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The Effects of Storage Technology and Training on Post-Harvest Losses

Evidence from Small-Scale Farms in Tanzania

Martin Julius Chegere, Håkan Eggert, and Måns Söderbom

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The Effects of Storage Technology and Training on Post-Harvest Losses:

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Martin Julius Chegere, Håkan Eggert, and Måns Söderbom*

Abstract

We analyze the impact of a new storage technology and training on post-harvest losses among small-scale maize farmers in rural Tanzania. The analysis is based on data collected by means of a randomized controlled trial (RCT) in which farmers were randomized into one of three groups: a control group and two treatment groups. Farmers in the first treatment group received training on post-harvest management practices, and farmers in the second treatment group were provided with hermetic (airtight) bags for storing maize, as well as the training administered to the first treatment group. We show that both interventions had a significant effect in reducing storage losses. The intervention with hermetic bags improved the quality of maize grain, increased the market price of maize, and reduced the cost of storage protection using insecticides. We show that both interventions are economically feasible, and relate our findings to the larger literature on the roles of physical and human capital in economic development.

Key Words: randomized controlled trial, post-harvest losses, training, hermetic bags, small-scale farmers, cost-benefit analysis

JEL Codes: C93, Q18, Q16, D61

1. Introduction

Food insecurity, poor nutrition, hunger, and low incomes are chronic problems facing millions of poor smallholder farming households in Sub-Saharan Africa (SSA). Productivity growth in African agriculture has been stagnant over several decades. Several explanations for the poor performance of the sector have been proposed. These include credit constraints, limited access to individual savings accounts, lack of information about input quality, uncertainty, and behavioral mechanisms (Bold et al., 2017; Brune et al., 2016; Duflo et al., 2011; Liu, 2013; Suri, 2011). This literature has primarily focused on farmers' decisions prior to harvest, e.g. type of crop, type of seed, and decisions on irrigation and fertilizer. However, it is increasingly recognized that reducing post-harvest losses (PHL) may offer a more cost-effective and environmentally sustainable way to promote food and nutrition safety than focusing solely on increased productivity (FAO and the World Bank, 2010). The costs of post-harvest losses in African agriculture are considerable. Post-harvest physical grain losses in SSA range from 10 to 20 percent of the total grain production, at a value of USD 4 billion per year (World Bank, 2011). Moreover, some of the traditional post-harvest practices used by East African maize farmers have become less effective due to climate change and novel pests like the Larger Grain Borer[1] (Gitonga et al., 2013; Ndegwa et al., 2016). New PHL reduction technologies have been developed and promoted, but the adoption rate is low, especially among smallholder farmers (World Bank, 2011). FAO and the World Bank (2010) estimate that about half of the USD 940 billion needed for investment to eradicate hunger in SSA by 2050 should be geared toward the post-harvest sector, including investments in cold and dry storage, rural roads, and rural and wholesale market facilities.

In this paper, we contribute to a small but growing literature that emphasizes the importance of post-harvest practices and management for the economic performance of agriculture (Sheahan and Barrett, 2017). Using a randomized controlled trial (RCT), we investigate whether a short training program, combined with a relatively simple and cheap storage method, can boost profitability in Tanzanian maize farming. We consider a reasonably broad range of outcome variables, including post-harvest losses, market price, maize quality and insecticides used to protect stored maize. Our data cover almost the entire period from when maize is harvested to just a month before the next harvesting season, enabling us to do a cost-benefit analysis based on the full benefits and costs incurred by the farmer in the post-harvest system. We estimate the internal rate of return (IRR) to the training program on storage practices at approximately 14%, and, combining training

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[1] The Larger Grain Borer (*Prostephanus Trancatus*) spread from Central America to Africa in the late 1970s and has become one of the most destructive pests affecting stored maize (Boxall, 2002).

with distribution of hermetic storage bags, the IRR rises to 35%. These estimates suggest that small-scale investments in storage methods can be quite profitable.

The design of our field experiment is as follows. We began by randomly drawing 21 villages in the Kilosa district, in the Morogoro region of Tanzania. We randomly assigned the villages to two treatment groups – Bags and Training (six villages) and Training only (six villages) – and the control group (nine villages). In the first treatment group (Bags and Training), 120 farmers in the six villages were trained on maize post-harvest handling and storage techniques. They were then provided with hermetic bags and trained on how to use them. Agronomists, specialized in maize production and post-harvest management, and with field experience in working with farmers, designed and conducted the training. In the second treatment group (Training only), 120 farmers received the same training on maize harvesting and post-harvest handling, including the benefits of effective storage in reducing PHL and various technologies available to achieve them, but were not given hermetic bags. In both treatment groups, subjects were given the training manuals and a leaflet with verbal and pictorial explanations and illustrations about post-harvest technologies. The control group consisted of 180 farmers from nine control villages, who continued with business as usual. By comparing outcomes across the treatment and control groups, we can credibly estimate the causal effects of our interventions, i.e. the training and the storage bags. As the training provided to the farmers is reasonably generic, the results of the training-only treatment may be more generalizable to other contexts than the results of the bags-and-training treatment.

The paper is organized as follows: Section 2 presents an overview of efforts to reduce post-harvest losses; Section 3 presents the experimental design; Section 4 describes the data; Section 5 describes the estimation strategy; Section 6 presents the results; Section 7 provides the cost-benefit analysis for the economic effectiveness of the interventions; and Section 8 is the conclusion.

2. Storage and Post-Harvest Losses

Maize is the staple food crop in most SSA countries. In Tanzania, it comprises more than 70 percent of total cereals production in the country (National Bureau of Statistics, 2012) and contributes about 35 percent of the daily calorific intake. Production is highly seasonal, while consumption is relatively constant during the year in Eastern and Southern Africa (Gitonga et al., 2013). Maize storage is therefore important for food security because it smooths the supply throughout the year, but the difference in price is still in the range of 30% between trough and peak (Gilbert et al., 2017).

Currently in Tanzania, the use of polypropylene bags (sacks) is popular among small-scale farmers. These sacks are cheap; portable in case of emergencies (e.g., floods, fires); make it easy to monitor quality; can be kept within the house after loading, serving as a protection against spillage and theft; take up less space in the room (as opposed to a large woven granary that fills a whole room, whether empty or full); and are always ready for marketing in case of need for emergency or opportunistic sales (World Bank 2011; Ndegwa et al., 2016). However, these sacks do not provide protection against moisture and storage pests. To limit storage pest infestation, farmers apply several methods, such as the use of pesticides, insecticidal plants and ashes (Farrell and Schulten, 2002). The efficacy of these methods, their accessibility and their economic effectiveness are highly variable. Meikle et al. (2002) found that use of maize storage chemicals was not economically viable. Moreover, use of pesticides can have negative impacts on the environment and can be hazardous for human health (Kumari et al., 2012; FAO and WHO, 2016).

To avoid high losses due to lack of suitable grain storage structures and absence of storage management technologies, smallholders tend to sell their maize immediately after harvest. Consequently, they receive low market prices for their maize because they sell when the market is flooded. In addition, they may be forced to buy grain for consumption at a higher price just a few months after harvest, when their stock is exhausted (Gilbert et al., 2017).

