Invited paper presented at the 2018 Annual Meeting of the Allied Social Sciences Association (ASSA), January 5-7, 2018 in Philadelphia, PA

Information, Technology, and Market Rewards: Incentivizing Aflatoxin Control in Ghana

Vivian Hoffmann
International Food Policy Research Institute

Nicholas Magnan
University of Georgia

Gissele Gajate Garrido
Independent consultant

Daniel Akwasi Kanyam
University of the Cumberlands

Nelson Opoku
University for Development Studies

Information, Technology, and Market Rewards: Incentivizing Aflatoxin Control in Ghana

Vivian Hoffmann[1], Nicholas Magnan[2], Gissele Gajate Garrido[3], Daniel Akwasi Kanyam[4], and Nelson Opoku[5]

[1]International Food Policy Research Institute
[2]Department of Agricultural and Applied Economics, University of Georgia
[3]Independent consultant
[4]University of the Cumberlands
[5]Department of Biotechnology, University for Development Studies

December 15, 2017

Abstract

Food safety hazards arising at the farm level affect the health of agricultural households as well as access to high value markets, which typically require that produce meets strict quality and food safety standards. Smallholder farmers face a number of barriers to improving the quality and safety of their produce, including a lack of awareness about safety and quality standards, the cost of equipment required to improve these, and the failure of premium prices to pass through to farmers. In this paper, we examine how lifting each of these barriers affects Ghanaian groundnut farmers' adoption of post-harvest practices that reduce aflatoxin contamination. Aflatoxins are carcinogenic secondary metabolites of certain molds, which cause serious health problems including liver cancer. Common in groundnuts and maize, staple foods in much of Africa, aflatoxins pose a major threat to food safety and hinder the development of local agricultural value chains and export markets. Aflatoxin contamination can be substantially reduced through low-tech, low-cost post-harvest practices. We conducted a randomized control trial in northern Ghana with 1,005 farmers over the course of two seasons to test the imapct of three interventions to improve post harvest practices and reduce aflatoxin levels: (1) farmer training on aflatoxin and its prevention, (2) distribution of free drying tarps, and (3) a price premium for groundnuts found to comply with the local aflatoxin regulation. Training farmers substantially improves post-harvest practices. Tarp receipt further improves some practices, particularly with regards to drying surface. Surprisingly, we find that the price premium had little effect on reported or observed practices, and few farmers even sold nuts at this premium despite achieving compliance. Relative to training alone, tarp distribution reduced afaltoxin contamination by approximately 50 percent in the region and year when background levels were highest. The market premium also reduced aflatoxin levels, although to a lesser extent.

1 Introduction

Recent analysis indicates that the global health burden attributable to unsafe food compares to that of malaria or tuberculosis, and disproportionately affects developing countries (Havelaar et al., 2015). Further, food safety hazards, many of which arise at the farm level, can lock farmers out of valuable markets, and may tarnish the reputations of entire nations, limiting export opportunties. Many barriers prevent farmers in developing countries from adoptoing better food safety practices. First, long-neglected agricultural extension systems mean that information on food safety hazards and their prevention is scarce (Anderson and Feder, 2004). Second, the small scale of production and low incomes of farm households can make adoption of technologies to improve the safety of produce unprofitable, or simply unaffordable. Finally, premiums for safer food and other difficult to observe qualities often do not pass through to the primary producer (Fafchamps, Hill, and Minten, 2008). In this paper, we examine the importance of each of these barriers to farmers' adoption of practices that reduce the risk of afaltoxin contamination in their produce.

Aflatoxins are a common food safety hazard in developing countries, particularly in Africa. These toxins are secondary metabolites of the fungi *Aspergillus flavus* and *A. parasiticus* that contaminate many foods including maize, groundnuts, cottonseed, and tree nuts (Payne, 1998). They are tasteless, odorless, invisible, and are known to increase the risk of liver cancer (IARC, 1993), especially for carriers of hepatitis B and C (Turner et al., 2003). More recently aflatoxins have been associated with impaired physical development in children (Gong et al., 2002, 2003, 2004). Consumption of aflatoxin-contaminated feed reduces livestock productivity and may pose health risks to humans who consume the products of affected animals, though contamination in animal products is far lower than that found in crops (Keyl and Booth, 1971; Diekman and Green, 1992; Iqbal et al., 2014). Acute exposure to high doses of aflatoxin, or aflatoxicosis, can be deadly; an outbreak in western India resulted in 106 deaths in 1974 (Krishnamachari et al., 1975) and outbreaks from 2004-2006 in Kenya resulted in over 150 deaths (Wagacha and Muthomi, 2008).

Aflatoxins also have negative economic impacts through channels besides health. While the impact of aflatoxin contamination on African exports is difficult to separate from other challenges facing the region, one study estimated that strict aflatoxin standards and expensive testing protocols in Europe cost African producers hundreds of millions of dollars in exports per year (Otsuki, Wilson, and Sewadeh, 2001).[1] Recently, produce from Ghana had such a difficult time meeting European standards that several Ghanaian news sources (incorrectly) reported the EU had banned cereal and groundnut imports from the country altogether (GhanaWeb, 2015; Citi Business News, 2015; The Ghanaian Times, 2015). Even in domestic markets, aflatoxin risk has prevented groundnut farmers from selling to large-scale formal sector buyers and potentially receiving higher prices (Watt, 2015).

Aflatoxin exposure is rarely problematic in high-income countries due to routine testing and strict regulatory enforcement. The US regulatory limit is 20 parts per billion (ppb), and for the EU it is even stricter at 4 ppb. These standards ensure that producers and intermediaries use best practices, described in greater detail below, to reduce risks. While standards do exist in some African countries—in Ghana the official regulatory limit for groundnuts is 15 ppb—such standards are practically never enforced in domestic markets (Wagacha and Muthomi, 2008; Wu and Khlangwiset, 2010; Masters, Daniels, and Sarpong, 2013). Furthermore, even if enforced such standards would not affect food produced for household consumption or local informal trade, which account for the majority of production. Farmers would have an incentive to reduce aflatoxin risk in production for home consumption if they were aware of the problem. However, awareness among farmers, intermediaries, and consumers is low (Florkowski and Kolavalli, 2013; Jolly et al., 2009; Wagacha and Muthomi, 2008).

The pervasiveness of informal markets in developing countries presents numerous hurdles to the enforcement of standards. Informal markets are characterized by a lack of branding and a large number of anonymous small-scale producers and intermediaries. Whole-

[1]Others contest the degree to which European standards versus domestic supply issues impede trade (Xiong and Beghin, 2011).

salers, retails, and ultimately consumers of agricultural goods rarely know the conditions under which they were produced, stored, and transported (Hoffmann and Gatobu, 2014; Fafchamps, Hill, and Minten, 2008). Furthermore, consumers are only able to learn about product quality through visual inspection or upon tasting, so producers focus on providing these traits only (Fafchamps, Hill, and Minten, 2008). Because food products are generally consumed in combination, and resulting illnesses occur with some delay, food safety is in many cases a credence good—unknown to the consumer even after consumption.

Under these conditions quality (and specifically food safety) is not rewarded with a higher price and will be under-provided in the market (Antle, 2001; Pouliot and Sumner, 2008). This can happen in both the case of asymmetric information, as first described by Akerlof (1970), or symmetric imperfect information, where neither producers nor consumers know the quality of the good (Antle, 2001). Empirical evidence supports the disconnect between quality and price in unbranded produce. In Kenya, Hoffmann et al. (2013) find no relationship between aflatoxin content and price of unbranded maize, whereas in branded maize flour Hoffmann and Moser (2017) find a negative relationship.[2]

It is generally accepted that farmers will adopt a practice if the expected benefits of doing so exceed the cost, absent constraints (Feder, Just, and Zilberman, 1985). In the case of practices to improve food safety among semi-subsistence farmers, benefits include improved health and potentially higher revenue. Ghanaian groundnut farmers (and consumers generally) are largely unaware of the health risks posed by aflatoxin, and the markets they serve do not reward aflatoxin safety. However, a small number of buyers in Ghana do test for aflatoxin and pay a premium price; this market will likely grow as awareness of the problem increases.[3]

[2]The relationship between price and aflatoxin content in branded maize is not due to farmers receiving a higher price for low aflatoxin maize; it is because mills offering premium flour brands are more likely to test and reject lots of maize with high levels of aflatoxin. While intermdiaries do recieve higher prices from premium millers, farmers generally do benefit due to the lack of traceability in this market (Hoffmann and Moser, 2017).

[3]Corporations with a global brand to protect, and producers of nutritional supplements for malnourished children are among those currently willing to pay a premium (Roberts, 2017). Media coverage of aflatoxin in Ghana is growing; a Google News search for "aflatoxin Ghana" found 23 articles publshed in 2017, 22 in 2016, and 16 in 2015, up from just 8 in 2014 and 2013, and only one per year from 2010-2012.

On the cost side, many aflatoxin prevention measures are simple and inexpensive (Strosnider et al., 2006; Turner et al., 2005; Udoh, Cardwell, and Ikotun, 2000). These measures do, however, generally involve some costs (both time and cash out of pocket) and are incurred at harvest time, when farmers are busy and cash-constrained. Thus even if farmers are aware of aflatoxin and how to prevent it, and believe the market would reward aflatoxin safety, they still may not make the appropriate investments.

In this study we test three interventions designed to encourage smallholder farmers in northern Ghana to adopt good post harvest practices to decrease aflatoxin levels in groundnuts. We do this using a randomized controlled trial over the course of two years. The first intervention addresses the information problem. All farmers aside from those assigned to a pure control treatment in year 1 of the study were trained in a group setting by a local extension agent on aflatoxin, the health consequences of exposure, and how to prevent it. The second intervention, intended to address the cost problem, is the provision of free drying tarps to a subset of treatment group farmers. The third intervention, intended to address the lack of market incentives for provision of safe food, is the offer of a market premium from a "special buyer" for groundnuts that test below the regulatory limit.

In year 1 of the study there were three treatment groups and one control group. The first treatment group received information only, the second received information and free tarps, and the third received information and a market premium offer. The control group received nothing. In year 2, all farmers received information (there was no longer a pure control), a new subset of farmers received free tarps, and another group received the market premium offer.

