Peanut CRSP 2012 Final Report for Project UGA136.

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1. Final Summary

a. Overall Goal

The overall goal of project UGA136 was and remains to minimize crop losses due to groundnut rosette disease (GRD) and foliar pathogens in sub-Saharan Africa. GRD is the most destructive viral disease of groundnut in sub-Saharan Africa (SSA). The disease, which is endemic to SSA, causes greater yield losses than any other virus disease affecting groundnut in the world. In addition to yield losses, GRD epidemics have a long-term debilitating impact on groundnut production since farmers typically decrease production following epidemics to avoid future risk. In addition to GRD, a number of foliar pathogens significantly affect groundnut yields in SSA, especially late leaf spot disease (LLD). High yield losses caused by these pathogens coupled with low yielding cultivars were typical problems that farmers had to address in production prior to this project. Therefore, our approach to managing these diseases and to increasing yields was to identify GRD and LLD resistance in high-yielding groundnut varieties with drought tolerance that would subsequently be released to farmers or would be used in a breeding program to introduce the resistant traits into high yielding cultivars for release. The technology transfer of the new GRD and LLD resistant varieties would be significant tools in alleviating food security issues and reducing poverty in Uganda specifically and East Africa in general.

Five approaches were taken to address this goal during the last project cycle:
(1) Screen for and evaluate germplasm from ICRISAT for GRD and LLD resistance and drought tolerance in Uganda and East Africa.
(2) Breed GRD resistance from available resistant cultivars into susceptible landraces and cultivars preferred by farmers and consumers.
(3) Disseminate released germplasm with GRD and LLD resistances and drought tolerance to groundnut growing countries of East and West Africa
(4) Provide a rigorous and robust educational program (extension) to farmers on GRD-resistant cultivars, sustainable disease management strategy and technology transfer.
(5) Begin developing transgenic groundnut with genetically engineered resistant the GRD.

b. Significant technical Achievements:

Host Country

i). At the beginning of the project (2008) 75 ICRISAT-Malawi germplasm lines were imported and screening was initiated to identify lines with resistance to GRD, leaf spot disease and leafminer infestation. Crosses were also initiated with local

landraces (Egoromoit, Acholi White, Erudurudu Red, and Gwerinut) and released lines with GRD resistance to introgress GRD and late leaf spot resistance into locally preferred cultivars. Subsequently, in 2010, additional lines from ICRISAT-Mali were introduced into the screening program for GRD and late leaf spot disease resistances. The outcome of the present project has been the release within Uganda of 9 new high yielding varieties having various levels of resistance to GRD and late leaf spot disease (LLD). Of the newly released lines, 8 are the Virginia botanical type while one is a Spanish botanical type. Half have red seed coats while half have tan coats to take into account consumer preferences, as well as having soft shells for easy shelling, sweet taste, high kernel yield, good confectionary qualities, ease of harvest and high oil content of up to 48%. All are early maturing (90-100 days for the Spanish type and 100-110 days for the Virginia types) and are therefore drought resistant in that they mature before the unpredictable weather patterns occur late in the growing seasons.

In addition to the released lines a number of elite groundnut accessions with resistance to GRD (7 Spanish-type and 9 Virginia type) and LLD (2 Spanish type and 4 Virginia type) have been identified and recommended for GRD and LLD management programs. Some of these accessions will be released following further evaluations.

ii). Enhanced germplasm with GRD and LLD resistance previously released in Uganda with support from UGA136 has been requested by and disseminated to South-Sudan, Sudan, Ethiopia, Mozambique, Ghana, Ivory Coast, Sierra Leone and the Central African Republic. Because GRD and late leaf spot are endemic to sub-Saharan Africa, the disseminated varieties are in high demand.

