AflaSTOP:

Drying and Storage for Aflatoxin Prevention

(Formerly the Post-Harvest Drying and Storage for Aflatoxin Prevention Project)

Cooperative Agreement No: AID-OAA-A-12-00010

Annual Report, November 2013-March 2015

PROJECT SUMMARY:

AflaSTOP aims to develop and commercialize technologies for post-harvest storage and drying of staple grains to help prevent and control the incidence of aflatoxin. Aflatoxin is a highly toxic substance caused by growth of Aspergillus fungi. The toxin is known to cause cancer, immune-system suppression, growth retardation, liver disease, and death in both humans and domestic animals. Aflatoxin affects many important food crops in sub-Saharan Africa. Aflatoxin threatens efforts in sub-Saharan Africa to achieve agricultural development, food security and better health.

The AflaSTOP project will identify and develop commercialization strategies for existing, commercially viable, small-scale storage devices and develop new low cost drying technology that will either be affordable to the farmer as an investment or as a service. Storage and drying technology will also reduce post-harvest losses and improve crop handling and management practices. AflaSTOP is using a market-led approach, and is coordinating closely with the Partnership for Aflatoxin Control in Africa (PACA). AflaSTOP will promote the scaling-up of proven technologies across Sub-Saharan Africa by synthesizing and distributing lessons learned to different countries.

USAID and the Bill & Melinda Gates Foundation (BMGF) are funding the AflaSTOP project through a Global Development Alliance (GDA). Meridian Institute, ACDI/VOCA and Agribusiness Systems International (ASI) are implementing the project (the Implementing Partners). In this annual report, the Implementing Partners report on progress since the previous annual report, submitted in October 2013.

PROJECT ACCOMPLISHMENTS

Following the decision by the GDA Partners in April 2013 to proceed with obtaining a project license from Kenya's National Environmental Management Agency (NEMA), the Implementing Partners put several activities on hold while they conducted a full Environmental Impact Assessment. On March 4, 2014, NEMA issued – and AflaSTOP Implementing Partners accepted – the project license (registration Number 0021367). During the GDA Advisory Group meeting on April 11, 2014, GDA partners confirmed their support to continue AflaSTOP as planned.

In addition to the NEMA license, Implementing Partners obtained a license from Kenya's National Council on Science, Technology and Innovation on September 24, 2014 and ethical approval from Maseno University Ethics Review Committee for on-farm testing of storage devices on February 16, 2015.

Following receipt of the NEMA license, GDA Partners agreed that in order to fully implement AflaSTOP and maximize the developmental impact, the project required an increase in funds and an extension of the period of performance. On January 29, 2015, USAID approved a time extension through June 31, 2016 and a budget increase of $402,170 (matched by BMGF for a total increase of $804,340), resulting in a new total project budget of $4,804,340. The GDA MOU was subsequently amended on March 26, 2015 to reflect the funding and timeline modifications.

Implementing Partners have been working on implementation of the *Work Plan: AflaSTOP* that was updated September 6, 2012 and approved on October 20, 2012. Since 2012, Implementing Partners proposed, and GDA Funding Partners approved, several updates to activities included in the Work Plan. For instance, on March 15, 2013, Funding Partners approved a change in the Phase 1 off-farm storage test research methodology; Implementing Partners would conduct research with locally purchased contaminated maize instead of using inoculated maize. Implementing Partners created a detailed, updated research methodology, which was approved by Funding Partners and NEMA. In preparation for Phase 2 on-farm storage testing, Implementing Partners developed an updated "Research Protocol for On Farm Testing of Storage Devices." On February 24, 2015, upon approval by Maseno University Ethics Review Board, the Funding Partners approved the Phase 2 Research Protocol. Implementing Partners are currently updating the Work Plan for the remainder of the project and will submit the updated Work Plan for approval by the Funding Partners in May 2015.

Key Activity 1: Identify commercially viable small scale storage technology that prevents further aflatoxin contamination

Phase 1: Off-farm Testing of Storage Devices

During Phase 1 (off-farm testing of storage devices), AflaSTOP investigated performance of six storage devices in a controlled environment. Table 1, below, provides an overview of each of these devices. The tested hermetic storage devices create varying degrees of airtight storage of grains. AflaSTOP tested the hypothesis that enhanced storage would prevent insect infestation, increases in aflatoxin and fumonisin over a 6 month storage period.