We find that training farmers leads improvements in reported and observed practices relative to a pure control group. Demand for equipment to improve the safety of nuts is low, even when a premium price is offered. While provision of tarps results in high rates of observed use, it only leads to modest changes in other post-harvest practices. In the region with higher baseline aflatoxin levels, provision of tarps reduced contamination by approximately 50 percent in year 2 of the study. (levels were too low to detect an impact anywhere during year 1). The market incentive has little discernible impact on tarp purchases, observed use, or reported practices in year 1 of the study, and few farmers sold for the premium price despite eligibility to do so. The impact of this incentive on aflatoxin levels in year 2, however, appears of slightly smaller magnitude to that of tarp provision. This suggests that motivated farmers are capable of improving aflatoxin safety even without externally provided inputs, but that the credibility of promises to pay a premium may take time to establish.

The literature on technology adoption in developing countries is vast (see Feder, Just, and Zilberman (1985), Foster and Rosenzweig (2010), and Jack (2013) for reviews of different vintages). To our knowledge, the only other paper focuses on the adoption of practices to improve food safety is Hoffmann and Jones (2017). That paper, which utilizes a similar design as ours, finds that Kenyan maize farmers who produce for sale have significantly poorer post-harvest practices at baseline, and are less likely to adopt a drying technology that reduces aflatoxin contamination, but are more responsive to both subsidies and market incentives for food safety, than pure subsistence farmers. Other studies that examine barriers to production of higher quality or higher value crops pose similar questions to ours: do farmers not adopt because they do not know the benefits of doing so (either monetary or non-monetary)? Do they not have the capital to make the required investments? Or do they lack the necessary information about how to produce higher quality crops?

Perhaps the closest analog to adoption of practices to increase food safety is adoption of biofortified crops. Like food safety, the nutritious content of foods is in most cases a credence good, and will not be rewarded by the market unless consumers are informed of the benefits of biofortificaiton and can recognize biofortified crops. Hotz et al. (2012) and Low et al. (2007) test a multi-faceted intervention to encourage adoption of biofortified orange fleshed sweet potatoes (OSP), which are high in Vitamin A, in Uganda and Mozambique, respectively. Like groundnuts in Ghana, much of OSP production goes to home consumption. Both studies introduce free materials (vines), farmer training on production practices, and community education on child and maternal nutrition. The community education component not only targets farmers, but traders and other potential market participants. Both studies find that the intervention package substantially increases OSP consumption and Vitamin A intake (they do not explicitly look at OSP production as an outcome). Neither tests different components of the intervention independently. A more distant analog is the production of cash crops with an uncertain (to the farmer) market price. In an evaluation of the DrumNet program in Kenya, Ashraf, Giné, and Karlan (2009) find that offering farmers credit, technical training, and the assurance of a high price does incite farmers to switch from subsistence to export crops. Again, this study does not test these interventions separately with the exception of credit for inputs, which is offered to one of two treatment groups.

Our study addresses a gap in the literature by investigating barriers preventing smallholder farmers from adopting practices to produce safer foods. While others have shown how effective simple best practices can be at reducing aflatoxin risk in an African context (Turner et al., 2005), our paper investigates how farmers can be encouraged to adopt these practices. We demonstrate the impact of providing information on food safety (in an environment where little exists), and the additional impact of offering either free access to technology or a market premium for safe food. We find that all three barriers discussed above —lack of information, input costs, and lack of a market incentive —hinder the adoption of these practices. There is growing interest among donors and African governments in reducing aflatoxin risk for both health and economic reasons. Our findings demonstrate that information campaigns can incite farmers to improve practices, and that input provision and market rewards can augment the incentive to do so and further reduce aflatoxin risk. Such approaches could be used in health programing by the public sector or nongovernmental organizations, or by buyers in the context of contract farming arrangements.

The remainder of this paper is organized as follows: In section 2 we provide additional background on aflatoxin prevention and detection, in section 3 we describe our interventions in detail, in section 4 we describe the study setting and data collection process, in section 5 we present our results, and in section 6 we conclude.

2 Aflatoxin prevention and detection

Once aflatoxin occurs it is nearly impossible to destroy. It is heat stable and extremely difficult to remove or neutralize once present in food (Galvez et al., 2003). While fermentation and other processing techniques (Shetty, Hald, and Jespersen, 2007) and enterosorbents (Phillips et al., 2008) hold promise for mitigating the harmful effects of aflatoxins, each of these approaches faces obstacles in terms of consumer acceptance and cost. Preventing contamination is thus the preferred approach to risk reduction.

Aflatoxin contamination can occur at several stages. During planting, farmers can use biological agents to reduce toxigenic molds (Wu and Khlangwiset, 2010). Typically, these agents are atoxigenic strains of *Aspergilli* that outcompete toxigenic strains in colonizing the crop. At $10-20 per acre, this approach is a promising solution, but must be adapted and approved for local conditions, and is not yet widely available in Africa (of Tropical Agriculture, 2016), including in Ghana.

There are many simple practices that prevent the spread of aflatoxins after harvest. Controlling humidity is essential, and can be achieved by thoroughly drying the crop before storing it, and making sure the storage area is well aerated and kept at a cool temperature (Strosnider et al., 2006; Turner et al., 2005; Udoh, Cardwell, and Ikotun, 2000). Using new storage containers (usually woven plastic or jute bags) or cleaning containers before each use helps prevent the introduction of mold spores or insect eggs. Damaged nuts are more susceptible to mold. Sorting out damaged or moldy nuts throughout the drying and storage process is highly effective at preventing aflatoxin (Wu and Khlangwiset, 2010). Farmers can also prevent some damage by applying insecticide to the storage area (Hell, Cardwell, and Poehling, 2003; Lamboni and Hell, 2009). A package of interventions including training and provision of post-harvest technologies including pallets, jute storage bags, and insecticide was shown effective through field trials in the Gambia (Turner et al., 2005).[4] However, little is known about farmers' willingness to invest in aflatoxin reducing technologies, particularly in settings where awareness of the problem is low.

A major barrier to compliance with aflatoxin standards is the high cost and difficulty of testing (Zheng, Richard, and Binder, 2006). Rapid quantitative tests (ELISA, fluorometric assay) give a numeric value for aflatoxin content, and require a reader costing upwards of $4000 in addition to test kits cost $6 per sample or more. Rapid qualitative tests (lateral flow tests, flow-through immunoassay) do not require expensive equipment, but still costs upwards of $4 per sample. Efforts to develop easy to use, low-cost testing methods are ongoing, but these technologies remain years from market. In Ghana, potential buyers of safe nuts include a ready-to-use therapeutic food (RUTF) factory and international food manufacturers such as Nestle and Hershey, whose commercial interests could be seriously threatened by a food safety incident. Currently, these buyers either source groundnuts internationally, or spend heavily to visually sort nuts, re-testing until the aflatoxin standard is achieved.[5] If technical and operational hurdles can be overcome, offering farmers premium prices could potentially be a worthwhile investment for such firms. Subsidies for such efforts could also be warranted, as under the current approach to meeting safety requirements, contaminated nuts are removed from high-value uses but inevitably utilized in lower-value markets, thus concentrating exposure aflatoxin among poorer consumers.

3 Interventions

We test the effects of three interventions over the course of two years. In year 1, we test the effects of information on aflatoxin prevention, tarp provision and a market premium on farmer

[4]The package used in (Turner et al., 2005) cost approximately $50 per household for an average of 1.25 MT of production.

[5]The RUTF manufacturer, Project Peanut Butter, reports spending 13 percent of the value of nuts on sorting.

practices and aflatoxin levels. In year 2, after all farmers have received the information, we test the effects of tarp provision and a market premium on aflatoxin levels.

In year 1 of the study we formed three treatment groups and one control group. Given nonexistent awareness of aflatoxin among farmers during formative research, all three treatment groups received information. We gave free tarps to one of these three treatment groups and offered a market premium to a second. The other treatment group received only information, allowing us to isolate the effects of receiving tarps or a market premium from those of information alone. To achieve adequate statistical power we assigned treatment at the household level. Assignment to the control group (versus any of the three treatments) was stratified by village and using a re-sampling routine to improve balance along several outcome variables of interest (see Appendix 1 for details). The particular treatment group to which a household was assigned was determined through a random draw conducted after the information session, to which all treatment households were invited.

Aflatoxin levels can vary greatly from year to year, and were extremely low throughout Ghana after year 1 of the study. Therefore a second year of the intervention was added to capture the impact of the interventions on aflatoxin. At the conclusion of year 1, control farmers participated in information sessions to fulfill commitments made during the ethical approval process leaving only three groups in year 2: information only, tarp provision, and market premium (there is no longer a pure control). This allows us to test for the impact of tarp provision and a market premium conditional on having received information. The year 2 interventions and how they were assigned are described in more detail in subsection 3.4.

3.1 Information

Two months before the 2015 groundnut harvest (year 1), farmers assigned to one of the three treatment groups were invited to participate in an information session. The research team visited farmers the day before the session, and told them that they would have a chance to receive free tarps at the meeting. At the time of invitation, the enumerator asked the farmer whether or not he had planted groundnuts, how the season was progressing, and what quantity of groundnuts he expected to harvest. This last question determined how many tarps the farmer would receive if he were to be selected for the free tarps treatment group. If the respondent was not expecting to harvest any groundnuts, a household member who was expecting to do so was invited to the information session. 725 of 752 households invited to send someone to the information session did so. No farmers in the control group attended.

A trained agricultural extension agent conducted the information session from a script. The agent first explained the how aflatoxin contamination arises, and the health consequences of dietary exposure. He made clear that contamination cannot be eliminated through cooking or processing groundnuts, aside from pressing the nuts for oil and disposing of the remaining cake. He then described recommended practices for aflatoxin reduction during harvest, plucking (removing pods from vines), drying, and storage. The specific practices covered in the training can be found in Appendix 2.

At the conclusion of the information session, participants drew numbers which determined their assignment to one of the three treatment groups: information only, tarp provision, or market premium. The latter two treatments are discussed in more detail below. The three groups were physically separated, and farmers took a pictorial quiz on post-harvest practices to reduce aflatoxin and then reviewed the correct answers with a research team member. After the quizzes farmers in all treatment groups were told tarps would be available for purchase in their village one to two weeks later at a price of 10 GHC (rougly $4 at the time).[6] Participants were given a non-transferable coupon for tarp purchase, and were told that the tarps were available for sale to study participants only. Farmers in all three treatment groups were reminded of best practices during a post-harvest visit immediately after the groundnut harvest (described in subsection 4.2.2).

[6]This was the price at which tarps could be purchased in Tamale, the regional capital and commercial center. Tarps were not observed for sale in any of the villages or nearby towns.

