I. OVERVIEW

The McKnight CCRP project "Groundnut varieties improvement for yield and adaptation, human health and nutrition" has completed its second year of implementation (1 September 2011 - 31 August 2012). The overall goals of the project are to: i) reduce poverty by improving income levels; ii) increase food and nutrition security through improving groundnut yields; iii) document the level and causes of aflatoxin contamination in Malawi and Tanzania and its effects on human health; and iv) design and implement strategies for reducing aflatoxin contamination. The project is addressing these constraints through breeding to address low yields and increase resistance to diseases (rosette, ELS, and rust), through surveys to document aflatoxin contamination in food and in human blood, testing pre-harvest aflatoxin mitigation methods, and also by capacity building of partners.

The problem

Groundnut is one crop that is extensively grown by smallholder farmers throughout Malawi and Tanzania, and is therefore, a conduit for lifting large numbers of people out of poverty. The crop is grown on 710,000 ha in the two countries, accounting for more than 2.8 million households. Groundnuts are nutritious (with high protein [12-36%], and high oil content [36-54%]), and thrive under low rainfall and poor soil fertility conditions (it fixes atmospheric nitrogen). The Malawi and Tanzania Poverty Reduction Strategy Papers (MPRS 2007, TPRS 2011) reported that more than half of the populations in these two countries live below the poverty data line. Rural poverty is estimated at 52.4% (Malawi) and 34% (Tanzania). Groundnut is important in crop rotations as it contributes to soil fertility, which is a major constraint to crop productivity in both countries. Groundnut fodder is also highly nutritious as livestock feed. Furthermore, groundnut is popular and widely traded in local, regional, and more recently in international markets. The introduction of improved groundnut varieties, along with proven technologies for the management of aflatoxin contamination could have an important impact on women farmers who have tended to be excluded from growing traditional cash crops, notably tobacco, especially in Malawi. Increased consumption of groundnut can help overcome severe nutritional deficiencies, especially among children and pregnant women. More than 49% of Malawian and more than 40% of Tanzanian children below five years in the rural areas are malnourished and their development retarded. In fact the child mortality rate is as high as 189 and 141 per 1000 live births in Malawi and Tanzania, respectively. Severe malnutrition has several causes which include reduced production of food, and the fact that the diet of the majority of farmers lack nutrients, such as protein, fat and vitamins. Fats are essential for the absorption of vitamins A, D, E and K, the lack of which affects growth and development of children. But mycotoxin contamination in groundnut reduces the absorption of nutrients, especially vitamins.

Major constraints to groundnut production in both the countries are biotic (diseases/pests and aflatoxin contamination), abiotic (drought), socio-economic, and institutional. In sub-Saharan Africa, mycotoxin contamination is widespread in staple crops (groundnut, maize, millet, wheat, rice, sorghum, and soybean), certain processed food and feeds, and even in milk and meat products. Due to its deleterious effects on human and animal health, aflatoxin contamination of groundnut, maize and milk has gained global significance in the last four decades. The presence of aflatoxin in food and its consumption retards growth and productivity in both humans and animals. It affects absorption of nutrients and also leads to several health effects including growth retardation, immune suppression and liver cancer (hepatocellular carcinoma). Reduced nutrient absorption due to aflatoxin contamination leads to malnutrition. Ascertaining the scale of mycotoxin exposure would help in the development of appropriate policies and strategies for mitigating the problem. Also, use of appropriate pre- and post-harvest management practices and development of aflatoxin resistant varieties would be key to minimizing aflatoxin contamination. Project impact will contribute to improvement of rural livelihoods, better human health, as well as increased incomes from trade in both countries where over 80% of the population engage in agriculture. This will significantly contribute towards poverty reduction. Appendix D (i) depicts the overall path the project has taken and the intended outputs to be achieved by the end of four years.

II. NARRATIVE REPORT

Investigators

Partner Institutions

- International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) - Malawi
- National Smallholder Farmers' Association of Malawi (NASFAM) - Malawi
- Kamuzu Central Hospital - Malawi
- Department of Research and Training (DRT), Ministry of Agriculture and Food Security - Tanzania
- Sokoine University of Agriculture - Tanzania

Investigators at ICRISAT (*project leader)

Emanuel S. Monyo*

Sam Njoroge

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Ms Betty Chinyamunyamu
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Investigators at Kamuzu Central Hospital – Lilongwe
Dr Frank Madinda
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Sokoine University of Agriculture
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Dr Monica Lyimo

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Dr Omari Mponda
Dr Elly Kafiriti

Objectives

The four main expected outputs of the project are:

- High-yielding farmer- and market-acceptable groundnut varieties with resistance to foliar/viral diseases and aflatoxin contamination developed;
- Nutritional status, dietary diversity, human health and mycotoxin contamination problem spatially characterized;

- Adoption rates of improved farmer- and market-acceptable varieties and production technologies enhanced;
- Capacity of partners for management of mycotoxins in food, variety development and an enabling policy environment enhanced.

Objective 1: High-yielding farmer- and market-acceptable groundnut varieties with resistance to foliar/viral diseases and aflatoxin contamination developed

1.1. Identify and introgress germplasm for yield components farmer/market preferences and adaptation to biotic and abiotic (drought) traits
Sources of resistance to various constraints, which includes rust, groundnut rosette disease (GRD), early leaf spot disease (ELS), and aflatoxin contamination were identified and are now being incorporated into the breeding program. One hundred and twenty-two crosses introgressing resistance to aflatoxin, rust, early leaf spot (ELS), and Groundnut Rosette Disease (GRD) were developed. Some crosses introgressing multiple resistances into farmer- and market-preferred varieties of Tanzania, Mozambique, and Zambia were also developed. Work on backcross nurseries (BC1F1 and BC3F1) continues at Chitedze Research Station, ICRISAT, using farmer-preferred and well-adapted varieties as recurrent parents. Three hundred and thirty-two backcrosses for GRD, rust and aflatoxin resistance have been developed so far.

1.2. Develop diverse groundnut breeding lines and populations while developing capacity to screen for GRD and foliar disease resistance in Tanzania
In this reporting period the groundnut breeding lines were screened for ELS, GRD and rust resistance under high disease pressure, through artificial inoculations. The nurseries in Chitedze and Chitala were given high disease pressure using infector row techniques. In addition to this repeated aphid seeding technique for GRD were used. The result shows a good number of materials with potential sources of resistance for these traits.

Good X good crosses developed in the first phase of the project are currently in F6 generation and are under advanced testing at Chitedze Research Station. F7 segregating populations for rust, GRD, early and late leaf spot are available for utilization in the region. One F7 rust phenotype population, JL 24 x ICGV 94114 was supplied to Tanzania for further evaluation. Additionally, one hundred and seventy-six sets consisting of lines ranging from 1 to 289 were distributed to other national programs in the region for further disease screening and adaptive evaluation.

The nucleus seed of 306 lines were produced in quantities ranging from 2 to 50 kgs in Malawi. Additionally, 7.96 tons of breeder seeds for the varieties ICGV-SM 90704, ICG 12991, CG 7, JL 24, Nyanda, Chalimbana, ICGV-SM 01513 and MGV 5 have been produced in Malawi. In Tanzania, nucleus seed of 9 varieties were produced in quantities ranging from 1.9 to 3.5 kgs. Similarly, a total of 2.3 tons of breeder seeds for 7 varieties were produced at Naliendele Research Station, Tanzania.

1.3. Develop advanced breeding lines and varieties of groundnut with special emphasis on resistance to aflatoxin contamination
Two sets of international aflatoxin screening trials involving 100 lines for Spanish and 49 lines for Virginia were planted at Chitedze Research Station during main season and in Kasinthula

Research Station during off-season. The varieties J11 and 55-437, which were identified in earlier screening activity were used as resistant checks. Results are expected in the next reporting period.

Objective 2: Nutritional status, dietary diversity, human health and mycotoxin contamination problem spatially characterized

2.1. Define the scale of the mycotoxin contamination problem and identify the hotspots depicting pockets of the populations where mycotoxin occurrence is higher
Population densities of *Aspergillus flavus* were analyzed in soil samples collected during the survey in Tanzania. The result shows that population densities of *Aspergillus flavus* were lowest in Nanyumbu, with 0.5 log colony forming units/gram of soil, followed by Bukombe with 1.07 log cfu/g soil, and the highest was from Bahi with 1.5 log cfu/g of soil. Grain contamination of *Aspergillus flavus* in Nanyumbu was also lower. The lower densities of *A. flavus* in soils in Nanyumbu may explain why grain contamination was also relatively lower in this district. Further tests will be needed to determine if a higher proportion of *A. flavus* isolates from Bahi are aflatoxigenic. Analysis of grain samples for aflatoxin from Tanzania shows that there is a higher risk of exposure to aflatoxin in Bahi and Bukombe than in Nanyumbu. Contamination levels (<4 ppb) showed that 56% of samples from Nanyumbu would be acceptable in the European market which has a limit of 4 ppb.

2.2. Assess the relative exposure of humans to mycotoxin contamination of food in drought prone regions and other vulnerable areas and nutritional benefits from aflatoxin free foods
A total of 133 blood samples were collected from the two districts of Malawi (Mchinji and Salima) and analyzed for the presence and level of aflatoxin in humans. Eleven samples out of 133 were found positive for aflatoxin, which is 8.2% of the total sample. This initial results from the currently ongoing study on aflatoxin contamination in humans in Malawi suggests that environmental contamination of aflatoxin reported in food products tested across the country may be responsible for different liver diseases, such as cirrhosis of liver, chronic liver disease and hepatocellular carcinoma observed at Kamuzu Central Hospital in patients from Mchinji and Salima.

2.3. Assess aflatoxin load in exposed populations and relationships to health related ailments
Patients who came to Kamuzu Central Hospital (KCH) with liver problems including cirrhosis of liver, chronic liver disease, liver cancer, hepatitis B and C were analyzed from the hospital's database. It was found that the majority of liver patients were from Mchinji and Salima. Interestingly Nkhotakota had more liver patients than Mchinji and Salima, and samples are still being collected and are yet to be analyzed. The aflatoxin analysis results from Mchinji and Salima shows that there is a considerable relationship between patients coming from the mentioned areas and the surge in liver diseases, such as cirrhosis of liver, chronic liver disease and liver cancer as well as cancer of the esophagus at KCH. More data from the remaining parts of the study will be very crucial to consolidate this emerging relationship.

2.4. Assess aflatoxin load in exposed populations and relationships to nutrition as determined by body mass index (BMI)
As part of the nutritional component of this project in Tanzania, sensory evaluation was conducted with 40 mothers of targeted children, in the age group of 6-24 months, on four recipes composed of cereals and groundnuts. Furthermore, mothers of these targeted children were trained step-by-step on how to prepare the recipes based on groundnuts. These mothers are currently trying out the procedures on their own in their respective homes after which researchers will make follow-up visits to test their knowledge and skills acquisition before they start feeding their children with these developed recipes. The knowledge and skills acquisition will help the research team to determine the initial nutritional status of the targeted children, which in turn helps in instructing the mothers to start feeding children with the developed recipes. This forms a basis for subsequent nutritional measurements. Nutrition and aflatoxin contamination in the diets of this group along with a non-target group will be collected for purposes of comparison.

Objective 3: Adoption rates of improved farmer- and market-acceptable varieties and production technologies enhanced

3.1. Conduct participatory adaptive trials to assess mycotoxin management practices relating to crop production in pre- / post-harvest operations, and demonstrations for post-harvest handling, food processing methods, consumption patterns and diets
Twenty farmer-friendly options for the management of aflatoxin and twenty farmer-friendly options for the management of GRD were successfully demonstrated at farmer's fields in Malawi which involved 400 collaborating farmers. The results show reduction in rosette incidence and gain in yield which was obtained through a combination of resistant varieties, early planting and high plant density. Significant reduction in aflatoxin contamination was also observed through use of a resistant variety, box ridges and early planting. An on-station trial aimed at identifying more farmer-friendly options for managing aflatoxin showed that amending soil with lime and phosphorus reduces aflatoxin contamination. For Participatory Variety Selection, 20 mother trials were evaluated by twenty farmer groups in Malawi. Farmer rating of varieties showed that ICGV-SM 99556 (Spanish type) and ICGV-SM 01731 (Virginia type) are the most preferred genotypes. In Tanzania, participatory adaptive trials were conducted in two villages – Changwale and Namankha in Nanyumbu District – in which five new and promising lines were compared to two local checks called Pendo and Mnanje. Farmer preference shows ICGV-SMs 02724, 03516, and 90704 as the most preferred genotypes.