U.S.A

A total of 15 transformed groundnut lines have been generated and small seed increases have been done. Testing of the lines for genetically engineered resistance to GRD in Uganda awaits the approval of Ugandan agencies with regulatory control over the propagation of genetically modified organisms. The lines cannot be analyzed for functional resistance in the USA since the viral disease is not present.

c. Significant Issues/Challenges:

While the breeding program has gone well with the release of 9 enhanced germplasm lines, two issues have been challenging. The first is the lack of reputable seed companies in Uganda and throughout East African. Distributing pure seed to farmers remains a challenge. While the national seed bank distributes genetically pure seed effectively and NGOs assist in this process, the eventual evolution of reputable private seed companies would greatly expedite the process and are needed to support the growing agricultural sector. Second, the Ugandan agencies that regulate the testing and propagation of transgenic plants, in this case transgenic

groundnut, have been very slow in approving the testing of transgenic plants, although Uganda is transgenic friendly and continues to move forward with transgenic research in general. I expect that the regulatory agencies will speed up the process as the time passes and transgenic research programs within Uganda continue to expand and grow. However, when approved, the testing of transgenic lines will be expensive and will require additional resources.

Early in the last grant cycle three projects in Uganda formed a collaborative approach to addressing broad, but overlapping, goals. Initially there were growing pains as the three projects started to coordinate the various scopes of work and determine the extent to which budgets would overlap. The end result was collaboration between projects UGA136, NMS172 and UCN139, which resulted in a very productive approach to addressing the goals of the three projects based on leveraging limited resources. The diverse intellectual approach was highly successful and productive in quantifying the extent of impact made by the projects in Uganda and East Africa.

d. Capacity development:

Host Country:

i). The Groundnut Breeding Laboratory at the National Semi Arid Resources Research Institute (NaSARRI) near Soroti, Uganda was renovated during the project period, which included the purchase and installation of a new solar power system to provide a dependable source of power to the facility.

ii). A new Nissan pickup truck was purchased for the project and is used to visit trial sites throughout the growing seasons.

iii). A Weather Hawk weather station was purchased and located at NaSARRI

iv). 3 computers were purchased for the laboratory and the PI's use on the project.

v). Two GPS units were purchased for the project to better document trial sites involving research and farmers fields during extension related interactions.

vi). 15 tally counters were provided for data collection and determining incidence in trials and during on-farm visits.

vii). An SLR camera was purchased to digitally document disease incidence and severity levels, as well as extension and public relation events.

vii). Numerous hybridization kits and molecular biology kits and reagents were provided for research.

e. Human Capacity/training

David Kalule Okello
Male
Uganda
Ph.D. candidate
2015 estimated
Training in host country – Uganda

Is presently also the National Groundnut Breeder for the National Agricultural Research Organization (NARO) in Uganda.

f. Key workshops/short-term training

In collaboration with project UNC139.

Location	Type of Training	Male	Female	Date of Training
Uganda, Soroti	Workshop: Enterprise Budgeting… and farm Profitability Analysis	14	3	October 2012

g. Publications:

Refereed manuscripts and other articles

Okello, D.K., Biruma, M., and Deom, C.M. 2010. Overview of Groundnut research in Uganda: Past, Present and Future. African Journal of Biotechnology. 9(39): 6448-6459.

Thuo, M., Bell, A.A., Bravo-Ureta, B.E., Okello, D.K., Okoko, E.N., Kidula, N.L., Deom, C.M., Puppala, N. 2013a. Social Network Structures Among Groundnut Farmers. Journal of Agricultural Education and Extension. 19 (3). DOI: 10.1080/1389224X.2012.757244.

Thuo, M., Bell, A, Bravo-Ureta, B. E., Okello, D. K., Okoko, N., Kidula, N., Deom, C. and Puppala, N. "Effects of Social Network Factors on Information Acquisition and Adoption of Improved Groundnut Varieties: The Case of Uganda and Kenya." *Agriculture and Human Values* (2013b): Revise and resubmit.

