AFTER THE PROJECT IS OVER: MEASURING LONGER-TERM IMPACTS OF A FOOD SAFETY INTERVENTION IN SENEGAL

by

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To my family, for being a constant source of support, encouragement, and reality checks.

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ABSTRACT

Few studies in the economics of food safety literature follow-up with participants in the years after an intervention. This is particularly true in the context of food safety interventions in developing countries, which limits our ability to assess an intervention's longer-term benefits, sustainability, and cost-effectiveness. Responding to this shortfall, the present article follows up with about 2,000 smallholder households in Senegal, two years after participating in a randomized controlled trial (RCT) aimed at reducing levels of aflatoxins in smallholders' stored maize. In the initial intervention, treated households were provided with training on proper post-harvest practices, low-cost moisture meters for testing if maize was sufficiently dry to store, plastic tarps for drying maize of the ground, and hermetic (airtight) storage bags to mitigate aflatoxin development in stored maize. Our findings show that in the longer-term, providing a combination of training, a moisture meter, and a tarp decreased levels of aflatoxins, by about 20 percent compared to the control group. Marginal effect estimates of the different technologies, indicated that the tarp was the key input driving these results. In the initial impact assessment from 2017 hermetic bags were found to be the most effective technology at reducing aflatoxins, but in the longer-term follow-up, they did not have a statistically significant impact. This is likely due to the bags more limited durability compared to tarps and the difficulty that respondents had purchasing replacement bags from the market. Cost-effectiveness estimates suggested providing training and a tarp is at least moderately cost-effective based on WHO guidelines for public health interventions. Our results demonstrate that providing information and simple, low-cost technologies can bring about sustained reductions in aflatoxins in smallholders' maize. Finally, differences between the short-term and longer-term findings underscore the need for longer follow-up periods after conducting an intervention.

CHAPTER 1. “AFTER THE PROJECT IS OVER: MEASURING LONGER-TERM IMPACTS OF A FOOD SAFETY INTERVENTION IN SENEGAL”

1.1 Introduction

A shortfall of the current economics of food safety literature is that few studies continue to follow-up with the participants in the years after the intervention. Two systematic literature reviews of food safety interventions listed the short duration of most interventions as an important limitation (Woldt and Moy 2015; Egan et al. 2007). Lack of longer-term follow-ups makes it difficult to assess an intervention’s longer-term benefits, sustainability, and cost-effectiveness, even if the results are promising in the short term. the lack of longer-term studies is particularly true in the context of less developed countries (LDCs) and specifically for interventions that aim to reduce aflatoxin contamination in staple grains. Aflatoxins are toxic substances produced by certain species of fungi and are largely unobservable by sight, smell, and taste; detection is difficult without a costly and often prohibitively expensive chemical test (NTP (National Toxicology Program) 2016; Wacoo et al. 2014). An estimated 4.5 billion people in LDCs experience chronic exposure to aflatoxins. Failure to prevent chronic exposure to aflatoxins greatly increases the risk of liver cancer, birth defects, and immunosuppression (World Health Organization and Joint FAO/WHO Expert Committee on Food Additives (83rd 2017)).

The problem is that there are numerous barriers to producing food that is safe to eat, and it is not clear what sort of intervention is capable of sustainably increasing food safety in developing contexts over the longer term. The few food safety studies that followed up with participants over an over an extended period found mixed results. A two-year longitudinal study in Vietnam found a community-based information and education intervention sustainably reduced the prevalence of childhood diarrhea (Takanashi et al. 2013). However, another study done in Thailand on a food safety campaign found that while it was effective for the first two years, outcomes deteriorated by year three due to deeply-ingrained cultural norms surrounding the consumption of raw pork at certain festivals (Loetthong et al. 2017). Besides uncertainty around the longer-run effectiveness of food safety interventions, it is also unclear which households benefit the most from these types of interventions. In the face of limited resources, policymakers need this information when deciding which projects and programs to support, as well as how to best target these programs.

With these considerations, the present study estimates the effectiveness of different combinations of training and inputs at reducing aflatoxin levels in stored maize amongst smallholder farmers in southern Senegal two full years after the intervention concluded. The study follows up with about 2,000 maize-producing households in 200 villages who participated in the randomized controlled trial (RCT) analyzed by Bauchet, Prieto and Ricker-Gilbert (2020). In that study, treated farmers received training before harvest in October 2016, and up to three low-cost inputs designed to reduce aflatoxin contamination by improving maize drying and storage. The intervention relieved up to three constraints on farmers' ability to manage aflatoxin contamination depending on treatment assignment: i) lack of knowledge about aflatoxins in terms of the health risks and how to prevent contamination, ii) lack of access to affordable drying technologies, and iii) lack of access to affordable storage technologies. Households received up to four inputs depending on treatment assignment. The inputs were: i) a low-cost moisture meter called a hygrometer, ii) a plastic tarp, and iii) a hermetic (airtight) storage bag. The authors then tested aflatoxins levels in stored maize among participants a few months post-harvest in March-April of 2017. The present study returned to re-test aflatoxins levels in the same farmers' stored maize two years later in April-May of 2019. After two years, we expected some of the provided technologies would start to wear out and need to be replaced, so following up at this point could indicate if project benefits persist over time.

In addition to analyzing the longer-term impacts of a food safety intervention, this study makes two contributions to the literature. First, we contribute to the existing technology adoption literature by experimentally assessing the impacts of providing smallholder farmers with access to simple technologies. Second, we provide more evidence on which low-cost technologies are the most effective at reducing aflatoxins under field conditions in the longer term.

Economists have long studied agricultural technology adoption and its potential impacts on smallholder farmers in LDCs (see Foster and Rosenzweig 2010 for a review). One particularly relevant line of research focuses on the returns to agricultural extension (Anderson and Feder 2004). Related RCTs tested the impacts of extension on technology adoption (Kondylis, Mueller and Zhu 2017; Ambler, de Brauw and Godlonton 2018; Benyishay and Mobarak 2019). Others examined the role of learning by doing and learning from others in technology adoption (Conley and Udry 2010; Foster and Rosenzweig 1995). We contribute to this literature by experimentally measuring the longer-term effects of an extension-based intervention that provided smallholder farmers with information and simple technologies.

Second, our experimental design allows us to analyze the impacts of several technologies, and their combination, rather than one input in isolation, and do so over a longer time horizon than in earlier studies. Recent research demonstrates that, at least in the short run, relieving information and technology constraints can reduce aflatoxin contamination among smallholder farmers in LDCs. Bauchet, Prieto and Ricker-Gilbert (2020) found that providing training, a hygrometer, a tarp, and a hermetic (airtight) storage bag significantly reduced aflatoxins in smallholder farmers' stored maize in southern Senegal. Analysis of each input's marginal effect showed the hermetic bag was the key input responsible for those reductions. In contrast, Magnan et al. (2019) conducted a similar RCT and tarps significantly reduced aflatoxins by 25-50 percent among groundnut farmers in Ghana, depending on the region. In another RCT, Pretari, Hoffmann and Tian (2019) provided households with training, tarps, access to hermetic storage, and access to a mobile-drying service. They found providing tarps reduced aflatoxin contamination in maize by 53 percent when measured three months post-intervention. Turner et al. (2005) provided training, fiber mats and bags, insecticide, and wooden pallets to groundnut farmers and found that the intervention decreased blood-aflatoxin levels by more than 50% in the treatment group when tested three- and five-months post-harvest.

The present intervention was conducted as an RCT with villages assigned to four treatment groups (Groups 2-5) and a control group (Group 1). Inputs were provided to each group in a cumulative manner. Group 2 only received training; Group 3 received training and a hygrometer; Group 4 received training, a hygrometer, and a tarp; and Group 5 received training, a hygrometer, a tarp, and a hermetic bag.

Using follow up data on aflatoxin levels and drying and storage practices from 2019 along with baseline demographic data from 2016, we estimate both the longer-term intention-to-treat (ITT) effects and the treatment on the treated (TOT) effects that the four inputs provided on households' aflatoxins levels in stored maize. The ITT analyses estimate the intervention's average effect by treatment group, but this may underestimate the true impact for households who complied with recommended post-harvest practices and adopted the recommended technologies. The TOT analyses estimate the local average treatment effects (LATE) of the intervention, that is its impacts on those who were driven by the intervention to follow best practices or use a given technology.

Since the decision to follow these practices or adopt a technology was not random, we instrumented the usage decision with the exogenous, random treatment group assignment to get an unbiased estimate. Outside of our main models, we conducted a heterogeneity analysis to test if households with different characteristics benefit differently from the intervention. We interacted each treatment assignment with various household characteristics, including the woman's level of involvement in the intervention.

Our findings show that in the longer-term, only providing training, a hygrometer, and a tarp had a significant impact on households' levels of aflatoxins in 2019. These households who were in treatment group 4, were on average seven percentage points less likely to have maize over the US regulatory limit of 20 parts per billion for aflatoxin, and 30 percent less than the control group to be over the same limit on average. Marginal effects estimates indicated that the tarp was the key input driving these results, and unlike in the short run, the hermetic bag did not have a significant effect. Providing training on its own did not have a statistically significant marginal effect on aflatoxins in the longer-term, and who adopted the improved technologies did have lower levels of aflatoxins. However, usage of the hygrometers and hermetic bags significantly decreased over time, likely because these inputs were not widely available for purchase in the local area following the intervention. Our heterogeneity analysis found no significant differences in outcomes based on education, income, women's involvement in the intervention, household size, or women's empowerment. Cost-effectiveness estimates suggested providing training and a tarp is at least moderately cost-effective based on WHO guidelines for public health interventions. Our results demonstrate that providing information and simple, low-cost technologies can bring about sustained reductions in aflatoxins in smallholders' maize. Finally, differences between the short-term and longer-term findings underscore the need for longer follow-up periods after conducting an intervention.

1.2 Background

Maize is an important staple crop for 900 million low-income consumers in 125 LDCs. Of the total 153 million hectares devoted to maize production worldwide, 100 million hectares are located in developing countries. Besides its importance to smallholder farmers, maize is also an important source of calories, providing consumers in 33 LDCs with over 20% of their daily calorie intake (CGIAR Research Program on Maize n.d.). Demand for maize is rising, and by 2025 maize will surpass rice and wheat to be the most important crop for LDCs; by 2050, the demand for maize will double (Rosegrant et al. 2009). Producers often prefer maize over traditional cereals due to its relatively greater resistance to pests and higher yields (Zorya, Morgan and Rios 2011).

Maize is also one of the most susceptible crops to aflatoxins, so eating maize is the primary way people in Sub-Saharan Africa are exposed to aflatoxins (Bankole, Schollenberger and Drochner 2006; Shephard 2008). *Aspergillus flavus* is the predominant aflatoxins-producing fungi that affects maize, and several factors promote its accumulation. Levels of aflatoxins tend to spike when plants are under stress due to drought, extreme heat, or insect damage. Insects also directly increase aflatoxin contamination by spreading fungal spores around in the storage vessel as they move. They also make the grain more susceptible to contamination by eating holes through the kernels (Gnonlonfin et al. 2013). Scientists have concerns that these pathways to contamination will be harder to combat due to climate change as weather patterns become more extreme and new pests move in (Magan, Medina and Aldred 2011). Inferior drying methods also contribute to aflatoxin contamination through direct contact between maize and contaminated soil, or prolonged drying periods due to high humidity levels or rewetting of maize with rainfall (Tubbs et al. 2017). Moisture during the storage period is also an issue, even if the maize goes in dry. Traditional storage methods are often permeable or easily compromised, letting insects and outside moisture in (see Kumar and Kalita (2017)).