3.2 Tarp provision

In year 1 we aimed to give farmers in the tarp provision group as many tarps as needed to dry their projected groundnut production, but no more. We intended for farmers to have enough tarps so they did not combine groundnuts dried on tarps with groundnuts dried on bare ground in storage, but not so many tarps that they could sell or give them to others in their community. Due to supply constraints, we limited the number of tarps a single farmer could receive to six. This limit was binding for 126 of 266 farmers receiving tarps.

3.3 Market premium

At the conclusion of the information session, a research team member explained to farmers in the market incentive treatment the nascent demand in Ghana for groundnuts with low levels of aflatoxin. The team member then told farmers that they would receive 15 percent above the prevailing market price for groundnuts meeting the Ghanian regulatory aflatoxin standard of 15 ppb or less,[7] and led farmers through a table showing the premium for various market prices.

Based on a market survey conducted the previous year, we set the main purchasing period to be 2-3 months after the harvest, concurrent with the first follow-up survey. By this time, the impact of post-harvest practices on aflatoxin levels should be apparent, but most farmers would still have groundnuts in storage. Farmers were also given the phone number of a buying agent they could call to sell nuts to after this time. Farmers in this treatment group were reminded of the opportunity to sell to our buyer shorty after harvest during the post-harvest visit, and were called several days before the follow-up survey and groundnut purchase visit. Tests would be performed in the village at the time of sale, and farmers would be shown the result indicating whether or not the buyer would purchase the groundnuts at a premium.

[7]This premium was set through discussions with groundnut buyers, but was financed using research funds, as it was not possible to match the timing and volume of supply from study farmers to demand from existing premium markets.

Despite the fact that nearly all farmers qualified for the premium, only a few would sell their groundnuts. There are several factors that could have prevented them from doing so: poor timing, a lack of flexibility over when farmers could sell, a confusing (and inadequate) premium, and mistrust given it was the first year such an offer was made. In year 2 we attempted to make selling to the special buyer more attractive.

3.4 Year 2 interventions

Treatment status in year 2 was randomly assigend stratified by year 1 treatment status and village. The randomization was set up so that no farmer received a tarp in both years, or a tarp in year 1 and the market premium in year 2. We provided tarps to 64 farmers in the year 1 control group and 59 in the year 1 information only treatment. These farmers, plus the 277 farmers assigned to receive tarps in year 1, are in the year 2 tarp treatment.[8] We offered the market premium to 119 farmers who were offered it in year 1, 60 farmers from the year 1 information only treatment, and 63 farmers from the year 1 control group. 118 farmers from the year 1 information only treatment, 119 farmers from the year 1 market premium treatment, and 126 farmers from the year 1 control group were not given a tarp or offered a market premium in year 2 and thus compose the year 2 information only treatment. These numbers total to 363 farmers were in the year 2 information only treatment, 400 in the year 2 tarp treatment, and 242 in the year 2 market premium treatment.[9]

The research team provided farmers in the tarp (market premium) treatment group with tarps (the opportunity to sell at the premium price) through door-to-door visits approximately one month before harvest. In addition, they reminded all farmers about the best practices on which they had previously been trained, and given an opportunity to purchase tarps one to two weeks after the household visit.

[8]The woven plastic tarps dispersed by the research team are rugged and have a multi-year life.

[9]Our initial design was to have four treatment groups of equal size: (1) information only, (2) tarps, (3) market premium, and (4) tarps and market premium. We changed to three groups, but due to a coding error, the fourth group was not redistributed evenly among the other three leaving half in the tarp treatment group (those who received a tarp in year 1) and half in the information only treatment group.

To make the premium price offer more attractive in year 2, farmers were able to call the buyer at any time after harvest. The buyer would make as many purchase visits as needed to the village to purchase nuts at when farmers wished to sell. Also, instead of using a percentage premium we offered an additional 25 GHS per bag. Typically, bags sell for 100 GHS after the harvest and for as much as 300 GHS immediately preceding the next year's harvest. We believe the flat rate was easier for farmers to understand, and would also incite them to sell earlier rather than waiting for the price to increase.

4 Data

4.1 Study area and sample

In Ghana, groundnuts provide income for farmers and are an important source of macro and micronutrients (Florkowski and Kolavalli, 2013).[10] Over the past decade, Ghana has produced an average of 500,000 MT of groundnuts annually, making it the tenth largest producer worldwide (FAOSTAT, 2016). Eighty percent of Ghanaians consume groundnuts in some form at least once a week (Jolly et al., 2009). While awareness of aflatoxin and associated health risks is generally low in Ghana (James et al., 2007), the issue has received some media coverage in recent years (Ghana News Agency, 2013).

Our study takes place in two of the three regions in northern Ghana: Northern Region and Upper East Region. Over 80 percent of national groundnut production occurs in Northern Region (Tsigbey, Brandenburg, and Clottey, 2003), which accounts for the majority of land in northern Ghana and thirty percent of the country's total land area. Upper East is about one-eight the size of Northern Region.[11] Northern Ghana is dry, with a single rainy season. In Northern Region the rainy season goes from April/May to September/October, and in Upper East it goes from May/June to October. It is during this time that groundnuts,

[10]Groundnuts contain high levels of fats, proteins dietary fiber, potassium, magnesium and iron.

[11]The third region in northern Ghana is Upper West, which was not included in our sample due to security concerns.

as well as most other crops, are cultivated.

The initial sample consists of 1,005 farmers selected from 20 villages in Northern Region and 20 villages in Upper East. In each region we selected the five districts (the geographic unit below the region) closest to our bases of operation (Tamale in Northern Region and Navrongo in Upper East). Within each district, we selected four villages at random that satisfied three criteria. First, we only included villages where a large proportion of households grow groundnuts according to the Ministry of Agriculture. Second, we only selected villages with between 100 and 300 households so that they would be large enough to contain at least 25 groundnut producing households, but small enough to conduct a village census. Third, we included only villages within two hours of a base of operation to limit costs.

4.2 Data collection

Fieldwork for this study took place from December 2014 to May 2017. A project timeline that includes groundnut cultivation, interventions, and data collection activities can be found in figure 1.

In December 2014 (Northern Region) and January 2015 (Upper East) we conducted a baseline survey and collected groundnut samples from each household's storage for aflatoxin testing. In July (Northern Region) and August (Upper East) 2015, we conducted our year 1 interventions approximately two months before the groundnut harvest (July 2015 in Northern Region and August in Upper East). Immediately following the interventions we began offering tarps for sale and recording these sales. Shortly after harvest (September 2015 in Northern Region and October in Upper East) we conducted a series of post-harvest observational surveys and visits. One year after the baseline survey we conducted the year 1 endline survey and again collected groundnut samples for aflatoxin testing.

Year 2 interventions took place in August (Northern Region) and September (Upper East) 2016, and again we immediately began offering tarps for sale. There were no post harvest observational visits in year 2, and only a brief endline survey conducted in May 2017 at the same time groundnuts were sampled for aflatoxin testing.[12]

4.2.1 Baseline survey

In each village, we selected 25 groundnut farming households from the village census. Upon arriving at a selected household, enumerators asked for the member who harvested the most groundnuts in 2014 and still had some in storage. If this person was not available, the enumerator asked to speak with another member who harvested groundnuts in 2014 and still had some in storage. If no adult household members grew groundnuts and had some in storage, a replacement household was selected from a randomly ordered backup list drawn from the village census. Every effort was made to ensure the respondent to the baseline survey attended the information session described above.

The baseline survey contained questions on groundnut production, post-harvest practices, and marketing as well as demographics, asset ownership, and groundnut consumption. At the conclusion of each survey, the enumerator asked to purchase a small sample of groundnuts for aflatoxin testing. When applicable, separate samples were taken for groundnuts intended for sale and groundnuts intended for home consumption. The enumerator took a sample representative of all groundnuts in storage intended for each use by randomly choosing bags to pull groundnuts from, and pulling from multiple locations within each bag. Samples were then taken to the Opoku laboratory at University for Development Studies, ground, and tested for aflatoxin using fluorometric assays.[13] We surveyed 1,005 farmers at baseline and collected groundnut samples from 920 of them (the others did not harvest groudnuts).

[12]The endline survey was shortened due to budgetary constraints, and the endline survey and groundnut sampling were conducted much later than in year 1 due to funding delays.

[13]FluoroQuant reader and kits from Romer Labs, Union, MO.

4.2.2 Post-harvest observation

Coinciding with the year 1 groundnut harvest we conducted a short visit and survey with all households to directly observe drying and storage practices, both for validation of reported practices and for use as outcomes for analysis. Given that post-harvest activities occur at different times, it was not possible to make complete observations of all practices in all households. Visits were timed to maximize the probability of observing drying, based on farmers' anticipated harvest dates. In addition to observing the surface on which nuts were being dried and the conditions under which they were stored, a survey was administered about various post-harvest activities, including the timing of harvest, length of time between uprooting and plucking, removal of visibly damaged or diseased nuts, and tarp purchase or possession. If the farmer had not yet begun drying, the enumerator returned for a second visit. Farmers assigned to any of the three treatment groups were reminded of best practices to prevent contamination during this visit, reinforcing messages from the aflatoxin training. We observed and interviewed 922 farmers at this stage: 108 farmers yet to harvest, 130 farmers with their groundnuts pulled and in the field, 307 farmers during the drying phase, 453 during the storage phase, and 54 who were no longer in possession of their groundnuts.

4.2.3 Year 1 follow-up surveys and groundnut testing

One year after the baseline survey we conducted a follow-up survey containing many of the same questions about groundnut production, post-harvest practices, marketing, and consumption. In addition, the survey contained questions about tarp purchase and use.

At the conclusion of the survey, enumerators attempted to purchase groundnuts at the market price (for the information only treatment, tarp treatment, or control group) or at a premium price (for the market incentive group). Very few farmers agreed to sell, and in this case enumerators instead purchased a sample of groundnuts for aflatoxin testing. As in year 1, when applicable separate samples were taken for groundnuts intended for sale and home consumption. Unlike at baseline, farmers we asked to shell and sort their nuts for home consumption as they would before preparing a meal. Because testing needed to be done at the point of sale, we used a mobile rapid testing procedure for all aflatoxin testing at endline.[14] This method was validated by one of the authors prior to use in the present study, and also independently validated in several laboratories (Rhoads et al., 2016). We located 913 of our original 1,005 farmers for the year 1 endline survey and collected groundnut samples from 737 of them.