Okello, D.K., Biruma, M., Deom, C.M., Puppala, N., Ininda, J., Monyo, E., and Oloka, H.K. (2013a). Groundnut Production Guide for Uganda: Recommended Practices for Farmers and Processors. National Agricultural Research Organisation, Entebbe, Uganda

Li, A., B. E. Bravo-Ureta, D. K. Okello, C. M. Deom and N. Puppala. "Groundnut Production and Climatic Variability: Evidence from Uganda." *Zwick Center, Working Paper*, February 2013.

Okello, D.K., Deom, C.M., Monyo, E., Puppala, N., Bravo-Ureta, B.E., Oloka, H.K. (2013b). Reaction of Elite Groundnut Lines to groundnut Rosette and Late leaf Spot Diseases in Uganda. Plant Health Progress – In review.

In Preparation

Okello, D.K., Deom, C.M., Puppala, N., Monyo, E. Bravo-Ureta, B. Registration of "Serenut 5R" Groundnut. Journal of Plant Registration. Manuscript in Preparation, 2013.

Okello, D.K., Deom, C.M., Puppala, N., Monyo, E. Bravo-Ureta, B. Registration of "Serenut 6T" Groundnut. Journal of Plant Registration. Manuscript in Preparation, 2013.

Asekenye, C., B. E. Bravo-Ureta, Mukherjee, A. Kihaga, D. Kalule Okello, N. Okoko, N. Kidula, M. Deom and N. Puppala. Productivity Gaps among Smallholder Groundnut Farmers in Uganda and Kenya: A Stochastic Production Frontier Approach. UConn, Manuscript in Progress, 2013.

Invited presentations at major international conferences:

D. K. Okello, C.M. Deom, B.U. Boris, H.D. Upadhyaya, P. Payton, K.R. Kottapalli, P. Kottapalli, S. Sanogo and N. Puppala. 2009. Screening for Rosette Resistance in Valencia Mini Core Collection in Uganda. American Peanut Research and Education Society (APRES) Conference. Raleigh, North Carolina USA. 2009.

Okello, D. K., Biruma M., Anguria, P, Nalyongo, P.W, and Deom, C.M. 2009. Participatory Improvement of Serenut 1R and Serenut 2 in Uganda. Program for Africa's Seed System Conference. Bamako, Mali. 2009.

D.K. Okello, C.M. Deom, and N. Puppala. 2010. Screening Groundnut Accessions for Rosette Virus and Leaf Spot Diseases in Uganda. ACS International Annual Meeting. Long Beach, California, USA. 31 October - 4 November 2010.

Posters

Mulindwa, J., Kaaya, A. N., Puppala, N., Okello, D. K., Deom, C.M., Bravo-Ureta, B. (December 2011). "Development of a stable vitamin-A Rich Nutrient Peanut Butter for School age Children". Peanut CRSP Strategic Research Conference, Peanut CRSP, Malta, Europe

Kwesiga, J., Ssebuliba, J. M.,Puppala, N., Okello, D. K., Deom, C.M., Bravo-Ureta, B. "Effect of Rhiozobium Inoculation on Growth and Yield of Peanut (Arachis hypogaea L.) Culivars in Uganda". Peanut CRSP Strategic Research Conference, Peanut CRSP, Malta, Europe. December 2011.

Okello, D. K., Deom, C.M., Puppala, N., Bravo-Ureta, B. "Evaluating ICRISAT Breeding Material for Groundnut Rosette and Late Leaf spot Diseases in Uganda". Peanut CRSP Strategic Research Conference, Peanut CRSP, Malta, Europe. December 2011.

Nalugo, G. R., Ssebuliba, J. M., Puppala, N., Okello, D. K., Deom, C.M., Bravo-Ureta, B. "Introgression of Groundnut Rosette Virus Resistance into Valencia Peanut Varieties using Conventional Breeding". Peanut CRSP Strategic Research Conference, Peanut CRSP, Malta, Europe. December 2011.

Wambi, W., Tukamuhabwa, P., Puppala, N., Okello, D. K., Deom, C.M., Bravo-Ureta, B. "Introgression of Late Leaf Spot Resistant Genes in Valencia Peanut". Peanut CRSP Strategic Research Conference, Peanut CRSP, Malta, Europe. December 2011.