There are several reasons why aflatoxin contamination persists in developing contexts. First, awareness of aflatoxins is often low, and therefore farmers cannot take steps to reduce its prevalence through good agricultural practices (Ezekiel et al. 2013; De Groote et al. 2016; Johnson et al. 2018; James et al. 2007). Additionally, the informal grain markets of SSA provide little incentive to manage aflatoxins levels. While the US and EU have maximum allowable aflatoxins limits in consumer products at 20 and 10 ppb, Senegal had no equivalent regulations at the time of our intervention (FDA 1969; European Commission 2006). Even if there are legal limits on aflatoxins, these are challenging to enforce since aflatoxins are mostly unobservable (Masters et al. 2013; Wagacha and Muthomi 2008). Informal markets cannot distinguish between good quality grain and contaminated grain, so, there is no associated price premium for crops with lower levels of aflatoxins. Farmers may be unable or unwilling to invest in technologies that reduce contamination without a financial incentive.

Existing empirical evidence shows that each technology our intervention provided is independently effective at reducing contamination in stored maize. Commercial moisture meters are prohibitively expensive for the vast majority of subsistence households. The Mini Digital hygrometer we provided is both affordable and accurately distinguishes between moisture levels. Researchers at Purdue University developed a protocol for this device and demonstrated it reliably measures maize's moisture content. Farmers place a handful of maize in a plastic baggie with the hygrometer. After fifteen minutes, if the reading is below 65% relative humidity, the equivalent of 13% moisture content, their maize is adequately dry to store (Tubbs et al. 2017). The next input we provided were plastic tarps. These tarps potentially reduce aflatoxin contamination by up to 50% by preventing contact between the kernels and the aflatoxin-contaminated soil (Pretari, Hoffmann and Tian 2019). We also provided Purdue Improved Crop Storage (PICS) bags. These bags are triple-layer polypropylene hermetic storage bags, which have demonstrated abilities across multiple studies to prevent accumulation. Initially developed for use with cowpeas (Baoua et al. 2012). PICS bags are useful for many types of crops, including maize (Williams, Murdock and Baributsa 2017; Baributsa et al. 2017; Mutungi et al. 2015; Mutungi et al. 2014). When filled with sufficiently dried food and sealed, PICS bags prevent further growth of aflatoxin-producing fungi and suffocate insects that could otherwise move fungi throughout the vessel. Moisture content stays constant, and oxygen cannot penetrate the bag (Ng'ang'a et al. 2016; Williams, Baributsa and Woloshuk 2014; Walker et al. 2018; Ndegwa et al. 2016).

1.3 Intervention

This article evaluates a longer-term impact evaluation of the intervention designed and reported by Bauchet, Prieto and Ricker-Gilbert (2020), which was conducted with maize-growing households in the department of Vélingara in the Kolda region in southern Senegal. Southern Senegal is the only part of the country that grows significant amounts of maize, as other regions receive too little annual rainfall for maize production (Diedhiou et al. 2011). Prior to conducting the intervention, the authors assessed local post-harvest challenges and observed that many farmers dried their shucked maize directly on the ground. Because this practice increases contact between kernels and the soil, the assessment indicated that households in the area were at increased risk of aflatoxin contamination in their maize (Shrestha 2017).

1.3.1 Training (Received by 1,599 households)

Extension agents from the national agricultural extension agency (Agence Nationale de Conseil Agricole et Rural, ANCAR) visited all of the villages in the four treatment groups (2,3,4,5) and provided training on best post-harvest practices in September and October of 2016, shortly before that year's maize harvest. Using local extension agents helped our intervention gain support from local leaders and ensured trainers understood the local context and were familiar with its associated challenges. Men and women from households participating in our study received an explicit invitation to the training. However, anyone in the village was allowed to attend and approximately 3,800 households chose to do so. Agents gave demonstrations on effective drying and storage technologies as well as information about mitigating the risks of exposure to aflatoxins. For example, agents explained to households the importance of preventing contact between maize kernels and soil. One way to do this, they explained, is to dry maize with the husks on and to stook the stalks instead of piling it. Husking the stalks or piling the maize increases contact between the kernels and the soil. Piling the maize makes it hard for maize at the bottom of the pile to dry, further increasing contamination. During the storage period, maize should still be kept off the ground to avoid increased contamination.

1.3.2 Hygrometer (Received by 1,209 households)

Households in groups 3, 4, and 5 received a hygrometer. This device was the cheapest of all of the provided items at $1.13, so it was given to the most households. At baseline, these devices were not available to purchase in the study region, so we imported them from China. No households in our sample owned a moisture meter at baseline, which is unsurprising given moisture meters typically cost over 100 US dollars. Baseline willingness-to-pay estimates (stated preference) for the hygrometer showed that households were on average willing to pay $1.79.

1.3.3 Tarp (Received by 812 households)

Households in groups 4 and 5 received a 10 m^2 plastic tarp to dry their maize on, instead of directly on the bare soil, which 25% of the sample did at baseline. These tarps cost $3.27 locally. Willingness-to-pay estimates suggested households valued the tarp at $5.36. Farmers can dry 200 kg of their maize on the tarp at one time over the course of a couple days, weather permitting. Most households produce more maize than that so they batch dry their maize.

1.3.4 Hermetic Bag (Received by 404 households)

Only households in group 5 received a hermetic Purdue Improved Crop Storage (PICS) bag. These bags fit 50 kg of maize each and cost $2.60. At baseline, PICS bags were not available in the study region, so they were imported from Nigeria by the project. Since the bags were bulkier and were not locally available, the fewest households received this input. At baseline, no households were using hermetic storage bags. Both PICS bags and hygrometers were made available for purchase in each municipality of the study region in 2018.

1.4 Data

From the complete list of villages in the department of Vélingara, we eliminated those unsafe to travel to and those in regions that were too urban to have much maize production. From this list of 307, we randomly selected 200 villages to participate in the intervention. Treatment assignment took place at the village level, with villages randomly assigned to one of five groups (1,2,3,4,5). The team conducted a rapid census in each village and then ten households were randomly selected in each village. For villages with less than ten households, we randomly selected more households from the closest non-intervention village until we had enough. In total, our sample comprises 1,981 households in 209 villages.

Enumerators completed baseline data collection in 2016 and interviewed one man and one woman in each household. After baseline, we conducted a balance test (see appendix Table A.1) using a multinomial logit model to be certain groups did not differ based on observable characteristics (McKenzie 2015). There were slight differences in the likelihood of households having maize in storage and likelihood to dry maize on the ground. The control group was less likely than Groups 2 and 4 to have maize in storage, which was statistically significant at the five percent level. At the ten percent level, households in Group 5 were less likely to have maize in storage than control, and Group 4 was less likely to dry maize on the ground than control. To account for these potential differences, we estimate our main models with and without these variables, and the coefficients are robust to the inclusion of controls.

We implemented the intervention in October 2016, a few months after the baseline survey, and just before the 2016 maize harvest. This region has only one maize-growing season with the harvest taking place in October/November, depending on when the rains stop. Follow-up surveys took place in January 2017, May 2017, and April 2019. In May 2017 and April 2019, we took samples of each household's maize to test them for aflatoxins. Enumerators noted the drying and storage method to analyze the relationship between the drying and storage methods, type of intervention, and the level of aflatoxins present in the sample. If households used more than one storage container, two samples were taken from two different containers. Otherwise, one sample was taken from the bottom of the storage container and the other from the top. Each sample was placed in a separate baggie and analyzed separately by ISRA lab technicians, who cleaned testing equipment between each sample to avoid cross-contamination. Technicians used VICAM Afla-V AQUA kits to prep samples for analysis in the VICAM Vertu™ lateral flow reader.

The endline questionnaire was mostly the same as midline with some minor additions. We asked all groups, regardless of treatment assignment, whether or not they purchased any of the drying or storage technologies commercially in the seasons following the intervention, and if so, how many. We also added questions about whether, with how many people, and with whom specifically the respondent has lent their hygrometers and tarp to, as well as whom they had spoken to about various drying and storage-related topics. Since a hermetic bag is likely not an item that one would just use for a short period of time, we did not ask respondents if they lent out the hermetic bag.

We show baseline descriptive statistics in Table 1, both by treatment group and as a whole. On average, village centers were 14 km away from the nearest paved road. The typical household is headed by a man in their forties, often with little formal education (only one third had any formal education (not including Koranic schooling)), with about 20 years of maize farming experience. Very few households had a female head, about half a percent. For the 2015 harvest, on average, households devoted 1.7 hectares of their 4.4 total hectares of land to maize production. In 2015, the average harvest was 675 kg of maize. Many households dried maize directly on the ground, around 25 percent. As expected, baseline knowledge of aflatoxins was low at 28 percent.

Table 1. Descriptive Statistics

	Mean in Group					Overall Mean	Overall Std Dev
	1	2	3	4	5		
Panel A. Baseline Household Characteristics							
Household Size	12.2	12.6	12.5	11.8	12.3	12.3	6.7
Age of household head (years)	46	47	47	48	48	47	12
Household head had any formal education (%)	0.35	0.35	0.32	0.30	0.30	0.32	0.47
Woman access mobile phone (%)	0.67	0.71	0.70	0.70	0.69	0.69	0.46
Distance from village to nearest paved road	12	15	13	15	13	14	16
Panel B. Crop production and storage							
Maize farming experience of hhold head at baseline (years)	19	20	20	20	21	20	12
Area cultivated at baseline (ha)	4.1	4.2	5.3	4.3	4.2	4.4	12.8
Area of maize cultivated at baseline (ha)	1.8	1.5	1.4	2.2	1.7	1.7	6.0
2015 (Baseline) maize harvest (kg shelled)	643	732	615	723	660	675	904
2016 (Midline) maize harvest (kg shelled)	244	381	434	417	373	371	594
2018 (Endline) maize harvest (kg shelled)	708	679	702	639	646	673	1005
Weeks that maize stored for consumption lasted at baseline	13	13	13	15	14	14	13
Still had maize in storage at baseline (%)	57	65	64	68	67	64	48
Baseline harvest duration (days)	9.6	9.1	9.5	10.1	10.2	9.7	9.9
Respondent knew that aflatoxins are toxic at baseline (%)	25	28	30	31	28	28	45
Dried some maize directly on ground at baseline (%)	25	29	29	19	24	25	43
Dried some maize on tarp at baseline (%)	5	4	2	3	3	3	18

Groups 2-5 received training on aflatoxins and how to prevent contamination with post-harvest practices; Groups 3-5 received a low-cost moisture meter called a hygrometer; Groups 4 and 5 received a plastic tarp for drying maize; and Group 5 received a 50 kg hermetic (airtight) storage bag.

1.5 Empirical Framework

1.5.1 Longer-term impacts of the treatment assignment

Our analysis focuses on the impacts of the treatments (implemented in 2016) on levels of aflatoxins in 2019. We first estimate the intention-to-treat (ITT) effect of being assigned to each treatment group for household i in village j as follows:

$$(1)\ A_{ij2019} = \beta_1 + \beta_2 Group2_{ij} + \beta_3 Group3_{ij} + \beta_4 Group4_{ij} + \beta_5 Group5_{ij} + \delta X_{ij} + \lambda E_j + \varepsilon_{ij},$$

where A is a binary variable equal to one if the sample's aflatoxin level in 2019 was above the level designated as safe for human consumption. Since the EU and the US have different established limits, we estimate the model for both thresholds at 10ppb and 20ppb respectively. Additionally, we estimate the model using the exact level of aflatoxins as a continuous variable between the range of 0-100ppb. Group2, Group3, Group4, and Group5 are binary variables equal to one if the household was assigned to a given group and zero otherwise. Group 2 only received training; Group 3 received training and a hygrometer; Group 4 received training, a hygrometer, and a tarp; and Group 5 received training, a hygrometer, a tarp, and a hermetic bag. We calculate the marginal impact of receiving each input by subtracting the regression coefficient of a given group minus the coefficient of the group that received one less input. We then test these differences using F-tests to see if they are statistically different than zero. The vector of covariates that were unbalanced at baseline (having maize in storage and drying maize on ground) is denoted by X_{ij}. Next, we include E_j, a vector of six binary variables that control for the seven extension agents who trained households and handed out inputs in each village j. We include these controls because randomization was stratified by extension agent. The error term is denoted by ε_{ij}. Since the intervention was randomized at the village level, we cluster standard errors at this same level (Glennerster and Takavarasha 2013).