4.2.4 Year 2 follow-up survey and groundnut testing

Six months after the year 2 intervention we conducted a second follow-up survey with questions designed to understand farmers' expectations regarding the market premium treatment and their groundnut sales. This survey was far shorter than the previous follow-up survey, and took place several months later in the year, due to funding constraints. Enumerators collected groundnut samples at this time for aflatoxin testing, following the same protocol as in previous rounds. Because collection was done much later than in year 1, the vast majority of farmers no longer had groundnuts sorted out for multiple uses and a single sample was taken. We re-interviewed 928 of our original 1,005 farmers and collected groundnuts from 752 of them.

4.3 Baseline sample characteristics

Table 1 presents summary statistics for demographic and groundnut production, post-harvest practices, and aflatoxin levels at baseline. Column 1 contains full sample averages and columns 2 and 3 compare the Northern and Upper East Regions.

Most households (84 percent) in the sample are male headed, but 32 percent of respondents—the primary groundnut producer in the household—are women. Only 13 percent of respondents are literate. On average respondents cultivate just under two acres of groundnuts, have approximately five tropical livestock units (TLU), and have been farming for 19

[14] Neogen test strips (Neogen, Lansing, MI) and Mobile Assay strip reader (Mobile Assay, Boulder, CO).

years.

At baseline, farmers generally did not exhibit good groundnut post-harvest practices. Sixty percent dry their groundnuts on bare ground and only one percent use tarps. Only sixteen percent hand sort their nuts before storing them, and seventeen percent dispose of visibly bad nuts. Twenty-seven percent of the sample treat their storage unit with pesticide and 44 percent store their groundnuts in new bags. On a more positive note, Eighty-one percent report storing their groundnuts on raised pallets.

There are substantial differences between the two study regions. Upper East respondents are more likely to be female, and households more likely to be female-headed and have less members than in the Northern Region. Upper East respondents were twice as likely to be litterate and have four more years farming experience. Groundnut acreage per household is half as large in Upper East than in Northern Region, and post-harvest practices also vary. Drying on dirt is less common in Upper East, whereas drying on concrete (either roofs of slabs on the ground) is twice as common. In Upper East approximately five percent of households sorte groundnuts by hand and dispose bad ones, whereas in Northern District nearly 30 percent do. Treating the storage area and storing on pallets is less common in Upper East than Northern.

To test for balance between treatments we use the joint test of orthogonality suggested McKenzie (2015) and regress treatment status on the 16 variables shown in table 1 using a multinomial logit. We fail to reject the null hypothesis of joint orthogonality ($p = 0.25$ for the year 1 randomization and $p = 0.75$ for the year 2 randomization), indicating our sample is balanced across treatments.

4.4 Aflatoxin levels

Table 2 reports distributions of aflatoxin levels during the three rounds of data collection (baseline, endline year 1, and endline year 2), as well as the percentage of samples above key thresholds. We report values from all farmers at baseline, control farmers only at year

1 endline, and information only farmers at year 2 endline to mitigate the influence of our interventions.

Mean aflatoxin level for the entire study sample at baseline is 60 ppb, well above the Ghanian (and any) regulatory standard. In the Northern region it is 100 ppb, and in the Upper East region it is 25 ppb. High mean aflatoxin levels are driven in a large part by long right tails in the distribution, indicative of infrequent but explosive outbreaks. The median level of aflatoxin for the entire sample is only 11 ppb, under the regulatory limit, and the difference between regions is less pronounced: 14 ppb in Northern and 9.5 ppb in Upper East. The 75th percentile is also well below the mean in both regions. Nevertheless, a substantial portion of sampled groundnuts are above the Ghanian 15 ppb limit in both regions: 46 percent in Northern and 22 percent in Upper east. Over 90 percent are above the European 4 ppb limit in both regions.

Aflatoxin levels can vary greatly from year to year. The baseline sample was taken after the 2014 planting season, the year of the aforementioned concerns over trade bans from Europe. In contrast, at year 1 endline levels were extremely low. Mean contamination in the year 1 sample is 2.8 ppb (3.7 ppb in Northern and 2.1 in Upper East). Less than three percent of samples are above 15 ppb (4.2 percent in Northern and 1.9 percent in Upper East) and less than 7 percent above the European limit (10 percent in Northern and 5.7 percent in Upper East). Other research teams confirm these very low levels throughout northern Ghana.[15] Given such low aflatoxin levels, it is highly unlikely our interventions could have much of an effect.

To potentially observe intervention effects on aflatoxin levels we extended the study another year. At year 2 endline, aflatoxin levels are higher than year 1 but not nearly as high as at baseline. Mean contamination is 3.5 ppb (5.5 in Northern and 1.6 in Upper East). Six percent (7 percent) of samples are above 15 ppb (4 ppb), and these are nearly all concentrated in Northern Region.

[15]Personal communication, Dr. Mumuni Abdulai, CSIR-Savanna Agricultural Research Institute, Tamale.

In all three years of groundnut samples, aflatoxin levels are higher for Northern Region than Upper East.[16] As shown in Table 1, farmer characteristics and practices also differ substantially between the two regions. For this reason we will test for treatment effects by region in the section to follow, as well as for the full sample.

5 Results

In the bulk of this section we test the impact of our interventions on post harvest practices, both observed and reported, at year 1 endline. In section 2 we described a number of practices farmers can adopt after harvest to reduce aflatoxin risk. Here we test for impacts on ten specific practices divided into three categories:

1. *Drying practices*: Drying on dirt (bad), drying on tarps (good), drying on concrete (better than dirt, not as good as tarps), drying for at least seven sunny days

2. *Sorting practices*: Sorting before storage, sorting before consuming, and disposing of the worst nuts

3. *Storage practices*: Treating the storage area with pesticide, using new bags to store groundnuts, storing groundnuts on raised pallets

In addition to testing individual practices, we will reduce the dimensionality of analysis by testing impact on the total number of good drying practices (storing on dirt counts negatively), total number of good sorting practices, total number of good storage practices, and overall total number of good practices.

Next we will test the impact of our intervention on tarp purchase and ownership.Using tarps to dry groundnuts was a focal point of our information intervention. Tarps are an inexpensive and easy to use technology that we found to be effective at reducing aflatoxin

[16] At baseline and year 2 endline these differences were significant at $p < 0.05$. At year 1 endline year the difference was not significant ($p=0.12$).

levels in a pre-study pilot. Tarps were only readily available in the study area through the research team, and were available for purchase at several occasions at a subsidized price.

Finally we test for impacts of aflatoxin contamination in groundnut samples collected from study farmers. Because of the long right tails common in aflatoxin distributions, we do this for both aflatoxin levels and logged values (using the inverse hyperbolic sine transformation). We also test for impacts on the probability of being above the Ghanian (15 ppb) or European (4 ppb) regulatory limit using linear probability models.

For outcomes at year 1 we estimate the following:

$$y_{ij}^{E1} = \beta_I Info_{ij} + \beta_T Tarps_{ij} + \beta_M Mkt_{ij} + \beta_1 y_{ij}^B + \beta_2 missing_{ij}^B + \theta_j + \varepsilon_{ij} \tag{1}$$

In equation 1, y^{E1} is the outcome at year 1 endline, $Info$, $Tarps$, and Mkt are the information only, free tarps, and market premium treatments, respectively, y^B is the outcome at baseline, and $missing^B$ is a dummy variable for a missing baseline value. We control for village dummies θ, the year 1 treatment stratification variable.[17] ε_{ij} is an individual error term.

For outcomes at year 2 we estimate the following:

$$y_{ij}^{E2} = \beta_T Tarps_{ij} + \beta_M Mkt_{ij} + \beta_1 y_{ij}^B + \beta_2 missing_{ij}^B + \theta_j + \varepsilon_{ij} \tag{2}$$

In equation 2, y^{E2} is the outcome at year 2 endline, $Tarps$ and Mkt are the free tarps and market premium treatments, respectively. Recall that after endline 1 control farmers received the information treatment. The variables y^B and $missing^B$ are as above. We control for village dummies θ and year 1 treatment, which are the year 2 stratification variables. ε_{ij} is again an individual error term.

[17] Whether a farmer was assigned any treatment or placed in the control group was determined by stratifying on village and other variables as described in Appendix 1.

5.1 Post harvest practices

Table 3 contains impacts on good drying (columns 1 and 2), sorting (columns 3 and 4), and storage (columns 5 and 6) practices. Columns 7 and 8 show impacts on the overall number of good practices. All three treatments improve the number of overall good practices adopted. Looking at subsets of practices we see that all three treatments increase the number of good sorting and storage practices. Drying practices are unsurprisingly improved by distributing free tarps, and the market incentive has a marginally significant positive impact on drying practices in the full sample, but information alone had no effect. The tarp treatment has a significantly higher impact than information alone on drying and storage practices, but not sorting practices. The market premium does not have a significantly greater impact on any subset of practices (or overall practices) than information alone, but point estimates are mostly higher.

When we look at impact by region, we observe stronger effects of all treatments on good sorting and storage practices in Upper East than we do in Northern Region. Tarps have a similar effect on the number of good drying practices across regions, but the point estimate is greater for Northern Region, where ground drying is more common.

Table 4 contains treatment effect estimates for specific drying practices. Giving farmers free tarps unsurprisingly shifts drying from the ground and concrete to tarps in both regions. We see much weaker evidence of this shift from the information only treatment and no significant effect of the market premium treatment, both of which require that farmers purchase their own tarps (which we discuss in section 5.2 below). We see a significant positive impact of the market premium on the length of drying time, but by less than half a day.

Table 5 contains estimates for specific sorting practices. The three treatments have similar impacts on sorting before storage, which prevents the spread of aflatoxin in a farmer's groundnut stock. Thus, the information is effective at improving this practice but giving free tarps or offering a market premium has no additional effect. This effect is concentrated among Upper East farmers. We also find that the information treatment increases the probability that farmers dispose of their worst nuts, although somewhat perplexingly that effect is larger with free tarps and muted with the market premium.

Table 6 contains estimates for specific storage practices. These practices require capital inputs, albeit modest ones. the information treatment has no effect on the probability of using pesticide use or new containers, however the tarp treatment does, suggesting crowding in of investment rather than crowding out; the farmer has used a tarp to produce better nuts and wants to maintain that quality through better storage practices. The market premium treatment also increases pesticide use significantly, and the estimated effect on using new containers approaches significance ($0 = 0.113$). The three treatments have approximately the same effect on using pallets, although we only see this using farmer reports; observed pallet use did not increase. Perhaps this is due to farmers having a broader definition of what constitutes a raised pallet than enumerators,[18] or perhaps farmers who underwent training claimed to use pallets to please them. Effects on storage practices are again concentrated in the Upper East Region.