News articles published about David Kalule Okello's Ugandan groundnut breeding program and its success

http://www.monitor.co.ug/Magazines/Farming/New-groundnut-varieties-perform-to-expectations/-/689860/1705536/-/klv2ba/-/index.html

http://community.sciencecareers.org/ctscinet/articles/2010/12/the-best-of-science-careers-2010.php

http://sciencecareers.sciencemag.org/career_magazine/previous_issues/articles/2010_02_12/caredit.a1000016

http://www.naro.go.ug/Information/narodocuments/groundnut%20aflatotoxin%20mgt%20manual%20Uganda.pdf

2. Final Interpretation

a). Importance of Technical Achievements.

Host Country

In many developing countries of SSA, groundnuts are the principal source of protein, oil, and vitamins and also provide cash income that contributes significantly to food security and alleviating poverty. As a legume, groundnuts improve soil fertility by fixing nitrogen, thereby increasing productivity of the semi-arid cropping systems. Therefore, yield losses resulting from GRD and LLD diseases in cultivars with less than superior agronomic traits have a direct bearing on the nutritional and economical status of smallholder farmers in developing countries of SSA. While insecticide control of the aphid vector is known to reduce the disease incidence, the approach is seldom used by smallholder farmers for financial reasons. Presently, the most economical and efficient way to manage GRD and LLD is through the use of resistant varieties. We believe that the released lines, as well as the elite accessions in the pipeline, have superior agronomic traits that strengthen food security in Uganda and East African. High-yielding, early-maturing cultivars have GRD and/or LLD resistance will significantly increase groundnut production and income growth.

Increase production will immediately assist poor smallholder farmers that grow the majority of groundnut by increasing their income and extend benefits that have already been realized. In many groundnut-growing countries of SSA women predominantly grow and manage the crop, from production through post-harvest and processing activities. Therefore, increased groundnut production has a direct bearing on the overall economic and financial well-being and nutritional status of women and children. Over time as increased production of GRD and LLD resistant cultivars occur then multiplier effects take over. In rural communities increased groundnut production will generate jobs in production and post-harvest related industries. As production increases then the poor in rural and urban areas will benefit as groundnut becomes more affordable and groundnut-related jobs increase. While these benefits have and will occur following newly developed and released GRD-resistant lines, we expect these benefits to be even greater when increased production and consumption occurs following release of preferred consumer varieties with GRD resistance.

Such a breeding program to develop cultivars with resistance to GRD, LLD and drought tolerance will eventually lead to the identification of additional beneficial agronomic traits through the selection process that can eventually be breed into other cultivars for groundnut growing regions of the world where the diseases are not a problem.

U.S.A

Enhanced germplasm releases increasing groundnut production in SSA will contribute to food security and poverty reduction. The outcome will be an increased awareness of groundnut throughout sub-Saharan Africa, which could expand the international market for U.S. grown groundnuts and groundnut products. These benefits in addition to increased education and training will assist in promoting an infrastructure that will increase political stability and self-sufficiency. Lastly, the potential for GRD to emerge in the U.S. exists since the aphid vector is found worldwide including the U.S. Therefore, having management programs in place for controlling GRD in Africa would be of great importance to U.S. groundnut production in the event the disease ever emerged in the U.S.

b. Importance of physical and human capacity development.

Host Country

The major physical benefit of the project in Uganda is the improved infrastructure at the groundnut research laboratory at NaSARRI in Soroti. NaSARRI is the only peanut research station in East Africa, so reliable facilities are very important for year around research. The laboratory was basically non-

functional prior to the Peanut-CRSP supported renovations. Probably the most important aspect of the renovation was the installation of a solar power system to insure reliable electricity to the laboratory in a region notorious for power outages. Equally important was the purchase of a Nissan pickup truck by the UGA136 project. Groundnut is grow in all regions of Uganda, so access to reliable and dedicated transportation is an absolute necessity for the research program to be vital and be able to routinely visit trial sites, farmers fields and regional extension events. Other equipment, such as a camera and GPS units, allow documentation and increases the efficiency of data collection.