The model in equation (1) allows us to test the following hypotheses:

1. Providing training on aflatoxins has no impact on reducing aflatoxins in stored maize two years post-intervention ($\widehat{\beta_2}$= 0).
2. Providing training and drying technologies has no impact on reducing aflatoxin in stored maize two years post-intervention ($\widehat{\beta_3}$= 0 and $\widehat{\beta_4}$= 0).

3. Providing training, drying technologies, and a storage technology has no impact on reducing aflatoxin in stored maize two years post-intervention ($\widehat{\beta_5}$= 0).

1.5.2 Longer-term impacts of actually using the inputs

Additionally, we estimate the following treatment-on-the-treated (TOT) effects. TOT measures the effect of the intervention on those who actually attended the training session or adopted effective post-harvest technologies (who, absent the treatment assignment, would not have received the training or technology). Since the decision to attend the training or adopt a technology is non-random, we use an instrumental variable approach as follows:

$$(2)\ A_{ij2019} = \beta_1 + \beta_2 \widehat{INT}_{ij} + \delta X_{ij} + \lambda E_j + u_{ij}$$

$$(3)\ INT = \beta_1 + \beta_2 Group2_{ij} + \beta_3 Group3_{ij} + \beta_4 Group4_{ij} + \beta_5 Group5_{ij} + \delta X_{ij} + \lambda E_j + b_{ij}$$

where A_{ij2019} is as described in Equation (1), INT is a binary variable that indicates if a household member attended the training or used a provided input (hygrometer, tarp, or hermetic bag). We run the model four times for each of those variables. Since the decision to attend the training or continue adopting a given technology is non-random, we instrument these variables with the exogenous treatment group assignments. The vector of covariates that were unbalanced at baseline (having maize in storage and drying maize on ground) is denoted by X_{ij}. Next, we include E_j, a vector of six binary variables that control for the seven extension agents who trained households and handed out inputs in each village j. The vector of parameters for extension agent controls is denoted as λ. The error term is denoted by u_{ij} in equation (2) and b_{ij} in equation (3).

As such, the model in equation 2 tests the following hypothesis:

4. Complying with a treatment (INT) has no impact on reducing aflatoxin in stored maize two years post-intervention ($\widehat{\beta_2}$= 0)

1.5.3 Heterogeneous impacts

Finally, we conduct a heterogeneity analysis to see if households with certain characteristics benefit differently from the intervention in the longer-term. We estimate several iterations of the following model:

$$(4)\ A_{ij2019} = \beta_1 + \beta_2 Group2_{ij}Z_{ij} + \beta_3 Group3_{ij}Z_{ij} + \beta_4 Group4_{ij}Z_{ij} + \beta_5 Group5_{ij}Z_{ij} + \omega Z_{ij} + \sigma X_{ij}Z_{ij} + \lambda E_j + a_{ij}$$

where A_{ij2019} and the other variables are the same is as described in Equation (1). Next, we interact the exogenous group assignments with a given variable Z for household i in village j. This variable Z changes for each iteration and represents the following household characteristics: household size, age of the household head, education level of the household head, household wealth, whether any woman in the household has access to a mobile phone (binary variable), and whether any woman from the household attended the training session (binary variable). The last two variables are likely correlated with a woman's level of empowerment in her household, so these variables are essentially proxies given that empowerment is difficult to measure. We include Z_{ij} on its own to control for its effects on aflatoxins. We also include an interaction term between unbalanced baseline controls and the various household characteristics, $X_{ij}*Z_{ij}$. The error term is denoted by a_{ij}. Standard errors are clustered at the village level. The coefficients β_2, β_3, β_4, and β_5 indicate whether the impacts of the treatment assignment differ by each characteristic Z.

1.5.4 Dependent variable censoring

It is important to note that the exact level of aflatoxins (the dependent variable in our analysis) in each sample was censored at 100 parts per billion (ppb). If the true level of aflatoxins in the sample was above 100 ppb, the VICAM reader gave an "out of range" message; to find the true level, the sample had to be diluted and run through again with a new test strip. To limit costs and reduce logistical complexity, we elected not to retest out of range samples in 2017. In 2019, we retested all "out of range" samples to avoid the censoring problem. The tests are not calibrated beyond 300 ppb, however, so measures above that level are only indicative, and become less and less precise as aflatoxins levels increase. Less than ten percent of samples in 2019 tested above 100 ppb. To ensure censoring at 100 ppb did not bias our regression estimates, we tested the model with total aflatoxins as the dependent variable using both censored and uncensored measurements. We found that using uncensored measures distorts the mean (99.97 vs 20.41). We include these uncensored regressions in Table A.8.

1.5.5 Attrition

With any sort of a follow-up study, it is important to make sure that attrition is balanced across groups. If the control group disproportionally decided to self-select out of the intervention since they did not receive any inputs, this could cause selection bias. In 2019, we were able to interview 1787 out of the original 1981 households, for an overall attrition rate of 9.8% (see Table A.2). As a balance check, we regressed treatment assignment on a binary variable equal to one if we did not interview the household in 2019. We found no statistically significant differences in the likelihood of being interviewed between the treatment groups and the control group, even when controls are included (see Table A.3).

1.5.6 Incidental truncation from having maize in storage for testing

A related but different problem from household attrition, is that we can only analyze levels of aflatoxins from households who still had maize in storage in April/May 2019. This could bias our impact estimates if having maize in storage in April/May 2019 is itself a function of the treatment assignment, which is a possibility given that each provided input can reduce the probability of storage losses. Regression estimates indicate that Group 3 was 10 percentage points more likely than the control group to have maize in storage that could be sampled (see Table A.4). To control for this potential selection bias, we implement a Heckman selection model. We instrument the availability of maize for sampling in 2019 with the availability of maize for sampling in 2017, which are highly correlated (coefficient = 0.488). Having maize sampled in 2017 is unlikely to affect aflatoxins two seasons later in 2019; aflatoxins are most directly influenced by weather, yields, and drying/storage methods. Having maize sampled in 2017 is also likely uncorrelated with other factors in the error term, such as climate conditions during the 2018 growing season. Coefficients in the selection model were very similar to our standard OLS models and, regardless of which controls were included, the Inverse Mills Ratio (IMR) was consistently not statistically significant alleviating our concerns about this type of bias (see results of Heckman selection model in Table A.5).

1.6 Results

1.6.1 Longer-term impacts of the treatment assignment

Table 2 reports the intention-to-treat estimates from equation (1) that shows how our intervention from 2016 affected aflatoxin in stored maize 3-4 months after harvest in 2019. Our data showed significant impacts for Group 4 only. Specifically the provision of a tarp lowered the probability of having aflatoxins above the US threshold of 20ppb in columns (3) and (4) and on total aflatoxins levels in columns (5) and (6), but had no significant impacts for the EU threshold of 10 ppb. Being assigned to Group 4 reduced the likelihood of having maize test above the US safety threshold by 7 percentage points, a 30 percent decrease from the control group average of 23 percent (p=0.033). Similarly, when the actual aflatoxins level was the dependent variable, regressions showed that receiving training, a hygrometer, and a tarp lowered aflatoxins by about 5 ppb (a 20 percent decrease from the control group average of 20.41 ppb), although the regression coefficient is only statistically significant at the 10 percent level (p=0.089). Coefficients on Group 5 those who also got a hermetic bag, while insignificant, were extremely close to those of Group 4 (-4.67 and -4.81 respectively). Group 5's data seemed to be slightly noisier than Group 4's (2.85 vs 2.82 standard errors), so the p-value on Group 5's coefficient was just barely out of the significant range at 0.103. None of the combinations of inputs, however, had a longer-term impact on the likelihood of having maize test below the EU level (p-value on Group 4 coefficient was close at 0.115).

Estimates of the marginal impacts of each input showed that the tarp was the key input for these reductions, with no other inputs having a significant marginal contribution. Receiving a tarp (in addition to training and a hygrometer) reduced the likelihood of having aflatoxins above the US threshold by 7 percentage points (control group average was 23 percent), which was significant at the 5 percent level (p=0.046). This estimate was the same as Group 4's ITT estimate, providing more evidence that the training and hygrometer did not have significant marginal impacts.

In Table A.6, we run the model including the level of aflatoxins in 2017 as a control, in case levels are correlated across years. We found that the 2017 average level was not significantly correlated with the 2019 average level (coefficient=0.0484). Including the 2017 level as a control reduced our sample size by half and weakened our statistical power.

Table 2. Intention-to-Treat OLS Models

VARIABLES	(1) >10ppb (EU std)	(2)	(3) >20ppb USU std)	(4)	(5) Total aflatoxins (ppb)	(6)
Group 2 (training only)	-0.01	-0.01	-0.01	-0.01	-1.79	-1.83
	(0.04)	(0.04)	(0.03)	(0.03)	(2.87)	(2.88)
Group 3 (training + hygrometer)	-0.01	-0.01	-0.00	-0.00	-0.40	-0.44
	(0.04)	(0.04)	(0.03)	(0.03)	(2.90)	(2.91)
Group 4 (training + hygrometer + tarp)	-0.06	-0.06	-0.07**	-0.07**	-4.67*	-4.81*
	(0.04)	(0.04)	(0.03)	(0.03)	(2.77)	(2.82)
Group 5 (training + hygro + tarp + hermetic bag)	-0.04	-0.05	-0.04	-0.04	-4.59	-4.67
	(0.04)	(0.04)	(0.03)	(0.03)	(2.84)	(2.85)
Had maize in storage at baseline		0.02		0.00		1.01
		(0.02)		(0.02)		(1.78)
Dried maize on ground at baseline		-0.01		0.00		-0.36
		(0.03)		(0.02)		(1.82)
Constant	0.23***	0.22***	0.19***	0.19***	17.83***	17.28***
	(0.04)	(0.05)	(0.04)	(0.04)	(3.39)	(3.60)
Observations	2,117	2,117	2,117	2,117	2,117	2,117
R-squared	0.03	0.03	0.02	0.02	0.02	0.02
Trainer fixed effects included	Yes	Yes	Yes	Yes	Yes	Yes
Mean of dependent variable in group 1 (control)	0.28		0.23		20.41	
Marginal impact of hygrometer (G3-G2)	0.00	0.00	0.01	0.01	1.39	1.39
Marginal impact of tarp (G4-G3)	-0.05	-0.05	-0.07**	-0.07**	-4.27	-4.37*
Marginal impact of PICS (G5-G4)	0.02	0.01	0.03	-0.11	0.08	0.14

Groups 2-5 received training on aflatoxins and how to prevent contamination with post-harvest practices; Groups 3-5 received a low-cost moisture meter called a hygrometer; Groups 4 and 5 received a plastic tarp for drying maize; and Group 5 received a 50 kg hermetic (airtight) storage bag. Aflatoxins levels are censored at 100 ppb. Robust standard errors are clustered at the village level (*** p<0.01, ** p<0.05, * p<0.1).

In Figure 1, we show a cumulative distribution plot of the 2019 results and we see differences between groups existed across the distribution. The figure indicates average reductions in aflatoxins were not a result of a large reductions for small number of households. In 2019, Group 4's plot was visibly to the left of all of the other groups, but closest to Group 5. Other groups were largely indistinguishable from each other. Table A.7 reports average aflatoxins levels by group and also showed Group 4 had the lowest average levels (12.79 ppb) and the lowest proportion of samples above the EU safety threshold (18.46 %). Average levels in Group 5 (13.25 ppb) were lower than control (17.61 ppb), but not statistically different from Group 4 (p=0.805). Lasting improvements in Group 5's aflatoxin levels likely came from receiving a tarp.