Improved storage technologies, mainly hermetic storage methods, have been developed in response to those storage challenges. These include metal silos and hermetic bags. Metal silos are airtight and have proven to be effective in protecting the maize grains from both storage insects and rodent pests (FAO, 2008). Though metal silos could potentially reduce post-harvest losses and allow storage for a longer period, they are expensive and unaffordable to most small-scale farmers. Moreover, the metallic structure means that they permanently occupy space, whether they are used or not, and that they cannot be easily stored in the bedroom to prevent theft during food shortage periods. The effectiveness of metal silos may also decrease when grain is removed because oxygen levels are likely to increase (Tefera et al., 2011; Ndegwa et al., 2016).

Hermetic storage bags offer a recently developed technology. These bags have two or more layers. The outer layer is the normal sack (polypropylene bag) and the inner layers are special plastic (high-density polyethylene) linings, which are air-proof. They are cheap, at a cost of about USD 2 for a 100-kg bag. These bags are accessible and affordable to farmers. In addition, they are easier to use. Hermetic bags kill storage pests by depriving them of oxygen. Once some grains are off-loaded from the bag, the bags can easily be tightened again to keep them airtight and reduce the oxygen level to prevent insect pests from surviving.

3. Experimental Design

3.1 Study Area

The study was conducted in the Kilosa district in the Morogoro region in eastern Tanzania. According to the 2012 population census, the district had a population of 438,175. The district offers a variety of agro-ecological conditions for cultivation of different crops, such as maize, rice, millet, cassava, beans, bananas and cowpeas (Kajembe et al., 2013). Crop farming is the main economic activity for 55% of the households in the district (TNBS, 2012). Maize is the main food crop in Kilosa and, in a normal year, the district is a surplus producer of maize.

The Kilosa district receives an average annual rainfall of 800-1400 mm (Kajembe et al., 2013) distributed during two rain seasons, the short rains between November and January and the long rains between March and early June. Despite having two rain seasons, the pattern and amount of rainfall in the district allow for only one harvest of the main staples per cropping season. The climatic conditions of the Kilosa district are typical for maize production in SSA.

Despite efforts to increase production, the goals of improving food security, reducing rural poverty and ensuring environmental sustainability have been constrained by post-harvest losses. Results from the baseline survey show that post-harvest losses in maize are significantly correlated with household food insecurity and lead to income losses equivalent to a month of household income per year (Chegere, 2018).

3.2 Sample Selection

The sampling framework comprised households in villages which met two criteria: (1) maize is the main crop produced by the villagers, and (2) maize is the main staple food in the village. The selection of these villages was done after consulting the district administrative secretary and the district agricultural officer and then confirmed by respective village leaders and village agricultural officers. This selection was important to ensure that our interventions were targeted to the most relevant group of farmers. We used a two-stage sampling process to recruit participants in our survey. In the first stage, we randomly selected 21 villages from the list of villages that met the above criteria. In the second stage, we randomly selected 20 maize-farming households from each village from the household roster obtained from the village office. In total, the sample consisted of 420 households in 21 villages.

During April and May 2015, prior to the main baseline survey, we carried out consultations with village agriculture extension officers and focus group discussions and interviews with farmers and village leaders in two villages in the Kilosa district that were not included in the main survey. The responses show that farmers normally plant one crop of maize per year and most of them use propylene sacks for maize storage; none of them were aware of the hermetic bags technology. We also conducted a pilot survey to test our questionnaire with 20 households in one village that was not included in the main survey.

We conducted the main survey between the last week in June and mid-July in 2015[2]. In each household, we interviewed either the head of household or the spouse. The baseline questionnaire collected information on demographic and other socioeconomic characteristics, household food security, maize production practices, and post-harvest losses and post-harvest management practices in the previous agricultural season. Since the survey was carried out at the end of the maize farming season, the loss figures reported covered almost the entire post-harvest period for grain.

By the end of July 2015, we implemented the intervention. The aim of the intervention was to test the effect of post-harvest management training and introduction of hermetic bags storage technology in terms of impact on PHL. We worked in collaboration with an agronomist in providing the training on post-harvest management practices and with two companies manufacturing hermetic bags to distribute the bags and explain their usage. During the baseline period, only 22 percent of the farmers reported ever having attended training on post-harvest losses, and none of them had ever used hermetic bags.

In order to minimise spill-over effects from treatment groups to the control group, we assigned treatments at the village level. We randomly assigned the villages to the two treatment groups – Bags and Training (6 villages) and Training only (6 villages) – and the control group (9 villages). Figure A1 in the appendix shows the map of the study area and the distribution of villages according to experimental groups.

In the first treatment group, 120 farmers in six villages were given training on maize post-harvest handling and storage techniques. Then they were provided hermetic bags and trained on how to use them. We will refer to this group as the 'training and hermetic bags' treatment. The training was designed and conducted by agronomists who are specialised in maize production and post-harvest management and have field experience in working with farmers. The content and material for the course were gathered from various sources, including maize harvesting and post-harvest management guidelines from the ministries and departments of agriculture in East Africa,

[2] The timeline of the events is shown in Figure A1 in the Appendix.

consultation with NGOs working with maize farmers and dealing with post-harvest losses, researchers[3] and academic articles, and field experience.

The topics covered included: time to harvest; requirements during the harvesting process; harvesting; drying; shelling; storage and storage structures; and losses due to poor storage. The training sessions lasted almost two hours. In each village, farmers were trained in either one or two groups depending on convenience. One trainer conducted the training on maize post-harvest management in all villages and another trainer did so for the use of hermetic bags. Farmers were given the training guide to read and follow and had the chance to ask questions and seek clarification as much as they wished during the training session and at the end.

The farmers in the 'training and hermetic bags' treatment got additional training on how to use the hermetic bags directly after the post-harvest handling training. They were also given a two-page leaflet about the hermetic bags. Farmers were also informed about the adverse effects that can happen if the bags are not used properly. For example, storing maize with high moisture content in the hermetic bags can cause fungal growth and rot all the grain in the bag; also, if a bag is perforated by rodents, then it loses its air-proof quality.

At the end of the session, each farmer received the hermetic bags. In the baseline survey, we had asked farmers how many acres of land they had planted in maize during the prevailing season and how much maize they expected to harvest. We gave them the number of bags that would store about 60% of their expected harvest. This was done for three reasons. First, farmers tend to be optimistic about the amount they can harvest and thus the expected harvest would in most cases be larger than the true amount harvested. Second, it is recommended that, once the grains are stored in hermetic plastic bags, the bag should remain sealed for at least six weeks to stop oxygen from entering the bag, which could revive the pests that were dying of suffocation. Thus, some of the maize, which would be used for food or sales within six weeks after storage, would not be stored in the hermetic bags. Third, this was intended to minimise the chances that some farmers would end up with excess bags and decide to sell them, which could contaminate our experiment.

Farmers were asked to use the hermetic bags solely for maize storage and were asked not to give or lend them to other farmers. To facilitate this, we asked them to inform their neighbors and relatives that they had an agreement with the researchers from the University of Dar es Salaam to use all the bags themselves, and that the researchers would be checking periodically to assess their use. In November and December 2015, random visits to about 50 percent of the farmers who received the bags were made at their homes to observe whether the bags were used and whether

[3] Alliance for a Green Revolution in Africa (AGRA) and the NAFAKA project are the NGOs that were consulted. They work closely with maize farmers. Consultation was also done with researchers at Sokoine University of Agriculture.

the farmers had any challenges in using them. Of the farmers visited, none had experienced any challenges in using the bags and they all used all of the bags that had been given to them.