3.2.Conduct field days, agricultural shows & rural seed fairs with farmers, researchers & market players to promote improved mycotoxin management including testing of resistant cultivars
Five field days were conducted in three districts of Mchinji, Mzimba and Nkhotakota in Malawi engaging various stakeholders in order to increase knowledge on the harmful effects of aflatoxin. The groundnut production technologies were demonstrated on farmers' fields. The activity also involved participants in variety selection to elicit views on varieties under on-farm trials. Eight hundred and twenty-six participants, comprising collaborating and non-collaborating farmers, extension workers, officials from the Ministry of Agriculture & Food Security and NGOs attended these field days. In Tanzania, one field day was conducted at Changwale in Nanyumbu. The activity attracted a total of 302 participants and the Honorable Kiswaga, District

Commissioner was the guest of honor. The activity showcased the available recommended varieties as well as improved groundnut production practices. The project is engaging the Department of Agriculture, Nutrition and Soil Fertility, and Ekwendeni Hospital, Malawi, to help in promoting groundnut production technologies. This includes options for the management of aflatoxin contamination and Groundnut Rosette Disease, post-harvest handling of groundnuts and participatory variety selection. The Department worked with over 9,000 farming families and established structures in the northern part of Mzimba District with the primary aim of uplifting the livelihood of farmers using various enterprises.

3.3. Enhance institutional innovations to improve access of the poor to good quality seeds of improved high yielding adapted varieties

In Malawi, the project supplied 5.5 tons of groundnut seed variety ICGV-SM 90704 and 1 ton of ICGV-SM 99568 to partners, targeting new project sites for the development of new community seed banks. In Tanzania the project provided improved seed of variety Pendo to new Farmer Research Groups in five villages of Changwale, Pachani, Namaka, Chinyanyila, and Mnonia in Nanyumbu District. These villages are in addition to the already existing seed-village groups. Each group received 100 kgs of seeds for multiplication. The project also continued to work with farmer research groups established in the previous season in Southern and Central Tanzania. These farmers have produced a total of 28,080 kg of seeds for the variety Pendo, and 2,115 kg of seeds for the variety Mnanje. Farmers in these villages were also trained on principles of seed production.

Objective 4: Capacity of partners for management of mycotoxins in food, variety development and an enabling policy environment enhanced

4.2. Degree training program to MSc to develop regional capacity for pathology work including screening of commodities for aflatoxin contamination

Athanas Minja is currently pursuing MSc training at Sokoine University of Agriculture with a major focus on mapping the alleles responsible for groundnut rosette disease resistance. The project planned to train another MSc student to study the mechanism of infection that involves the signal for fungal infection and aflatoxin production in the groundnut host, but have not been able to secure admission to the US University where we believe the best knowledge could be gained. We are considering other training opportunities in the region.

4.3. Conduct sensitization workshop for policy makers, NARS / NGOs / private sector

To formulate awareness strategies on the harmful effects of aflatoxin the project conducted a baseline survey in Tanzania to identify farmers' perspectives of aflatoxin and management strategies. The survey was conducted in Nanyumbu, Bahi and Bukombe districts from 20 May to 6 June 2012. The result shows that both farmers and traders pay little attention to the issues of quality assurance and therefore this underlines the importance of instituting a multi-sectoral approach to realize effective aflatoxin awareness campaign. The survey findings show that there is need for a stakeholders' information meeting in order to develop concerted approaches for mitigating the problem.

4.3.1. Linkages with the health and other sectors will be developed and maintained for future collaboration

Kamuzu Central Hospital (KCH), Lilongwe, Malawi, in collaboration with ICRISAT, is playing an important role in exploring the possible relationships between aflatoxin intake through food, presence of aflatoxin in human blood, and its health effects. This outcome is expected to provide a platform for policy that would help in designing appropriate intervention strategies. Ekwendeni Hospital has also been engaged through its Department of Agriculture, Nutrition and Soil Fertility to help in sensitizing communities on the hazardous effects of aflatoxin on trade and health. Our collaborating partner, Dr Frank Madinda (formerly Consultant Surgeon at KCH) is now Chief of Surgery at Arusha Lutheran Medical Center (Tanzania), and his interest in the research continues. This gives us an opportunity to also engage one medical facility in Tanzania.

4.3.2. Develop and share project reports, policy briefs and journal articles

Training workshops were organized in Malawi to provide feedback to partners on the outcomes of trials and demonstrations on farmer's fields. Flyers carrying information about current technologies were discussed and distributed to participants. More interest was focused on variety, time of planting and water management techniques, and on aflatoxin contamination. The activity which targeted lead farmers, government extension officers, NASFAM field officers and promoters attracted a total of 100 participants. One thousand five hundred flyers were distributed and two community radio stations – M'mudzi Wathu and Nkhotakota – covered key areas of the training. The workshop also provided a platform for sharing outcomes from the aflatoxin information meeting conducted previously at ICRISAT, Lilongwe.

4.4. Establish a strategy and time frame for impact monitoring and reporting

Dr Carolyn Nombo facilitated a planning meeting to review the monitoring and evaluation tool. Issues that emerged during this meeting includes the need to conduct a survey to establish the benefits that farmers obtained through the seed bank program, assess the number of non-collaborating farmers who managed to access seed through this activity and determine the proportion of groundnuts from project areas that have aflatoxin levels equal to or less than the WHO standards. The meeting took place on 23 May 2012 at ICRISAT, Chitedze Research Station, Malawi.

Challenges

- Erratic rainfall experienced in Malawi had a negative impact on some of the on-farm demonstrations;
- Traders compete for groundnuts from farmers which makes them pay little or no attention to issues of quality;
- J 11 is an aflatoxin resistant variety; however, farmers have not fully appreciated it due to its susceptibility to GRD and poor yields;
- Some mothers under the nutritional component of the project in Dodoma are illiterate, and therefore unable to read training manuals;
- There was no consistent rosette incidence in a few areas where management of GRD was demonstrated. As a consequence, the results may not be conclusive.

Insights and lessons learned

- Farmers and extension workers were showing enthusiasm to participate in project activities in both countries;
- Information about hazardous effects of aflatoxin on human health needs to be properly disseminated, as some farmers think that all groundnuts cause liver cancer;
- Community radio stations command good listenership in Mchinji and Nkhotakota. Hence this provides an additional opportunity for reaching more farmers and the community at large if these radios are optimally used;
- There are existing forums in districts where various stakeholders including our partners conduct periodical meetings discussing development issues for the district. These could also be entry points in which stakeholders could be convinced to take on board relevant messages, especially on aflatoxin, into their development activities.

Year	Quarter	Activity number	Type of milestone	Description of Milestone	Time due*	Means of verification
2 2	2 3	1.1.1	Activity	• Additional sources of resistance to foliar diseases and or aflatoxin contamination identified from the groundnuts reference set, core collections, local and wild germplasm (2010 - 2014) • Farmer preferred varieties with local adaptation identified and hybridization (including back crosses) initiated for introgression of resistance to aflatoxin, GRD and foliar fungal disease resistances (2011-12)	June 2012 Sept 2012	• List of sources of resistance for hybridization • List of varieties with farmer- / market-preferred traits
				•		•
3 2	2 3	1.1.3	Activity Activity	• Advanced breeding lines and breeder seed of improved groundnut varieties available to NARS and NGOs in ESA on an annual basis (2010 - 2014) • Sick plots for resistance to aflatoxin contaminated developed and screening and testing activities initiated	June 2013 Aug 2012	• Seed requests / signed MTAs • List showing quantities of germplasm distribution by country • List of entries screened and report of performance

Year	Quarter	Activity number	Type of milestone	Description of Milestone	Time due*	Means of verification
2	3	2.2.1	Activity	• Aflatoxin testing of survey samples from Tanzania – (Oct 2010; Aug 2012)	Aug 2012	• Report of aflatoxin levels in Tanzania
2	3	2.2.1	Activity	• *A. flavus* testing of soil and grain samples from Tanzania – (Oct 2010; Aug 2012)	Aug 2012	• Report of *A. flavus* abundance in selected districts in Tanzania
2	3	2.2.3	Activity	• Aflatoxin testing of human samples from Malawi – (Oct 2010; Aug 2012)	Aug 2012	• Report of aflatoxin load in tested samples
2	3	2.3.4	Activity	• Nutrition studies initiated in Tanzania – (Jul 2011 – Aug 2012) link with Post-harvest project	Aug 2012	• Child feeding / nutrition report
3	3	3.1.1	Activity	• Varieties for wide scale on-farm adaptive testing with farmer participation (2010 – 2014)	Aug 2013	• List of varieties for on-farm testing in PVS in each country
3	3	3.2.1	Activity	• Field days, demonstrations, agricultural shows and seed fairs conducted at select farmer field school sites annually (2010 - 2014)	Aug 2013	• Number of field days, number and type of stakeholders participating • No. of demonstrations mounted • List of traders and others involved in g/nut trading • No. of farmers demonstrating at seed fairs and list of varieties preferred by farmers & market
3	4	3.3.1	Activity	• Engagement with at least two non-governmental organizations for	Dec 2013	• No. of seed delivery innovations operational

Year	Quarter	Activity number	Type of milestone	Description of Milestone	Time due*	Means of verification
				community seed supply of improved groundnut varieties (2010 - 14)		• Quantity of seed produced and sold • Publications
3 2 3	1 3 1	4.2.2	Activity	• Training partners in disease screening • Training partners in aflatoxin detection • Training new technicians on hybridization techniques (Feb and Sept in alternative years)	Mar 2013 Sept 2012 Feb 2013	• Training report • Training report • Training report
2	4	4.5.1	Activity	• Project Annual Review for internal monitoring established and functioning (Oct-Nov 2010 - 2014)	Oct – Nov 2012	• M&E plan • Progress reviews and annual work plans

The majority of smallholder farmers in sub-Saharan Africa (SSA) including Malawi and Tanzania, strive to attain their nutritional well-being from the meager harvests of their main staples. Staple diets in these regions are usually composed of cereals (maize, sorghums, millets) and legumes (groundnut, beans, pigeonpea), with significant dependence on cassava and sweet potato. Groundnut [*Arachis hypogaea* (L.)] is rich in digestible protein (25-34%), fat (44-56%), amino acids, and vitamins. It is an important food and cash crop, and a major source of dietary oil for both urban and subsistence dwellers. But groundnut yields are severely constrained by fungal foliar and viral diseases. In addition to maize, cassava, and other commodities, groundnuts also have been found to be prone to aflatoxin contamination which is known to cause liver cancer (HCC), suppress the human immune system, cause growth retardation and other ill-effects on health. The suppressed immune systems of HIV- and AIDS-infected members of the community are prone to many other diseases. Through previous efforts, ICRISAT has identified drought tolerant varieties, with resistance to groundnut rosette disease (GRD), rust and early leaf spot (ELS) with special focus on resistance to *Aspergillus* spp. While continuing with these efforts, a few of these materials have already provided the much needed resistance for introgression into farmer/market preferred varieties.

Progress of outputs

1.1. Identify and introgress germplasm for yield components farmer/market preferences and adaptation to biotic and abiotic (drought) traits.

Additional sources of resistance to foliar diseases and aflatoxin identified from core collection, local germplasm and wild germplasm

One hundred and twenty-two new crosses introgressing resistance to aflatoxin, rust, early leaf spot, Groundnut Rosette Disease (GRD), and crosses introgressing multiple resistances into varieties released in Tanzania, Mozambique and Zambia were developed. The materials used as sources of resistance are varieties ICG 14705, ICG 13099, ICG 9449 and ICG 15405, for groundnut rosette disease (GRD), varieties ICGV 02194, ICG 11426, ICGV 01276 and ICGV 02286 for rust, and J11, Ah 7223, ICGV-SM 02538, ICGV 93280, ICGV 92280 and ICGV 95494 for aflatoxin.