Table 1: Storage Devices

Storage technology	Characteristics	Storage Capacity and Estimated Price
Metal silo	Produced by local artisans, made out of aluminum, placed on a pallet, size ranges from 200 - 1,000 kg	~312 kg Costs ~$144
Plastic silo	Produced by local large scale commercial water tank manufacturer Kentainers, made out of heavy duty reinforced plastic, placed on a pallet	~350 kg Costs ~$92
Grain Pro Grain Safe II - Bulk Bag	Produced by Grain Pro and imported into the country duty free, made out of patented plastic technology, placed on custom made frame, capacity ranges from 800 - 1,300 kg (they are introducing a new 500kg bag)	Up to 1,300 kgs Frame and bulk bag ~$260
PICs bag	Triple layer plastic bag introduced to W Africa by Purdue University, 90 - 100 kg now manufacture in Kenya by Bell Industries needs to be placed on a pallet, capacity ranges 90	~90 kg Costs ~$2.80 per bag

	- 100 kg	
Grain Pro Super Grain Bag	Produced by Grain Pro and imported into the country duty free, made out of patented plastic technology, needs to be placed inside another bag and placed on a pallet capacity ranges 90 - 100 kg	~90kg Costs ~$2.50 each (plus an additional PP bag at about $0.50)
PP bag	Control: Traditional storage bad made of polypropylene. These are non-hermetic and widely available and used.	$0.50

AflaSTOP used a randomized complete block design and a repeated measurement design (nested in the randomized complete block design) with two treatments (wet grain with a moisture above 14% moisture) and dry grain with moisture below 13.5%) in two districts of the Eastern Province, Makueni and Meru. AflaSTOP acquired locally grown maize in each district, and thoroughly homogenized the maize and set baseline levels of grain moisture before storing the maize. AflaSTOP monitored performance of each device and collected data monthly for a total of six months. AflaSTOP analyzed all samples obtained from the devices during the six month storage period for aflatoxin, fumonisin, moisture content, insect count and damage and discoloration. Assessment of insect damage and grain quality factors (discolored and moldy kernels) are ongoing. AflaSTOP engaged an independent statistician to conduct a comprehensive statistical analysis of the influence of storage device, grain moisture content, and location on aflatoxin and fumonisin results. AflaSTOP shared a draft report with USAID and BMGF on February 6, 2015. GDA Partners discussed the preliminary results on February 9, 2015. Implementing Partners presented the preliminary results to USAID staff on April 16, 2015. AflaSTOP is currently developing a final report. Preliminary Results of Phase 1 testing of storage devices include the following.

- ***Aflatoxin development as a function of grain moisture:*** AflaSTOP did not find statistical differences between maize stored with 13.72 and 14.22% moisture levels ('wet') compared to grain stored at 12.20 and 13.12% moisture levels ('dry). This implies that moisture levels up to 15% do not effect aflatoxin development in stored maize. Moisture levels above 15% have not been investigated and the importance of moisture at higher levels cannot be ruled out completely.[1] Regardless, maize in all devices stored at higher moisture levels developed a strong odor. The odor indicates additional microbial activity and a likely occurring fermentation, which might make the grain unacceptable to farmers.
- ***Aflatoxin development as a function of storage devices:*** AflaSTOP compared aflatoxin increase over time as compared to the traditional PP bags. All tested devices showed a significantly reduced increase in total aflatoxin content, compared to the traditional PP bags. However, AflaSTOP found performance differences among devices for both the aflatoxin content (ppb) and the average percentage of increase at five months. The top performing three devices (Bulk bag, PICs bag, and Metal Silo) limited aflatoxin increase to below 5% increase per month compared to the control, the traditional PP bag which experienced a 92% increase per month.
- ***Performance evaluation per location:*** The effectiveness of the Bulk Bag, PICS bag and Metal Silo was not affected in the different locations within and across regions.