In the second treatment group, which we will refer to as the 'training only' treatment, 120 farmers received the same training on maize harvesting and post-harvest handling, including the benefits of effective storage in reducing PHL and various technologies available to achieve it, but were not given hermetic bags. In both treatment groups, subjects were given the training manuals and a leaflet with verbal and pictorial explanations and illustrations about post-harvest technologies. The control group consisted of 180 farmers from 9 villages, who continued with business as usual. The farmers in the control group were unlikely to be contaminated by the intervention. At the time of the intervention, the technology had not spread to the region and none of the farmers were aware of the technology during the pilot interviews. During the baseline survey, only two had heard of it after visiting relatives in another region where the technology was first introduced.

4. Data and Descriptive Statistics

The data used in this study was collected in two separate household surveys. The baseline survey was conducted June-July 2015 and the follow-up survey was carried out in June 2016. In the baseline, the questionnaire was administered to the heads of households, their spouses or another adult in the household involved in maize farming decisions. The follow-up survey interviewed the same person. The baseline consisted of 420 households. During the follow-up and in several attempts thereafter, 22 households could not be induced to respond to the survey. One household was dropped from the analysis because it was an outlier, operating on a large scale and not representative of smallholders. Overall, the data consists of 397 observations, although there are sometimes missing items on single questions.

In the baseline and follow-up surveys, we collected information on PHL experienced after the previous harvest at three stages: between harvesting and storage, during storage, and during marketing. The information was self-reported and involved a recall period of about ten months. The farmers reported the loss at each stage in terms of kilograms, number of buckets, or number of bags, depending on what they found easiest to estimate. All the quantities were converted into kilograms.[4] We asked the following questions to elicit the losses:

(i) How much was the loss from the time you harvested to storage time (taking into account all losses during transporting, drying, shelling and winnowing)?

[4] In each village, we explored the weights of maize when put in different vessels used by farmers in carrying maize. We also probed whether farmers knew how much maize weighs when put in those vessels. In most cases, their responses were the same as our measurements.

(ii) *How much was the maize loss between the time you stored and the moment you used it for consumption or took it for sale?*

(iii) *How much was the loss at the marketing stage (taking into account all the stages from taking the grain from storage to weighing and transporting it)?*

To minimise recall bias in estimates of the losses experienced by farmers, the losses were assessed step-wise with indirect cross-checking questions for greater robustness. Enumerators were also well trained and tested off the field and on the field during the pilot, to ensure effective collection of data. After the baseline data collection, we instructed farmers to keep an account of the amount of maize they harvested, consumed and sold, at least at the end of each month, to be used in the follow-up. We also collected information on maize farming practices, post-harvest activities (including storage and marketing), and food security, during both baseline and follow-up surveys. The information on the socio-demographic characteristics of the households and social networks was collected in the baseline only.

Table 1 presents selected summary statistics measured at the baseline for the 397 households, together with tests for balance across treatment groups. The majority of the heads of households are male (86%), 47 years old on average with 7.1 years of schooling, which is similar to completion of primary school in Tanzania. The households have 5.4 members, of which 3 are active workers[5]. Mean annual income is USD 1,053, which translates to approximately USD 0.60 per person per day. Their stock of assets is valued on average at USD 4,289.

The subjects have on average 19 years of experience with maize farming and most of their agricultural land is devoted to maize production, with 1.7 hectares (ha) of 2.6 ha on average. They harvested about 2.8 tons of maize in the 2014 season, or about 1.6t/ha, which is above the national average of 1.3 t/ha and above the district average of 0.98 t/ha in 2007, reported in the Tanzania Agricultural sample survey, 2007/08. Most of the households (89%) sold some of their maize from the 2014 harvest season. Overall about half of the production was sold and 60% of that was sold within three months after harvesting. We compare 33 variables between the two treatment groups and the control group. Of the 99 comparisons, none is significantly different at the 1% level (although 5 of 99 differ at the 10 or 5% levels), which confirms that the randomization was successful.

The post-harvest losses figures were self-reported by the subjects. They were divided into three stages: the losses occurring between harvesting and storage (referred to as pre-storage losses in this study); storage losses, which occurred during storage until the time of consumption or sales;

[5] We define active workers as household members aged 15 to 64 years without health or physical impediments to working.

and marketing losses, which occurred in the process of selling maize. On average, farmers experienced a total of 11.7% post-harvest losses relative to the quantity harvested. Of the three stages, farmers experienced the most losses during storage, averaging 7.9% of the amount harvested. The main stated causes of storage losses were rodent attacks, insect infestations, moisture and rotting. Pre-storage losses were on average 2.9%, occurring mainly during shelling, drying and transporting to the homestead. Marketing losses were low, about 1%, as most farmers sell their maize to agents who collect them from their homes. Attrition was not a big problem in this experiment, as only 22 of 420 households were not found in the follow-up survey.[6]

5. Estimation Strategy

Because the treatments were randomly assigned at village level, the impact of the interventions can be identified by simple mean comparison across the groups. Using a simple regression framework, for each outcome, the estimation equation is:

$$Y_{iv} = \alpha + \gamma B_v + \delta T_v + X'_{iv}\beta + \varepsilon_{iv} \qquad (1)$$

where Y_{iv} is the outcome variable of interest for household i in village v. B_v is an indicator variable equal to 1 if the village received training on post-harvest management and hermetic bags for maize storage. T_v is an indicator variable equal to 1 if the village received training on post-harvest management only. For each outcome, regressions were run both with and without the household level socioeconomic controls, X'_{iv}. The inclusion of controls improves efficiency if they predict variance in the dependent variable (Mutz and Pemantle, 2011). ε_{iv} are the error terms. The coefficient γ measures the combined effect of post-harvest management training and hermetic maize storage bags on the outcome of interest. The effect of post-harvest management training only is measured by δ.

The dependent variables of interest are PHL at pre-storage and storage stages; maize grain qualities; use of storage protectants; maize price; and household food insecurity index.

We also considered the issue of statistical inference in our case, where we have few (21) clusters. With a small number of clusters, the usual techniques for calculating cluster-robust standard errors based on asymptotic theory provide downward-biased standard errors. So, with few clusters, the standard asymptotic tests tend to over-reject the null of no effect (Bertrand et al., 2004; Cameron et al., 2008). We use the wild cluster bootstrap approach proposed by Cameron1 et al.

[6] Generally, attritors have fewer years of experience with maize, and are relatively poor, but have experienced lower post-harvest losses in the previous season.

(2008) for making inferences.[7] In the estimation results tables, we report the p-values of tests of the null that the coefficient is 0, computed using the wild-bootstrap cluster-t procedure. Clustering is done at village level.

6. Results

This section describes the impact of training and hermetic bags interventions on post-harvest losses and assesses the economic effectiveness of hermetic bags in maize storage.

6.1 Impact on Post-Harvest Losses

We first examine the impact of the interventions on quantitative post-harvest losses at two stages: between harvesting and storage (pre-storage) and during storage (storage losses), as presented in Table 2. Columns [1] and [3] in Table 2 represent the results of estimation models without socioeconomic controls, whereas Columns [2] and [4] include socioeconomic controls.