The varieties targeted for improvement includes Pendo, ICGV-SM 01721, ICGV-SM 01711, ICGV-SM 99555 and ICGV-SM 99557 for Tanzania; Chalimbana, CG7 and JL 24 for Malawi, ICGV-SM 01514 and ICGV-SM 05701 for Mozambique and MGV 4 and MGV 5 for Zambia. Work on backcross nurseries (BC1F1 and BC3F1) continues at Chitedze Research Station, ICRISAT using some of these target and adapted varieties as recurrent parents. A total of 332 backcrosses for GRD, Rust and Aflatoxin resistance have been developed. The project also continues to evaluate the reference set, for additional sources of rust resistance. A total of 289 lines were evaluated at Chitala Research Station in Malawi and Naliendele Research Station in Tanzania, both being hotspots for rust. The result shows that varieties M 13, ICGV 86590, ICGV 02446 and ICG 11088 has good rust resistance, and had scores <3 on a 1-9 scale based on one scoring date (80 days after emergence).

1.2. Develop diverse groundnuts breeding lines and populations while developing capacity to screen for GRD and foliar disease resistance in Malawi and Tanzania

In this reporting period the groundnut breeding lines were screened for ELS, GRD and rust resistance by providing high disease pressure by artificial inoculation through the infector row techniques. In addition to this, repeated aphid seeding technique for GRD was used. Eight nurseries of early leaf spot high disease pressure and 6 nurseries of rosette high disease pressure were screened at Chitedze Research Station. Six nurseries of rust and late leaf spot were screened at Chitala Research Station. Apart from this, 6 nurseries of drought stress were screened at Ngabu Research Station. A reference set was also evaluated for rust resistance at Chitala Research Station in Malawi.

In Tanzania, the 2 sets of trials focused on drought and groundnut rosette disease. The Regional Drought Resistance Trial was evaluated at Naliendele while the Regional Rosette Disease Resistance Trial was evaluated at Nachingwea and Naliendele Research Stations. The results show a good number of materials with potential sources of resistance for these traits. For drought, the varieties ICGV-SMs 01514, 08556 and 08503 showed good potential in Tanzania with $p = 0.05$ and kernel yields of 1247 kg/ha, 1361.4 and 1494.2 kg/ha respectively. This yield is higher than JL 24 which gave kernel yield of 1000 kg/ha (Appendix 1b).

In Malawi the Virginia type varieties ICGV-SMs 05558, 07599 and 03710 were the best genotypes for drought resistance, and with kernel yields of 1496, 1354 and 1238 kg/ha respectively (Appendix 1a). For rosette resistance, the varieties ICGV-SMs 01731 and 02724 showed promise in Tanzania (Appendix 1c); in the same way the varieties ICGV-SMs 01711, 08501 and 01709 performed well in Malawi with GRD incidences less than 3% in both countries. For rust trials in Malawi, the varieties ICGV-SM 08581 and ICG 10979 showed best resistance with a score of <1.5 on a 1-9 disease rating scale. The varieties M13, ICGV 86590, ICGV 02446 and ICG 1108 showed resistance for rust with the score being <3 on a 1-9 disease rating scale.

Good x good crosses developed in the first phase are currently in F6 generation advance at Chitedze Research Station. F7 segregating populations for rust, GRD, early and late leaf spot are also available for regional utilization. One F7 rust phenotype population (JL 24 x ICGV 94114) was evaluated in Tanzania. Additionally, one hundred and seventy-six sets consisting of lines ranging from 1 to 289 were distributed to various national programs in the region for disease screening and adaptive evaluation. Crosses for introgressing resistance to aflatoxin into farmer- / market-preferred varieties including some of the newly released varieties resulted in 100 progenies which are currently in F2 generation. About 80 crosses for introgressing aflatoxin resistance that failed to produce enough seed for generation advance during the 2010-11 main season were repeated.

With additional support from the TL-II project, segregating progenies for 3 major biotic constraints were produced and are currently in F7. Available populations include 1752 lines with 5 populations for Rust, 1614 lines with 4 populations for Early and Late Leaf Spot, and 900 lines with 4 populations for Groundnut Rosette Disease (GRD).

1.2.1. Germplasm exchange between Malawi, Tanzania, Mozambique and other partners

a) Nucleus seed of elite lines produced annually for testing and breeder seed production

The nucleus seed comprising 306 lines were produced in quantities ranging from 2 to 50 kgs in Malawi. In Tanzania, nucleus seed of 9 varieties were produced in quantities ranging from 1.9 to 3.5 kgs.

b) Breeder seed of improved groundnut varieties available to NARS and NGOs in ESA region on annual basis

In this reporting period 7960 kgs of breeder seeds were produced in Malawi. This includes 3120 kgs of seeds for groundnut rosette disease resistance variety ICGV-SM 90704, 160 kgs of seeds for aphid resistant variety ICG 12991, 2480 kgs of seeds for high yielding variety CG 7, 1095 kg of seeds for early maturing variety JL 24, 375 kgs of seeds for early maturing variety Nyanda, 280 kgs of seeds for the variety MGV 5, 270 kgs of seeds for the variety Chalimbana, and 180 kgs of seeds for the variety ICGV-SM 01513. The variety ICGV-SM 01513 is newly released in Mozambique. Similar efforts are underway in Tanzania where a total of 2.3 tons of breeder seed for Pendo (720 kgs), Mnanje (400 kgs), Mangaka (520 kgs), Nachingwea (300 kgs), Masasi (10 kgs), Johari (100 kgs) and Nyota (250 kgs) were produced at Naliendele Research Station.

Table 1 (below) shows groundnut breeding materials distributed to National programs during the reporting period in the sub region.

Table 1. Breeding material distribution to National Programs – 2011-12 season (reporting period)

Nursery	*Tanzania*	*Mozambique*	*Uganda*	*Total no of sets*
International Trial sets				
(a) On-farm	46	40	21	107
(b) On-station	30	24		54
Advanced Breeding Lines (sets)	1			1
Early generation breeding material/population (sets)	1			1
Germplasm samples				
Others (varieties, breeder seed)	12	1		13
	90	65	21	176

1.3. Develop advanced breeding lines and varieties of groundnut with special emphasis on resistance to aflatoxin contamination

To keep up with demand for aflatoxin resistant varieties and breeding materials, the project has embarked on an extensive aflatoxin resistance screening activity from a wide range of ICRISAT germplasm. Two sets of international aflatoxin screening trials involving 100 lines of Spanish and 49 of Virginia were planted at Chitedze Research Station during the main season and in Kasinthula Research Station during winter season. The varieties J11 and 55-437 which were identified in earlier screening activity were used as resistant checks. The trials were arranged in 10 x 10 and 7 x 7 lattice designs for Spanish and Virginia respectively. Both sets have been harvested and are currently being processed. A 100g sample from each entry will be collected and subjected to aflatoxin analysis using ELISA at ICRISAT Laboratory. Results for this activity are expected in the next reporting period. This effort, it is hoped, will avail not only new sources of resistance but also established varieties that could be carrying additional important traits.

In Tanzania, two sets of Virginia and Spanish genotypes each with 20 lines all in an advanced testing stage in the region were evaluated for both yield and reaction to Groundnut Rosette Disease (GRD) at Nachingwea and Naliendele Research stations. Some of these materials are also being evaluated for aflatoxin resistance at Chitedze Research Station in Malawi. Sets were planted in a randomized complete block design using CG7 and Chalimbana for Virginia, and Chitala and Kakoma for Spanish trials. Important data were collected including stand count, pod yield and rosette count. Very low rosette incidences were experienced at both sites with almost all genotypes registering 0% incidence at Naliendele.

The results for pod yield, kernel yield and rosette incidence show no significant differences amongst Virginia types implying similar performance for genotypes for yield and reaction to GRD. However, two of the promising genotypes, ICGV-SMs 05558 and 06711 performed the best. ICGV-SM 05558 gave yields of 2082 kg/ha for pod, 1227 kg/ha for kernel. Similarly ICGV-SM 06711 gave yields of 1989 kg/ha for pod and 1233 kg/ha for kernel (Appendix 1d). Although rosette incidences were low, the varieties ICGV-SMs 05702, 01709 and 90704 were the most resistant genotypes with incidences of 0.563 %, 0.596% and 0.6345 respectively. There were however, significant differences in pod and kernel yields for Spanish genotypes. At least 6 of the promising genotypes yielded above the checks. ICGV-SMs 08577, 07544 and 08583 were the most yielding genotypes with pod and kernel yields greater than 2100 kg/ha and 1030 kg/ha respectively. These activities will help widen the genetic base from which the region could exploit for further testing for other agronomic traits or introgressing of aflatoxin resistance into locally adapted and or farmer/market preferred varieties. Further evaluation of promising materials will ensure continuity for participatory adaptive trials on farmers' fields.

Implication of the research findings

Development of resistant varieties with special focus on aflatoxin will be an important finding for the region as currently there is no released variety known to offer such resistance. Introgressing aflatoxin resistance into newly released and farmer preferred varieties will yield varieties displaying more than one important trait – a development key to improving income, health and nutritional status of farmers and the safety of consumers at large. Additionally, availing more sources of resistance particularly materials combining resistances for more than one trait will strengthen efforts already in place in various NARS programs.

Objective 2: Nutritional status, dietary diversity, human health and mycotoxin contamination problem spatially characterized
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Problem statement

Aflatoxin, produced by the fungi *Aspergillus flavus / A. parasiticus,* has been reported to retard growth and productivity in both humans and animals. Aflatoxin is also linked to immune suppression and diseases like Hepatic Cellular Carcinoma. Further, poor nutrition usually attributed to food insecurity may be exacerbated by exposure to aflatoxins. Exposure to aflatoxins therefore can aggravate the already delicate condition in smallholder populations, such as those in many areas of Malawi and Tanzania, who subsist on legume and cereal-based. This objective targets generation of information that will inform policy and feed into relevant national initiatives that target food safety in the two countries for development of appropriate standards and or regulatory frameworks.

Progress of outputs

2.1. Define the scale of the mycotoxin contamination problem and identify the hotspots depicting pockets of the populations where mycotoxin occurrence is higher

ICRISAT in collaboration with Naliendenle Agriculture Research Station implemented a project to map the occurrence, significance and distribution of Aflatoxin contamination in Tanzania, and also implemented activities to enhance national capacity for management of mycotoxin in food. The survey was commissioned in Nanyumbu, Bahi and Bukombe districts. Respondents were drawn from 4 villages per district and 240 households were interviewed. A structured questionnaire was used to collect both quantitative and qualitative household data on household demographic characteristics, land and asset ownership, crop production data for 2010/11 season, crop utilization data, groundnut production data and its production constraints, groundnut variety preferences, awareness of aflatoxin and control measures, groundnut post-harvest handling, groundnut marketing, sources and types of marketing information, important groundnut marketing constraints, major sources of income, food and nutrition security, extension services, participation in technology evaluation and trial and access to markets and quality of road infrastructure. Groundnut, soil samples and geographical information were collected from the interviewed households.

Grain samples collected were analysed using ELISA. ELISA is an immunology technique based on antigen-antibody reaction. The antibody (developed at ICRISAT) binds with aflatoxin (antigen) and forms a complex. This reaction can be visualised by adding an enzyme-labelled antibody and its substrate. The suitable substrate added to the antigen-antibody-enzyme complex will develop a color when it reacts with enzyme. Based on the intensity of the colour developed the concentration of aflatoxin can be measured. The colour development is indirectly proportional to the concentration of aflatoxin in the sample.

The results of soil fungi population density analysis shows there was lowest population densities of *Aspergillus flavus* in Nanyumbu, at 0.5 log colony forming units/gram of soil, followed by Bukombe at 1.07 log cfu/g soil and the highest was from Bahi at 1.5 log cfu/g of soil. The grain contamination in Nanyumbu was also lower compared to the other Districts. The lower densities of *A. flavus* in soils in Nanyumbu may be the reason why grain contamination was also relatively lower in this district. Further tests would be needed to determine if a higher proportion of *A. flavus* isolates from Bahi are aflatoxigenic. According to the baseline survey, farmers in Nanyumbu were more aware of aflatoxin (Table 2) and therefore this might also have contributed to lower contamination levels in the district. Further, the survey showed that a greater proportion of farmers in Nanyumbu grade their groundnuts compared to farmers from Bahi or Bukombe.