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[1] Scott W., Baributsa D., Woloshuk C. 2014. Assessing Purdue Improved Crop Storage (PICS) bags to mitigate fungal growth and aflatoxin contamination

- ***Fumonisin***: AflaSTOP detected fumonisin in the stored maize. Fumonisin levels generally increased over time. AflaSTOP analysis indicates no significant differences among devices, treatments and regions in terms of fumonisin levels or increases over time.
- ***Insect infestation:*** Insect infestation will be investigated once the grading results have been collected. However, preliminary observations show insect infestation at various degrees in all tested devices. Certain bulk devices (Bulk Bag, Metal Silo and Plastic Silo) had some level of live insects at the outlet and some also had insects at the inlet. Both the PICs bag and the Super Grain bag were penetrated from the outside (presumably by grain borers as they were seen both outside and inside the bags) and the SuperGrain Bag was more badly penetrated than the PICs bag. Traditional PP bags became heavily infested with insects. AflaSTOP did not apply insecticides or other insect controls.

Next Steps:
Implementing Partners are finalizing the Phase 1 report for GDA Partners in May 2015. The final report will include grading results, including assessment of insect damage and grain quality factors (discolored and moldy kernels). Implementing Partners will prepare Phase 1 reports and articles for the scientific community, storage producers, and storage users.

Phase 2: On-farm Testing of Storage Devices

Phase 1 showed that reduced oxygen content helps control aflatoxin levels in the tested devices. In Phase 2, which started in December 2014, AflaSTOP will test the influence of smallholder farmer practices, including daily handling of stored grain, on the performance of storage devices. Real world manipulation and use of the storage devices is an important aspect of its overall effectiveness and acceptability for smallholder farmers. During Phase 2, AflaSTOP will gather and assess answers to the following types of questions:

- Do the devices continue to arrest aflatoxin increases when used to meet day to day farm requirements?
- Can farmers use the devices effectively without training?
- Are farmers willing to pay for storage devices?
- How does different information and knowledge influence the willingness to pay?
- Will farmers differentiate investment for home consumption use as compared to store to sell grain?

Based on evaluation of storage devices during Phase 1,[2] GDA Partners selected the following three devices for on-farm testing.

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[2] AflaSTOP evaluated storage devices using the following criteria:
- Superior to traditional storage device, polypropylene bags (PP bags)
- Prevent aflatoxin and fumonisin increase
- Prevent insect and rodent damage of both the device itself and the stored grains

Device	% aflatoxin level increase per month	Purchase price
Grain Pro Bulk Bag (Up to 1000 kg)	No increase	$270
PICs Bag (90 kg)	1.8%	$2.80
Metal Silo (90 – 3000 kgs)	3.1%	$144 (e.g. 300 kgs)

Since starting Phase 2 in December 2014, AflaSTOP refined the design for Phase 2 on-farm tests. To determine whether training in storage device set up is required for proper performance, AflaSTOP created two treatments: 1) key decision makers from each farming family receive training to set up their storage device; 2) families receive the storage devices with only the instructions provided by the manufacturer. AflaSTOP created a paired t-test design in which each farming family in one treatment is paired with a similar farming family in the other treatment. To establish pairs, AflaSTOP used two key criteria: 1) estimated volume stored by the farming family; and 2) number of members in the farming family. The paired t-test design requires a sufficient number of replicates to establish confidence in the statistical results. If the number of replicates is insufficient at the end of Phase 2, then AflaSTOP will analyze the entire group of results.

Since December 2014, AflaSTOP identified and recruited farmers according to the protocols approved by Maseno University Ethics Review Committee. AflaSTOP pre-identified over 450 farmers in the Makueni area as the initial pool of study participants. During further selection, AflaSTOP narrowed this group to 165 farmers from 32 villages. AflaSTOP conducted aflatoxin awareness meetings to ensure that all farmers were equally informed about aflatoxin issues. The meetings were held at the local Chief's office with occasional representation from Ministry of Agriculture extension officers. At the end of March 2015, AflaSTOP provided storage devices to 133 farmers (the other farmers did not show up) and provided training in setting up the devices to half of these farmers.

Next Steps:
Phase 2 testing will continue through December 2015. During this period, AflaSTOP will take maize samples from farmers' storage devices and check moisture levels. AflaSTOP will take and store sub-samples until testing can begin. AflaSTOP engaged a consulting firm to develop and administer willingness to pay surveys.