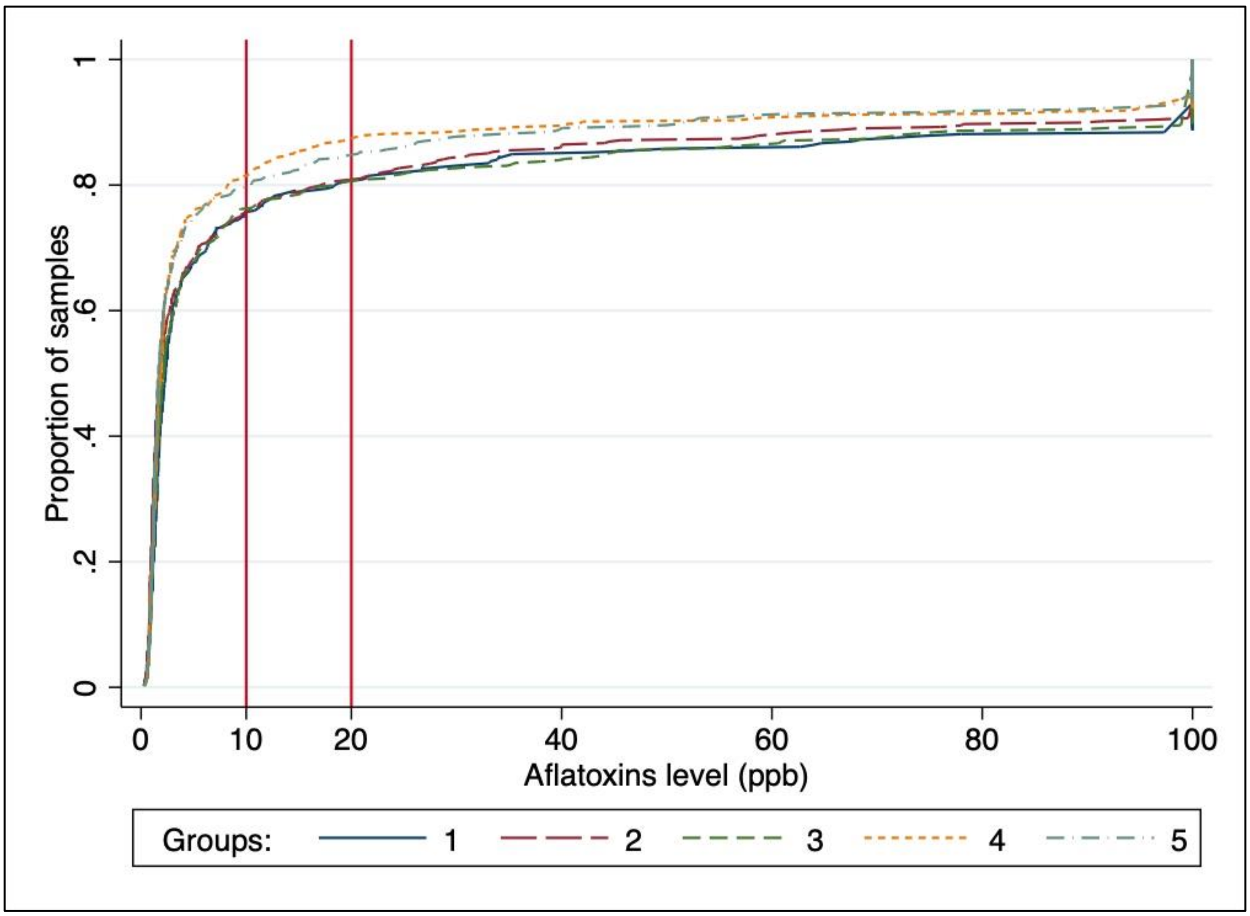

Figure 1. Cumulative Distribution Function of Aflatoxins in 2019 by Treatment Group

1.6.2 Longer-term impacts of actually using the inputs

Table 3 reports our treatment-on-the-treated estimates. These estimates represent the effect of attending training or using a given technology in the 2018-19 season for households who acquired them through our intervention two years prior but would otherwise not have accessed them. In contrast to the lack of effects of being assigned to one of the four treatment groups, effects of actually using these technologies were large in magnitude, statistically significant for most specifications, but typically only at the 10 percent level.

Using the hygrometer reduced the probability of a household's maize testing above the US threshold by 18 percentage points (p = 0.050) and reduced total aflatoxins levels by around 12 ppb (p = 0.088). The hygrometer had no significant effect when the EU threshold was the dependent variable (p=0.104), although it was very close to the 10% level. Using the tarp in the past season reduced the probability of having maize test above the US threshold by 25 percentage points (p=0.068) and reduced total aflatoxins by 20 ppb (p=0.067). The tarp had no significant effect on the probability of maize testing above the EU threshold (p=0.131). For the US threshold and actual aflatoxins levels, the effects of using a hygrometer and using a tarp were significant regardless of controls and coefficients were not sensitive to specification.

Storing maize in a hermetic bag reduced the total aflatoxins levels by the largest amount, 54 ppb on average (p=0.091), but had no significant effect on the likelihood of a household's maize testing over the US threshold (p=0.172) or the EU threshold (p=0.232). Attending training had no significant effect on aflatoxins in 2019 (p=0.228), or the likelihood of being above the US threshold (p=0.274) or above the EU threshold (p=0.379). Coefficients for attending training were only 3 percentage points different from Group 2's in the ITT models. Nearly 99 percent of households who were invited to training had at least one household member attend, so the fact that the ITT and TOT were this close to each other is not surprising.

Table 3. Treatment-on-the-Treated 2SLS Models - Second Stage Regressions

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variables	>10ppb (EU std)	>20ppb USU std)	Total aflatoxins (ppb)	>10ppb (EU std)	>20ppb USU std)	Total aflatoxins (ppb)
	$\widehat{INT}$ = Attended Training			$\widehat{INT}$= Used Hygrometer in 2019		
$\widehat{INT}$	-0.032	-0.032	-3.091	-0.170	-0.176**	-12.220*
	(0.036)	(0.029)	(2.564)	(0.105)	(0.090)	(7.165)
Constant	0.221***	0.189***	17.557***	0.250***	0.220***	19.012***
	(0.049)	(0.041)	(3.663)	(0.050)	(0.044)	(3.666)
Trainer fixed effects included	Yes	Yes	Yes	Yes	Yes	Yes
Controls included	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,117	2,117	2,117	2,117	2,117	2,117

	(7)	(8)	(9)	(10)	(11)	(12)
Dependent Variables	>10ppb (EU std)	>20ppb USU std)	Total aflatoxins (ppb)	>10ppb (EU std)	>20ppb USU std)	Total aflatoxins (ppb)
	$\widehat{INT}$ = Used Tarp in 2019			$\widehat{INT}$= Used PICS in 2019		
$\widehat{INT}$	-0.241	-0.253*	-19.734*	-0.567	-0.593	-54.855*
	(0.160)	(0.138)	(10.761)	(0.474)	(0.434)	(32.450)
Constant	0.254***	0.225***	19.872***	0.204***	0.169***	15.342***
	(0.058)	(0.051)	(4.240)	(0.042)	(0.038)	(3.304)
Trainer fixed effects included	Yes	Yes	Yes	Yes	Yes	Yes
Controls included	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,117	2,117	2,117	2,117	2,117	2,117

Groups 2-5 received training on aflatoxins and how to prevent contamination with post-harvest practices; Groups 3-5 received a low-cost moisture meter called a hygrometer; Groups 4 and 5 received a plastic tarp for drying maize; and Group 5 received a 50 kg hermetic (airtight) storage bag. Aflatoxins levels are censored at 100 ppb. Robust standard errors are clustered at the village level (*** p<0.01, ** p<0.05, * p<0.1).

1.6.3 Heterogeneous impacts

We estimate whether the impacts of the inputs differed by various observable household characteristics. Across specifications (see Table A.11), we found no significant differences for household size, age of the household head, education level of the household head, household wealth, whether a woman in the household has access to a mobile phone, and whether a woman attended the training session.

In the context of our study, if a woman attended the training session, it usually means that a woman attended the training session with her husband. Training attendance records showed that less than 7 percent of households only sent a woman to the training session. In other words, this variable means the woman had the same access to information as the male household head. Results from this part of the heterogeneity analysis are shown in Table 4. If a woman attended the training, households were between 20 and 30 percent less likely to have aflatoxins over the EU limit. However, when we slightly change the dependent variable to the US limit or actual aflatoxins levels, the coefficients become smaller or even positive, but insignificant. Most likely, what we found are Type 1 errors; when we calculated sharpened q-values, none of the coefficients were significant anymore.

Table 4. Heterogeneity Analysis – Women's Attendance

	(1)	(2)	(3)	(4)	(5)	(6)
	Interaction variable: =1 if woman from household attended training, 0 otherwise					
Dependent Variable	>10ppb (EU std)		>20ppb (US std)		Total aflatoxins (ppb)	
Group 2 * interaction in heading	-0.220*	-0.221*	-0.083	-0.077	8.706	8.757
p-value	(0.088)	(0.090)	(0.472)	(0.515)	(0.143)	(0.156)
sharpened q-value	[0.253]	[0.345]	[1.000]	[1.000]	[0.637]	[1.000]
Group 3 * interaction in heading	-0.245**	-0.244**	-0.010	-0.094	9.446**	9.545*
p-value	(0.044)	(0.048)	(0.349)	(0.389)	(0.048)	(0.055)
sharpened q-value	[0.217]	[0.321]	[1.000]	[1.000]	[0.508]	[0.847]
Group 4 * interaction in heading	-0.297**	-0.296**	-0.113	-0.103	6.893	7.320
p-value	(0.016)	(0.019)	(0.301)	(0.367)	(0.204)	(0.197)
sharpened q-value	[0.205]	[0.307]	[1.000]	[1.000]	[0.760]	[1.000]
Group 5 * interaction in heading	-0.231*	-0.230*	-0.081	-0.075	10.780**	10.988**
p-value	(0.054)	(0.058)	(0.444)	(0.491)	(0.033)	(0.036)
sharpened q-value	[0.220]	[0.321]	[1.000]	[1.000]	[0.508]	[0.817]
Observations	1,819	1,819	1,819	1,819	1,819	1,819
R-squared	0.036	0.036	0.026	0.027	0.025	0.026
Trainer fixed effects included	Yes	Yes	Yes	Yes	Yes	Yes
Controls variables included	No	Yes	No	Yes	No	Yes

Groups 2-5 received training on aflatoxins and how to prevent contamination with post-harvest practices; Groups 3-5 received a low-cost moisture meter called a hygrometer; Groups 4 and 5 received a plastic tarp for drying maize; and Group 5 received a 50 kg hermetic (airtight) storage bag. Aflatoxins levels are censored at 100 ppb. Robust standard errors are clustered at the village level (*** p<0.01, ** p<0.05, * p<0.1).

1.6.4 Limitations

Our main regression analysis is limited in the sense that since we cannot test every possible combination of technologies, the estimated marginal impacts of the inputs are not completely teased out. For example, we cannot say that providing a tarp in and of itself, without training and a hygrometer, is effective at reducing aflatoxins in smallholders stored maize in the longer-term. These marginal effects have to be evaluated in the context of the intervention as the effect of receiving a technology in addition to any other received inputs. Further research should continue to test different combinations of inputs as well as more inputs in isolation.

Another limitation is that we only observe aflatoxins at one point in the season, several months into the storage period. We did not test maize aflatoxins levels in the field before harvest or before being put into storage. Observing aflatoxins at various points of the production process would have (1) provided a more detailed picture of when maize was becoming the most contaminated, and (2) if usage of certain inputs kept maize that came out of the field with higher aflatoxins levels from becoming even more contaminated. Additionally, levels at various points in time could have been useful controls and may have increased our explanatory power.