With respect to pre-storage losses, the training and hermetic bags treatment had a negative but insignificant effect, as shown in Column [1] of Table 2. The intervention reduced pre-storage losses by 0.46 percentage points, which is equivalent to a 16% decrease in pre-storage losses. As for storage losses, Column [3] of Table 2 suggests that the training and hermetic bags intervention reduced such losses by 6.7 percentage points, which is a 73% reduction in storage loss. This effect is statistically significant at 1%. Not surprisingly, the results are substantially the same after the inclusion of socioeconomic controls, because of the random assignment of villages to experimental groups (Table 2, Columns [2] and [4]).

The results in Columns [1] and [3] indicate that training on post-harvest management helped farmers reduce pre-storage and storage losses. Farmers who received training experienced lower pre-storage losses, by 0.63 percentage points (a 22% reduction in losses), compared to those in the control group. However, this effect is not statistically significant. Post-harvest management training led to a 2.8 percentage point reduction (30% reduction) in storage losses. The effect is statistically significant at the 1% level. The impacts of both interventions remain the same after including the socioeconomic controls in Columns [2] and [4].

6.2 Impact on Maize Grain Quality, Sales and Price

Physical quality of the grain is important for maize marketing as well as for consumption. It is used to signify the nutrient content of the maize grain. Farmers were asked if the size, shape,

[7] We used the Stata code cgmwildboot.ado, available on Judson Caskey's website https://sites.google.com/site/judsoncaskey/data, which reports the OLS estimation coefficient as well as the p-values of tests of the null that the coefficient is 0, computed using the wild-bootstrap cluster-t procedure.

aroma, taste and color of the maize grain were maintained after being stored. They responded whether they greatly agree = 4, agree = 3, disagree = 2, or greatly disagree = 1 with the statement.

They were also asked to compare the degree of maize infestation and rotting before and after storage, to which they responded that it remained the same = 1, increased = 2 or increased greatly = 3. We also asked them the amount of maize they sold three months after harvesting. Using that information, we calculated the proportion sold three months after harvest relative to the total amount of maize harvested. We asked farmers who sold maize the highest and the lowest price they obtained in their transactions, then calculated the mean value to obtain the average price of maize. We estimate the impacts of the interventions on those qualitative outcomes and on sales price for those who sold maize.

Columns [1] - [4] of Table 3 show that both 'training and hermetic bags' and 'training only' treatments have positive impacts on the physical characteristics of the stored maize grain. However, only the effects of 'training and hermetic bags' on size and shape of maize and maize aroma are significant, at 5% and 10%, respectively. The use of hermetic bags seems to add more to the qualitative characteristics of the maize grain when bundled with training. These results imply that better management combined with hermetic technologies can potentially increase the market value of maize. We also find that there were statistically significantly lower degrees of pest infestation and rotting of maize after storage in the 'training and hermetic bags' treatment compared to the control group (Columns [5] and [6] of Table 3). The degrees of pest infestation and rotting of maize were also lower in the 'training only' treatment, but the effects are not statistically significant.

Column [7] of Table 3 shows that the farmers in the treated groups sold 4.9 and 2.3 percentage points less in the first three months in the 'training and hermetic bags' group and 'training only' group, relative to the control. However, the effects are not statistically significant. Because hermetic bags reduce the risk of storage losses, they may allow farmers to store grain for a longer period and make opportunistic sales. Column [8] indicates that households in 'training and hermetic bags' and 'training only' treatments sold their maize at USD 12.96 (equivalent to 5.8%) and USD 6.61 (equivalent to 3%) more per ton respectively compared to those in the control group. The effect is statistically significant at 5% for the 'training and hermetic bags' intervention but insignificant for the 'training only' intervention. Based on a separate regression where the dependent variable is the average price of maize, we find a negative and highly statistically significant effect of a variable measuring the percentage of maize sold within three months of harvest (the results are shown in the appendix, Table A1). Maize quality, in contrast, is wholly statistically insignificant in this regression.[8] These results thus suggest that opportunistic sales play a more significant role than maize quality for price.

6.3 Impact on Maize Protectants Use and Cost of Protection

One of the advantages of using hermetic bags is that it kills pests by depriving them of oxygen. This means that a farmer will have a reduced need to use insecticides and thus will save money, as well as avoiding the negative health effects of pesticide residues. Column [1] of Table 4 shows that the proportion of farmers who protected[9] their stored crops was significantly lower for those who received the hermetic bags compared to other groups. Specifically, a significantly lower proportion of farmers in the 'training and hermetic bags' treatment group used chemical protectants compared to other groups (Column [2]). However, a significantly higher proportion of those in the 'training and hermetic bags' treatment used rat traps and poisons compared to those in other groups (Column [3]). This is intuitive because an attack by rodents on the hermetic bags will perforate them and render them useless as airtight storage.

An estimation of the total cost of protecting stored maize in Column [4] shows that farmers in the 'training and hermetic bags' treatment group spent USD 2.59 less to protect a ton of stored maize, compared to those in the control group. There are no significant differences between the 'training only' treatment and the control group in any of those aspects.

6.4 Mechanism

We have shown the effects of the 'training and hermetic bags' and 'training only' interventions on PHL reduction and on the physical qualities of maize grain. We now examine whether the interventions led to adoption of the 'good' post-harvest management practices that were presented in the training. Table 5 presents the estimated effects of the interventions on five post-harvest management practices: harvest at maturity; spreading maize after harvesting; sorting maize after harvesting; number of days maize was dried; and whether maize storage was cleaned and disinfected. The results show that, although more farmers in the treatment groups adopted 'good' post-harvest management practices compared to those in the control group, the differences are not statistically significant. There might be some constraints to adoption, such as the cost of

[8] The index was constructed using the principal component analysis.

[9] This includes those who applied at least one technique of protection, such as chemical protectants, ashes, plants, herbs, rat traps or rat poison.

adoption of each practice relative to the conventional practices[10] and the possible side effects of the practices.[11]

7. Economic Effectiveness of the Interventions

We found that the interventions reduced PHL, increased market price of maize, and saved money from not using storage insecticides. To conduct the analysis of the economic effectiveness of training on post-harvest management practices and the use of hermetic bags, we use the estimated marginal effects, that is, the mean difference between losses experienced by the farmers in the treatment group and those in the control group. We obtain the total amount of maize loss abated in a treated group by multiplying the marginal effects at each stage of the post-harvest system (harvest, storage and marketing) by the total amount available at the beginning of the stage.[12] We then calculate the monetary value of the amount of loss abated by multiplying the amount abated by the market price.

A farmer in a treatment group can also gain by using less insecticide or by selling maize at a higher price. We use the marginal effects obtained from regression results, that is, the mean difference between the cost incurred or price obtained by the farmers in the treatment group and the control group. Then we multiply these marginal gains by the total amount available at the beginning of the stage to get the total gain by the hypothetical average farmer in a treated group.

In the next step, we multiply the value of the loss abated (or incurred) at each stage (harvest, storage and selling) by the proportion of farmers who acted at that stage, to get the total gain by the hypothetical average farmer in a treated group in the entire post-harvest system. Then we multiply the total gain of the hypothetical average farmer by the total number of farmers to get the total gains.

We start with the economic analysis of training on post-harvest management practices. Table 6 shows the calculation of the total value gained by a hypothetical average farmer in the 'training only' group, compared to the average farmer in the control group. This farmer will abate 13.6 kg of loss of maize at the pre-storage stage and 33.6 kg at the storage stage, compared to the results if she were in the control group. These losses abated are valued at USD 2.72 and USD 6.72 (at the price of USD 0.2 per kg of maize). This farmer will also gain USD 9.00 from selling all the maize she brought to the market, compared to her sales if she were in the control group. So, in total,

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[10] For example, in the study area the conventional way is to let maize dry while on the stalks in the field after maturity.
[11] For example, pesticide residues might cause health problems.
[12] For pre-storage loss abated, we multiply by the amount harvested; for the storage loss abated, we multiply by the amount stored; and, for gains at the marketing level, we multiply by the amount sold.

this farmer gains USD 16.15 per maize season compared to the case if she were in the control group.