Key Activity 2: Identify commercially viable drying technology suitable for smallholder farmers

AflaSTOP aims to develop and test three possible technologies suitable for smallholder farmers to invest in as an on-farm asset or buy in as a service from someone moving the technology from farm to farm. Catapult Design, a design consulting firm, developed a Sourcebook of available dryers, and designed,

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- Prevents secondary mold growth and silaging (note: all devices with wet grain exhibited a pungent, bad smell after about five months)
- Presents an economic and generally acceptable alternative to PP bags

fabricated and tested three dryers[3] in November 2014. AflaSTOP tested the following three dryers to compare functionality, performance and potential manufacturability.

- Modified plastic tarpaulin solar dryer: a dryer design targeting smallholder farmers willing to make a small investment to improve their ability to dry harvested product.
- Shallow bed batch dryer and furnace: this mechanical dryer's basic configuration included a furnace, a heat exchanger, and a supply of air (fans). The combination of these units creates heat in the furnace and moves this heat through the heat exchanger and through a raised bed containing the grain.
- Cross flow column dryer and furnace: the dryer uses the same furnace, heat exchanger and fans as the shallow bed dryer, but requires that the grain be loaded into the top of two ~10cm wide columns with hot air passing from the middle out through the grain. The grain finally emerges dried at the bottom.

The tests in November 2014 showed that the performance of the enhanced solar dryer was unsatisfactory when compared to traditional methods of drying. The cross flow column dryer was, in comparison to the shallow bed dryer, a more expensive investment, with about equal operating costs, but more difficult to operate since the grain had to be constantly moved from the bottom to the top to mix it. The column dryer could be adapted to dry larger volumes (2- 3 metric tons per day), but this would require additional extensive design work and probably require an auger to facilitate movement of the grain during the drying process. AflaSTOP did not take these two designs to beta testing.

The shallow bed dryer was easy to set up, relatively easy to transport on the back of a pickup truck, and easy to operate. Currently, smallholder farmers dry their maize by laying it on the ground. The shallow bed dryer intuitively works in a similar way. Farmers can easily check handfuls of the grain for dryness. The dryer operated within operating efficiencies by drying 500 kilograms to below 13.5% within 4 hours. Because of the good test results, including ease of use and efficiency, AflaSTOP took the shallow bed dryer to Beta testing.

In November 2014, Implementing Partners and Catapult engaged with private sector partners, researchers and NGOS to observe the dryers and provide input. These stakeholders provided helpful suggestions about alternative dryer configurations and alternative materials. As a result of their engagement during the November 2014 dryer tests, the International Food Policy Research Institute ordered eight dryers to support a project in Eastern Kenya.

In March 2015, Implementing Partners and Catapult Design worked on a range of design improvements and AflaSTOP took a revised design to the field to conduct further tests with Meru farmers and sheller operators from Meru and from Rift Valley. The dryer was very effective. Both the local businessmen

[3] Dryer designs were shared with GDA Partners. Pictures, are available at: https://www.dropbox.com/sh/90vfgayyp4i9ho2/AACrfcIGlHFXhB0Bx0YwVW4_a?dl=0

(sheller operators) and the farmers were excited about the dryer's operation and performance. AflaSTOP identified several re-design aspects that are being addressed by Catapult Design.

Next Steps:
AflaSTOP will finalize the shallow bed portable dryer design, create a manufacturing manual and complete the dryer source book. In addition, AflaSTOP plans to investigate the capacity of the informal (artisan) sector to manufacture the shallow bed dryer and the impact of informal manufacturing on the performance of the dryer. With this information, AflaSTOP would gain insights into the feasibility of engaging the informal sector in manufacturing and marketing the dryer.

Key Activity 3: Commercialization of Project Technology

Activity 3 will begin in May 2015. AflaSTOP plans to document steps necessary for commercial success and market penetration of the most promising storage and drying technologies, including production, distribution, marketing, sales and customer support. Considering the unique situation of the storage and drying technologies, AflaSTOP will develop a customized approach for each technology.

Storage commercialization strategy: AflaSTOP will not know the final results of the Phase 2 on-farm testing until approximately February 2016. AflaSTOP will work with private sector partners to develop commercialization strategies for all three technologies in 2015, but will only recommend those devices that effectively mitigate aflatoxin during Phase 2.

Dryer commercialization strategy: the shallow bed dryer is untested in the market. Therefore, AflaSTOP will first develop the business case to determine whether building, selling and using the dryer offers value propositions for all potential businesses involved in taking the product from manufacturing to farmer. AflaSTOP will conduct analysis to determine if the product has commercial potential. If one or more of the points in the business case is negative, AflaSTOP will assess whether the constraint can be addressed. AflaSTOP will then develop a commercialization strategy for the dryer.