Table 2. Level of aflatoxin awareness and proportion of farmers grading groundnuts

District	Level of aflatoxin awareness %	Proportion of farmers grading g/nuts %
Nanyumbu	58	75.6
Bahi	6.5	29.2
Bukombe	25.5	46.7

2.2. Assess the relative exposure of humans to mycotoxin contamination of food in drought prone regions and other vulnerable areas and nutritional benefits from aflatoxin free foods

Groundnut is one crop which got affected seriously by aflatoxin contamination in Malawi (Monyo et al. In press). When this toxin is ingested by humans through contaminated groundnuts it undergoes metabolism and the result is the formation of epoxides which damage liver cells by binding with protein albumin and also with DNA and cause mutation, which finally end in hepatocellular carcinoma and other ailments in human beings. To assess the exposure of humans to aflatoxin B1 contamination, blood samples were collected randomly from regions of Malawi (Mchinji and Salima) based on reported areas with high environmental contamination of aflatoxin levels in groundnuts (Monyo et al. 2012). Data on the diet profile of each individual was documented using a data sheet designed for this purpose. The objective of the study was clearly explained to the participants. A signed consent on an Ethics Committee Approved form, both in English and Chichewa (locally spoken language) languages, was obtained from selected individuals who were willing to participate in the study. The demographic data were also obtained for each participant. The collected blood samples were transported to Kamuzu Central Hospital and serum was separated and stored at -80 ^{o}C. The collected serum samples were then transported to Aflatoxin diagnostics laboratory, ICRISAT, Lilongwe. Indirect competitive Enzyme linked immunosorbant assay (IC-ELISA) was performed typically as described in Anitha et al. (2011) to determine the levels of aflatoxin in human blood. In this part of an ongoing study we analyzed aflatoxin level quantitatively in 133 blood samples collected from two different regions of Malawi. It was found that 8.2% of 133 (11/133) samples were positive to aflatoxin with the levels ranging from 50-400 pg mg^{-1} of albumin. This shows that environmental contamination of aflatoxin can find its way into humans in Malawi and there is a considerable intake of aflatoxin through contaminated food. Table 3 shows the mean aflatoxin contamination and the range of contamination of groundnuts sampled in Nanyumbu, Bukombe and Bahi districts.

Table 3. Mean aflatoxin contamination[a] and range of contamination of groundnuts sampled in the three districts

District	Mean Elevation (Masl)	Mean Latitude Deg. S	Mean Longitude Deg. E	Samples N	Mean AFB_1	AFB_1 <5	$AFB_1 \geq 5, \leq 20$	AFB_1 >20
Nanyumbu	327	10	38	93	93	52	35	6
Bukombe	1178	3	32	85	121	23	41	21
Bahi	999	6	35	68	115	21	32	15

[a]Contamination of aflatoxin B_1 in parts per billion; elevation in meters above sea level, latitude in Degrees South of Equator and Longitude in Degrees East of Greenwich.

2.3. Assess aflatoxin load in exposed populations and relationships to health related ailments

To assess the exposure of humans to aflatoxin B1 contamination in Malawi, data on the diet profile of each individual who provided a blood sample was documented using a purposefully designed protocol. The objective of the study was clearly explained to the participants. A signed consent on an Ethics Committee Approved form, both in English and Chichewa (the locally spoken language) was obtained from selected individuals who were willing to participate in the study. The demographic data, including (i) age; (ii) family history of liver diseases; (iii) habits like smoking, alcohol consumption; (iv) dietary profile; and (v) clinical profile including liver function test, was obtained. The collected blood samples were transported to Kamuzu Central Hospital and serum was separated and stored at -80 ^{o}C. The collected serum samples were then transported to the aflatoxin diagnostics laboratory at ICRISAT, Lilongwe.

The history of these participants confirms that they consume groundnuts and they lack correct and appropriate information about the effects of aflatoxin on their health. Patients who came to

KCH with liver problems including liver cirrhosis, chronic liver disease, liver cancer, hepatitis B and C were analyzed from the hospital database and it was found that the majority were from Mchinji and Salima, the areas where the aflatoxin study was conducted. Interestingly, Nkhotakota had more liver patients when compared to Mchinji and Salima, unfortunately samples from there are still being collected and are yet to be analyzed. The number of participants tested and results from these areas give a clear indication that there is a relationship between patients coming from the areas mentioned and the surge in diseases, such as liver cancer and cancer of the esophagus at Kamuzu Central Hospital. More data coming in from the remaining parts of this study will be very crucial for confirming this emerging relationship as information will be collected from other areas attended by KCH staff within the central region.

2.4. Assess aflatoxin load in exposed populations and relationships to nutrition as determined by body mass index (BMI)

As follow-up on a nutrition baseline survey conducted in Tanzania, the team from Sokoine University of Agriculture (SUA) is currently working with 40 mothers of children aged between 6-24 months in two districts of Chamwino and Bahi in Dodoma. The activities focused specifically on the two villages of Muungano and Mundemu in Chamwino and Bahi, respectively. In this reporting period, the focus was, firstly, to conduct sensory evaluation of the developed recipes based on groundnuts with the mothers of the targeted children.

Four recipes comprising cereals and groundnuts, in a ratio of 2:1 for different age groups (6-8, 9-11 and 12-24 months) were introduced. The recipes introduced were based on: i) Maize: Groundnuts, ii) Sorghum: Groundnut, iii) Millet: Groundnut, and iv) Finger millet: Groundnut. Sensory evaluation was meant to find out the acceptability of the recipes in terms of taste, texture, appearance, color, odour and general acceptability using the five point hedonic scale (1=like very much, 2=like moderately, 3=undecided, 4=dislike moderately and 5= dislike very much). Furthermore, the mothers of the targeted children were trained step-by-step on how to prepare the developed recipes. In June 2012, three training sessions were conducted in these villages focusing on preparation of the basic ingredients, recipe mixtures for different age groups (6-8, 9-11 and 12-24 months), and the process of porridge cooking for these recipes. A training manual was developed and distributed to the target mothers. Mothers are currently trying out these procedures on their own in their respective homes after which researchers will make follow-up visits to test their knowledge and skills acquisition before they start feeding their children with the developed recipes. The knowledge and skills acquisition will help the research team to determine initial nutritional status of the targeted children, which in turn will help in instructing the mothers to start feeding children with these developed recipes. This will form a basis for subsequent nutritional measurements. Sensory evaluation results show that all four recipes were acceptable, ranging from 1–2.5 on the scale, with pearl millet being the most preferred recipe in the two villages (Figure 1). Figure 2 (below) shows mothers who participated in the training feeding their children with porridge.

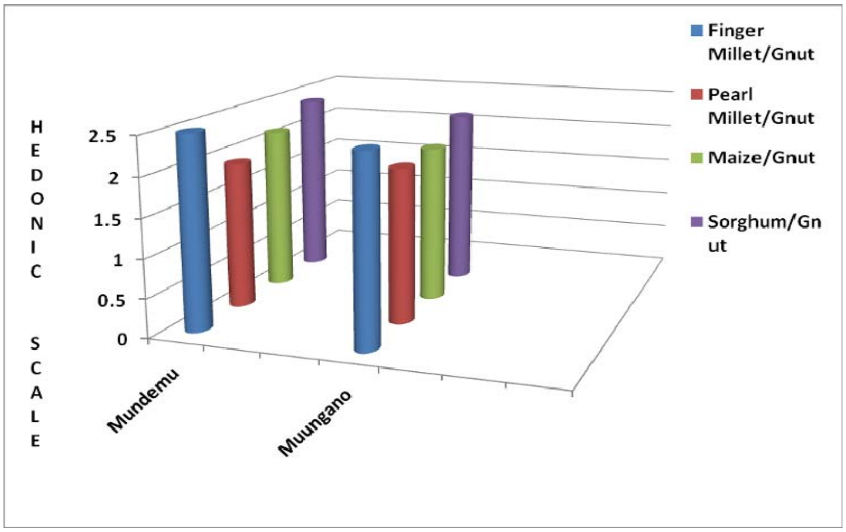

Figure 1. General acceptability of complimentary recipes

Figure 2. Mothers feeding their children with porridge, after being trained

Implication of the research findings

Based on the Malawi experience, defining the scale of mycotoxin contamination as well as assessing aflatoxin loads in exposed populations in Tanzania will help in planning appropriate sensitization campaigns as well as develop inclusive approaches for management of aflatoxin contamination in food in the country leading to better food and safety policy advocacy.

For policy

Policy will be impacted through information sharing so as to facilitate decision making. Policy guidelines and direction will be positively impacted by maintaining standards, e.g., allowable levels of mycotoxins in food and feed, along with acceptable nutritional status. This will also strengthen health laboratories for including aflatoxin capacity.

Objective 3: Adoption rates of improved farmer and market-acceptable varieties and production technologies enhanced

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Problem Statement

In spite of a wide range of available technologies (including groundnut varieties), adoption rates by small scale farmers remain low, chiefly because farmers are not aware of their availability. Thus continued development and strengthening of the already existing platforms and / or communication mechanisms is key to an effective and efficient technology dissemination program. Such will avail of the project's islands of success and contribute to meaningful adoption of technologies by farmers. The multi-disciplinary partnership approach used in the first phase has again been employed to deal with this multifaceted problem and so far farmers, community leaders, researchers, extension agents, traders and processors have been engaged in order to achieve wide scale adoption of best practices for pre- and post-harvest management of aflatoxins. Conducting demonstrations of improved technologies on farmers' fields will improve their understanding of the problem (learning by doing) and enhance adoption of such technologies and also present a forum for selecting and promoting preferred varieties and best bet resource management interventions.

Since the imposition of strict limits to aflatoxin levels in imported groundnuts by the EU, aflatoxins continue to be a major limitation to trade in groundnuts. As a result, any improvement in management of contamination at the farm level would potentially result in increased trade with regional and international partners. Providing better information on the distribution of aflatoxins and underlying factors will support efforts to manage contamination at the farm level.

Progress of outputs

3.1. Conduct participatory adaptive trials to assess mycotoxin management practices relating to crop production in pre- / post-harvest operations, and demonstrations for post-harvest handling, food processing methods, consumption patterns and diets

a) Evaluation of technologies for the reduction on aflatoxin contamination (on station trials) in Tanzania and Malawi

In a bid to develop more farmer friendly management options to mitigate pre harvest aflatoxin contamination, an on-station trial was again established in Malawi on 18 January 2012. The objective underlying this trial was to compare a new set of improved methods for farmer practices. The trial is set to run for at least two years, outcomes of which will help to design an appropriate combination of treatments for on-farm testing. Currently, the trial arranged in factorial design, has 3 factors. The first factor deals with varieties at 3 levels that includes J11, a resistant variety; ICGV-SM 99557, a newly released variety in Tanzania; and ICGV-SM 99568, a susceptible check. The second factor deals with water management at two levels that included tied ridges vs open ridges; and the third factor is soil amendment factors at 3 levels that includes manure 0 kg/ha vs 1.75 t/ha; lime 0 kg/ha vs 200kg/ha; and single super phosphate (SSP) 0 kg/ha vs 400kg/ha. Among these varieties were the main plot factors, water management being sub-plot and soil amendment factors as sub-sub plot with each of the sub-sub plot factors operating at two levels. Farmyard manure supplying 1.28% N, 2.29% K, and 0.48% P was used. Additionally SSP supplying 80kg/ha of P_2O_5 was also used. Factors were purposefully chosen, all being critical to minimizing exposure of groundnuts to fungal infection where exposure is chiefly penetration through pod and seed coat. Data collected included plant stands and pod weight. A 100g sample for groundnuts was then subjected to aflatoxin analysis using Enzyme Linked Immunosorbent Assay (ELISA).