In addition, farmers incurred more costs to adopt 'good' post-harvest management practices. We take these costs into account too and present them in Table 7. We collected information from farmers on the labour hours, amount of money, or both, required to adopt each of the practices. Then we converted the labour hours into monetary terms by multiplying by the labour cost per hour in the study area.[13] We obtain the total monetary costs of adoption of post-harvest management practices per ton of maize. We then multiply this cost by the average amount of maize harvested or stored, depending on the stage at which the practice is done, and then multiply by the marginal effects to get the cost of adoption of each practice by a treated farmer relative to one in the control group.[14] In total, the hypothetical average farmer incurs USD 6.52 more in costs for adoption compared to a farmer in the control group.

Therefore, the total net benefit of a hypothetical average farmer in the 'training only' treatment is USD 9.63 (USD 16.15 minus 6.52) in one season. The total cost of providing this training for 120 farmers was USD 4000, which is equivalent to USD 33.33 per farmer.[15] Assuming that the effects of the training last five seasons and that the net benefits during that period are constant (USD 9.63) in every season, then, with the initial investment of USD 33.33, the internal rate of return (IRR) for this intervention is 14%.[16] It is important to note that in this case we have not considered the spillover effects of the training to other people in the village. We also assume training of twenty people per village as we did, but in reality more than that can be covered at a very small additional cost.

Next, we conduct a similar analysis for the economic effectiveness of the training and use of hermetic bags intervention. Again, we assume a hypothetical average farmer in the 'training and hermetic bags' treatment. Table 8 shows that this farmer, compared to the case if she were in the control group, will abate a loss of 11.9 kg of maize during pre-storage, and 97.5 kg during storage. These losses abated are valued at USD 2.38 and USD 19.5. This farmer will also gain USD 4.6 and USD 17.5, respectively, for not using (or using less) storage insecticides and from selling all the maize she brought to the market, compared to the case if she were in the control group. After

[13] We calculated the average labour cost per hour in the study area from different farm activities; it is about USD 0.50 per hour.
[14] Multiplying by the marginal effect captures the difference in adoption rates between the treated group and the control group.
[15] The costs take into account trainers' fees, transport and other logistics to organise the training sessions.
[16] Internal rate of return (IRR) is a discount rate that makes the net present value (NPV) of all cash flows from a particular project equal to zero. IRR calculations rely on the same formula as NPV: $NPV = \sum_{t=1}^{T}(B_t/(1+r)^t) - C_0$ where B_t is the net flow of benefits at time t and C_0 is the initial cost at time zero, r is the discount rate, and T is the number of time periods.

assigning weights, in total, this hypothetical average farmer in the 'training and hermetic bags' treatment gains USD 41.0 more, compared to the case if she were in the control group.

The monetary costs of adoption of post-harvest management practices per ton of maize are presented in Table 9. The average farmer incurs USD 7.13 more cost for adoption compared to the farmer in the control group. Therefore, the net benefit of an average farmer in the 'training and hermetic bags' treatment is USD 33.87 (41 minus 7.13), compared to the farmer in the control group, for one season.

Again, the total cost of providing the post-harvest management training for 120 farmers was USD 4000, which is equivalent to USD 33.33 per farmer. On average, a farmer in the 'training and hermetic bags' treatment received 12 hermetic bags, which in total cost USD 24 (at a price of USD 2 per bag). So, the total initial investment is USD 57.33 (33.33 + 24). We assume the hermetic bags to last three seasons. Considering the investment horizon of three seasons and assuming the net benefits during that period are constant (USD 33.87) in every season, then, with the initial investment of USD 57.33, the internal rate of return (IRR) for this intervention is 35%.

Are bags profitable if they last for one season? To conduct the analysis, we make a simplifying assumption that the effects of the two interventions are additive. In that case, we can calculate the net gain of using hermetic bags by subtracting the 'training only' gains from the 'training and hermetic bags' gains. So, the net gain of using hermetic bags only is USD 24.24 (33.87 minus 9.63) for an average farmer in the 'training and hermetic bags' treatment. On average, farmers were given 12 bags, making the net gain per bag USD 2.02 in one season. One hermetic bag costs about USD 2. Thus, the use of hermetic bags breaks even in one season.

8. Conclusions

Agriculture in sub-Saharan Africa employs two-thirds of the labour force and generates about one-third of gross domestic product (GDP) growth. According to the World Development Report (World Bank, 2008), GDP growth originating in agriculture is about four times more effective in reducing poverty than GDP growth originating outside agriculture. For this reason, policies that increase net revenues in agriculture can have a substantial impact on food security and poverty reduction. Reducing Post-Harvest Losses (PHL) and improving storage possibilities are potential low-cost options to achieve those objectives.

We have carried out an RCT experiment where Tanzanian maize farmers received training in post-harvest management and were equipped with hermetic bags. Analyzing the data from this experiment, we find that both interventions had a significant impact. A combination of both interventions led to a reduction in PHL of more than 70% or almost 7 percentage points. In addition, quality increased, and, compared to the control group, the training and bags group got a significant 6% higher price for their maize. Hence, training and bags increase income, which in turn could facilitate the financing of purchases of modern agricultural inputs, potentially leading to additional increases (Adjognon et al., 2017). Further, a significantly lower proportion of farmers who received hermetic bags used storage insecticides, which likely include non-monetary benefits in terms of improved health and less environmental impact.

Our results confirm that the main mechanism driving these results is reduced storage losses. In both interventions, a greater proportion of farmers perceived that the physical characteristics of their maize grain were maintained during storage, which was confirmed by the higher price paid compared to the control group. We find that a significantly higher proportion of farmers who received hermetic bags invested more in controlling rodents, but they significantly reduced the net cost of storage protection. We observe that higher proportions of farmers in the treatment groups adopted post-harvest loss-mitigating practices, compared to those in the control group. This adoption, plus the use of the hermetic bag itself, may explain the success of the intervention.

Our cost-benefit estimations show that provision of training on post-harvest management is beneficial, assuming that the effects of the training last for at least five years. There are reasons to believe that the effects can last longer. First, the more farmers use the adopted techniques, the more they become familiar with them, and thus can implement them at a lower cost. Second, through social networks, more farmers might adopt due to learning from early adopters about the suitability, profitability, and methods of using the new technology, as documented in literature on technology adoption (Maertens and Barrett, 2013; Magnan et al., 2015).

The results in our study thus indicate non-negligible returns to training and considerable returns to training and physical capital (hermetic bags) combined. Our study relates to a much larger literature on the relative importance of physical and human capital for economic development. Bigsten et al. (2000) report far higher returns on physical than human capital in Africa's manufacturing sector, and remark that this finding is consistent with high (shadow) costs of capital. A similar argument can be made in our context. Since the purchase cost of a hermetic bag is relatively modest, other capital cost components must be substantial. In our setting, the farmers have poor access to the market for new technology and new knowledge. If the obstacles for technology and knowledge diffusion can be mitigated or removed, the gains can thus be substantial.