Key Activity 4: Synthesize and Distribute Lessons Learned

AflaSTOP has been engaging with many partners throughout the project, including: the scientific community working on solutions to mycotoxins and post-harvest technologies; funders and implementers; regional bodies such as PACA and EAGC; Kenya's Ministry of Agriculture; farmers in areas with high aflatoxin prevalence; and private sector businesses (e.g. manufacturers, local service providers, and distributors). As AflaSTOP achieves major milestones during the remaining project period, it will document and share lessons learned and findings with this broad range of partners and stakeholders.

Key Activity 5: Expanding Technology to Different Countries

During the next 15 months, AflaSTOP will consider the minimum requirements needed to expand the effective storage and drying technologies to different countries in Africa. AflaSTOP will review its experimental design and identify what additional testing might be needed in different climatic environments before the device could be promoted as effectively arresting aflatoxin growth. AflaSTOP will identify potential minimum requirements for the private sector to produce or import the storage or drying devices in other countries. AflaSTOP will then identify distribution channels needed, as well as financial aspects that affect the manufacturing, distribution and purchase of storage technology. AflaSTOP will document key elements that determine farmers' willingness to pay for enhanced storage devices and drying and identify which aspects should be explored further in order to determine whether the storage and drying technologies are acceptable in other countries.

Other Activities

In addition to the Key Activities outlined in the work plan, Implementing Partners completed several additional activities that contribute to the goals of identifying and commercializing low-cost storage and drying technology. These include:

- **Raising farmers' awareness on aflatoxin issues**: out of concern over very high levels of aflatoxin in Meru, the Meru County Director, Ministry of Agriculture asked ACDI/VOCA to help with increasing awareness of aflatoxin and the importance of post-harvest handling within Meru. In December 2014, ACDI/VOCA and Meru Ministry of Agriculture staff trained 100 farmers and 15 extension officers (agriculture and health). Subsequently, these farmers – supervised by Meru Ministry of Agriculture extension officers – conducted awareness meetings on aflatoxin and reached at least 3,554 additional farmers. The Meru County Director intends to expand this awareness to the whole of Meru County.

- **Disposal of contaminated maize and cleaning of the stores:** A licensed operator collected and incinerated all contaminated maize, bags, and pallets used during Phase 1. AflaSTOP fumigated each of the stores to kill of any remaining insects and then the stores were scrubbed clean using a 10% bleach solution.

- **Attending PACA and other aflatoxin events:** AflaSTOP staff attended several key meetings, including: PACA Partnership Platform Meeting, Addis Abba; East Africa Community Aflatoxin Road Map Discussion, Kigali; AflaSafe Factory Opening, Makueni. These events offered an opportunity to share information on the project and develop valuable connections and linkages to other entities working to address aflatoxin in Africa.

PROJECT ACCOMPLISHMENTS AND PROJECT GOALS

As described above, most project activities were on hold during 2013 while AflaSTOP conducted an Environmental Impact Assessment and awaited NEMA approval. Upon receiving the NEMA license in January 2014, AflaSTOP continued all project activities in full. On May 2, 2014, Implementing Partners submitted an AflaSTOP Revised Implementation Timeline to USAID and BMGF. AflaSTOP is on track to implement the project according to the updated timeline. The main difference with the updated timeline resulted from a delay in the completion of the Alpha designs of the three dryers; Catapult Design – the consultant working on the drying designs – found the physics behind grain drying more complicated than expected, which resulted in slight delays.

As described on page 3, the GDA Partners discussed and approved several detailed adjustments to the work plan regarding Phase 1 and 2 storage tests in 2013, 2014 and 2015. These adjustments included:

- Revised Phase 1 off-farm storage test research methodology to conduct research with locally purchased contaminated maize, approved on March 15, 2013;
- Revised timeline to accommodate the NEMA approval process, approved on January 29, 2015;
- Updated Phase 2 on-farm storage testing "Research Protocol for On Farm Testing of Storage Devices", approved on February 24, 2015.

The Implementing Partners are currently updating the AflaSTOP Work Plan to fully reflect the revised implementation timeline. The updated Work Plan will be submitted to USAID and BMGF for approval in May 2015.

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