the USAID network and the breeding resources through Intertek, the markers – once validated – will be immediately available for all breeders. All they have to do is send leaf or seed chips and they will get genotypes back for their lines telling them which lines contain the genes for resistance.

Pan-Africa team collaborates to share diversity, find resilience

A network of plant breeders across Africa continues to grow and produce results for farmers.

Brought together by innovation lab projects and funding, a network of plant breeders in nine countries spanning West Africa and East and Southern Africa have been sharing germplasm and knowledge, which has led to new varieties in Malawi and soon will lead to another new variety in Zambia.

While plant breeders have worked with colleagues in neighboring countries for years, a Peanut Innovation Lab project to assess the genetic diversity of peanut across the continent has created a more formal network and equipped the group with a common data management platform and ontology to work together.

Beginning in 2018, the project called on breeders to nominate the lines that they use in their breeding programs, compiled those 1050 lines, performed DNA analysis, and selected 300 lines for a core collection to be phenotyped by all the breeders.

Technicians in Mozambique harvest groundnut as part of work to phenotype lines that represent the diversity of groundnut across Africa.

While that work has led to many successes and accomplishments – including repatriating Togo's germplasm collection, which was lost in a power outage – 2021 brought a particular success in Zambia.

The groundnut breeder there – Lutangu Makweti – selected eight lines from the core collection to use as parents in the Zambian groundnut breeding program. The lines – which came from Uganda, Senegal and Togo – hold traits like resistance to early leaf spot and groundnut rosette disease. The increased diversity has been a boon to the breeding program, Makeweti said.

At the same time, a variety developed by the breeder in Uganda and part of the core collection – Serenut 14 – seems perfectly adapted to Zambia, and has been submitted for Distinctness, Uniformity, and Stability (DUS) tests and Value for Cultivation and Use (VCU) tests, and is expected to be released in Zambia in 2023.

When asked why the network has worked so well, one of the breeders said that they all see the benefit from having access to so many diverse lines, but most importantly they all trust each other. Going forward, the breeders are looking to welcome additional countries to the network and meet the demands for better groundnut varieties in Africa.

Leveraging digital communication tools in a pandemic

Communicating in a pandemic can be tricky. Whether researchers were looking to collect data or deliver messages, they had to use creativity.

The ongoing Covid-19 pandemic created a host of challenges in 2021, but digital tools helped the Peanut Innovation Lab continue to empower farmers though information, even as governments limited travel and extension programs limited face-to-face training to prevent disease spread. With in-person farmer field days limited due to the pandemic, innovation lab scientists brainstormed ways to continue to provide information about basic agronomic practices to smallholder farmers.

ANIMATIONS

Working with Scientific Animations Without Borders (SAWBO), the Peanut Innovation Lab created a pair of animations giving farmers valuable advice on growing, harvesting, drying and storing groundnut, relaying to smallholder farmers proven methods to protect and improve yield.

The lab began planning for the animations by surveying agricultural researchers, agro-business professionals and extension specialists in Malawi in early 2020. The survey asked their opinions about what information is most important for farmers to know, as well as what gaps they see in farmers' knowledge. That feedback was used to make a voice-over script, then graphics artists went to work bringing the lessons to life.

The animation was recorded in English, as well as Chichewa, the local language, and in both male and female voices.

While the videos can be presented at in-person educational events, trainings and meetings, they also are shared on blogs, in traditional media and through social media. While there is no way to know how many people share the videos once they download them, the two animations have been viewed nearly 2,000 times and anecdotally are very popular with trainers and farmers alike.

GROUNDNUT ACADEMY

Even before the Covid-19 pandemic, colleges around the world started to use a mix of classroom and digital courses to help students learn.

Following this trend in digital learning platforms, the Peanut Innovation launched the Groundnut Academy, a digital learning platform that allows students around the world to log on and learn about good production practices, food safety and other topics of interest.

The first course in Basic Agronomy, which published in June, covers the fundamentals of groundnut – the physiology of the plant, how it grows and some of the most important considerations in cultivating the plant. A second course in aflatoxin management followed in the late summer.

Each lesson quizzes students to allow them to evaluate whether they absorbed the most important information. At the end of the course, a final exam reviews the material and a passing grade of 80% earns a certificate to demonstrate completion of the course.

The Groundnut Academy can grow to serve all those audiences and give people a place to learn at their own pace. The courses are designed and taught by experts in their particular area of groundnut, allowing the Peanut Innovation Lab to connect students to its global network of peanut scientists. In the first three months, 40 students from 18 countries completed a basic course in Groundnut Agronomy.

GLOBAL TRAINING

These digital adaptations were tested throughout the year, as the lab trained extension workers who were then deployed to train farmers.

First through training with the USAID Malawi Agricultural Diversification Activity, the lab offered video lectures to relay important agronomic information to agents working for agrobusinesses. Paired with the second edition of the Guide to Groundnut Production in Malawi and live sessions over video conference, the lab was able to offer context and answer questions on par with an in-person training.

Partners also have begun to use the Groundnut Academy to prepare trainers who work with producers through the USAID Farmer-to-Farmer program. By taking courses at their convenience, trainers prepare themselves to meet with experts through video conference.

This Annual Report (covering Fiscal Year 2021, which ended September 30, 2021) is a publication of the Feed the Future Innovation Lab for Peanut, also called the Peanut Innovation Lab.

Published December 2021

"This report was made possible through support provided by the U.S. Agency for International Development under the terms of Cooperative Agreement No. 7200AA18CA00003. The opinions expressed herein are those of the author(s) and do not necessarily reflect the views of the U.S. Agency for International Development."

USAID
FROM THE AMERICAN PEOPLE

UNIVERSITY OF GEORGIA
Peanut Innovation Lab
College of Agricultural & Environmental Sciences