1.7 Pathways to Impact

There are several factors that explain the relative success of Group 4 and the tarp, and the lack of evidence of impact of the other inputs (training, hygrometer, and hermetic storage bag). In this section, we describe two main pathways to this impact: differences in longer-run usage of the provided technologies, and spillovers to the control group.

1.7.1 Usage of Technologies

Hygrometers. The fact that the ITT analysis found no marginal effect on aflatoxins for the hygrometer, in spite of significant TOT effects for those who used the hygrometer, suggests that the lack of effect is likely due to low overall usage. Table 5 shows only 20 to 30 percent reported having used the hygrometer to dry their maize in 2019. Households reported three main issues with using the hygrometer in 2019. First, since the hygrometers could not be easily turned on and off, batteries died over time; the type of replacement batteries required still were not available. Only within the last year of endline data collection have replacement hygrometers been commercially available locally. Second, over a quarter of the sample reported having lost the hygrometer, or it had been destroyed, as the reason for why they no longer possessed it. Last, hygrometers became less accurate by 2019. We gave each enumerator a hygrometer in working order and had them compare the readings between the good hygrometer and the household's hygrometer (if the household still had it). On average, hygrometers' measures of relative humidity were off by 6.5 percent, which could have hindered households' ability to tell when their maize reached critical the critical point of 65% relative humidity. That being said, we do not know how accurate the hygrometers were at the time of use as we only observe their accuracy well into the post-harvest period, which would have been 3-4 months later.

Tarps. Tarps were adopted at the highest rates in the longer-run and they were effective for those who used them. This is likely why tarps were the only input that had a significant marginal effect on aflatoxins in our ITT estimates. More respondents in Group 4 indicated they had used the tarp we provided compared to Group 5 (the only other group that received tarps), 43 percent and 36 percent respectively (p=0.044). The conditions of the tarps we gave out in 2016 deteriorated over time but just 8 percent of the tarps were actually in bad condition, as judged by the enumerators. On average, 12 percent of households across all groups went out and purchased additional tarps between 2017 and 2019, which was a higher percentage of people than who purchased hygrometers (7 percent). Those who bought tarps also tended to buy several.

Even though some people in other groups went out and bought tarps, the fact that our intervention provided a tarp to Group 4 and Group 5 in 2016 mattered for tarp usage even in 2018/19. This could explain why Groups 4 and 5 were more successful than the other treated groups. Just learning that a tarp could prevent aflatoxins may not be enough to induce a widespread behavior change. Only groups who received a tarp from the intervention were more likely than the control group to dry their maize on the tarp and less likely than the control group to dry their maize directly on the ground, a crucial pathway for reducing aflatoxins. In Table A.9, we present the first stage regressions from our treatment-on-the-treated models. Households assigned to Group 4 were around 15 percent more likely to dry on a tarp (p=0.001) and households assigned to Group 5 were 22 percent more likely to dry their maize on the tarp (p=0.000).

Hermetic Bags. Very few households used hermetic bags during the 2018/19 season. Just 6 percent of Group 5, all of whom received a hermetic bag from the project in 2016, used the bag to store maize during the follow up. This low usage rate likely explains why TOT estimates for the bags showed a significant effect on total aflatoxins (54 ppb average reduction) but the marginal impact of the bag was zero on average in the ITT estimate. ITT models likely lacked the power to pick up the small effect of 6 percent of group 5 having good outcomes from using the hermetic bag. Additionally, fewer people went out and bought hermetic bags than either the hygrometer, which became locally available at the same time as the hermetic bags, or the tarp.

First stage regressions in Table A.9 show that for the hermetic bag, unlike for the other inputs, there was a group who did not receive a bag that was still statistically more likely to use it than control in 2019. Members of Group 4, who did not receive a hermetic bag in 2016, were 3 percentage points (p=0.001) more likely to use a hermetic bag than the control group in 2019. These people likely went out and bought hermetic bags on their own between 2016 and 2019. Members of Group 5 who received a hermetic bag in 2016 were 8 percentage points (p=0.000) more likely to use the hermetic bag than control in 2019. This could further explain why our marginal estimates for the hermetic bag were insignificant. Some portion of Group 4's aflatoxins reductions could be coming from those households buying and then using hermetic bags. Since usage of hermetic bags was so low overall, a small increase in use in Group 4 could have been enough to wipe out the marginal effect of providing a bag to Group 5.

Table 5. Descriptive Statistics by Technology

	Mean in Group 1	2	3	4	5	Overall Mean	Overall Std Dev	Obs.
Hygrometer								
Still had hygrometer in 2017 (%)			0.85	0.90	0.88	0.87	0.33	1209
Still had hygrometer in 2019 (%)			0.53	0.62	0.61	0.59	0.49	1091
Received a hygrometer and used it in 2017 (%)			0.44	0.45	0.42	0.44	0.50	1209
Received a hygrometer and used it in 2019 (%)			0.19	0.30	0.25	0.25	0.43	1091
Hygrometer reported it destroyed/lost in 2017 (%)			0.08	0.07	0.09	0.08	0.27	1209
Hygrometer reported it destroyed/lost in 2019 (%)			0.28	0.25	0.27	0.27	0.44	1091
Absolute deviation of hygrometer from true humidity in 2019 (%)			6.42	7.75	5.11	6.51	9.74	120
Used a hygrometer in 2019 (%)	0.08	0.11	0.26	0.30	0.29	0.21	0.41	1787
Purchased a hygrometer in the last year (%)	0.07	0.09	0.07	0.09	0.05	0.07	0.26	1787
Tarps								
Received a tarp and used it in 2017 (%)				0.97	0.95	0.96	0.20	812
Received a tarp and used it in 2019 (%)				0.43	0.36	0.40	0.49	735
Used a tarp in bad condition in 2017 (%)				0.02	0.01	0.01	0.10	812
Used a tarp in bad condition in 2019 (%)				0.10	0.05	0.08	0.27	735
Dried some maize on tarp in 2017 (%)	0.10	0.15	0.09	0.40	0.43	0.25	0.43	1981
Dried some maize on tarp in 2019 (%)	0.16	0.16	0.23	0.31	0.37	0.25	0.43	1787
Purchased at least one tarp in the last year (%)	0.09	0.12	0.13	0.13	0.12	0.12	0.32	1787
Average number of tarps purchased	10.38	13.51	5.94	9.43	2.97	8.32	11.67	209
PICS Bags								
Received a PICS bag and still had it in 2017 (%)					0.95		0.23	404

Table 5 continued

Received a PICS bag and still had it in 2017 (%)					0.95		0.23	404
Received a PICS bag and still had it in 2019 (%)					0.48		0.64	357
Received PICS bag and used it to store maize in 2017 (%)					0.196		0.397	404
Received PICS bag and used it to store maize in 2019 (%)					0.062		0.241	357
Stored some maize in PICS bag in 2019 (%)	0.000	0.008	0.003	0.021	0.062	0.019	0.137	1787
Purchased at least one pics bag in the last year (%)	0.07	0.09	0.04	0.06	0.04	0.06	0.24	1787
Average number of pics bags purchased	14.14	10.09	10.60	14.00	6.43	11.31	8.00	108

Groups 2-5 received training on aflatoxins and how to prevent contamination with post-harvest practices; Groups 3-5 received a low-cost moisture meter called a hygrometer; Groups 4 and 5 received a plastic tarp for drying maize; and Group 5 received a 50 kg hermetic (airtight) storage bag.

1.7.2 Learning over time by the control group

Over time, knowledge of aflatoxins and actual aflatoxins levels converged across treatment groups. First, we look at spillovers in awareness and then we look at spillovers in usage of inputs.

While attending training by itself did not have a significant effect on aflatoxins levels in 2019, it seems to have increased awareness of aflatoxins among our sample. In Figure 2, we plot the changes in knowledge of aflatoxins by group over time. Baseline knowledge that aflatoxins are toxic was very low across all groups at around 28 percent. After the intervention was implemented, we saw large gains in knowledge of aflatoxins across all treated groups as a result of the training in 2016/67. However, by 2019 knowledge of aflatoxins in the treated groups remained high, further increasing in Groups 2 and 5. Perhaps most interestingly, knowledge of aflatoxins shot up in the control group to 64 percent, which is still lower than the treated groups but not by much. This suggests that there could have been knowledge spillovers between treated villages and control villages in the 2+ years following our intervention in 2016/17.

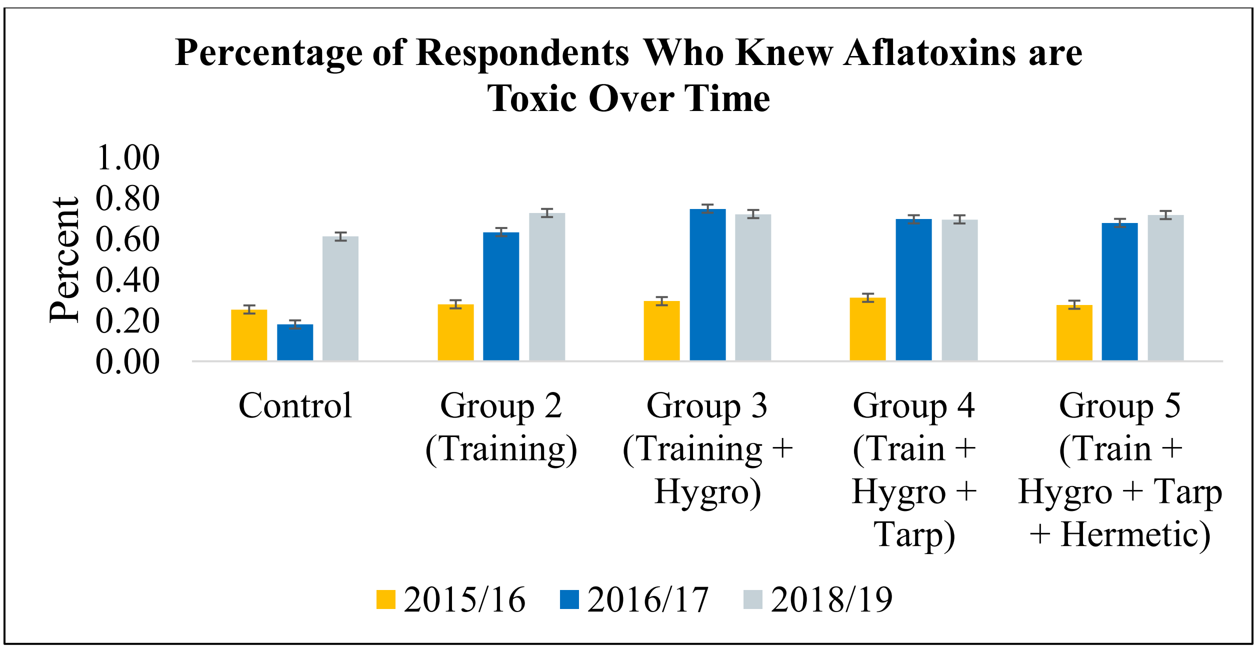

Figure 2. Percentage of Respondents Who Knew Aflatoxins are Toxic Over Time

In Table A.10, we show descriptive statistics on reported discussion of various topics as well as lending of technologies. Over 30 percent of the control group indicated they had discussed aflatoxins, drying challenges, and storage challenges with at least one person. Some of these spillovers may be attributable to additional local extension efforts in making hygrometers, tarps, and hermetic bags more accessible to smallholders between 2017 and 2019.

We also see evidence of control group households actually going out and buying effective post-harvest technologies. The most notable piece of evidence is that the control group used tarps at a rate three times higher than it was at baseline: 16 percent of the control group dried some maize on a tarp at endline (Table 5) compared to 5 percent at baseline. Households in the control group also purchased hygrometers, tarps, and hermetic bags at similar rates to those in the treated groups (Table 6). Both improvements in knowledge and input usage in the control group likely contributed to the lack of significant effects for Groups 2 and 3.