Both liming and phosphates application had a positive effect on aflatoxin reduction but the effect was not significant. Manure application did not show any effect probably because the levels applied (≤2 tons) were low. All soil amendment efforts had a positive effect on pod yield (Appendix 2). Significant differences in aflatoxin contamination (AFB1) were detected among varieties. ICGV-SM 99568, a susceptible check had the highest levels of contamination, 6412 ppb compared to 1507 ppb and 2292 ppb for ICGV-SM 99557 and J 11, respectively. High values may likely have been caused by persistent droughts within and at the end of the season experienced at Chitedze Research Station (Appendix 11) The station generally received low rainfall with a cumulative total of 796.5 mm in five months compared to the station's average of 892 mm of which 85% falls between November and March, coupled with the fact that effective planting rains (late planting) occurred in January.

b) Demonstrate technologies for the reduction of aflatoxin contamination in smallholder conditions

The objective of the trial was to validate and promote options for the management of aflatoxin contamination of groundnuts on farmers' fields especially in new project sites. Even though aflatoxin contamination could occur at any point in the groundnut value chain, the main point of contamination occurs at the pre-harvest stage, therefore technologies that would minimize aflatoxin contamination of groundnuts in farmers' fields are best options for arresting this problem.

To this effect, 20 demonstration plots were planted on farmers' fields in three districts, Mchinji, Mzimba and Nkhotakota, however, the report will focus only on the results from 11 demonstrations as some were lost due to drought, especially in Nkhotakota and Mzimba. Three options are arranged in a Randomized Complete Block Design using farmers as single replicates. These three options were: time of planting, which was early vs late (3 weeks later); genotype, which was resistance variety J11 vs susceptible variety ICGV-SM 99568; and water management which was box vs open ridges. Plots contained 4 rows each, 10m long with ridges spaced at 60 cm and 10 cm between plants and tied every 2m for box ridged treatments. Important data was collected including stand count and pod weight. Groundnut samples were transported to Chitedze Research Station for further processing. A 100g sample was subjected to aflatoxin analysis using Enzyme Linked ImmunoSorbent Assay (ELISA) to evaluate levels of AFB1 contamination in various treatments.

There was no significant differences at p=0.05 between treatments but results consistently showed high levels of AFB1 in ICGV-SM 99568 (susceptible variety), open ridged and late planted treatments. ICGV-SM 99568 had aflatoxin contamination level of 64 ppb when compared to J 11 which had 5 ppb. Open ridged treatment had 57 ppb when compared to box ridged treatments which were 5 ppb, late planted treatments had 69 ppb when compared to early planted treatments which was 5 ppb (Figure 8). Significant differences were shown for treatment interactions. The worst treatment combination was ICGV-SM 99568 planted late and on open ridges with contamination levels up to 239 ppb compared to 1.72 ppb for J 11 planted early and on box ridges (Appendix 3). There was little variation in AFB1 levels in the four treatment combinations with J 11 (resistant variety), with 2-10 ppb emphasizing the extent to which use of resistant varieties could help mitigate the problem of aflatoxin contamination in farmers' fields.

c) Demonstrate technologies for the reduction of GRD on smallholder conditions

The trial aims to popularize available and common disease management technologies among smallholder farmers and validate best cultural practices with specific improved varieties. This would also help small scale farmers to improve food security and incomes through reduction of GRD. The trial was planted on 16 farmers' fields in the three districts.

Three options were arranged in a Randomized Complete Block Design which includes time of planting, namely, early vs late (3weeks later), genotype of resistant vs susceptible, and plant density which was high vs low. Plots contained 4 rows, each 10m long with ridges spaced at 75cm and 60cm with 30cm and 10 cm between plants for low and high population density, respectively. Data were collected on stand count, rosette disease count and pod weight.

The result for rosette incidence and kernel yield shows significant differences at p=0.05, for individual treatment factors (genotypes, time of planting and plant density). In addition to lower rosette incidence, resistant varieties yielded more than susceptible varieties. The varieties Nsinjiro and Baka had yield of 675 kg/ha and 608 kg/ha, respectively, compared to Chalimbana and Malimba which had yield of 414 kg/ha and 405 kg/ha, respectively. Similarly high population density and early planting gave a substantial yield advantage over low density and late planting (Appendix 4). There were no significant differences at p=0.05 for interactions, results however show reduced rosette incidences for both resistant and susceptible varieties when planted early and at high population density, implying that farmers would still have considerable yields even when susceptible varieties are planted as long as these varieties are planted early and at high plant density (Appendix 5). Even though resistant varieties had generally low rosette incidences, there were higher incidences at late planting and low plant density. The worst treatment combination was Chalimbana (susceptible variety) planted late with low plant density giving an average incidence of 35.5%. There was also a strong negative correlation (-0.588) between rosette incidence and kernel yield implying that an increase in rosette incidence resulted in a decrease in kernel yield. These results demonstrate vividly that substantial yield gains and reduction in rosette incidence are achievable through a combination of resistant varieties, early planting and high plant density.

d) Participatory variety evaluation

Collaborating farmers and non-collaborating farmers, traders and NGOs continue to be engaged in order to elicit more views on variety selection in all project areas for both Malawi and Tanzania, covering the three agro-ecological zones, which include low, medium and high altitude groundnut growing regions.

In Malawi the activity undertaken in Nkhotakota, Mchinji and Mzimba directly involved 400 farmers. A total of 20 mother trials each for Virginia and Spanish genotypes were established by 20 groups. Each group consisted of about 20 members. Additionally, 30 baby trials by individual farmers were also established. Trials which included 6 + 2 (checks) for Spanish varieties and 6 + 2 (checks) for Virginia varieties were conducted. For Virginia type trials, varieties included ICGV-SMs 01708, ICGV-SM 01731, ICGV-SM 01724, ICGV-SM 99772, ICGV-SM 01728, 92R/704 and the two checks, ICGV-SM 90704 and Chalimbana 2005 while Spanish varieties included ICGV-SMs 01514, 08501, 08503, 99551, 99556, 99567 and the two checks, ICGV-SM 99568 and JL 24. Similarly, in Tanzania adaptive trials were carried out at two sites, Chagwale and Namankha, to test their performance as well as to elicit farmers' views through participation.

Sets were planted in a Randomized Complete Block Design using farmers as replicates. Each trial had 8 plots and each plot contained 4 ridges, each 6m long, spaced at 60cm with 15cm and 10cm between plants for both Virginia and Spanish varieties. At least two weedings were carried out and important data collected, which included stand count, disease severity, pod weight, and farmers' preferences. Farmer chosen preference criteria included yield, taste, seed size, disease resistance and maturity duration. This was evaluated on a 1-4 rating scale (excellent to poor).

Variety performance

For Virginia trials, result showed significant differences for rosette incidence, which implies that there was differential reaction displayed by these genotypes to rosette infection. ICGV-SM 01731 had the lowest level of rosette incidence (1.38%) similar to ICGV-SM 90704 (1.54%), which is a known GRD resistant variety (Appendix 6). Additionally, most genotypes showed better resistance than Chalimbana 2005, one of the checks. No significant differences, at p = 0.05, were observed for both pod and kernel yields. The best yielding variety however, was ICGV-SM 90704 with a yield of 2673 kg/ha and 1542 kg/ha for pod and kernel respectively, followed by ICGV-SM 01731 with a yield of 2089 kg/ha and 1155 kg/ha for pod and kernel respectively. Most of the promising lines yielded above the mean yield (1968 kg/ha and 1048 kg/ha for pod and kernel yield respectively) as well as that of Chalimbana 2005.

Significant differences in rosette incidence were observed for Spanish type trials. All promising lines were more resistant to groundnut rosette disease than JL 24, a local susceptible check (Appendix 6). No significant differences, at p = 0.05, were observed for both pod and kernel yields, however ICGV-SM 99556 was the best yielding genotype with 1786 kg/ha and 1071 kg/ha for pod and kernel yield, respectively. The genotype also yielded above the checks (ICGV-SM 99568 and JL 24).

For Tanzania, five promising genotypes, ICGV-SMs 02724, 03516, 07553, 90704 and 94114, were tested against two standard checks Mnanje and Pendo in two locations. Even though no significant differences were shown between genotypes for kernel yield, the varieties ICGV-SM 02724 and 03516 were the highest yielding genotypes with a yield of 1075 and 1150 kg/ha, respectively (Appendix 7). These yields were also above the two checks as well as the overall mean. Higher yields were observed at Namankha as compared to Chagwale, which were 997 and 571 kg/ha, respectively.

Following successful results from on-farm (PVS) and on-station trials, the project with additional funds from TL-II, has identified 9 new candidate varieties (ICGV-SMs 02724, 01731, 90704 and ICGs 10149, 13350, 8331, 3311, 8326, and 14335) for release. Figure 3 depicts three of the nine lines proposed for release. These varieties will now enter National Performance tests at Tanzania Official Seed Certification before official release that is expected by 2013.

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Figure 3. Some of the candidate varieties proposed for release in Tanzania

Variety ranking in Malawi and Tanzania

Two sets of trials (Virginia and Spanish), each with eight varieties were set up in farmers' fields in the three project sites with the objective of soliciting farmers' views on the different elite materials under the breeding program responding to various biotic and abiotic stresses. The selection was based on farmer-chosen criteria, which included yielding ability, seed size, taste, earliness of maturity and disease resistance with main focus on groundnut rosette disease. For Spanish varieties, ICGV-SM 99556, a new promising line, was the most preferred genotype especially for its seed size, taste and early maturity; and ICGV-SM 99568, one of the released varieties and also used as a check was equally rated for its high yielding ability, taste and earliness in maturity (Appendix 8). For Virginia varieties, ICGV-SMs 01731 and 01724, new promising lines, were the most preferred genotypes over Chalimbana 2005. However, another check ICGV-SM 90704, tallied with the two promising lines especially for its high yielding ability and resistance to diseases (Appendix 9). In spite of the general poor ranking of Chalimbana 2005, the variety attracted farmers' attention especially for its large seed size.

Variety selection was also conducted based on gender to find out if there would be any divergent views in choices between the two groups. For Spanish, ICGV-SM 99551 was the most preferred genotype for women citing taste and yielding ability as reasons for their choice, while ICGV-SM 99568 was the preferred variety for men especially for its good seed size and yielding ability (Appendix 10). For Virginia varieties, ICGV-SM 90704 was the most preferred genotype due to its taste for women while ICGV-SM 01731 was the most preferred genotype for men due to its seed size and yield. Result shows that taste is a very important trait among women which may imply that their primary concern is home use while men had seed size and yielding ability as priority traits implying market-oriented views.

A few lines with high farmer preferences are currently being tested for possible release by the national program. These varieties include: ICGV-SMs 01721, 01711, 01514, 99772, 03572. Variety evaluation in Tanzania was carried out in two villages, Changwale and Namankha in Nanyumbu District. Five promising lines, ICGV-SMs 02724, 90704, 03516, 07553 and 94114 were evaluated against two local checks called Pendo and Mnanje. The local evaluation criteria included pod size and pod yield. The result for overall preference shows ICGV SM 02724 and Pendo tallying as the most preferred varieties (Appendix 10 b). Other preferred varieties included ICGV SMs 03516 and 90704. Each village, however, had a different ranking order with Changwale preferring ICGV-SM 02724, Pendo and ICGV-SM 90704 and Namankha preferring Pendo, ICGV-SMs 02724 and 03516.

3.2. Conduct field days, agricultural shows and rural seed fairs with farmers, researchers and market players to promote improved mycotoxin management including testing of resistant cultivars

Field days, demonstrations on farmers' fields, and the interaction among various players in the groundnut value chain gives an opportunity for effective variety selection and technology transfer. They also provide a platform for researchers to provide scientific reasoning with farmers and other stakeholders.

In Malawi, 5 major field days were conducted at Mikundi (Mchinji), Jenda, Bwabwa and Luhomero (Mzimba) and Linga in Nkhotakota. In Mchinji and Nkhotakota, field days were conducted on 13 and 19 April 2012 respectively while in Mzimba field days were conducted from 3-6 June 2012. A total of 826 participants (Table 4) including collaborating and non-collaborating farmers, officials from the Ministry of Agriculture & Food Security and NGOs attended these field days. The project team used "*Improving income, nutrition and health of farmers through improved groundnut production technologies"* as the theme for the field days. For Tanzania, one field day was conducted at Changwale village in Nanyumbu District specifically to show participants the available improved and recommended varieties and production practices. The activity attracted a total of 302 participants that included farmers from all research groups and non-collaborating farmers, extension staff, district and ward leaders, and researchers. Hon Kiswaga, the District Commissioner was the Guest of Honor at this field day. The Guest of Honor drew the attention of the farmers to the importance of using recommended groundnut varieties and improved agronomic practices so as to increase productivity. He also emphasized the importance of researchers and extension officers who work closely with farmers in order to disseminate important research findings. Input generated from participants especially on variety selection has always been of vital importance in core breeding activities. Figures 4 and 5 show a field day session at Mikundi in Mchinji and a women's group displaying their flyers soon after a field day at Linga in Nkhotakota, respectively.