5.2 Tarp purchases

One objective of this study is to see if training or market rewards incite farmers to invest in new technology (in this case tarps) themselves. To accomplish this we offered to sell farmers drying tarps at subsidized prices. In year 1 (table 7) we were somewhat successful in selling tarps. We gave out vouchers for subsidized tarps to treatment farmers only. However, eight percent of farmers (5 precent in Northern Region and 12 percent in Upper East) report buying at least one tarp (from nobody in particular), and observational data reveals an average of 0.16 tarps in each farmer's compound in the control group (0.11 in Northern and 0.23 in Upper East). Thus, it was possible for control farmers to obtain tarps.

The information treatment increases the probability a farmer reports purchasing at least

[18]Enumerators were looking for something that allowed airflow underneath the bags, whereas a farmer may have considered any raised structure, such as a large rock, to be a pallet.

one tarp by 10 percent (columns 3 and 4). The point estimate is slightly lower in the free tarps treatment and slightly higher in the market premium treatment (in Upper East, farmers in the tarps treatment group purchased no tarps but those in the other two treatment groups did). Perhaps unsurprisingly, farmers given free tarps are less likely to purchase additional ones, although nearly half of the sample did not receive enough free tarps for their entire projected harvest. Effects on the number of tarps purchased are proportionate, indicating that farmers who did purchase tarps bought roughly three on average. The number of observed tarps at farmers' compounds in the information treatment and the market incentive treatment group is larger than in the control group, although not significantly so. The number of tarps observed at the compounds of the free tarp households is much higher, roughly by the average number of tarps given out, indicating that they did not sell or give them away.

In year 2 we again sold tarps. Six percent of farmers purchased at least one, but there is no discernible difference between treatment groups (point estimates for tarp purchase are negative). Perhaps all farmers motivated to purchase a tarp already did so by this time, as everyone had been given the information treatment and been offered to purchase tarps and we found no additional effect of the treatments beyond information on purchases in year 1.

5.3 Aflatoxin levels

Overall, aflatoxin contamination levels in the study area were very low in 2015, apparently due to climatic conditions. The mean contamination of groundnuts collected from households in the study sample is just 3.3 ppb, well below the regulatory limit of 15 ppb in Ghana; only 4.6 percent of samples are above 15 ppb. Within this context, between-group differences in aflatoxin levels are difficult to detect. Furthermore, there is little room for improvement making it unlikely our interventions could have an effect. Table 9 indeed shows that our interventions have no effect on aflatoxin levels, despite having improved post-harvest practices.

In year 2 aflatoxin levels were higher in Northern Region, although similarly low to year 1 levels in Upper East (mean contamination was in fact lower). Table 10 contains estimates of treatment effects on aflatoxin, log aflatoxin, probability of exceeding the Ghanaian regulatory limit of 15 ppb and probability of exceeding the EU limit of 4 ppb. In the overall sample we see no effects, besides a marginally significant four percent reduction in the probably of exceeding the EU limit under the market incentive treatment.

When we look at the Northern Region, where the mean level of contamination was 5.5 ppb, we do see effects. The tarp treatment reduces contamination by 3.5 ppb. The point estimate for the market premium treatment is a reduction of 1.7 ppb ($p = 0.16$). When we use logged aflatoxin contamination to account for right skewed distributions we observe a 31 percent decrease in the tarp treatment and a 22 percent decrease in the market premium treatment. When we look at critical threshold levels of aflatoxin, we find that the tarp treatment reduces the probability of exceeding the Ghanian limit by eight percent and the EU limit by six percent. The market incentive treatment decreases these probabilities by five and eight percent, respectively. In Upper East neither treatment has any effects on aflatoxin contamination.

5.4 Discussion

A buyer who wishes to procure safe produce in Ghana and similar settings can use one of two approaches, or a combination of these. An incentive payment can be offered to farmers for producing safe food, which is then tested prior to purchase. Alternatively or in addition, inputs to increase the expected level of safety can be provided unconditionally.

Under a market incentive, farmers face two types of uncertainty. First, for many food safety hazards, contamination above an acceptable threshold is a stochastic process; adopting improved practices increases the probability that compliance with the standard will be achieved but does not guarantee it. Second, there is a risk that the buyer does not follow through on the promise to pay a premium, despite the farmer achieving compliance. This risk is especially great in the first season the premium is offered. Both types of risk reduce the expected utility associated with adoption of a food safety practice, and may depress farmers' investment in technologies and practices to improve food safety. Further, the existence of a market premium for safer food does not necessarily translate into incentives for farmers to adopt good practices, or to a safer overall food supply. Interviews with groundnut traders during the formative stage of this research indicated that it is common to remove visibly damaged nuts from lots destined for high-value uses or markets, and direct the outsorts to lower-value uses. This does not reduce the overall level of aflatoxin in the food supply and could in fact increase exposure among poorer consumers.

In contrast, offering subsidized (or free) food safety enhancing inputs to farmers up-front is risk-free from the farmers' perspective. Such an approach can be effective for improving the quality of marketed food as long as inputs are not selectively applied to produce reserved for home consumption versus produce destined for the market. The groundnut farmers described in this study do not appear to apply practices selectively to nuts based on their intended use unlike the Kenyan maize farmers described by Hoffmann and Jones (2017).

As demonstrated through this study, providing free technology can be highly effective for improving practices and reducing contamination. The need to provide a number of services to smallholder farmers in order to facilitate their inclusion in value chains that reward quality attributes has been noted by others to include extension, aggregation of produce, and possibly provision of inputs (Barrett et al., 2012). When we offered tarps at a slightly subsidized price, however, demand was very low. Further research will be needed to determine what level of subsidization is necessary to incite farmers to invest in technology themselves.

6 Concluding Remarks

There are several reasons why farmers may not adopt practices and technologies to produce safer food. They may not be aware of food safety threats and how to prevent them, they may not be rewarded by the market for doing so, and they may not be able make the necessary investments in technology. In this study use a randomized control trial in northern Ghana over two years to test three interventions, each designed to deal with one of the aforementioned hurdles.

We find that providing farmers with information improves some agricultural practices, and offering market incentives has an additional impact. Providing farmers with drying tarps substantially improves drying practices, and also improves some storage practices, providing evidence of a free input crowding in investment rather than crowding it out.

In the year we collected data on post-harvest practices aflatoxin levels were too low throughout the study area to detect an impacts of the interventions on aflatoxin contamination. In the following year we tested two of the interventions again in the same sample of farmers, and found that tarp provision lowers aflatoxin contamination in the region where it was greater (in the other region it was again extremely low) by approximately 50 percent and the market premium lowers it by approximately 25 percent.

Both of these interventions show promise to lower aflatoxin content in the groundnut value chain. While farmers did react to a market incentive to adopt better post-harvest practices, the possibility of paying market premiums based on testing appears far off given the cost and availability of tests. But with institutional and technological improvements, it may eventually become a possibility, and future research should address how to accelerate this process. In the meantime, educating farmers about aflatoxin prevention and providing them with assistance acquiring key inputs is a viable strategy to improve food safety.

References

Akerlof, G.A. 1970. "The Market for" Lemons": Quality Uncertainty and the Market Mechanism." *The Quarterly Journal of Economics* 84:488–500.

Anderson, J.R., and G. Feder. 2004. "Agricultural extension: Good intentions and hard realities." *The World Bank Research Observer* 19:41–60

Antle, J.M. 2001. "Economic analysis of food safety." *Handbook of agricultural economics* 1:1083–1136.

Ashraf, N., X. Giné, and D. Karlan. 2009. "Finding missing markets (and a disturbing epilogue): Evidence from an export crop adoption and marketing intervention in Kenya." *American Journal of Agricultural Economics* 91:973–990.

Barrett, C.B., M.E. Bachke, M.F. Bellemare, H.C. Michelson, S. Narayanan, and T.F. Walker. 2012. "Smallholder participation in contract farming: comparative evidence from five countries." *World Development* 40:715–730.

Bruhn, M., and D. McKenzie. 2009. "In Pursuit of Balance: Randomization in Practice in Development Field Experiments." *American Economic Journal: Applied Economics* 1:200–232.

Citi Business News. 2015. "EU denies placing ban on cereals and groundnuts from Ghana."

Diekman, M.A., and M.L. Green. 1992. "Mycotoxins and reproduction in domestic livestock." *Journal of Animal Science* 70:1615–1627.

Fafchamps, M., R.V. Hill, and B. Minten. 2008. "Quality control in nonstaple food markets: evidence from India." *Agricultural Economics* 38:251–266.

FAOSTAT. 2016. "FAOSTAT online database."

Feder, G., R.E. Just, and D. Zilberman. 1985. "Adoption of agricultural innovations in developing countries: A survey." *Economic development and cultural change* 33:255–298.

Florkowski, W.J., and S. Kolavalli. 2013. "Aflatoxin control strategies in the groundnut value chain in Ghana." *IFPRI Ghana Strategy Support Program Working Paper* 33.

Foster, A.D., and M.R. Rosenzweig. 2010. "Microeconomics of technology adoption." *Annu. Rev. Econ.* 2:395–424.

Galvez, F., M. Francisco, B. Villarino, A. Lustre, and A. Resurreccion. 2003. "Manual sorting to eliminate aflatoxin from peanuts." *Journal of Food Protection* 66:1879–1884.

GhanaWeb. 2015. "EU to ban Ghana from exporting peanut."

Gong, Y., K. Cardwell, A. Hounsa, S. Egal, P. Turner, A. Hall, and C. Wild. 2002. "Dietary aflatoxin exposure and impaired growth in young children from Benin and Togo: cross sectional study." *British Medical Journal* 325:20–21.

Gong, Y., S. Egal, A. Hounsa, P. Turner, A. Hall, K. Cardwell, and C. Wild. 2003. "Determinants of aflatoxin exposure in young children from Benin and Togo, West Africa: the critical role of weaning." *International Journal of Epidemiology* 32:556–562.