1.8 Cost-Effectiveness Analyses

We conducted two cost-effectiveness analyses of Group 4's treatment, since they were the only group who had significantly lower levels of aflatoxins than control in 2019. The first was rather simple and calculated the costs of the intervention per ppb of aflatoxins reduced. The second, more-detailed analysis compared the costs of the intervention with the estimated economic gains from reduced aflatoxins in maize. Since maize is largely a subsistence crop in Senegal, we did not factor in economic gains from trade. Rather, we estimated the economic benefits of reduced aflatoxins through reductions in morbidity.

1.8.1 Simple cost-effectiveness analysis

It cost $6,100 to train 3,800 households for a unit cost of $1.60, a hygrometer costs about $1.13, and each tarp was purchased for $3.27. The total cost of all of these inputs was $6.00. Since average aflatoxin levels in Group 4 were 4.82 ppb lower than control, we estimate the cost-effectiveness to be $1.24 per ppb of aflatoxin reduced. However, providing hygrometers did not lower total aflatoxin levels. Another cost-effectiveness estimate that just considers training and providing a tarp would be $1.01 per ppb reduced ($4.87/4.82). Both are likely underestimates, because the benefits of training and tarps last for longer than one year, and because one could provide less-costly training focused on just aflatoxins and tarps (the $6,100 estimate for the cost of training used in the calculation is the total cost for the intervention, including lengthier training in group 5 which received all inputs).

1.8.2 Detailed cost-effectiveness analysis

This analysis uses World Health Organization (WHO) cost-effectiveness guidelines for public health interventions. Under WHO guidelines, a project is considered highly cost efficient if the total cost of the intervention is smaller than the averted loss of disability adjusted life years (DALYs), a measure of disease burden, times the GDP per capita of the relevant country. If the project does not meet this threshold, there is another threshold that considers a project moderately cost efficient if the total cost of the intervention is less than three times the GDP per capita times the DALYs averted (Sachs and WHO 2001). We chose to evaluate the cost-effectiveness of providing training and a tarp for two reasons. One, tarps were the only provided input that had a significant marginal effect on aflatoxins in the longer-term, and two, households need training in order to understand the purpose of the tarp and how to use it to dry their maize.

Results from this analysis are presented in Table 6. First, we calculated the per-person, annual equivalent costs of providing training and a 10 m_2 tarp. All dollar amounts are in 2016 dollars. The cost of the training per household ($1.60) was computed by taking the total costs of administering the training divided by the number of households who received the training ($6,082/3,806 households). Included in this training cost are extension agents' wages and transportation costs. In October 2016, tarps cost $3.27 locally. Since households do not have to be retrained and we estimate the life of a tarp to be 3 years, we converted these costs ($1.60 and $3.27) into annual equivalent costs using methods described in Campbell and Brown (2016). We used a 6.25% social discount rate as recommended by the US Federal Reserve for analyses relating to Senegal (Warusawitharana 2014). The annual equivalent costs of providing training ($0.10) and a tarp ($1.23) to a household summed to $1.34. Given the average household in the intervention is 12.3, we divided the annual equivalent cost ($1.34) by the average household size to get a per-person, annual equivalent cost of $0.11.

The benefits of the project were less straightforward to calculate but overall involved estimating the per person disease burden averted by the intervention and multiplying that value by the GDP per capita of Senegal. We started by taking the number of DALYs (per 100,000 people) attributed to aflatoxin-induced liver cancer in Senegal, 28, and subtracted off the US equivalent, 0.04 (Havelaar et al. 2015). This was done because there is no risk-free level of aflatoxin consumption. Any amount above zero carries some risk of negative health effects. We measured how many more households were able to produce maize below the US aflatoxin limit of 20 ppb, so it seemed reasonable to assume that if the households are eating maize at or below the US limit, their risk of aflatoxin-related liver cancer due should be comparable to the US equivalent. The next step was to convert this adjusted value of DALY aversion (27.96 per 100,000 people) into a per-person value (0.0002796)

One factor that cannot be ignored is that maize is not the only staple food in the study region that is prone to aflatoxin contamination. Groundnuts are a significant part of the Senegalese diet, and they too are prone to aflatoxin contamination. For simplicity's sake, this model operates under the assumption that the only dietary sources of aflatoxins are maize and groundnuts, the two largest sources of dietary aflatoxins (Wu & Khlangwiset, 2010). We used consumption data on how many grams of maize and groundnuts people consume per day in Senegal, 89.1 and 30.55 respectively (FAOSTAT 2020), to calculate the maize consumption proportion of these two foods. This proportion, 0.75, was included as a penalty, such that for each person, reducing maize aflatoxins only decreases 75% of the disease burden. Like Wu & Khlangwiset (2010), we assumed a linear dose-response relationship between reductions in aflatoxins exposure and reduction in disease burden. To calculate the DALY averted due to the intervention, we took the disease burden attributable to aflatoxins in maize, 0.0002, and multiplied it by the percent increase in of households having maize under the US safety limit due to the intervention, 7%. This gave a value of 0.00015 DALY averted per person as a result of providing training and a tarp.

At this point, with additional information on the Senegalese GDP per capita, $3,473.48[1], we had enough information to see how cost-effective this intervention is based on WHO guidelines. We found the intervention was moderately cost efficient. The total annual equivalent costs per person, $0.11, was less than $0.15, the value of 3 times the per-person total DALY averted multiplied by GDP per capita. Based on our estimates, the project was not highly cost efficient, as the costs are greater than the GDP per capita multiplied by the DALY averted, $0.05. That being said, it should be noted that because the WHO only provides aflatoxin-related disease data for just one condition, liver cancer, so our calculations likely underestimate the true benefits. Nevertheless,

[1] According to World Bank Open Data: https://data.worldbank.org/indicator/NY.GDP.PCAP.PP.CD?locations=SN, deflated to 2016 dollars using: https://data.worldbank.org/indicator/NY.GDP.DEFL.ZS?locations=SN

our findings suggest providing training and a tarp is moderately cost-efficient based solely on reductions in morbidity and mortality of aflatoxin-induced liver cancer.

Table 6. Cost-effectiveness of providing training and a tarp to maize producers

Parameter	Value (monetary values in 2016 US Dollars)	Source/reference
Training cost per household	1.60	Bauchet et al. (2020)
Cost of one 10 square meter tarp in October 2016	3.27	Bauchet et al. (2020)
Estimated life of a tarp (years)	3	
Social discount rate for Senegal (percent)	6.25%	Warusawitharana, M. (2014)
Annual equivalent cost of training (per household)	0.10	Campbell and Brown (2016)
Annual equivalent cost of tarp (per household)	$1.23	Campbell and Brown (2016)
Average household size (people)	12.3	Bauchet et al. (2020)
Annual equivalent costs of providing training and tarp, per person	$0.11	
Annual aflatoxin induced liver-cancer disease burden (Disability adjusted life years (DALY)) per 100,000 people in Senegal	28	Havelaar et al. (2015)
Annual aflatoxin induced liver-cancer disease burden (DALY) per 100,000 people in USA	0.04	Havelaar et al. (2015)
Additional disease burden (DALY) faced by Senegal compared to USA, per 100,000 people	27.96	
Additional disease burden (DALY) per person	0.0002796	
Total daily maize consumption (grams) in Senegal, per person	89.1	FAOSTAT (2020)
Total daily groundnut consumption (grams) in Senegal, per person	30.55	FAOSTAT (2020)
Maize consumption proportion of aflatoxin prone foods (maize and groundnut)	0.74467196	
Disease burden (DALY) attributable to aflatoxins consumed from maize, per person	0.00020821	

Table 6 continued

Parameter	Value (monetary values in 2016 US Dollars)	Source/reference
Decrease in likelihood of maize testing above US Threshold if received training and tarp (%)	7%	Present article
Total DALY averted due to intervention, per person	0.00001457	
2019 GDP per capita in Senegal (PPP adjusted, 2016 dollars)	$3,473.48	World Bank (2020)

WHO Guideline for Highly Cost-Efficient Designation

Total Cost < Total DALY Averted * GDP per capita

Total Cost (Annual Equivalent per person)		**Total DALY Averted * GDP per capita**
$0.11	>	$0.05

WHO Guideline for Moderately Cost-Efficient Designation

Total Cost < (Total DALY Averted * GDP per capita * 3)

Total Cost (Annual Equivalent per person)		**3*Total DALY Averted *GDP per capita**
$0.11	<	$0.15

1.9 Conclusion

In this article, we presented findings from a follow-up study of a post-harvest intervention in southern Senegal aimed at reducing aflatoxins in smallholders' stored maize. We followed-up with nearly 2,000 maize-producing smallholder households in 200 villages in southern Senegal who participated in the RCT analyzed by Bauchet, Prieto and Ricker-Gilbert (2020). The original intervention occurred in the 2016/17 season and we followed up in 2019 to measure the impacts more than two years later.

We found that, two years after the intervention was implemented, only the provision of a tarp significantly lowered aflatoxins levels. Households assigned to Group 4, the group who received training, a low-cost moisture meter (called a hygrometer), and a plastic tarp, were 30 percent less likely than the control group to have maize test above the US safety limit of 20 ppb. Marginal estimates indicated the tarp was the key input behind these decreases in aflatoxins; providing a tarp significantly increased the likelihood of using a tarp and decreased the likelihood of drying maize on the ground. This contrasts with Bauchet, Prieto and Ricker-Gilbert (2020)'s findings that only providing a hermetic bag significantly reduced aflatoxins, and this difference is likely due to low usage rates of hermetic bags for storing maize, two years post-intervention due to the bags wearing out and new bags not being purchased by participants. Our heterogeneity analysis showed that factors that often influence technology adoption such as household wealth and education levels were not associated with any differences in intervention outcomes.

Our finding that providing a tarp reduced aflatoxins by around 20 percent in smallholders' maize is consistent with, but smaller in magnitude than those of Magnan et al. (2019) and Pretari, Hoffmann and Tian (2019). Magnan et al. (2019) found that tarp provision reduced aflatoxins in Ghanaian smallholder farmers' groundnuts by 25-50 percent, depending on the region. Pretari, Hoffmann, and Tian (2019) conducted a similar study with maize in Kenya and found larger effects than we did, with tarp provision reducing aflatoxins by 53 percent. Regional differences in aflatoxins could explain why our findings were less dramatic, as evidenced by the fact that even within Ghana, Magnan et al. (2019) found large variations.

The results suggest three important ways to lower aflatoxins and improve food safety among smallholder farmers around the world. First, while awareness of aflatoxins is still low in many areas, our results suggest that information spreads readily from training and agricultural extension. More extension work or public information campaigns, particularly in rural zones, could create demand for safer foods.

Second, our evidence concurs with existing research showing that plastic tarps are a key input to improve post-harvest treatment of grains and lower aflatoxins. They are relatively low cost and the supply chain is well established; targeted subsidies could encourage tarp purchases and usage on a larger scale. Our cost-effectiveness calculations indicated that the economic gains of lower aflatoxins may outweigh the costs of tarp provision though; according to the WHO guidelines the intervention was considered moderately cost-effective.

Third, improving the supply chain for various post-harvest technologies is important, given the technologies' limited lifespan. Farmers need to be able to replace technologies that wear out, and purchase inputs in any quantity they need. In particular, solving "last mile" issues – such as the availability of batteries for hygrometers and lack of accessible hermetic bags – may be crucial to the sustainability of technology interventions, and deserves attention despite their apparent trivialness.

Finally, our findings underscore the need for continued follow-up with food safety interventions. We learned that solutions may seem promising in the short-run but can end up disappointing in the longer-run. Had we not had the funding to conduct this follow-up study, we would not have known that the benefits of providing a hermetic bag did not last in the absence of a well-developed input supply chain, or that providing training on aflatoxins and a tarp is a cost-effective intervention. Understanding the sustainability and cost-effectiveness of a given project is crucial for scale-up. In the face of limited resources, policymakers must prioritize, promote, and financially support studies that follow-up with participants in the years after the intervention.