Table 4. Field days participation (disaggregated by gender)

Country	**District**	**No of field days**	**Female**	**Male**	**Total**
Malawi	Mchinji	1	24	32	56
	Nkhotakota	1	60	88	148
	Mzimba	3	332	290	622
	Total for Malawi	5	416	410	**826**
Tanzania	Nanyumbu	1			302

Figure 4. Farmer field day in Mikundi-Mchinji

Figure 5. Umodzi Women's Club in Linga-Nkhotakota showing off the flyers

The project continues to involve the Department of Agriculture, Nutrition and Soil Fertility at Ekwendeni Hospital to help promote groundnut production technologies which includes options for the management of aflatoxin and Groundnut Rosette Disease, post-harvest handling of groundnuts as well as for showcasing elite materials for farmers' participation in variety selection. The Department works with 9000 farming families and has well-established structures in the northern part of Mzimba District with the primary aim of uplifting the livelihood of limited resource farmers using various enterprises including groundnut farming. Sets of trials and demonstration for the year 2011-12 from ICRISAT were dispatched to the Department for information dissemination with major focus on aflatoxin mitigation to both collaborating and non-collaborating farmers in Luhomero, Zombwe, Bwabwa and Thimalala as initial target areas. The project also continues to train promoters for the Department from various sections who work directly with farmers on best groundnut production practices. This venture has been very successful in penetrating into communities where NASFAM, our main collaborator, has not been able to establish its structures. Mzimba South Association, though under NASFAM, is a new project site and has also been engaged to promote these technologies through training of both farmers and Association Field Officers. This Association works with over 10,000 farming families whose major cash crop for the past years has been tobacco and with the challenges the tobacco sector is now facing, there is good opportunity for groundnuts to take over as a beneficial cash crop.

3.3. Enhance institutional innovations to improve access of the poor to good quality seeds of improved high-yielding adapted varieties

Community seed banks

During the 2011-2012 growing season, the project supplied a total of 6.5 tons (5.5 tons of ICGV-SM 90704 and 1 ton of ICGV-SM 99568) of groundnut seed through partners targeting new project sites for the development of new community seed banks. NASFAM received a total of 3.5 tons of the variety ICGV-SM 90704. From this Mikundi Association in Mchinji, received 1 ton, Elangeni Association in Mzimba (South NASFAM Association) received 2.5 tons. Apart from this, 1 ton of groundnut variety ICGV-SM 99568 was received for Linga under Nkhotakota Association, while the Department of Agriculture, Nutrition and Soil Fertility under Ekwendeni

Hospital received 2 tons of ICGV-SM 90704. The seed targeted 566 new beneficiaries. The activity has seen the development of 80 new seed banks.

A visit to some of the new seed banks with the National Groundnut Breeder, Malawi, Mr Albert Chamango, showed successful implementation of the activity and farmers expressed appreciation for being accorded a chance to access the seeds of improved varieties. A total of 40 tons of good seed has been recorded so far and produced as follows: 20, 15 and 10 tons for Elangeni, Ekwendeni and Mikundi, respectively. Most farmers have already paid back to the seed bank and the project is expected to work with about 1197 beneficiaries in these new sites. This excess seed has already found its way into ICRISAT's seed-revolving fund. Since inception, the project through this effort has developed a total of 230 seed banks directly reaching a total of 6600 farming families. There is need, however, to ascertain the number of non-collaborating farmers who have benefited from this exercise while capturing success stories from collaborating farmers.

Figures 6 and 7 below show i) a farmer in her groundnut field, and ii) a group of farmers displaying their products for sale.

Figure 6. Ms. Stafelo Lubanga in her field after planting 15 kg seed from ICRISAT-Elangeni (Mzimba)

Figure 7. Women farmers in Elangeni selling excess seed to ICRISAT's seed-revolving fund

Farmer exchange visit

Following much success in the 2010-11 season, the project facilitated another farmer exchange visit during one of the field days in Mzimba. Farmer groups within Ekwendeni were invited to a field day at Chotha Tembo club in Luhomero to appreciate benefits accrued by using the right seed production practices, examine technologies in the demonstrations, participate in the variety evaluation, as well as interact and share ideas with fellow farmers. A total of 20 farmers (13 female and 7 male) from three clubs (Kapiri, Zebedia and Mzuku) were invited. Visiting farmers expressed satisfaction on the manner in which the fields were managed and promised to emulate the same so as to realize the full gains to be attained from groundnut farming. It is hoped that the knowledge thus gained will have spillover effects in their respective areas. This activity was held on 6 June 2012.

In Tanzania the project provided improved seed variety Pendo to new Farmer Research Groups in five villages, Changwale, Pachani, Namaka, Chinyanyila and Mnonia in Nanyumbu District. These villages are in addition to the already existing seed groups. Each group received 100 kgs of seeds for multiplication. Farmers were also trained (Table 5) in specifications of seed production in order to produce quality declared seeds. The project also continued to work with farmer research groups established in the previous season, both in Southern and Central Tanzania. These farmers have produced a total of 28,080 kg of seed for variety Pendo and 2,115 kg of seed variety Mnanje.

Table 4. Seed production training in Nanyumbu District (disaggregated by gender)

Village	**Group name**	**Group members**		**Village leaders**	**Total**
		Male	Female		
Changwale	Jiungeni	5	5	2	12
Pachani	Amani	6	4	2	12
Namaka	Kilimo Kwanza	6	3	1	10
Chinyanyila	Jiendeleze	9	10	2	21
Mnonia	Toto star vijana	12	8	2	22
Total					**77**

Implication of the research findings

Progress made through seed banks will be an important key to increasing the rate of access and adoption of improved varieties, which is paramount to enhancing the nutritional and economic well-being of farmers. Community seed production has had a good effect on the livelihoods of farmers especially in areas where the project has run for the past four years. As such the project views this as one important hub of success and will continue to follow up with partners in order to reach out to many more farmers. On-farm demonstrations were able to validate the effectiveness of improved practices in the management of aflatoxin contamination and GRD. For GRD, results showed high yield gains and reduced rosette incidence through the use of resistant varieties, early planting, and optimum plant population. Additionally, use of box ridges, early planting and a resistant line showed good potential for minimizing aflatoxin contamination. These are important messages that the project can use to break through persistent low yields arising from the use of unimproved varieties and poor production practices. The involvement of various stakeholders in the field days remains a special highlight as the activity was again able to reach a wider cross section of the population in the project sites, an effort that will enhance adoption of the best practices for the management of foliar diseases and aflatoxin contamination.

Objective 4: Capacity of partners for management of mycotoxins in food, variety development, and an enabling policy environment enhanced

Authors

Malawi
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Dickson Mbughi – Project Research Technician, NASFAM

Problem statement
Engaging various stakeholders at every stage of the project's activities will enhance information flow and knowledge exchange on critical issues of mycotoxin, and also instill a collective approach towards mitigating the problem – something that is lacking in the region. This is an essential component of the project as it will make sure that policy makers are informed about the problem which would then result in an appropriate regulatory framework for products, especially for the local markets which don't have one. Increased knowledge will also help partners carry out future projects in a more focused approach and have appropriate harmonization of conventional breeding and farmer participatory approaches. Training offered to farmers on the use of best technological practices for managing aflatoxin will improve adoption of the practices and this would stay in the communities and have a multiplier effect beyond the project period.

4.1. Conduct training workshops for NARS staff

The project trained a total of 14 field staff, including 5 Government Extension Officers, 6 Association Field Officers of NASFAM, and 3 Promoters for the Department of Agriculture - Ekwendeni Hospital. The major focus of the training was on groundnut production practices and post-harvest handling of groundnuts. A total of 150 flyers, in addition to training notes, were given to these participants to facilitate further knowledge in their respective sections.

4.2. Degree training program to MSc student to develop regional capacity for pathology work including screening of commodities for aflatoxin contamination

Athanas Minja from Naliendele Agricultural Research Institute in Tanzania, who was identified earlier, is currently pursuing MSc training at Sokoine University of Agriculture. He is working on mapping the alleles responsible for groundnut rosette disease resistance. The other prospective student was not able to join a US University this year as planned because of GRE requirement in US Universities. We will investigate the possibility of this student joining one of the regional universities in Eastern and Southern Africa.

4.3. Conduct sensitization workshop for policy makers, NARES/ NGOs/ Private sector

Stakeholders' information meeting

An aflatoxin stakeholder information exchange meeting was conducted at Chitedze Research Station, ICRISAT to provide a forum for various players in the groundnut value chain and to exchange ideas on common practices that impact negatively on aflatoxin contamination in foods. Participants were also given a chance to get first-hand information from medical personnel on the effects of aflatoxin on human health. Information from similar activities conducted with farmers was also shared. The activity which took place in September 2011 attracted participation from traders, processors, farmer organizations, researchers, policy makers and medical personnel from Kamuzu Central Hospital. During the meeting, participants made pledges that they will act as instruments of change in their respective organisations.

The project also conducted a baseline survey in Tanzania to identify farmers' perspectives on aflatoxin and management strategies. The survey was conducted in Nanyumbu, Bahi and Bukombe districts from 20 May to 6 June 2011. Respondents were drawn from four villages per district. A total of 240 households were interviewed. The results show that farmers of Bahi have 6.5% awareness and farmers of Bukombe have 25.5% awareness on aflatoxin and management strategies. This awareness level is very low when compared to Nanyumbu where the awareness level of farmer's is 58%. It has also been shown that an average of 54.7% of the respondents in Nanyumbu grade their groundnuts before selling, but in the case of Bahi only 29% of respondents grade their groundnut before selling. These results imply that both farmers and traders pay little attention to the issues of quality assurance, so the importance of a multi-sectoral approach to realise an effective aflatoxin awareness campaign is considerable. These results also reveal the need for holding a stakeholders' information meeting to develop concerted approaches for mitigating the problem.

4.3.1. Develop and share project reports, policy briefs and journal articles

Leaflets, TV and radio programs

One way of ensuring farmer confidence in the technologies being demonstrated on their farms is by providing feedback on results or outcomes of these activities, especially for those who can't visualize while the crop is in the field. To achieve this, training workshops were organized in all the three project sites in Malawi. The training also focused on reorienting farmers on how best to implement trials and demonstration based on past year's experiences. Participants were given a chance to share challenges with researchers and map way forward with special emphasis on layout of trials, demonstrations and data collection. Flyers carrying results comparing improved and unimproved technologies were discussed and distributed to participants. More interest was drawn to the effects of variety, time of planting and water management techniques on aflatoxin contamination. The activity which targeted lead farmers, Government Extension Officers, NASFAM Field Officers and Promoters, and it attracted a total of 100 participants. The training is hoped to have multiplier effects as participants are expected to hold further trainings in their respective locations using the provided resources. Participants were also trained on post-harvest handling of groundnuts. A total of 1500 flyers were distributed. Two community radio stations

(M'mudzi Wathu and Nkhotakota) were used to develop a program covering key areas of the training.

4.3.3. Linkages with the health and other sectors developed and maintained for future collaboration

In Malawi, the Ministry of Health through Kamuzu Central Hospital (KCH) has played an important role in exploring the possible relationships between aflatoxin contamination in food, level of aflatoxin in human blood samples, and prevailing ailments. This study will provide a platform for both policy and designing appropriate intervention strategies. Blood samples collected by KCH were analyzed at ICRISAT laboratory to determine aflatoxin loads. Ekwendeni Hospital has also been engaged through the Department of Agriculture and Nutrition to help in sensitizing communities on the harmful effects of aflatoxin on health and trade. Project activities have fully been incorporated into their outreach programs. It is hoped that the health sector would deliberately create a specific policy to incorporate health-related issues of aflatoxin contamination, especially into their education sessions.