In human capacity building the UGA136 has advanced the reputation of the Uganda PI (David Kalule Okello, national groundnut breeder) throughout the region. Through UGA136 supported research, Mr. Okello has been able to obtained additional funds from the Alliance for a Green Revolution in Africa (AGRA) and Total Legume II (ICRISAT). Over the five years of the project 10 technicians have been trained in groundnut science, experimental approaches and data collection. These latter expertises will be useful in the future to promote sustainable growth in the peanut industry.

U.S.A.

Greater knowledge was acquired by the US PI about problems affecting groundnut production in African and approaches were developed to address and manage the problems (primarily GRD and LLD). This type of collaboration deepens the knowledge and skills of the US PI, which enables the PI to work more effectively with colleagues, farmers, commodity groups, processors, and seed companies in East Africa to strengthen the peanut industry. Downstream benefits allow the US PI to incorporate knowledge gained into course material, graduate training, and research proposals.

c. Heritage left from workshops and short-term training

Host Country

Legacy in training for the project is represented in acquired knowledge obtained by the members of the workshop and from the skills developed by the 10 technicians that have been trained during the project. This training will be invaluable for the long-term productivity of groundnut program in Uganda in technical as well as educational aspects when dealing with farmers, farm groups, and agro-business in the future.

U.S.A.

Researchers in the U.S. obtained invaluable information about agriculture production systems and cultures in developing countries. This information was obtained from a broad group resources, including farmers, scientists, and government employees. This breadth of information allows U.S. researchers to develop problem-solving skills to better assist the agricultural sector in

developing countries and to evolve the information for solving problems in the U.S.

d. Heritage left in publications

A number of papers are in various stages in the publication pipeline and their importance is briefly disgusted below.

- Okello et al (2010) is an overview and review of groundnut research in Uganda up to the present. The paper discusses the development of superior germplasm from early landraces to recent releases, the political and social factors that controlled groundnut development historically and future considerations and goals to optimize groundnut production. This is a must read for students and researchers working on groundnut in Africa.
- Thuo et (2013a) looks at the effects of social network factors on acquiring and adapting information on new seed technology among farmers in Uganda and Kenya. The paper describes the types of social networking in the two countries that are most associated with productivity. The implications enable policy makers to identify the relevant social relationships to focus on to increase capacities of poor farming communities.
- Thuo et al (2013b) acquisition of information about new seed varieties and productivity among groundnut farmers in Uganda and Kenya. Information acquisition and adoption were found to be correlated. Factors such as close associates and external supports like researchers and extension agents, partially influenced information acquisition, but did not influence adoption. This study provides insights on the importance of farmer participation in applied technology research and the impact of social interactions among farmers and external agents in agriculture.
- The Okello et al (2013a) publication is the new "Groundnut Production Guide for Uganda". This is the main production guide put out by the government and used by farmers and processors. This manual provides the newest recommendations on groundnut production (newest technologies available) and provides updates on groundnut storage to prevent aflatoxin contamination and optimize pest control. All aspects of groundnut production and storage are addressed.
- The paper by Li et al. (2013) assesses the impact of climatic variability on groundnut production in Uganda. The manuscript takes into account the various farming systems in the country based on cross-sectional time series data at the district level. The data includes 333 observations corresponding to 37 districts for 9 consecutive years, from 1992 to 2000. The results suggest that climatic conditions, based on the ENSO phenomenon, have a significant negative effect on output particularly for the warm phase. An important and alarming finding is a marked negative rate of technological change revealing productivity losses over the time period studied.
- The Okello et al. (2013b) paper reports the identification of new elite groundnut lines with resistance to groundnut rosette disease (GRD) and late

leaf spot disease (LLD) under natural agricultural conditions in Uganda, while examining their potential for management of GRD and LLD within Uganda. The use of these accessions in controlling the two diseases would boost groundnut production thereby contributing to income and food stability in Uganda and the region.