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APPENDIX

Table A.1 Multinomial Logit Model Test of Randomization Balance

	(1)	(2)	(3)	(4)
Dependent variable	Household assigned to treatment group			
	2	3	4	5
Household size	0.004	0.005	-0.021	-0.006
	(0.016)	(0.016)	(0.015)	(0.014)
Age of hh head (years)	-0.004	-0.005	0.003	0.004
	(0.009)	(0.009)	(0.010)	(0.009)
Household head has any formal education (%)	-0.043	-0.145	-0.245	-0.185
	(0.190)	(0.183)	(0.186)	(0.174)
Any woman in hh has access to a mobile phone (%)	0.186	0.240	0.073	0.106
	(0.176)	(0.198)	(0.170)	(0.201)
Distance from village center to nearest paved road (km)	0.030	0.012	0.035	0.017
	(0.023)	(0.025)	(0.022)	(0.021)
Maize farming experience of household head (years)	0.011	0.011	0.010	0.013
	(0.011)	(0.011)	(0.011)	(0.011)
Area of crop cultivation in 2015 (ha)	-0.000	0.006	0.001	0.001
	(0.013)	(0.005)	(0.005)	(0.005)
Area of maize cultivation in 2015 (ha)	-0.005	-0.015	0.009	-0.002
	(0.015)	(0.018)	(0.014)	(0.013)
2015 maize harvest (kg shelled)	0.000	-0.000	0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Duration 2015 maize stored for consumption lasted (weeks)	-0.009	-0.003	0.004	0.005
	(0.008)	(0.008)	(0.008)	(0.008)
2015 maize still in storage May 2016 (%)	0.439**	0.289	0.449**	0.416*
	(0.212)	(0.227)	(0.223)	(0.218)
2015 harvest duration (days)	-0.009	-0.002	-0.002	-0.000
	(0.010)	(0.010)	(0.009)	(0.009)

Table A.1 continued

Respondent knew that aflatoxins are toxic (%)	0.002	0.120	0.207	-0.013
	(0.203)	(0.209)	(0.200)	(0.198)
Dried some 2015 maize directly on the ground (%)	0.228	0.208	-0.435*	-0.054
	(0.198)	(0.219)	(0.223)	(0.207)
Stored some maize in a single layer plastic bag (%)	-0.228	0.070	-0.161	0.110
	(0.272)	(0.278)	(0.275)	(0.254)
Constant	-0.669	-0.325	-0.714	-0.842
	(0.744)	(0.737)	(0.734)	(0.689)
Observations	1,980	1,980	1,980	1,980

Groups 2-5 received training on aflatoxins and how to prevent contamination with post-harvest practices; Groups 3-5 received a low-cost moisture meter called a hygrometer; Groups 4 and 5 received a plastic tarp for drying maize; and Group 5 received a 50 kg hermetic (airtight) storage bag. At baseline, one household did not report how they dried their maize, which is why the number of observations is 1,980. Robust standard errors are clustered at the village level (*** p<0.01, ** p<0.05, * p<0.1)

Table A.2 Sample Size

	Group 1	2	3	4	5	All
Households surveyed at baseline (May 2016)	382	390	397	408	404	1981
Households who harvested maize in 2016 (October/November 2016)	255	292	295	343	310	1495
Households surveyed in the first post-intervention survey (January/February 2017)	382	390	397	408	404	1981
Households surveyed in the second post-intervention survey (May 2017)	382	390	397	408	404	1981
Households with stored maize available for testing (May 2017)	143	176	174	201	202	896
Number of samples taken for testing of aflatoxins (May 2017)	241	303	293	370	373	1580
Households surveyed in the endline post-intervention survey (April 2019)	337	359	356	378	357	1787
Households with stored maize available for testing (April 2019)	183	222	237	236	230	1,108
Number of samples taken for testing of aflatoxins (April 2019)	345	428	449	455	440	2,117

Groups 2-5 received training on aflatoxins and how to prevent contamination with post-harvest practices; Groups 3-5 received a low-cost moisture meter called a hygrometer; Groups 4 and 5 received a plastic tarp for drying maize; and Group 5 received a 50 kg hermetic (airtight) storage bag.

Table A.3 Attrition Balance Test

	(1)	(2)
VARIABLES	=1 if attrited in 2019, 0 otherwise	
Group 2 (training only)	-0.034	-0.033
	(0.028)	(0.028)
Group 3 (training + hygrometer)	-0.014	-0.014
	(0.038)	(0.038)
Group 4 (training + hygrometer + tarp)	-0.042	-0.041
	(0.029)	(0.029)
Group 5 (training + hygro + tarp + hermetic bag)	0.001	0.002
	(0.030)	(0.030)
Constant	0.197***	0.198***
	(0.049)	(0.054)
Observations	1,981	1,980
R-squared	0.032	0.033
Trainer fixed effects included	Yes	Yes
Controls included	No	Yes

Groups 2-5 received training on aflatoxins and how to prevent contamination with post-harvest practices; Groups 3-5 received a low-cost moisture meter called a hygrometer; Groups 4 and 5 received a plastic tarp for drying maize; and Group 5 received a 50 kg hermetic (airtight) storage bag. At baseline, one household did not report how they dried their maize, which is why upon inclusion of controls, the number of observations decreases to 1,980. Robust standard errors are clustered at the village level (*** p<0.01, ** p<0.05, * p<0.1)

Table A.4. Determinants of Having Maize in Storage to be Sampled in 2019

Dependent Variable	Tested (=1 if we took sample in 2019, 0 otherwise)			
	OLS		Probit	
Group 2 (training only)	0.09*	0.08	0.09*	0.08
	-0.05	-0.05	-0.05	-0.05
Group 3 (training + hygrometer)	0.12**	0.11**	0.12**	0.11**
	-0.05	-0.05	-0.05	-0.05
Group 4 (training + hygrometer + tarp)	0.10*	0.08	0.10*	0.08
	-0.05	-0.05	-0.05	-0.05
Group 5 (training + hygro + tarp + hermetic bag)	0.09*	0.07	0.09*	0.07
	-0.05	-0.05	-0.05	-0.05
Constant	0.44***	0.33***		
	-0.05	-0.08		
Observations	1,981	1,980	1,981	1,980
R-squared	0.04	0.06		
Trainer fixed effects included	Yes	Yes	Yes	Yes
Controls included	No	Yes	No	Yes

Groups 2-5 received training on aflatoxins and how to prevent contamination with post-harvest practices; Groups 3-5 received a low-cost moisture meter called a hygrometer; Groups 4 and 5 received a plastic tarp for drying maize; and Group 5 received a 50 kg hermetic (airtight) storage bag. At baseline, one household did not report how they dried their maize, which is why upon inclusion of controls, the number of observations decreases to 1,980. Robust standard errors are clustered at the village level (*** p<0.01, ** p<0.05, * p<0.1)

Table A.5. Heckman Selection Model

VARIABLES	(1) >10ppb (EU std)	(2) Sampled 19	(3) /mills	(4) >10ppb (EU std)	(5) Sampled 19	(6) /mills	(7) >10ppb (EU std)	(8) Sampled 19	(9) /mills
Sampled in May 2017		0.516***			0.493***			0.488***	
		(0.059)			(0.060)			(0.060)	
Group 2 (training only)	-0.011	0.207**		-0.010	0.202**		-0.007	0.201**	
	(0.042)	(0.093)		(0.043)	(0.093)		(0.042)	(0.093)	
Group 3 (training + hygrometer)	0.036	0.285***		0.036	0.280***		0.033	0.280***	
	(0.042)	(0.093)		(0.043)	(0.093)		(0.042)	(0.093)	
Group 4 (training + hygrometer + tarp)	-0.055	0.207**		-0.057	0.190**		-0.059	0.197**	
	(0.042)	(0.092)		(0.042)	(0.092)		(0.042)	(0.093)	
Group 5 (training + hygro + tarp + hermetic bag)	-0.020	0.161*		-0.021	0.150		-0.024	0.152	
	(0.042)	(0.092)		(0.042)	(0.092)		(0.041)	(0.092)	
Had maize in storage at baseline				0.016	0.153**		0.026	0.144**	
				(0.029)	(0.062)		(0.029)	(0.063)	
Dried maize on ground at baseline				-0.020	-0.038		-0.025	-0.037	
				(0.029)	(0.068)		(0.029)	(0.068)	
Household size							-0.000	0.009**	
							(0.002)	(0.004)	
Education level of hhold head							-0.092***	-0.005	
							(0.026)	(0.063)	
Farm size							0.002	-0.002	
							(0.002)	(0.002)	
Inverse Mills Ratio (IMR)			-0.017			-0.010			-0.019
			(0.083)			(0.089)			(0.089)

Table A.5 continued

Constant	0.221***	0.336***		0.210**	0.405***		0.243**	0.494***	
	(0.085)	(0.096)		(0.097)	(0.104)		(0.106)	(0.117)	
Observations	1,981	1,981	1,981	1,980	1,980	1,980	1,980	1,980	1,980
lambda (IMR)	-0.0170	-0.0170	-0.0170	-0.0101	-0.0101	-0.0101	-0.0193	-0.0193	-0.0193
lambda se	0.0832	0.0832	0.0832	0.0885	0.0885	0.0885	0.0892	0.0892	0.0892
lambda_p	0.838	0.838	0.838	0.910	0.910	0.910	0.829	0.829	0.829
Trainer fixed effects included	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Groups 2-5 received training on aflatoxins and how to prevent contamination with post-harvest practices; Groups 3-5 received a low-cost moisture meter called a hygrometer; Groups 4 and 5 received a plastic tarp for drying maize; and Group 5 received a 50 kg hermetic (airtight) storage bag. Aflatoxins levels are censored at 100 ppb. At baseline, one household did not report how they dried their maize, which is why upon inclusion of controls, the number of observations decreases to 1,980. Robust standard errors are clustered at the village level (*** p<0.01, ** p<0.05, * p<0.1)

Table A.6 ANCOVA Regressions

VARIABLES	(1) >10ppb (EU std)	(2)	(3) >20ppb (US std)	(4)	(5) Total aflatoxins (ppb)	(6)
Group 2 (training only)	-0.01	-0.01	-0.01	-0.02	-1.83	-2.88
	(0.04)	(0.06)	(0.03)	(0.05)	(2.88)	(3.74)
Group 3 (training + hygrometer)	-0.01	-0.01	0.00	-0.02	-0.44	-0.36
	(0.04)	(0.05)	(0.03)	(0.05)	(2.91)	(3.86)
Group 4 (training + hygrometer + tarp)	-0.06	-0.03	-0.07**	-0.05	-4.81*	-2.60
	(0.04)	(0.05)	(0.03)	(0.04)	(2.82)	(3.59)
Group 5 (training + hygro + tarp + hermetic bag)	-0.05	-0.03	-0.04	-0.06	-4.67	-3.89
	(0.04)	(0.06)	(0.03)	(0.04)	(2.85)	(3.65)
Had maize in storage at baseline	0.02	0.05	0.00	0.00	1.01	1.35
	(0.02)	(0.03)	(0.02)	(0.03)	(1.78)	(2.60)
Dried maize on ground at baseline	-0.01	0.01	0.00	0.02	-0.36	0.13
	(0.03)	(0.03)	(0.02)	(0.03)	(1.82)	(2.43)
2017 average aflatoxin level		0.00		0.00		0.03
		(0.00)		(0.00)		(0.04)
Constant	0.22***	0.15**	0.19***	0.18***	17.28***	15.02***
	(0.05)	(0.06)	(0.04)	(0.05)	(3.60)	(4.59)
Observations	2,117	1,066	2,117	1,066	2,117	1,066
R-squared	0.03	0.02	0.02	0.01	0.02	0.01
	(0.05)	(0.06)	(0.04)	(0.05)	(3.60)	(4.59)
Trainer fixed effects included	Yes	Yes	Yes	Yes	Yes	Yes
Mean of dependent variable in group 1 (control)						
Marginal impact of hygrometer (G3-G2)	0.00	0.00	0.01	0.00	1.39	2.52
Marginal impact of tarp (G4-G3)	-0.05	-0.02	-0.07**	-0.03	-4.37*	-2.24
Marginal impact of PICS (G5-G4)	0.01	0.00	-0.11	-0.01	0.14	-1.29

Groups 2-5 received training on aflatoxins and how to prevent contamination with post-harvest practices; Groups 3-5 received a low-cost moisture meter called a hygrometer; Groups 4 and 5 received a plastic tarp for drying maize; and Group 5 received a 50 kg hermetic (airtight) storage bag. Aflatoxins levels are censored at 100 ppb. Robust standard errors are clustered at the village level (*** p<0.01, ** p<0.05, * p<0.1)

Table A.7. Average Total Aflatoxins Levels by Treatment Group in 2019

	Group					
	1	2	3	4	5	All
Mean total aflatoxins level (ppb)	17.61	16.18	17.42	12.79	13.25	15.34
Samples > 10 ppb (%)	24.35	24.3	23.83	18.46	20.23	22.11
Samples > 20 ppb (%)	19.42	19.16	19.38	12.53	15.23	17.00
Samples >100 ppb (%)	11.59	9.35	10.47	8.13	7.27	9.26
Number of samples analyzed	345	428	449	455	440	2117

Groups 2-5 received training on aflatoxins and how to prevent contamination with post-harvest practices; Groups 3-5 received a low-cost moisture meter called a hygrometer; Groups 4 and 5 received a plastic tarp for drying maize; and Group 5 received a 50 kg hermetic (airtight) storage bag. Mean aflatoxins levels are censored at 100 ppb.

