THE IMPACT OF AUDIO PHONE REMINDERS ON KENYA FARMERS' KNOWLEDGE AND UPTAKE OF DROUGHT TOLERANT (DT) MAIZE

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ABSTRACT

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Changing climate, such as drought stress, can lead to harvest failures and losses in Eastern and Southern African (ESA) countries. Scientists have been breeding improved seeds that are resistant to drought. However, the demand for these drought tolerant (DT) maize varieties is still low. Farmers also lack knowledge about modern practices that can increase their productivities in growing DT maize. This study designed and tested two strategies of using information and communication technologies (ICTs) aiming to increase farmers' knowledge and uptake of DT maize. The first one is a locally-made or "participatory" video. The second one is a "multichannel" method that integrates the same video with timely mobile phone-based audio messages. We conducted a field experiment in Machakos and Makueni counties in south central Kenya. The experiment randomly allocated the two strategies to farmers in the study areas. We found that farmers in the multichannel group retained significantly higher knowledge about DT maize and its accompanying management practices than farmers in the control group. Though the difference is not statistically significant, farmers in the video-only group also had a higher score in knowledge of these practices than those in the control group. Further, farmers in the multichannel group were significantly more likely to be willing to plant DT maize in the next primary growing season. This study contributes to a greater understanding of farmers' learning and uptake of DT maize. The results suggest that ICT strategies that integrate contextualized knowledge and timely reminders could help farmers gain knowledge about DT maize and encourage them to try new seed varieties.

I dedicate this work to my parents and grandparents

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CHAPTER 1. INTRODUCTION

Maize comprises forty-five percent of calories consumed by people in Eastern and Southern Africa (ESA) and is a particularly important income source to the poor in this region1(Shiferaw, 2011). Farmers' most pressing concerns in the region are harvest failures and losses attributable to changing climate conditions, such as drought stress. Such changes affect food production both directly, through changes in agricultural productivity, and indirectly, through reducing agricultural incomes (Fisher et al., 2015). In response to changing rain patterns and climate, scientists have been breeding improved seeds, some of which are drought tolerant (DT)2. Hendrix & Glaser (2007) suggest that planting these new varieties, in conjunction with improved management practices can reduce yield loss by up to 40%. Although yields remain low and, as a result of changing climate conditions in ESA, variable, demand for DT maize seed still falls far short of the what it could be(Fisher et al., 2015). Moreover, while tests conducted in experimental stations suggest sizeable productivity increases from adoption of DT maize, farmers' actual profitability of doing so is unknown. The successful diffusion of improved seed in Asia and other regions indicates that technology adoption and impact at scale is a combination of innovative technologies and institutional and policy shifts, such as improvements to farmers' access to information, input, output and credit markets (Shiferaw, 2011).

In addition to posters, radio, television, and newspapers, the existing methods for communicating DT maize to farmers include field demonstrations and field days organized by

[1] Maize currently covers 25 million ha in sub-Saharan African, and an estimated 38 million metric tons are produced annually(Smale et al., 2011)

[2] The Drought Tolerant Maize for Africa (DTMA) project, led by the International Improved Maize and Wheat Center, released 160 drought tolerant maize varieties between 2007 and 2013 and disseminated them to farmers in 13 African countries. In addition to drought tolerance, the varieties have other attractive traits, such as resistance to major diseases and high protein content. Cost of DT maize seeds is similar to other non-DT commercial varieties.

extension officers and NGO experts (Fisher et al., 2015). However, due to a severe shortage of extension officers and NGO experts, farmers struggle to access relevant and up-to-date information (Lovo, 2013). Scholars believe that information communication technologies (ICTs) can be a potential solution (e.g. Nakasone & Torero, 2014).

This study assesses how different ICT-based extension approaches can improve farmers' knowledge about DT maize and its complementary practices. In particular, we test two approaches. The first approach includes locally made, or "participatory," videos. This approach is utilized by agricultural extensions workers and NGO staff who shoot videos featuring farmers from the same or a similar community. Our video integrates both contextualized social and cultural cues and technical information about DT maize and the modern management practices. The video also uses local farmers' narrative stories to inform audiences about potential risks of growing DT and its risk management practices. The second approach is a multichannel method. In addition to the participatory video farmers in this group received four audio messages on their mobile phone over a maize growing season. An audio system complements information in the video by "pushing" audio messages before the key decision points in the maize growing season. These audio messages are reminders that reinforce the knowledge farmers learned in the video and encourage adoption. The first message reminded farmers to purchase DT maize seed. The second and the third messages included content that reminded farmers of proper timing, practice, and quantity used in fertilizer micro-dosing. The last message informed farmers about post-harvesting practices about storage and moisture testing that can be used to manage DT maize, traditional varieties, or other improved varieties. Given that improved seed like DT maize is more sensitive to factors like soil fertility, these management practices are more critical to farmers who grow DT maize than to those who grow traditional varieties (Byerlee & Heisey, 1996 ; Foster & Rosenzweig, 2010).