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TABLE 1: Baseline Summary Statistics and Randomization Tests

	ALL			1-CONTROL		2-TRAINING		3-TRAIN+BAGS		[1 - 2]	[1 - 3]	[2 - 3]
Variable	Obs	Mean	Stdv	Mean	Stdv	Mean	Stdv	Mean	Stdv	Diff	Diff	Diff
Socioeconomic characteristics												
Sex	397	0.86	0.35	0.84	0.37	0.87	0.33	0.87	0.34	-0.035	-0.030	0.004
Age	397	46.9	12.1	48.6	11.6	46.6	11.4	44.7	13.1	1.95	3.88**	1.93
Years of schooling	397	7.06	2.81	7.16	3.11	6.65	2.59	7.32	2.51	0.516	-0.154	-0.67*
Number of active workers	397	3.03	1.57	3.06	1.66	3.11	1.72	2.91	1.27	-0.051	0.146	0.197
Household size	397	5.45	2.07	5.61	2.19	5.50	2.17	5.14	1.75	0.113	0.472**	0.360
Yearly Income (USD)	397	1053	1278	1060	1117	1019	1614	1077	1145	41.0	-17.7	-58.7
Value of assets (USD)	397	4289	7030	4742	7361	4407	6809	3487	6710	335.0	1254.8	919.8
Maize farming practices												
Maize experience (Years)	397	19.0	12.2	19.7	12.6	18.0	11.2	18.9	12.4	1.728	0.877	-0.851
Got PH training before	397	0.22	0.42	0.21	0.41	0.24	0.43	0.24	0.43	-0.028	-0-029	-0.000
Area of Land for agric (ha)	397	2.62	2.24	2.65	2.49	2.56	2.29	2.61	1.76	0.089	0.040	-0.050
Area of Land for maize (ha)	397	1.67	1.45	1.75	1.70	1.67	1.34	1.55	1.11	0.075	0.193	0.119
Number of maize plots	397	1.37	0.74	1.35	0.66	1.33	0.88	1.43	0.72	0.025	-0.077	-0.103
Amount harvested (Kgs)	395	2803	2766	2874	2912	2817	3104	2683	2148	56.6	191.2	134.6
Amount of maize stored (Kgs)	394	2645	2597	2749	2824	2618	2771	2510	2012	131.3	239.2	107.9
Sold maize (yes=1)	395	0.89	0.31	0.87	0.33	0.90	0.30	0.92	0.27	-0.027	-0.049	-0.022
Amount sold (Kgs)	353	1872	2234	1925	2423	1845	2457	1821	1688	80.6	104.2	23.6
Amount sold within 3 months (Kgs)	395	855	1049	860	1090	907	1227	797	769	-47.4	62.1	109.6
% sold in 3 months	395	0.29	0.19	0.28	0.21	0.29	0.18	0.30	0.18	-0.006	-0.018	-0.012
Average price per ton (USD)	351	179.4	43.74	178.6	45.66	180.7	49.06	179.5	35.19	-2.091	-0.968	1.123
Weather at harvest (Sunny=1)	393	0.81	0.39	0.80	0.40	0.86	0.35	0.78	0.42	-0.061	0.022	0.084
Harvest at maturity (yes=1)	394	0.19	0.39	0.18	0.39	0.19	0.40	0.19	0.40	-0.011	-0.012	0.000
Proper immediate handling (yes=1)	397	0.29	0.45	0.31	0.46	0.30	0.46	0.25	0.44	0.006	0.052	0.046
Maize sorted (yes=1)	395	0.51	0.50	0.51	0.50	0.53	0.50	0.51	0.50	-0.026	-0.003	0.023
Number of days maize dried	397	4.77	10.48	4.82	10.06	4.78	10.56	4.68	11.12	0.039	0.137	0.098
Store disinfected (yes=1)	394	0.45	0.50	0.47	0.50	0.44	0.50	0.45	0.50	0.025	0.014	-0.011
Used any means to protect (yes=1)	394	0.80	0.40	0.76	0.43	0.79	0.41	0.86	0.35	-0.027	-0.097**	-0.069
Used chemical protectants	394	0.60	0.49	0.60	0.49	0.61	0.49	0.60	0.49	-0.016	0.013	-0.003
Used traps and poisons	394	0.17	0.38	0.17	0.38	0.18	0.39	0.16	0.37	-0.009	0.015	0.024
Protections costs per ton (USD)	394	4.88	3.89	4.65	3.94	5.12	4.29	4.68	3.38	-0.470	-0.325	-0.145
Post-Harvest Losses												
Pre-storage losses	395	0.029	0.022	0.028	0.021	0.029	0.019	0.030	0.025	-0.001	-0.002	-0.001
Storage losses	395	0.079	0.057	0.084	0.061	0.077	0.051	0.074	0.053	0.007	0.010	0.003
Marketing losses	395	0.010	0.013	0.011	0.015	0.009	0.011	0.010	0.011	0.003*	0.001	-0.001
Total Losses	395	0.118	0.069	0.124	0.071	0.115	0.065	0.114	0.071	0.008	0.010	0.001

TABLE 2: Impact on Post-Harvest Losses

	[1]	[2]	[3]	[4]
VARIABLES	Pre-Storage Losses		Storage Losses	
Mean of Dep. Variable	0.029	0.029	0.093	0.093
Training + Bags	-0.0046	-0.0046	-0.0670***	-0.0676***
	(0.4970)	(0.4609)	(0.0040)	(0.0040)
Training Only	-0.0063	-0.0064	-0.0277**	-0.0283**
	(0.2886)	(0.2846)	(0.0120)	(0.0240)
Sex		-0.0098*		0.0063
		(0.0601)		(0.4890)
Age		-0.0002		-0.0002
		(0.2886)		(0.6773)
Years of schooling		0.0001		0.0007
		(0.9259)		(0.6533)
No. of active workers		0.0004		0.0037
		(0.7214)		(0.4128)
Wealth (USD)		0.0000		-0.0000
		(0.1924)		(0.7575)
Maize farming experience (years)		-0.0003		-0.0002
		(0.1884)		(0.6974)
Got PH Training before		-0.0506		-0.0137
		(0.2725)		(0.2084)
Constant	0.0292***	0.0490***	0.0926***	0.0864**
	(0.0000)	(0.0020)	(0.0000)	(0.0296)
Observations	395	395	390	390
R-squared	0.008	0.045	0.109	0.120

Wild-cluster bootstrap-t p-values in parentheses. Pre-storage losses are calculated as proportion of total amount of maize harvested. Storage losses are calculated as proportion of amount stored for those who stored maize. *** p<0.01, ** p<0.05, * p<0.1

TABLE 3: Impact on the Qualitative Characteristics of Stored Maize Grain, Sales Behavior and Price