Gong, Y., A. Hounsa, S. Egal, P.C. Turner, A.E. Sutcliffe, A.J. Hall, K. Cardwell, and C.P. Wild. 2004. "Postweaning exposure to aflatoxin results in impaired child growth: a longitudinal study in Benin, West Africa." *Environmental Health Perspectives*, pp. 1334–1338.

Havelaar, A.H., M.D. Kirk, P.R. Torgerson, H.J. Gibb, T. Hald, R.J. Lake, N. Praet, D.C. Bellinger, N.R. De Silva, and N. Gargouri. 2015. "World Health Organization global estimates and regional comparisons of the burden of foodborne disease in 2010." *PLoS medicine* 12:e1001923

Hell, K., K. Cardwell, and H.M. Poehling. 2003. "Relationship between management practices, fungal infection and aflatoxin for stored maize in Benin." *Journal of Phytopathology* 151:690–698.

Hoffmann, V., and K.M. Gatobu. 2014. "Growing their own: Unobservable quality and the value of self-provisioning." *Journal of Development Economics* 106:168–178.

Hoffmann, V., and K. Jones. 2017. "Market incentives for technology adoption: experimental evidence from the market for maize in Kenya." Working paper, International Food Policy Research Institute.

Hoffmann, V., and C. Moser. 2017. "You get what you pay for: the link between price and food safety in Kenya." *Agricultural Economics*, pp. .

Hoffmann, V., S. Mutiga, J. Harvey, R. Nelson, M. Milgroom, et al. 2013. "Aflatoxin contamination of maize in Kenya: observability and mitigation behavior." In *Selected Paper Prepared for Presentation at the Agricultural & Applied Economics Association's 2013 AAEA & CAES Joint Annual Meeting, Washington, DC, August*. vol. 4, p. e6.

Hotz, C., C. Loechl, A. Lubowa, J.K. Tumwine, G. Ndeezi, A.N. Masawi, R. Baingana, A. Carriquiry, A. de Brauw, J.V. Meenakshi, et al. 2012. "Introduction of β-carotene–rich orange sweet potato in rural Uganda resulted in increased vitamin A intakes among children and women and improved vitamin A status among children." *The Journal of nutrition* 142:1871–1880.

IARC. 1993. "Some naturally occurring substances: food items and constituents, heterocyclic aromatic amines and mycotoxins.", pp. .

Iqbal, S.Z., S. Nisar, M.R. Asi, and S. Jinap. 2014. "Natural incidence of aflatoxins, ochratoxin A and zearalenone in chicken meat and eggs." *Food Control* 43:98–103.

Jack, B.K. 2013. "Market inefficiencies and the adoption of agricultural technologies in developing countries." *White paper, Agricultural Technology Adoption Initiative*, pp. .

James, B., C. Adda, K. Cardwell, D. Annang, K. Hell, S. Korie, M. Edorh, F. Gbeassor, K. Nagatey, and G. Houenou. 2007. "Public information campaign on aflatoxin contamination of maize grains in market stores in Benin, Ghana and Togo." *Food additives and contaminants* 24:1283–1291.

Jolly, C.M., B. Bayard, R.T. Awuah, S.C. Fialor, and J.T. Williams. 2009. "Examining the structure of awareness and perceptions of groundnut aflatoxin among Ghanaian health and agricultural professionals and its influence on their actions." *The Journal of Socio-Economics* 38:280–287.

Keyl, A., and A. Booth. 1971. "Aflatoxin effects in livestock." *Journal of the American Oil Chemists' Society* 48:599–604.

Krishnamachari, K., V. Nagarajan, R. Bhat, and T. Tilak. 1975. "Hepatitis due to aflatoxicosis: an outbreak in western India." *The Lancet* 305:1061–1063.

Lamboni, Y., and K. Hell. 2009. "Propagation of mycotoxigenic fungi in maize stores by post-harvest insects." *International Journal of Tropical Insect Science* 29:31–39.

Low, J.W., M. Arimond, N. Osman, B. Cunguara, F. Zano, and D. Tschirley. 2007. "A food-based approach introducing orange-fleshed sweet potatoes increased vitamin A intake and serum retinol concentrations in young children in rural Mozambique." *The Journal of nutrition* 137:1320–1327.

Masters, W.A., J.A. Daniels, and D.B. Sarpong. 2013. "Assesment and recommendations for improving nutrition along the peanut value chain in Ghana." Report prepared for Global Alliance for Improved Nutrition.

McKenzie, D. 2015. "Tools of the trade: a joint test of orthagonality when testing for balance." Working paper, World Bank Development Impact Blog, February.

of Tropical Agriculture, I.I. 2016. "Aflatoxin mitigation in Africa."

Otsuki, T., J.S. Wilson, and M. Sewadeh. 2001. "Saving two in a billion: quantifying the trade effect of European food safety standards on African exports." *Food policy* 26:495–514.

Payne, G.A. 1998. *Process of contamination by aflatoxin-producing fungi and their impact on crops*, Marcel Dekker: New York, NY, USA, chap. 9. pp. 279–306.

Phillips, T.D., E. Afriyie-Gyawu, J. Williams, H. Huebner, N.A. Ankrah, D. Ofori-Adjei, P. Jolly, N. Johnson, J. Taylor, A. Marroquin-Cardona, et al. 2008. "Reducing human exposure to aflatoxin through the use of clay: a review." *Food additives and contaminants* 25:134–145.

Pouliot, S., and D.A. Sumner. 2008. "Traceability, liability, and incentives for food safety and quality." *American Journal of Agricultural Economics* 90:15–27.

Roberts, F. 2017. "Peanut processing facility brought to Ghana by interntational partners."

Shetty, P.H., B. Hald, and L. Jespersen. 2007. "Surface binding of aflatoxin B 1 by Saccharomyces cerevisiae strains with potential decontaminating abilities in indigenous fermented foods." *International journal of food microbiology* 113:41–46.

Strosnider, H., E. Azziz-Baumgartner, M. Banziger, R.V. Bhat, R. Breiman, M.N. Brune, K. DeCock, A. Dilley, J. Groopman, and K. Hell. 2006. "Workgroup report: public health strategies for reducing aflatoxin exposure in developing countries." *Environmental Health Perspectives*, pp. 1898–1903.

The Ghanaian Times. 2015. "EU threatens ban...Over quality of Ghana's cereals."

Tsigbey, F., R. Brandenburg, and V. Clottey. 2003. "Peanut production methods in Northern Ghana and some disease perspectives." *World Geography of the Peanut Knowledge Base Website* 9.

Turner, P., A. Sylla, Y. Gong, M. Diallo, A. Sutcliffe, A. Hall, and C. Wild. 2005. "Reduction in exposure to carcinogenic aflatoxins by postharvest intervention measures in west Africa: a community-based intervention study." *The Lancet* 365:1950–1956.

Turner, P.C., S.E. Moore, A.J. Hall, A.M. Prentice, and C.P. Wild. 2003. "Modification of immune function through exposure to dietary aflatoxin in Gambian children." *Environmental Health Perspectives* 111:217.

Udoh, J., K. Cardwell, and T. Ikotun. 2000. "Storage structures and aflatoxin content of maize in five agroecological zones of Nigeria." *Journal of Stored Products Research* 36:187–201.

Wagacha, J., and J. Muthomi. 2008. "Mycotoxin problem in Africa: current status, implications to food safety and health and possible management strategies." *International journal of food microbiology* 124:1–12.

Watt, A. 2015. "Hershey expands support of Ghanaian peanut farmers, Vivi." Working paper, candyindustry.com, September.

Wu, F., and P. Khlangwiset. 2010. "Evaluating the technical feasibility of aflatoxin risk reduction strategies in Africa." *Food Additives and Contaminants* 27:658–676.

Xiong, B., and J. Beghin. 2011. "Does European aflatoxin regulation hurt groundnut exporters from Africa?" *European Review of Agricultural Economics* 39:589–609.

Zheng, M.Z., J.L. Richard, and J. Binder. 2006. "A review of rapid methods for the analysis of mycotoxins." *Mycopathologia* 161:261–273.

Figures and tables

Figure 1: Study timeline

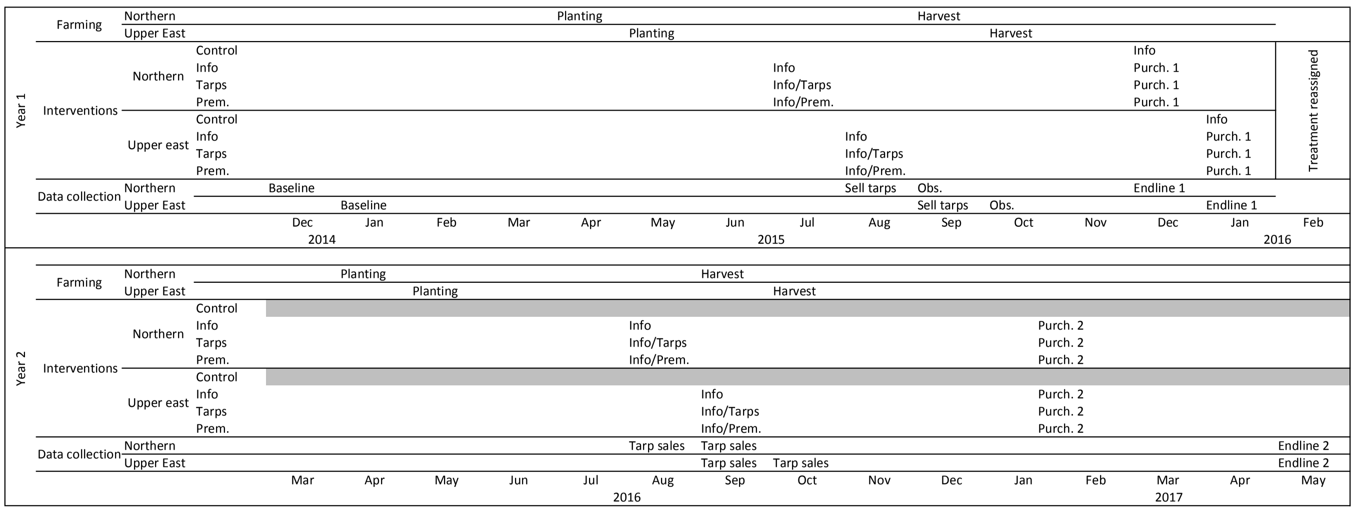

Table 1: Descriptive statistics and balance checks

	All	Northern	UE
Female	0.32	0.29	0.34*
	(0.01)	(0.02)	(0.02)
Male HH head	0.84	0.91	0.79***
	(0.01)	(0.01)	(0.02)
HH size	5.19	5.79	4.59***
	(0.09)	(0.15)	(0.10)
Literate	0.13	0.08	0.17***
	(0.01)	(0.01)	(0.02)
Years farming	18.75	16.84	20.63***
	(0.39)	(0.51)	(0.57)
Acres groundnuts	1.88	2.49	1.28***
	(0.05)	(0.10)	(0.04)
Livestock (TLU)	4.96	4.88	5.03
	(0.36)	(0.60)	(0.39)
Dry on roof	0.49	0.34	0.65***
	(0.02)	(0.02)	(0.02)
Dry on tarp	0.01	0.00	0.02***
	(0.00)	(0.00)	(0.01)
Dry on dirt	0.59	0.66	0.52***
	(0.02)	(0.02)	(0.02)
Hand sort	0.16	0.26	0.06***
	(0.01)	(0.02)	(0.01)
Dispose bad nuts	0.17	0.29	0.05***
	(0.01)	(0.02)	(0.01)
Treat storage	0.27	0.34	0.20***
	(0.01)	(0.02)	(0.02)
Use new bags	0.44	0.42	0.46
	(0.02)	(0.02)	(0.02)
Store on pallets	0.81	0.90	0.72***
	(0.01)	(0.01)	(0.02)
Aflatoxin(ppb)	55.00	86.87	23.81***
	(9.67)	(15.18)	(11.92)
N	1,005	497	508