Table A.8. Intention-to-Treat OLS (Uncensored and Censored Aflatoxins Levels)

VARIABLES	(1) Uncensored total aflatoxins (ppb)	(2)	(3) Censored total aflatoxins (ppb)	(4)
Group 2 (training only)	-57.31	-59.16	-1.79	-1.83
	(60.27)	(60.50)	(2.87)	(2.88)
Group 3 (training + hygrometer)	76.15	73.93	-0.40	-0.44
	(96.60)	(96.72)	(2.90)	(2.91)
Group 4 (training + hygrometer + tarp)	-38.22	-44.70	-4.67*	-4.81*
	(61.10)	(62.41)	(2.77)	(2.82)
Group 5 (training + hygro + tarp +hermetic bag)	-9.11	-13.89	-4.59	-4.67
	(65.21)	(65.28)	(2.84)	(2.85)
Had maize in storage at baseline		60.91		1.01
		(40.05)		(1.78)
Dried maize on ground at baseline		2.07		-0.36
		(42.05)		(1.82)
Constant	163.59**	122.54	17.83***	17.28***
	(72.86)	(76.41)	(3.39)	(3.60)
Observations	2,117	2,117	2,117	2,117
R-squared	0.01	0.01	0.02	0.02
Trainer fixed effects included	Yes	Yes	Yes	Yes
Mean of dependent variable in group 1 (control)	99.97		20.41	
Marginal impact of hygrometer (G3-G2)	133.46	133.09	1.39	1.39
Marginal impact of tarp (G4-G3)	-114.37	-118.63	-4.27	-4.37*
Marginal impact of PICS (G5-G4)	29.11	30.81	0.08	0.14

Groups 2-5 received training on aflatoxins and how to prevent contamination with post-harvest practices; Groups 3-5 received a low-cost moisture meter called a hygrometer; Groups 4 and 5 received a plastic tarp for drying maize; and Group 5 received a 50 kg hermetic (airtight) storage bag. Censored aflatoxins observations are censored at 100 ppb. Robust standard errors are clustered at the village level (*** p<0.01, ** p<0.05, * p<0.1)

Table A.9. Treatment-on-the-Treated 2SLS Models – First Stage Regressions

Dependent Variables	(1) INT =Attended Training	(2) INT =Used Hygrometer in 2019	(3) INT = Used Tarp in 2019	(4) INT = Used PICS Bag in 2019
Group 2 (training only)	0.936***	0.028	-0.013	0.011
	(0.032)	(0.049)	(0.038)	(0.008)
Group 3 (training + hygrometer)	0.922***	0.211***	0.051	0.005
	(0.036)	(0.060)	(0.039)	(0.005)
Group 4 (training + hygrometer + tarp)	0.913***	0.287***	0.147***	0.034***
	(0.035)	(0.056)	(0.042)	(0.010)
Group 5 (training + hygro + tarp + hermetic bag)	0.913***	0.266***	0.216***	0.084***
	(0.036)	(0.057)	(0.043)	(0.020)
Had maize in storage at baseline	0.012	-0.030	0.015	0.008
	(0.010)	(0.030)	(0.026)	(0.009)
Dried maize on ground at baseline	0.005	0.007	0.063**	0.000
	(0.014)	(0.034)	(0.031)	(0.009)
Constant	0.061***	0.161***	0.162***	0.001
	(0.026)	(0.059)	(0.055)	(0.012)
Trainer fixed effects included	Yes	Yes	Yes	Yes
Observations	2,117	2,117	2,117	2,117
R-squared	0.845	0.067	0.070	0.037

Groups 2-5 received training on aflatoxins and how to prevent contamination with post-harvest practices; Groups 3-5 received a low-cost moisture meter called a hygrometer; Groups 4 and 5 received a plastic tarp for drying maize; and Group 5 received a 50 kg hermetic (airtight) storage bag. Robust standard errors are clustered at the village level (*** p<0.01, ** p<0.05, * p<0.1).

Table A.10. Descriptive Statistics Discussion and Lending

	Mean in Group 1	2	3	4	5	Overall Mean	Overall Std Dev	Obs.
Discussion								
Discussed aflatoxins w/ at least one person	0.32	0.43	0.43	0.41	0.38	0.39	0.49	1787
Avg number of people w/ which respondent discussed aflatoxin	3.54	3.61	4.44	3.93	4.32	3.99	3.29	701
Discussed drying challenges w/ at least one person	0.32	0.37	0.36	0.36	0.34	0.35	0.48	1787
Avg number of people w/ which respondent discussed drying challenges	5.27	4.26	5.20	4.01	5.20	4.76	4.81	625
Discussed storage challenges w/ at least one person	0.31	0.33	0.34	0.36	0.32	0.33	0.47	1787
Avg number of people w/ which respondent discussed storage challenges	4.34	4.23	5.04	3.68	4.18	4.28	4.14	590
Discussed hygrometer w/ at least one person			0.35	0.39	0.38	0.38	0.48	1091
Avg number of people w/ which respondent discussed hygrometer			5.32	4.60	6.44	5.43	5.40	409
Discussed tarp w/ at least one person				0.35	0.36	0.36	0.48	735
Avg number of people w/ which respondent discussed tarp				4.41	6.11	5.25	4.89	264
Discussed pics bag w/ at least one person					0.39		0.49	357
Avg number of people w/ which respondent discussed PICS bag					6.34		5.33	139
Lending								
Lent out hygrometer to at least one person			0.05	0.09	0.06	0.07	0.25	1091
Avg number of people hygrometer lent to			3.43	3.62	5.94	4.24	4.07	73
Lent out tarp to at least one person				0.05	0.03	0.04	0.20	735
Avg number of people tarp lent to				2.47	2.08	2.33	1.19	32

Groups 2-5 received training on aflatoxins and how to prevent contamination with post-harvest practices; Groups 3-5 received a low-cost moisture meter called a hygrometer; Groups 4 and 5 received a plastic tarp for drying maize; and Group 5 received a 50 kg hermetic (airtight) storage bag. Robust standard errors are clustered at the village level (*** p<0.01, ** p<0.05, * p<0.1).

Table A.11. Heterogeneity Analysis

	(1)	(2)	(3)	(4)	(5)	(6)
	Household size		Education		Age	
VARIABLES	>10ppb (EU std)	>20ppb (US std)	>10ppb (EU std)	>20ppb (US std)	>10ppb (EU std)	>20ppb (US std)
Group 2 * interaction in heading	-0.001072	-0.002327	0.018015	0.015152	0.000890	0.002416
p-value	(0.649)	(0.624)	(0.789)	(0.824)	(0.774)	(0.365)
sharpened q-value	[1.000]	[1.000]	[1.000]	[1.000]	[1.000]	[1.000]
Group 3 * interaction in heading	0.002356	0.001723	0.053630	0.050900	-0.000024	0.001619
p-value	(0.852)	(0.693)	(0.456)	(0.485)	(0.994)	(0.542)
sharpened q-value	[1.000]	[1.000]	[1.000]	[1.000]	[1.000]	[1.000]
Group 4 * interaction in heading	0.000891	0.000668	0.108152	0.036712	-0.000597	0.000065
p-value	(0.652)	(0.871)	(0.118)	(0.593)	(0.841)	(0.980)
sharpened q-value	[1.000]	[1.000]	[0.512]	[1.000]	[1.000]	[1.000]
Group 5 * interaction in heading	0.004284	0.002690	0.006258	-0.011948	-0.002690	-0.001092
p-value	(0.856)	(0.568)	(0.932)	(0.866)	(0.368)	(0.715)
sharpened q-value	[1.000]	[1.000]	[1.000]	[1.000]	[1.000]	[1.000]
Observations	2,117	2,117	2,117	2,117	2,117	2,117
R-squared	0.035	0.026	0.042	0.028	0.036	0.029
Trainer fixed effects included	Yes	Yes	Yes	Yes	Yes	Yes
Controls variables included	Yes	Yes	Yes	Yes	Yes	Yes

Groups 2-5 received training on aflatoxins and how to prevent contamination with post-harvest practices; Groups 3-5 received a low-cost moisture meter called a hygrometer; Groups 4 and 5 received a plastic tarp for drying maize; and Group 5 received a 50 kg hermetic (airtight) storage bag. Aflatoxins levels are censored at 100 ppb. Robust standard errors are clustered at the village level (*** p<0.01, ** p<0.05, * p<0.1).

Table A.11. continued

VARIABLES	(7)	(8)	(9)	(10)
	Wealth		Woman phone	
	>10ppb (EU std)	>20ppb (US std)	>10ppb (EU std)	>20ppb (US std)
Group 2 * interaction in heading	-0.000017	-0.000002	0.113472	0.064939
p-value	(0.903)	(0.986)	(0.120)	(0.346)
sharpened q-value	[1.000]	[1.000]	[0.903]	[1.000]
Group 3 * interaction in heading	0.000049	0.000027	-0.000858	-0.027332
p-value	(0.718)	(0.842)	(0.991)	(0.687)
sharpened q-value	[1.000]	[1.000]	[1.000]	[1.000]
Group 4 * interaction in heading	-0.000029	0.000010	0.041525	0.036268
p-value	(0.793)	(0.926)	(0.533)	(0.581)
sharpened q-value	[1.000]	[1.000]	[1.000]	[1.000]
Group 5 * interaction in heading	-0.000076	-0.000060	-0.084154	-0.065523
p-value	(0.432)	(0.561)	(0.305)	(0.414)
sharpened q-value	[1.000]	[1.000]	[1.000]	[1.000]
Observations	2,115	2,115	2,117	2,117
R-squared	0.035	0.028	0.043	0.029
Trainer fixed effects included	Yes	Yes	Yes	Yes
Controls variables included	Yes	Yes	Yes	Yes

Groups 2-5 received training on aflatoxins and how to prevent contamination with post-harvest practices; Groups 3-5 received a low-cost moisture meter called a hygrometer; Groups 4 and 5 received a plastic tarp for drying maize; and Group 5 received a 50 kg hermetic (airtight) storage bag. Aflatoxins levels are censored at 100 ppb. Robust standard errors are clustered at the village level (*** p<0.01, ** p<0.05, * p<0.1).