- Okello et al 2013 (In preparation) describes Serenut 5R, a very popular Virginia type of groundnut having GRD and LLD resistance that is being used in Uganda and being distributed to East and West Africa.
- Okello et al 2013 (In preparation) describes Serenut 6T, a very popular Spanish type of groundnut having GRD and LLD resistant that is being used in Uganda and being distributed to East and West Africa.

All publications are (or will be) in the public domain and available to scientists working on groundnut research throughout sub-Saharan Africa and the world. All superior and advanced germplasm is available though ICRISAT or the National Center for Genetics Resources Preservation in Ft. Collins, CO.

All publication, posters and presentations supported by UGA136, as well as published news articles, have greatly increased the reputation of David Okello in groundnut breeding and production and have allowed Mr. Okello to leverage this exposure into additional sources of funding.

3. Final Summary of Accomplishments by Objective

Objective 1: Screen for and evaluate germplasm from ICRISAT-Malawi and ICRISAT-Mail for GRD and LLD resistance and drought tolerance in Uganda and East Africa. To date 9 lines have been released though the national program in Uganda. All 9 lines have varying levels of resistance to GRD and LLD and all are early maturing, which makes them drought tolerant toward the end of the two growing seasons. The 9 released lines are high yielding (2500-3700 kg/ha). Presently, there are 13 high yielding, early maturing elite lines with GRD and/or LLD resistance in the pipeline. The various lines were bred to take into account superior agronomic traits dealing with seed color (tan or red), ease of shelling, taste, kernel yield, confectionary qualities, ease of harvest and oil content.

Objective 2: Breed GRD resistance from available resistant cultivars into susceptible landraces and cultivars preferred by farmers and consumers. Crosses have been made between local landraces, Egoromoit, Acholi White, Erudurudu Red, and Gwerinut with GRD resistant released varieties (Serenut 1R, 2, 3R and Igola). These crosses have been advanced to the F5-F6 generation and have been selected to retain the traits in the landraces preferred by the farmers and consumers in addition to resistance to GRD. The landraces have traits that are very popular with the consumer and are part of the culture of Uganda. The addition of superior traits to the landraces has an enormous effect on consumer demand.

Objective 3: Disseminate released germplasm with GRD resistance and drought tolerance to groundnut growing countries of East and West Africa. As released lines have become more and more popular in Uganda they are becoming more accepted within the region. Because GRD is so widespread throughout sub-Saharan Africa, demand for resistant varieties is high. NaSARRI has been a major engine in releasing GRD germplasm in the last five years. Within the last granting cycle, GRD resistant varieties have been requested and disseminated to South-Sudan, Sudan, Ethiopia, Mozambique, Ghana, Ivory Coast, Sierra Leone and the Central African Republic. So far, the requests have been for established widely grown GRD resistant varieties. As the newer released varieties become more accepted by farmers then demand for these varieties will increase throughout sub-Saharan Africa.

Objective 4: Provide a rigorous and robust educational program (extension) to farmers on GRD-resistant cultivars, sustainable disease management strategy and technology transfer. As part of the project, considerable attention has been given yearly to out-reach/extension to education farmers about the new technologies (primarily GRD resistant germplasm) being developed and those that have been released. Multiple demonstration trial sites on-station are managed in every agro-ecological zone in Uganda, so that farmers from all regions of Uganda have easy access to the sites. Extensive time is also spent hosting and training farmer groups and extension agents, manning exhibits and demonstrations at regional agricultural shows and field days, radio talk shows and newspaper releases.

Objective 5: Begin developing transgenic groundnut with genetically engineered resistant the GRD. A total of 15 transformed groundnut lines have been generated and small seed increases have been done. Testing of the lines for genetically engineered resistance to GRD in Uganda awaits the approval of Ugandan agencies with regulatory control over the propagation of genetically modified organisms. The lines cannot be analyzed in the USA since the viral disease is not present.