4.4. Establish strategy and time frame for impact monitoring and reporting

The project team had a visit from Dr Carolyn Nombo, who facilitated a planning meeting just before the end of the 2011-12 season not only to review a monitoring and evaluation tool developed earlier to facilitate appropriate and timely implementation of activities but also to take stock of the current activities against the project's theory of change. The team critically looked at the project indicators and reviewed a time frame while focusing on the milestones, methods of data collection, the responsibility of specific individuals in data collection, frequency of reporting, the use of information generated by specific activities, and on what has been implemented and what is still under process. Some important issues that emerged included the need to conduct a survey to establish what benefits farmers have had through the seed banks program, and also to assess the number of non-collaborating farmers who managed to access seed through this activity. Moreover, the team would also determine the proportion of groundnuts from project areas that have aflatoxin levels equal to, or less than, the WHO standards. The meeting took place on 23 May 2012 at the ICRISAT Conference Room, Chitedze Research Station, Lilongwe.

The project team, made up of staff from ICRISAT, embarked on a two-week monitoring exercise from 4-17 January 2012 to ascertain the establishment of on-farm activities, to backstop and distribute data collection sheets in all the three districts (Mchinji, Mzimba and Nkhotakota). In all these places the team in collaboration with partners (NASFAM and Officers from Ekwendeni Hospital) visited all research groups and farmers under community seed production. This exercise, it is hoped, will encourage collaborating farmers to carry out activities based on crop phenology that would eventually help generate meaningful data which is central to providing validity to the different technologies and thus promote adoption. The team also had a chance to train farmers on correct production practices under the community seed production plan.

Appendix B
Publication summary

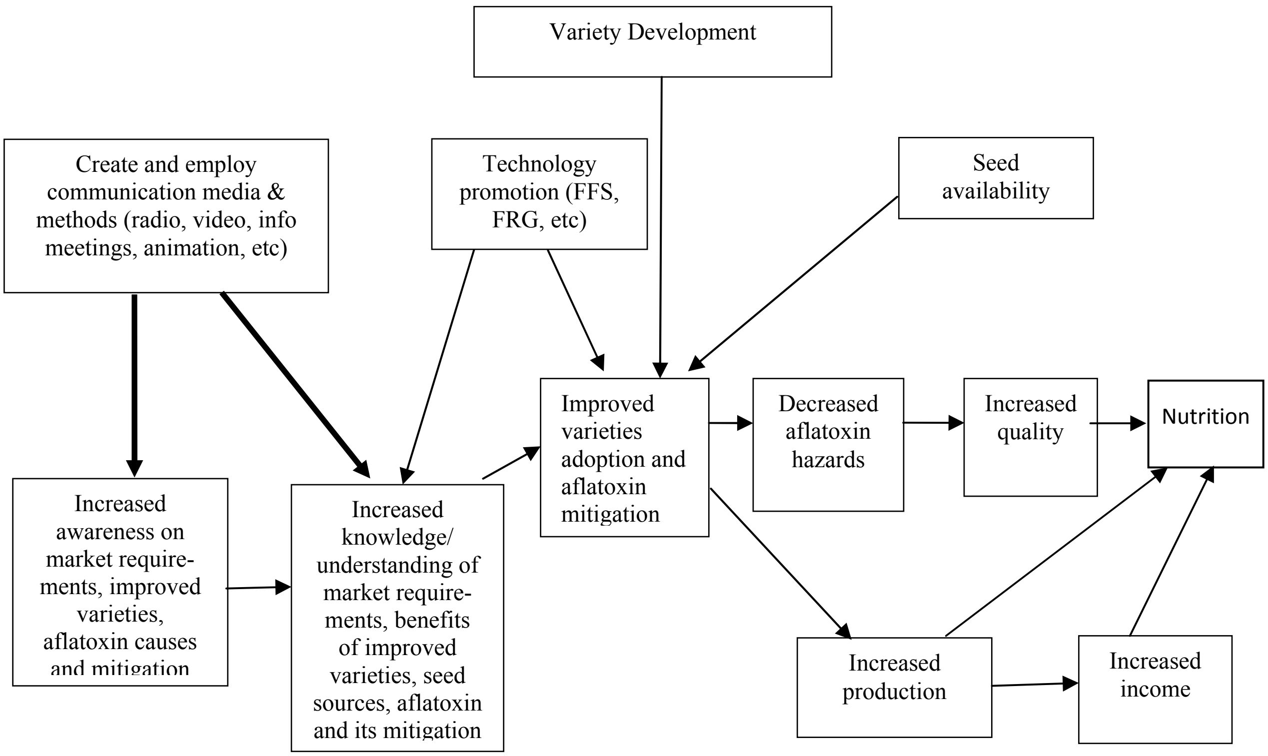
Monyo ES, Njoroge SMC, Coe R, Osiru M, Madinda F, Waliyar F, Thakur RP, Chilunjika T and Anitha S. (In press.) Occurrence and distribution of aflatoxin contamination in groundnuts [*Arachis hypogaea* (L)] and population density of *Aflatoxigenic Aspergilli* in Malawi crop protection.

Monyo ES, Siambi M, Njoroge S, Muzani Y, Munthali WM, Charlie H, Chinyamunyamu B, Mponda O. 2011. Groundnut varieties improvement for yield and adaptation, human health and nutrition. End of Project Report (McKnight CCRP) for East and Southern Africa, 31 August 2011.

Appendix C
Training and outreach

The project conducted two training sessions for Trainer of Trainers with the NGO, CARE-Malawi. The training, which took place in Zomba and Blantyre focused on principles of seed production, seed systems and post-harvest handling of groundnuts. The activity was undertaken from 5-10 August 2012.

Appendix D (i)
Theory of Change (TOC)



Appendix D (ii)
Summary Tables

Appendix 1a. Performance of genotypes under drought stress at Ngabu in Malawi – 2012 season

Cultivar name	Pod yield kg/ha	Kernel kg/ha	Cultivar name	Pod yield kg/ha	Kernel kg/ha
CG 7	1877	1251	Chitala	473	296
Chalimbana	1240	682	ICGV-SM 00537	1389	789
ICG 13338	530	278	ICGV-SM 01514	1621	1088
ICG 13345	1300	830	ICGV-SM 05738	891	494
ICGV 90099	999	484	ICGV-SM 06519	802	559
ICGV-SM 01709	1627	908	ICGV-SM 06525	737	397
ICGV-SM 01711	1674	960	ICGV-SM 06637	800	478
ICGV-SM 01731	1519	848	ICGV-SM 06737	1337	722
ICGV-SM 02724	2377	1519	ICGV-SM 07517	921	512
ICGV-SM 03708	1900	1161	ICGV-SM 07540	1248	630

Cultivar name	**Pod yield kg/ha**	**Kernel kg/ha**	**Cultivar name**	**Pod yield kg/ha**	**Kernel kg/ha**
ICGV-SM 03710	2131	1238	ICGV-SM 07544	1051	594
ICGV-SM 05558	2496	1496	ICGV-SM 07553	1344	767
ICGV-SM 05562	1846	1146	ICGV-SM 08572	1013	603
ICGV-SM 05693	1288	724	ICGV-SM 08577	702	399
ICGV-SM 05702	1512	1092	ICGV-SM 08583	831	510
ICGV-SM 06711	1492	900	ICGV-SM 08586	1032	601
ICGV-SM 07593	859	537	ICGV-SM 99537	612	337
ICGV-SM 07599	2063	1354	ICGV-SM 99551	784	420
ICGV-SM 08501	1751	1064	ICGV-SM 99566	1030	699
ICGV-SM 90704	1242	708	Kakoma	1142	702
Mean	1586	959	**Mean**	988	580
Fpr	0.002	0.001	**Fpr**	0.004	0.006
SEd	354	230.5	**SEd**	222.5	144.3
CV(%)	22.3	24	**CV(%)**	22.5	24.9

Appendix 1b. Performance of genotypes under drought screening in Tanzania – 2012 season

Genotype	**Pod kg /ha**	**kernel kg/ha**
ICG 12991	1083	633
ICG 14788	1513	868
ICGV 00331	2008	1208
ICGV-SM 01514	2532	1247
ICGV-SM 03519	1615	995
ICGV-SM 03520	1553	777
ICGV-SM 03530	1687	1022
ICGV-SM 05650	1147	629
ICGV-SM 05666	1465	788
ICGV-SM 05723	1098	576
ICGV-SM 08503	2342	1494
ICGV-SM 08528	1103	643
ICGV-SM 08533	1438	768
ICGV-SM 08538	1623	1012
ICGV-SM 08540	1438	807
ICGV-SM 08547	1237	768

Genotype	**Pod kg /ha**	**kernel kg/ha**
ICGV-SM 08556	2137	1361
ICGV-SM 08565	815	512
ICGV-SM 99568	1680	860
JL 24	1805	1001
Mean	**1566**	**898**
Fpr	**0.001**	**0.006**
SEd	**300.3**	**208.2**
CV (%)	**19.2**	**23.2**

Appendix 1c. Performance of genotypes under the Regional Rosette Trial in Tanzania – 2012 season

Nachingwea				**Naliendele**			
Genotype	**pod yield kg/ha**	**kernel yield kg/ha**	**Rosette incidence (%)**	**Genotype**	**pod yield kg/ha**	**kernel yield kg/ha**	**Rosette incidence (%)**
CG 7	1386	764	3	CG 7	1875	1247	2
ICG 12991	1485	687	5	ICG 12991	828	581	3
ICGV-SM 01731	1518	820	2	ICGV-SM 01731	2875	1976	2
ICGV-SM 02724	2112	969	3	ICGV-SM 02724	2587	1785	3
ICGV-SM 03590	1056	532	3	ICGV-SM 03590	1437	921	3
ICGV-SM 03710	1518	752	3	ICGV-SM 03710	1570	1020	3
ICGV-SM 05593	1650	733	2	ICGV-SM 05593	2397	1666	3
ICGV-SM 05688	1650	807	2	ICGV-SM 05688	1407	927	3
ICGV-SM 06518	1320	617	3	ICGV-SM 06518	1207	824	3
ICGV-SM 06519	1287	611	2	ICGV-SM 06519	1417	995	2
ICGV-SM 06525	1254	608	3	ICGV-SM 06525	997	678	2
ICGV-SM 06637	990	533	4	ICGV-SM 06637	1200	846	3
ICGV-SM 07517	1452	818	4	ICGV-SM 07517	758	469	3
ICGV-SM 07544	1056	478	2	ICGV-SM 07544	1013	601	3
ICGV-SM 07599	911	388	2	ICGV-SM 07599	1790	1257	2
ICGV-SM 08501	1716	861	2	ICGV-SM 08501	1877	1191	2
ICGV-SM 08503	1650	824	2	ICGV-SM 08503	1558	959	2
ICGV-SM 08560	1617	713	4	ICGV-SM 08560	1437	1016	2
ICGV-SM 90704	1221	505	3	ICGV-SM 90704	1502	876	3
JL 24	1881	1033	4	JL 24	1847	1307	2

Nachingwea				**Naliendele**			
Genotype	**pod yield kg/ha**	**kernel yield kg/ha**	**Rosette incidence (%)**	**Genotype**	**pod yield kg/ha**	**kernel yield kg/ha**	**Rosette incidence (%)**
Mean	1436	703	0.003	**Mean**	1579	1057	2.225
Fpr	0.078	0.232	2.65	**Fpr**	<0.001	<0.001	0.5
SEd	312.2	200.3	0.607	**SEd**	285.1	200.1	0.58
CV(%)	21.7	28.5	22.9	**CV(%)**	18.1	18.9	26.2

Appendix 1d. Performance of Virginia and Spanish genotypes at Nachingwea and Naliendele in Tanzania – 2012 season