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
VARIABLES	Size and Shape	Aroma	Taste	Color	Pest Infestation	Rotting	% Sold 3 Months After Harvest	Average Maize Price Obtained
Mean of dept. variable	3.45	3.41	3.43	3.51	1.29	1.24	0.18	USD 221.8
Training+Bags	0.4923**	0.4540*	0.4114	0.3370	-0.3107**	-0.2370**	-0.0483	12.983**
	(0.0240)	(0.0801)	(0.1403)	(0.1403)	(0.0120)	(0.0160)	(0.1924)	(0.0281)
Training Only	0.2238	0.2024	0.2209	0.1771	-0.1516	-0.0847	-0.0223	6.4583
	(0.2405)	(0.4088)	(0.3848)	(0.3768)	(0.1362)	(0.3046)	(0.6693)	(0.3367)
Sex	-0.1752	-0.0858	-0.06523	-0.1036	0.0517	0.0134	0.0376	3.5763
	(0.1963)	(0.4289)	(0.6012)	(0.2886)	(0.4930)	(0.8818)	(0.3327)	(0.7255)
Age	-0.0047	-0.0059	-0.0040	0.0000	-0.0028	-0.0015	-0.0011	-0.4480
	(0.3647)	(0.2926)	(0.3968)	(1.0000)	(0.2405)	(0.6493)	(0.2365)	(0.2485)
Years of schooling	-0.0133	0.0073	0.0000	0.0035	-0.0217*	-0.0069	-0.0007	1.2550
	(0.4930)	(0.6733)	(0.9820)	(0.9218)	(0.0721)	(0.5050)	(0.9218)	(0.1603)
No. of active workers	-0.0108	-0.0415*	-0.0258	-0.0135	0.0348	0.0072	-0.0081	0.8237
	(0.7735)	(0.0921)	(0.2766)	(0.6453)	(0.1643)	(0.7856)	(0.2445)	(0.5210)
Wealth (USD)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0006
	(0.1242)	(0.5010)	(0.7134)	(0.8297)	(0.4409)	(0.3126)	(0.8657)	(0.2445)
Years of experience	0.0052	0.0079	0.0049	0.0037	-0.0014	-0.0006	0.0000	-0.0656
	(0.2806)	(01723)	(0.3607)	(0.2766)	(0.7054)	(0.7615)	(0.9579)	(0.8457)
Got PH Training before	-0.0181	0.0581	0.0495	0.1165	-0.0229	-0.0604	-0.0141	3.0410
	(0.9299)	(0.53301	(0.5731)	(0.1764)	(0.8016)	(0.3126)	(06212)	(0.4810)
Constant	3.615***	3.463***	3.458***	3.372***	1.576***	1.418***	0.252***	220.59***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Observations	390	390	390	390	390	390	397	312
R-squared	0.084	0.073	0.060	0.050	0.075	0.041	0.017	0.070

Wild-cluster bootstrap-t p-values in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

TABLE 4: Impact on Maize Protectants Use and Cost of Protection

VARIABLES	[1] Protected Stored Maize (YES=1)	[2] Used Chemical Protectants (YES=1)	[3] Used Rats Traps and Poisons (YES=1)	[4] Cost of Protection (Per 1 Ton)
Training + Bags	-0.1725**	-0.3604***	0.1115*	-2.5935***
	(0.0361)	(0.0040)	(0.0841)	(0.0040)
Training Only	-0.0402	0.0171	0.0028	0.8960
	(0.6533)	(0.8898)	(1.0000)	(0.5451)
Sex	0.0846	0.0880**	0.0200	2.2680***
	(0.1042)	(0.0481)	(0.6453)	(0.0000)
Age	0.0003	-0.0033	-0.0005	-0.0635**
	(0.8657)	(0.1563)	(0.8697)	(0.0160)
Years of schooling	0.0081	-0.0008	0.0086	-0.0652
	(0.4770)	(0.8697)	(0.3607)	(0.6052)
No. of active workers	0.0078	0.0039	0.0120	-0.2700
	(0.6493)	(0.7816)	(0.3928)	(0.2926)
Wealth (USD)	0.0000	0.0000	0.0000	0.0003**
	(0.9339)	(0.7575)	(0.5370)	(0.0361)
Years of experience	0.0025	0.0031	-0.0010	0.0473
	(0.2244)	(0.2725)	(0.7014)	(0.1202)
Got PH Training before	-0.0108	0.0099	0.0080	-1.2070
	(0.8216)	(0.9339)	(0.8497)	(0.1924)
Constant	0.617***	0.627***	0.100	5.338***
	(0.0000)	(0.0000)	(0.4649)	(0.0040)
Observations	390	390	390	395
R-squared	0.042	0.114	0.027	0.137

Wild-cluster bootstrap-t p-values in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

TABLE 5: Effect of Interventions on Post-Harvest Management Practices

VARIABLES	[1] Harvested Immediately when Matured (Yes=1)	[2] Maize Spread After Harvest (Yes=1)	[3] Maize Sorted (yes=1)	[4] Number of Days Maize Dried	[5] Store Disinfected (yes=1)
Training + Bags	-0.0042	-0.0541	0.0320	-0.3070	0.0009
	(0.8898)	(0.5932)	(0.7054)	(0.7776)	(1.0000)
Training Only	-0.0041	0.0064	0.0428	-0.3490	-0.0157
	(0.9539)	(0.8737)	(0.5651)	(0.7535)	(0.8697)
Sex	-0.0155	-0.0999	0.0476	-1.1830	0.0341
	(0.7335)	(0.1483)	(0.4890)	(0.5250)	(0.6934)
Age	0.0005	-0.0013	0.0026	-0.1340***	0.0029
	(0.7735)	(0.5090)	(0.4329)	(0.0080)	(0.3246)
Years of schooling	0.0143**	0.0098	0.0195*	-0.0293	0.0179
	(0.0200)	(0.3527)	(0.0641)	(0.8216)	(0.1002)
No. of active workers	0.0324**	0.0281*	0.0488***	0.1690	0.0396**
	(0.0240)	(0.0681)	(0.0000)	(0.6373)	(0.0441)
Wealth (USD)	1.79E-06	6.87E-06	6.24E-06**	-7.14E-06	2.68E-06
	(0.4729)	(0.1322)	(0.0401)	(0.8136)	(0.5651)
Years of experience	-0.0012	0.0021	-0.0010	0.0153	-0.0002
	(0.5571)	(0.2886)	(0.7495)	(0.7054)	(0.9178)
Got PH Training	0.250***	0.2180***	0.0732	1.9940	0.1670**
	0.0000	(0.0040)	(0.2044)	(0.1242)	(0.0361)
Constant	-0.0636	0.1810	0.0245	11.190***	0.0057
	(0.4529)	(0.1042)	(0.8657)	(0.0040)	(0.8818)

Wild-cluster bootstrap-t p-values in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

TABLE 6: The Marginal Value Gained by a Hypothetical Average Farmer in the 'Training Only' Treatment

	Kgs			Marginal Effects	Amount Abated	Value Gained($)
Amount harvested	1850	x	Marginal pre-storage loss abated	0.0073	= 13.6	= 2.72
Amount stored	1777	x	Marginal storage loss abated	0.0189	= 33.6	= 6.72
Amount sold	1385	x	Gain from selling at higher price	0.0065		= 9.00
Total value gained	=		2.72+108/109*6.72+82/109*9.00			**= 16.15**

TABLE 7: The Marginal Cost of Adoption by a Hypothetical Average Farmer in the 'Training Only' Treatment

	[1]	[2]	[3]	[4]	[5]	[6]
	Labour Hours per Yon	Monetary Cost per Ton (USD)	Total Monetary Cost per Ton (USD) =0.5*[1]+[2]	Amount for Average Farmer(ton)	Marginal Effect	Cost of Adoption =[3]*[4]*[5]
Harvest at maturity	8.93		4.46	1.850	0.065	0.54
Proper immediate handling		6.37	6.37	1.850	0.111	1.31
Sorting maize	3.59		1.80	1.850	0.133	0.44
Drying an extra day	3.35		1.68	1.850	1.295	4.02
Disinfect store facility	2.10	4.26	5.31	1.777	0.022	0.20
					Total	**6.52**