Notes: Standard errors in parentheses.
*,**,*** denote significant differences between regions
at 0.1, 0.05, and 0.01 confidence level.

Table 2: Distribution of aflatoxin levels

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
		Baseline		Endline 1 (Control only)			Endline 2 (Info only)		
	All	Northern	UE	All	Northern	UE	All	Northern	UE
25th Percentile	7.38	8.02	6.84	0.70	0.90	0.60	0.40	0.20	0.70
Median	10.8	13.8	9.50	1.30	1.67	1.10	0.80	0.50	1.10
75th Percentile	17.6	24.5	14.1	2.35	3	2	1.30	0.90	1.50
95th Percentile	120.9	474.5	29.7	7.40	9.90	4.68	29	47.5	1.60
99th Percentile	1301.4	1733.4	68.1	40.1	51.7	29.8	58.1	58.6	7.50
Maximum	6061	3495.4	6061	51.7	51.7	40	58.6	58.6	56.7
Mean	60.1	99.7	24.8	2.78	3.72	2.14	3.54	5.54	1.56
Pct. $>$ 15 ppb	0.33	0.46	0.22	0.028	0.042	0.019	0.061	0.12	0.0076
Pct. $>$ 4 ppb	0.93	0.94	0.93	0.074	0.099	0.057	0.073	0.12	0.023
Observations	920	433	487	176	71	105	261	130	131

[a]15 ppb is the official standard for aflatoxin safety in Ghana. [b]4 ppb is the official standard in the EU.

Table 3: Treatment effects on post-harvest practices (Year 1)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Drying		Sorting		Storage		Overall	
Information Treatment	0.030		0.222**		0.175**		0.430***	
	(0.071)		(0.091)		(0.079)		(0.144)	
Free Tarp Distribution	0.832***		0.257***		0.399***		1.481***	
	(0.068)		(0.087)		(0.075)		(0.137)	
Market Incentive	0.122*		0.189**		0.298***		0.613***	
	(0.071)		(0.091)		(0.079)		(0.144)	
Info = Tarp	0		0.694		0.00379		0	
Info = Market	0.202		0.729		0.128		0.214	
Control mean	-0.0400		1.067		1.511		2.538	
Information x Northern		0.035		0.144		0.063		0.242
		(0.103)		(0.132)		(0.114)		(0.209)
Tarp x Northern		0.902***		0.196		0.220**		1.318***
		(0.100)		(0.128)		(0.111)		(0.203)
Market x Northern		0.163		0.111		0.168		0.442**
		(0.104)		(0.134)		(0.116)		(0.212)
Info = Tarp (Northern)		0		0.684		0.154		1.22e-07
Info = Market (Northern)		0.218		0.806		0.366		0.345
Control mean (Northern)		-0.0777		1.117		1.408		2.447
Information x UE		0.029		0.299**		0.254**		0.582***
		(0.099)		(0.127)		(0.109)		(0.201)
Tarp x UE		0.774***		0.296**		0.575***		1.645***
		(0.092)		(0.119)		(0.103)		(0.188)
Market x UE		0.087		0.271**		0.420***		0.779***
		(0.097)		(0.125)		(0.108)		(0.198)
Info = Tarp (UE)		0.00		0.981		0.00281		7.50e-08
Info = Market (UE)		0.562		0.830		0.138		0.338
Control mean (UE)		-0.00820		1.025		1.598		2.615
Observations	901	901	901	901	901	901	901	901
R-squared	0.216	0.217	0.095	0.087	0.175	0.175	0.202	0.198

Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1.
Village dummies and outcome at baseline (when available) included as controls.

Table 4: Treatment effects on drying practices (Year 1)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
	Dry on dirt				Dry on tarp				Dry on concrete				Drying days	
	Observed		Reported		Observed		Reported		Observed		Reported		Reported	
Information Treatment	-0.028		0.036		0.023		0.084**		-0.084**		-0.120***		0.084	
	(0.054)		(0.039)		(0.051)		(0.034)		(0.043)		(0.043)		(0.178)	
Free Tarp Distribution	-0.103**		-0.160***		0.548***		0.623***		-0.081**		-0.463***		0.254	
	(0.052)		(0.037)		(0.048)		(0.032)		(0.041)		(0.041)		(0.170)	
Market Incentive	0.012		-0.033		0.046		0.064*		-0.053		-0.030		0.354**	
	(0.055)		(0.039)		(0.051)		(0.034)		(0.043)		(0.043)		(0.178)	
Info = Tarp	0.153		2.24e-07		0.00		0.00		0.947		0.00		0.325	
Info = Market	0.470		0.0798		0.667		0.550		0.478		0.0420		0.137	
Control mean	0.197		0.280		0.0526		0.0444		0.316		0.676		4.987	
Information x Northern		-0.121		0.022		0.029		0.066		-0.005		-0.087		0.212
		(0.092)		(0.056)		(0.086)		(0.048)		(0.073)		(0.062)		(0.257)
Tarp x Northern		-0.197**		-0.140**		0.518***		0.723***		-0.004		-0.583***		0.257
		(0.089)		(0.054)		(0.083)		(0.047)		(0.070)		(0.060)		(0.249)
Market x Northern		0.016		-0.047		0.070		0.089*		-0.001		-0.042		0.281
		(0.097)		(0.057)		(0.092)		(0.049)		(0.077)		(0.063)		(0.261)
Info = Tarp (Northern)		0.359		0.00286		2.04e-09		0.00		0.989		0.00		0.857
Info = Market (Northern)		0.141		0.223		0.643		0.629		0.955		0.477		0.792
Control mean (Northern)		0.435		0.233		0.00		0.0388		0.00		0.728		4.563
Information x UE		0.018		0.053		0.009		0.107**		-0.122**		-0.160***		-0.044
		(0.066)		(0.054)		(0.062)		(0.046)		(0.052)		(0.059)		(0.247)
Tarp x UE		-0.056		-0.171***		0.563***		0.536***		-0.118**		-0.366***		0.245
		(0.063)		(0.050)		(0.060)		(0.043)		(0.050)		(0.056)		(0.231)
Market x UE		0.004		-0.021		0.033		0.043		-0.074		-0.022		0.419*
		(0.066)		(0.053)		(0.062)		(0.046)		(0.052)		(0.059)		(0.243)
Info = Tarp (UE)		0.271		2.20e-05		0.00		0.00		0.940		0.000417		0.231
Info = Market (UE)		0.841		0.182		0.707		0.178		0.375		0.0236		0.0667
Control mean (UE)		0.0943		0.320		0.0755		0.0492		0.453		0.631		5.344
Observations	306	306	901	901	306	306	901	901	306	306	901	901	901	901
R-squared	0.466	0.473	0.154	0.152	0.562	0.562	0.396	0.406	0.713	0.716	0.238	0.248	0.243	0.244

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1. Village dummies and outcome at baseline (when available) included as control variables.

Table 5: Treatment effects on sorting practices (Year 1)

	(1)	(2)	(3)	(4)	(5)	(6)
	Sort before storage		Sort before consuming		Dispose of worse nuts	
Information Treatment	0.126***		0.033		0.064*	
	(0.047)		(0.046)		(0.037)	
Free Tarp Distribution	0.140***		-0.018		0.132***	
	(0.044)		(0.043)		(0.035)	
Market Incentive	0.141***		0.013		0.038	
	(0.047)		(0.046)		(0.037)	
Info = Tarp	0.768		0.253		0.0626	
Info = Market	0.750		0.674		0.486	
Control mean	0.342		0.578		0.147	
Information x Northern		0.063		-0.034		0.106**
		(0.067)		(0.066)		(0.054)
Tarp x Northern		0.101		-0.039		0.134***
		(0.065)		(0.064)		(0.052)
Market x Northern		0.087		-0.009		0.028
		(0.069)		(0.067)		(0.054)
Info = Tarp (Northern)		0.557		0.941		0.582
Info = Market (Northern)		0.721		0.703		0.151
Control mean (Northern)		0.330		0.524		0.262
Information x UE		0.184***		0.096		0.025
		(0.065)		(0.063)		(0.051)
Tarp x UE		0.172***		0.000		0.129***
		(0.061)		(0.059)		(0.048)
Market x UE		0.188***		0.032		0.048
		(0.064)		(0.062)		(0.051)
Info = Tarp (UE)		0.854		0.121		0.0373
Info = Market (UE)		0.951		0.324		0.661
Control mean (UE)		0.352		0.623		0.0492
Observations	901	901	901	901	901	901
R-squared	0.096	0.098	0.124	0.126	0.159	0.161

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.
Village dummies and outcome at baseline (when available) included as controls.