Virginia				**Spanish**		
Genotype	**Pod yield kg/ha**	**kernel yield kg/ha**	**Rosette incidence %**	**Genotype**	**Pod yield kg/ha**	**kernel yield kg/ha**
ICGV-SM 05558	2082	1227	1.2	ICGV-SM 08577	2246	1147
ICGV-SM 06711	1989	1233	1.0	ICGV-SM 07544	2149	1030
ICG 13338	2040	1159	1.0	ICGV-SM 08583	2079	1101
ICGV 90099	1903	1096	1.1	ICGV-SM 07553	1860	960
ICGV-SM 05693	1818	1055	0.8	ICGV-SM 08572	1824	1000
ICGV-SM 01709	1878	1054	0.6	ICGV-SM 08586	1718	911
ICGV-SM 05702	1494	968	0.6	ICGV-SM 07540	1658	911
ICGV-SM 02724	1664	986	0.8	ICGV-SM 01514	1608	972
ICGV-SM 07599	1538	974	0.9	ICGV-SM 06737	1647	840
ICGV-SM 05562	1496	908	1.5	ICGV-SM 99537	1592	964
ICGV-SM 03708	1372	846	0.8	ICGV-SM 05738	1467	732
ICGV-SM 08501	1516	895	0.7	ICGV-SM 06525	1176	617
ICGV-SM 01731	1415	796	0.8	ICGV-SM 99566	1491	878
ICG 13345	1377	792	0.6	ICGV-SM 99551	1216	624
ICGV-SM 01711	1260	770	0.7	ICGV-SM 00537	1438	849
ICGV-SM 03710	1270	800	0.8	ICGV-SM 06519	1328	779
ICGV-SM 90704	1172	646	0.6	ICGV-SM 06637	1031	572
ICGV-SM 07593	935	552	1.3	ICGV-SM 07517	1182	687
Chalimbana	1452	769	0.9	Chitala	1423	784
CG 7	1920	1203	0.7	Kakoma	1631	918
Mean	1579	937	0.863	Mean	1588	864

Virginia				**Spanish**		
Genotype	**Pod yield kg/ha**	**kernel yield kg/ha**	**Rosette incidence %**	**Genotype**	**Pod yield kg/ha**	**kernel yield kg/ha**
Fpr	0.476	0.782	0.076	Fpr	<.001	0.009
SEd	451.5	321.7	0.257	SEd	272	150.7
Cv(%)	40.4	48.6	42.2	Cv(%)	24.2	24.7

Appendix 2. Effect of soil amendment factors on aflatoxin contamination – on-station trial in Malawi

Soil amendment factors(treatment)	**AFb1 contamination (ppb)**	**Pod yield/ha**	**kernel yield/ha**
No lime	3502	858	666
Lime applied	1481	1062	821
No manure	3833	910	707
Manure applied	4018	946	708
No Phosphorus	3984	781	611
Phosphorus applied	3604	899	731
Mean	3404	909	707
Fpr	0.575	0.025	0.104
SEd	1554	77.2	70.1
cv (%)	111.8	20.8	24.3

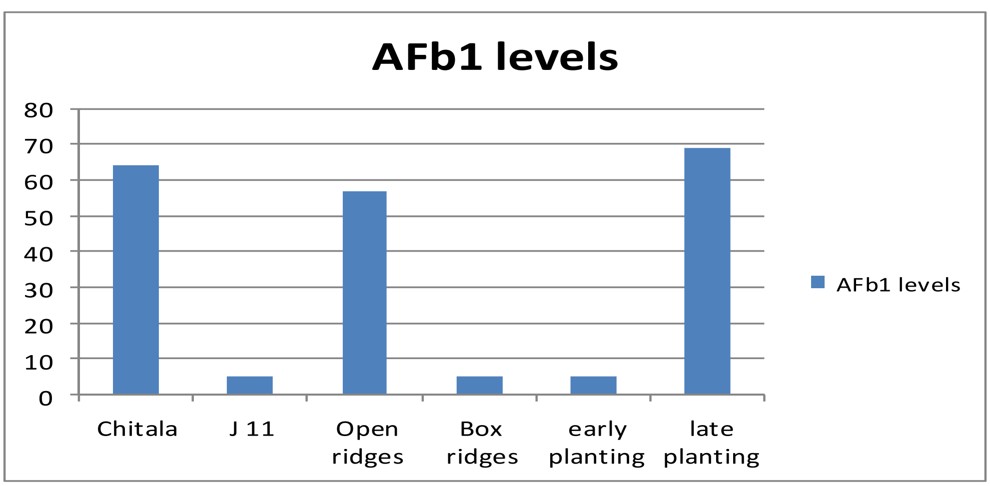


Figure 8. AFb1 levels in the six treatments demonstrated to farmers in Malawi

Appendix 3. Effect of genotype, water management and time of planting interaction in Malawi – 2012 season

Genotype	**Water management**	**Early planting**	**Late planting**
		AFb1 (ppb)	AFb1) ppb
ICGV-SM 99568	open ridges	7.69	239.17
	box ridges	6.66	2.08
J 11	open ridges	4.43	3.22
	box ridges	1.72	10.18
	Mean		34
	Fpr		0.09
	SEd		71.33
	Cv(%)		139

Appendix 4. Effect of individual treatment factors on rosette incidence and kernel yield – on-farm demonstration in Malawi – 2012 season

Geno type	**Incidence %**	**Kernel yield/ha**	**Time of planting**	**Incidence %**	**Kernel yield/ha**	**Plant density**	**Incidence %**	**Kernel yield/ha**
Chalimbana	20.86	414	Early planting	9	587	high density	7.44	610
Malimba	20.74	405	Late planting	15.22	464	Low density	16.78	441
Nsinjiro	3.09	675						
Baka	3.75	608						
Mean	12.11	525		12.11	525		12.11	525
Fpr	<0.001	<.001		<0.001	<.001		<0.001	<.001
SEd	1.84	35.7		1.67	28.5		1.6	27.3
Cv(%)	83.3	37.2		106.8	41.8		102.9	40.3

Appendix 5. Effect of genotype x plant density x time of planting interaction on rosette incidence (%) under on-farm conditions in Malawi – 2012 season

	Spacing	**High**		**Low**	
Genotype	**Time of planting**	**Early**	**Late**	**Early**	**Late**
Baka		0.84	3.5	4.8	5.86
Chalimbana		9.14	16.25	22.65	35.4
Malimba		8.82	15.27	22.08	36.77
Nsinjiro		1.51	4.17	2.11	4.55
Mean					12.11
Fpr					0.19
SEd					1.8

	Spacing	High		Low	
Genotype	**Time of planting**	**Early**	**Late**	**Early**	**Late**
Cv(%)					59.5

Time of planting (Early; First week Dec vs Late; 4th week Dec 2012), High Population Density (0.6m rows, 0.1m within rows vs 0.75m rows and 0.30m within rows)

Appendix 6. Participatory adaptive trials assessing genotype performance in Malawi – 2012 season

Genotype	Pod yield (kg)/ha	Kernel yield (kg)/ha	Rosette incidence (%)	Genotype	Pod yield (kg)/ha	Kernel yield (kg)/ha	Rosette incidence (%)
ICGV-SM 01708	1845	1095	2	ICGV-SM 01514	1654	797	6.08
ICGV-SM 01731	2089	1155	1.38	ICGV-SM 08501	1429	746	2.9
ICGV-SM 01724	2190	1091	1.86	ICGV-SM 08503	1536	816	2.21
ICGV-SM 99772	1776	882	7.27	ICGV-SM 99551	1759	906	7.8
ICGV-SM 01728	1913	1070	3.48	ICGV-SM 99556	1786	1071	7.36
92R/704	1282	706	8.47	ICGV-SM 99567	1690	963	9.63
ICGV-SM 90704	2673	1542	1.54	ICGV-SM 99568	1297	806	4.87
Chalimbana 2005	1977	845	9.29	JL 24	1016	638	16.75
Mean	1968	1048	4.41	Mean	1521	843	7.2
Fpr	0.205	0.124	<0.001	Fpr	0.499	0.66	<0.001
SEd	465	274.9	0.918	SEd	389.1	224.9	1.85
Cv(%)	55.5	61.5	48.8	Cv(%)	57.2	59.7	57.7

Appendix 7. Participatory adaptive trials assessing genotype performance in Tanzania – 2012 season

Cultivar	Kernel yield kg/ha	Location	Kernel yield kg/ha
ICGV- SM 02724	1075	Chagwale	571
ICGV- SM 03516	1150	Namankha	997
ICGV- SM 07553	890		
ICGV- SM 90704	500		
ICGV- SM 94114	650		
Mnanje	625		
Pendo	600		
Mean	784		784
Fpr	0.73		0.054
SEd	466.9		199.2
Cv(%)	59.5		47.5

Appendix 8. Direct matrix ranking for Spanish varieties in Malawi – 2012 season

	Traits						
Variety	**Yield**	**seed size**	**Taste**	**Disease res**	**maturity**	**Total**	**Rank**
ICGV-SM 01514	2	4	3	1	1	11	3
ICGV-SM 08501	1	1	2	2	3	9	2
ICGV-SM 08503	1	2	3	2	3	11	3
ICGV-SM 99551	2	1	1	3	1	8	1
ICGV-SM 99556	2	2	3	3	2	12	4
ICGV-SM 99567	3	2	3	3	2	13	5
ICGV-SM 99568	1	1	2	2	2	8	1
JL 24	3	3	1	3	1	11	3

Ranking scale: 1=best; 5=worst

Appendix 9. Direct matrix ranking for Virginia varieties in Malawi – 2012 season

	Traits						
Variety	**Yield**	**seed size**	**Taste**	**Disease resistance**	**maturity**	**Total**	**Rank**
ICGV-SM 01708	2	3	1	1	2	9	2
ICGV-SM 01731	2	1	2	1	2	8	1
ICGV-SM 01724	1	2	2	1	2	8	1
ICGV-SM 99772	2	3	3	3	1	12	4
ICGV-SM 01728	3	2	2	2	2	11	3
92R/704	4	4	3	3	3	17	6
ICGV-SM 90704	1	2	2	1	2	8	1
Chalimbana 2005	4	1	3	3	3	14	4

Ranking scale: 1=best; 5=worst

Appendix 10. Proportion of field day participants ranking of varieties in Malawi – 2012 season (disaggregated by gender)

Spanish type varieties				**Virginia type varieties**			
	Females	Males	Reason		Females	Males	Reason
No of participants	416	410			416	410	
Genotypes	%	%		Genotypes	%	%	
ICGV-SM 01513	15	3		ICGV-SM 01708	11	10	
ICGV-SM 08501	5	2.5		ICGV-SM 01731	21.5	41.5	seed size
ICGV-SM 08503	6	1		ICGV-SM 01724	10	6	
ICGV-SM 99551	30.5	20.5	yield/taste	ICGV-SM 99772	15	5.5	
ICGV-SM 99556	10.5	15.5		ICGV-SM 01728	5.5	10	
ICGV-SM 99567	6.25	10.5		92R/704	0	2	
ICGV-SM 99568	20.5	41.5	yield/seed size	ICGV-SM 90704	30.5	20	taste/yield

Spanish type varieties				**Virginia type varieties**			
	Females	Males	Reason		Females	Males	Reason
JL 24	6.25	5.5		Chalimbana 2005	6.5	5	
Total	100	100			100	100	

Appendix 11. Field day participants' ranking of varieties in Tanzania – 2012 season

Variety	**Changwale**	**Namankha**	**Mean**	**rank**
ICGV- SM 94114	0	1	0.5	6
ICGV- SM 90704	3	2	2.5	3
ICGV- SM 03516	2	4	3	2
ICGV- SM 07553	2	2	2	4
ICGV- SM 02724	5	4	4.5	1
Pendo	4	5	4.5	1
Mnanje	1	2	1.5	5
No of participants	17	20		

The preferred variety was the one which was selected by the majority of participants as 'best'.

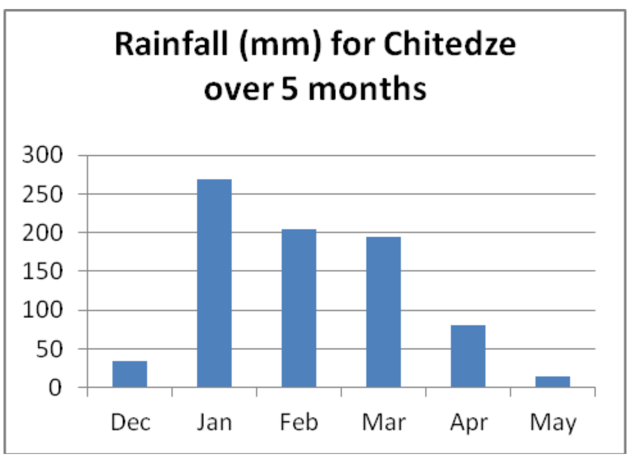


Figure 9. Rainfall distribution at Chitedze Research Station – 2011-12