TABLE 8: The Marginal Value Gained by a Hypothetical Average Farmer in the 'Training and Hermetic Bags' Treatment

	Kgs					Amount Abated		Value Saved
Amount harvested	1900	x	Marginal pre-storage loss abated	0.0063	=	11.9	=	2.4
Amount stored	1750	x	Marginal pre-storage loss abated	0.0557	=	97.5	=	19.5
Amount stored	1750	x	Gain from not using insecticides	0.0026			=	4.6
Amount sold	1350	x	Gain from selling at higher price	0.0130			=	17.5
Total value gained	=		2.38+112/114(19.5+4.6)+98/114x17.5				=	41.0

TABLE 9: The Marginal Cost of Adoption by a Hypothetical Average Farmer in the 'Training and Hermetic Bags' Treatment

	[1]	[2]	[3]	[4]	[5]	[6]
	Labour Hours per Ton	Monetary Cost per Ton (USD)	Total Monetary Cost per Ton (USD) =0.5*[1]+[2]	Amount for Average Barmer(ton)	Marginal Effect	Cost of Adoption =[3]*[4]*[5]
Harvest at maturity	8.93		4.46	1.9	0.076	0.64
Proper immediate handling		6.37	6.37	1.9	0.204	2.47
Sorting maize	3.59		1.80	1.9	0.118	0.40
Drying an extra day	3.35		1.68	1.9	1.093	3.49
Disinfect store facility	2.10	4.26	5.31	1.75	0.014	0.12
					Total	7.13

Appendix A

Figure A1: Timeline of Field Events

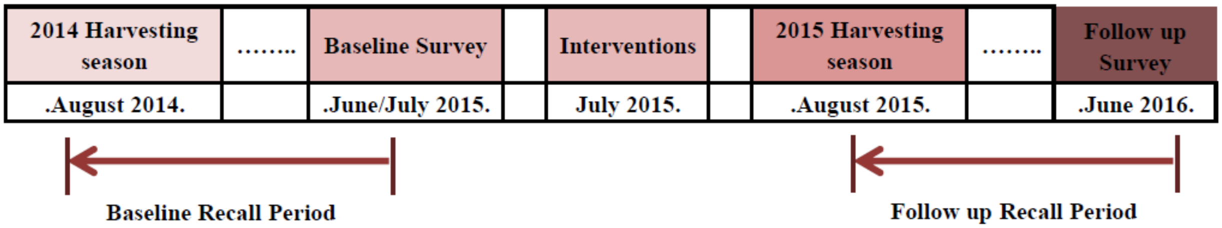

Figure A1: A Map of the Study Area Showing the Distribution of Villages According to Experimental Groups

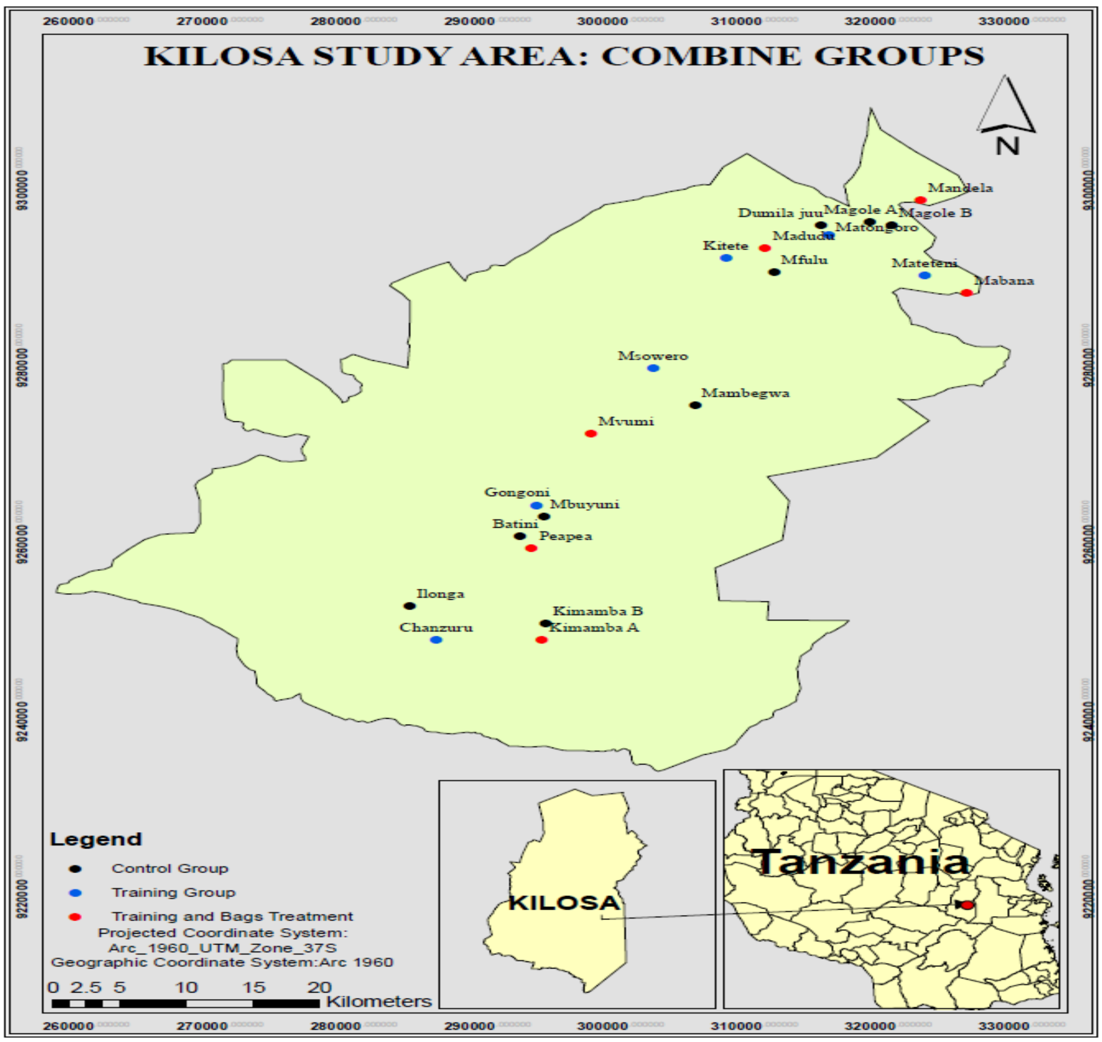

TABLE A1: Effect of Maize Quality and Opportunistic Selling on Maize Price

VARIABLES	Average Maize Price Obtained
Quality Index	1.0383
	(0.4449)
% sold within 3 months	-67.261***
	(0.0040)
Sex	7.1990
	(0.4368)
Age	-0.5630
	(0.1122)
Years of schooling	1.1550
	(0.1643)
No. of active workers	0.4599
	(0.6693)
Wealth (USD)	0.0051
	(0.3647)
Years of experience	-0.0512
	(0.8577)
Got PH Training Before	1.8590
	(0.5410)
Constant	245.700***
	(0.0000)
Observations	310
R-squared	0.192

Wild-cluster bootstrap-t p-values in parentheses.
*** p<0.01, ** p<0.05, * p<0.1