Table 6: Treatment effects on storage practices (Year 1)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Pesticide in storage area		New container to store nuts		Stored on pallets			
	Reported				Observed		Reported	
Information Treatment	0.003		0.043		0.022		0.125***	
	(0.042)		(0.046)		(0.061)		(0.038)	
Free Tarp Distribution	0.146***		0.115***		0.049		0.143***	
	(0.040)		(0.044)		(0.059)		(0.036)	
Market Incentive	0.088**		0.073		-0.012		0.144***	
	(0.042)		(0.046)		(0.061)		(0.038)	
Info = Tarp	0.000549		0.107		0.655		0.625	
Info = Market	0.0493		0.529		0.579		0.611	
Control mean	0.280		0.542		0.602		0.689	
Information x Northern		-0.033		0.025		-0.061		0.075
		(0.061)		(0.066)		(0.092)		(0.055)
Tarp x Northern		0.090		0.036		-0.002		0.095*
		(0.059)		(0.064)		(0.090)		(0.053)
Market x Northern		0.090		0.011		-0.134		0.076
		(0.062)		(0.067)		(0.093)		(0.056)
Info = Tarp (Northern)		0.0381		0.861		0.513		0.706
Info = Market (Northern)		0.0481		0.835		0.428		0.979
Control mean (Northern)		0.184		0.485		0.653		0.738
Information x UE		0.036		0.055		0.086		0.168***
		(0.059)		(0.063)		(0.082)		(0.053)
Tarp x UE		0.195***		0.184***		0.087		0.183***
		(0.055)		(0.059)		(0.078)		(0.049)
Market x UE		0.085		0.126**		0.079		0.203***
		(0.058)		(0.063)		(0.081)		(0.052)
Info = Tarp (UE)		0.00566		0.0391		0.983		0.770
Info = Market (UE)		0.408		0.281		0.940		0.519
Control mean (UE)		0.361		0.590		0.562		0.648
Observations	901	901	901	901	451	451	901	901
R-squared	0.175	0.178	0.106	0.110	0.243	0.249	0.101	0.105

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.
Village dummies and outcome at baseline (when available) included as controls.

Table 7: Treatment effects on tarp purchase and ownership (Year 1)

	(1)	(2)	(3)	(4)	(5)	(6)
	Tarps (#) observed		Reported purchasing tarp		Tarps (#) purchased	
Information Treatment	0.249		0.095***		0.283***	
	(0.163)		(0.034)		(0.084)	
Free Tarp Distribution	3.452***		0.060*		0.159**	
	(0.158)		(0.033)		(0.080)	
Market Incentive	0.192		0.134***		0.273***	
	(0.162)		(0.034)		(0.083)	
Info = Tarp	0		0.298		0.127	
Info = Market	0.730		0.258		0.910	
Control mean	0.156		0.0844		0.120	
Information x Northern		0.343*		0.098**		0.236*
		(0.207)		(0.049)		(0.121)
Tarp x Northern		3.887***		0.141***		0.263**
		(0.204)		(0.048)		(0.117)
Market x Northern		0.271		0.152***		0.320***
		(0.205)		(0.050)		(0.122)
Info = Tarp (Northern)		0		0.371		0.814
Info = Market (Northern)		0.906		0.637		0.378
Control mean (Northern)		0.106		0.0485		0.0583
Information x UE		0.092		0.097**		0.337***
		(0.257)		(0.047)		(0.116)
Tarp x UE		2.863***		-0.007		0.077
		(0.246)		(0.044)		(0.108)
Market x UE		0.061		0.119**		0.233**
		(0.259)		(0.046)		(0.114)
Info = Tarp (UE)		0		0.0248		0.0216
Info = Market (UE)		0.906		0.637		0.378
Control mean (UE)		0.233		0.115		0.172
Observations	616	616	901	901	901	901
R-squared	0.575	0.582	0.099	0.106	0.086	0.088

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1
Village dummies and outcome at baseline (when available) included as controls.

Table 8: Treatment effects on tarp purchase (Year 2)

	(1)	(2)	(3)	(4)	(5)	(6)
	Purchased any tarps		Number purchased		Expenditure	
Free Tarp Distribution	-0.013		-0.010		-0.020	
	(0.016)		(0.021)		(0.350)	
Market Incentive	-0.028		-0.022		-0.376	
	(0.018)		(0.025)		(0.402)	
Information only mean	0.0578		0.0669		0.973	
Tarp x Northern		0.004		0.023		0.594
		(0.023)		(0.031)		(0.503)
Market x Northern		-0.012		0.003		-0.130
		(0.026)		(0.035)		(0.578)
Information only mean (Northern)		0.0500		0.0563		0.825
Tarp x UE		-0.029		-0.042		-0.593
		(0.022)		(0.030)		(0.486)
Market x UE		-0.042*		-0.045		-0.609
		(0.025)		(0.034)		(0.559)
Information only mean (UE)		0.0651		0.0769		1.112
Observations	929	929	929	929	929	929
R-squared	0.047	0.049	0.041	0.044	0.041	0.044

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.
Village dummies and outcome at baseline (when available) included as controls.

Table 9: Treatment effects on aflatoxin content (Year 1)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Aflatoxin (ppb)		Log aflatoxin (ppb)		Aflatoxin > 15 ppb		Aflatoxin > 4 ppb	
Information Treatment	0.330		-0.049		0.015		0.006	
	(0.894)		(0.088)		(0.022)		(0.029)	
Free Tarp Distribution	1.269		0.076		0.034		0.032	
	(0.851)		(0.084)		(0.021)		(0.027)	
Market Incentive	1.009		0.047		0.024		0.011	
	(0.899)		(0.089)		(0.022)		(0.029)	
Info = Tarp	0.271		0.138		0.374		0.362	
Info = Market	0.454		0.283		0.702		0.873	
Control mean	2.777		1.203		0.0284		0.0739	
Information x Northern		0.895		0.047		0.020		0.034
		(1.379)		(0.136)		(0.034)		(0.044)
Tarp x Northern		1.275		0.112		0.037		0.063
		(1.340)		(0.132)		(0.033)		(0.043)
Market x Northern		1.770		0.195		0.039		0.061
		(1.391)		(0.137)		(0.034)		(0.045)
Info = Tarp (Northern)		0.772		0.613		0.595		0.491
Info = Market (Northern)		0.526		0.277		0.565		0.542
Control mean (Northern)		3.720		1.411		0.0423		0.0986
Information x UE		-0.084		-0.117		0.013		-0.013
		(1.176)		(0.116)		(0.029)		(0.038)
Tarp x UE		1.273		0.053		0.032		0.010
		(1.102)		(0.109)		(0.027)		(0.036)
Market x UE		0.447		-0.060		0.013		-0.025
		(1.181)		(0.117)		(0.029)		(0.038)
Info = Tarp (UE)		0.228		0.125		0.476		0.525
Info = Market (UE)		0.659		0.632		0.996		0.754
Control mean (UE)		2.139		1.063		0.0190		0.0571
Observations	737	737	737	737	737	737	737	737
R-squared	0.115	0.116	0.215	0.218	0.111	0.112	0.129	0.132

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.
Village dummies and outcome at baseline (when available) included as controls.

Table 10: Treatment effects on aflatoxin content (Year 2)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Aflatoxin (ppb)		Log aflatoxin (ppb)		Aflatoxin > 15 ppb		Aflatoxin > 4 ppb	
Free Tarp Distribution	-1.832		-0.144		-0.038		-0.031	
	(1.215)		(0.109)		(0.025)		(0.027)	
Market Incentive	-0.816		-0.093		-0.023		-0.038*	
	(0.998)		(0.089)		(0.021)		(0.022)	
Control mean	3.545		0.928		0.0613		0.0728	
Tarp x Northern		-3.553**		-0.314**		-0.080***		-0.060*
		(1.493)		(0.134)		(0.031)		(0.033)
Market x Northern		-1.969		-0.224*		-0.048*		-0.059*
		(1.385)		(0.124)		(0.029)		(0.031)
Control mean (Northern)		5.540		0.918		0.115		0.123
Tarp x UE		-0.253		0.013		0.001		-0.004
		(1.449)		(0.130)		(0.030)		(0.033)
Market x UE		0.320		0.037		0.002		-0.017
		(1.399)		(0.125)		(0.029)		(0.031)
Control mean (UE)		1.619		0.959		0.00806		0.0242
Observations	752	752	752	752	752	752	752	752
R-squared	0.060	0.065	0.079	0.085	0.064	0.071	0.078	0.081

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.
Village dummies and outcome at baseline (when available) included as controls.

Appendix 1: Stratification procedure (Year 1)

To obtain better balance between treatment and control, we stratify our randomization as follows. First, we generate strata of four households within each village based on aflatoxin levels recorded at baseline. Next, we randomly assign three out of four households to receive treatment and the fourth to control. Which treatment the household received was determined in a public lottery at the end of the information session, and therefore randomization across treatment groups was not stratified. For villages that did not have 20 or 24 farmers, either 20 households (for those with between 21-23 households) or 24 household (for those with more than 24 households) were stratified based on aflatoxin levels. The 1, 2, or 3 remaining households were assigned treatment at random so that no two of these remaining households received the same treatment. Next, we run 1000 re-randomizations to ensure balance along aflatoxin levels and a number of post-harvest practices, which are also outcomes of interest for this study. From these 1000 re-randomizations we eliminate any where the p-value for aflatoxin level was below 0.8. Of the remaining randomizations, we select the one with the maximum minimum p-value following Bruhn and McKenzie (2009).

Appendix 2: Information session content

The following is a summary of specific practices covered in the information session organized by production stage.

1. Harvest

    - Harvest when leaves begin wilting and turning yellow.
    - Check inside of ten sample pods to confirm crop is ready for harvest.

2. Plucking

    - Pluck pods from vines as soon as possible after harvesting.
    - Do not leave pods exposed to soil while waiting to pluck.
    - As you pluck, remove and discard visibly damaged pods (shriveled, have holes, broken, moldy, discolored)

3. Drying

    - Dry on a clean surface: use a tarp if possible, or otherwise a concrete slab or rooftop. Do not dry on bare dirt.
    - Dry on a smooth surface that will prevent water from puddling.
    - Avoid breaking pods when spreading them on the drying surface; use a rake, not feet.
    - Sort out visibly damaged pods from the drying area and dispose of them.
    - Protect pods from the rain; either bring them in or cover them with thatch (traditional) or tarp. Once the rain has stopped, spread them again immediately and dry the covering surface, is applicable.

4. Storage

- Use new bags or clean bags by turning them inside out and laying them out under the sun to kill insect eggs and mold.
- Remove and discard visibly damaged nuts before putting them in bags.
- Remove old stock from storage area before adding new stock.
- Store bags on raised platforms that allow for airflow (locally available or home made pallets).
- Store bags away from walls of storage area.