In total, 615 households in 27 villages were included in the study. We partnered with Farm Input Promotions Africa (FIPS), a local NGO, to design ICT strategies and to conduct a field experiment on the intervention in Machakos and Makueni Counties, Kenya. FIPS has worked in the study area for more than 10 years and operates in some of the villages in the sample. A detailed description of its activities in the study area is presented at the end of methods section. We randomly selected villages from a list of villages provided by FIPS. This list includes villages where FIPS is currently working and villages where FIPS planned to work but had no activity prior to and during this study. We assigned these villages to one of three groups. Farmers in the first group watched a video, and farmers in the second group watched the same video followed by four audio messages. The third one is a control group, so no video was screened and no audio messages were sent to these villages.

We study three research questions. First, we study whether the participatory video or the multichannel approach increased farmers' knowledge about DT maize and about the management practices relative to those in the video-only group and to those in the control group (RQ1). Second, we investigate whether there was any difference in willingness to try DT maize between farmers in the multichannel group relative to those who only watched the participatory videos and to those who in the control group (RQ2). Moreover, FIPS provides services related to DT maize in some villages sampled in the study. Therefore, this current study aims to understand the differential treatment impacts on farmers' knowledge and uptake according to whether they live in villages with FIPS services (RQ3).

We found that farmers in the multichannel group demonstrated higher knowledge about both DT maize and its accompanying management practices than farmers in the video-only group and in the control group. They also were more willing to plant DT maize in the next primary growing season. These effects were strongest in communities supported by FIPS.

This study has four main contributions. First, it provides new empirical evidence on the impact of using ICTs on agricultural knowledge provision. We also test new design principles that create a synergy among various ICTs to improve farmers' knowledge and uptake of innovations, building on previous literature that mainly discusses the effect of a single ICT (e.g. Gandhi, et al., 2009, Cole & Fernando 2012). Third, this study suggests the importance of designing ICT strategies based on farmers' cognitive capacity; the characteristics of agricultural innovations, such as whether farmers need to practice multiple steps over a long cycle; and functions of various ICTs. Lastly, the findings contribute to a greater understanding of farmers' learning and uptake of DT maize.

The rest of the paper is organized as follows. The second section presents a literature review about farmers' learning and uptake of improved seeds like DT maize. The same section discusses existing studies that use participatory videos and mobile phones in agricultural knowledge provision. The third section discusses the intervention, the study area, the experimental design, the sampling strategies and sample characteristics, and the estimation framework. Results are presented in the fourth section, followed by a discussion of contribution and implication of the research findings.

CHAPTER 2. LITERATURE REVIEW

2.1. Drought tolerant (DT) maize in sub-Saharan Africa (SSA)

Studies have found that farmers use different strategies to reduce the negative impacts of climate variability and change[3] to their maize production. Among these strategies, the adoption of drought tolerant crops can play an increasingly important role in coping with climate change and variability (Kassie et al., 2014). Research institutes like the International Wheat and Maize Improvement Center (CIMMYT) and seed companies have been researching and introducing Drought Tolerant varieties (DT)[4] to the ESA market for about a decade.[5] Between 2007 and 2013, 160 DT maize varieties were released to ESA market.[6] Field trials in ESA found that DT maize yield were higher than popular commercial varieties by 82-127% in controlled drought conditions, 26-47% in random drought conditions, and 25-56% in optimal rainfall condition[7] (unpublished data from Tsedeke Abate, DTMA project leader, March 2015, cited in Fisher et al., 2015 pp. 284-285). La Rovere et al. (2014) found that DT maize could increase average yield and lower yield variability. The authors also speculate that the yield advantage between DT and local varieties could be greater when there is a drought.

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[3] These methods include crop rotation, changing planting dates, switching crop species, crop diversification, and soil and water conservation techniques.

[4] Scientists use modern conventional methods to breed DT. Current DT varieties in ESA market are not genetically modified.

[5] Global efforts aiming to develop drought tolerant maize germplasm include drought-tolerant maize for Africa (DTMA), which was implemented by CIMMY, the International Institute for Tropical Agriculture (IITA), and the national research/extension institutions of 13 African countries.

[6] This is the total number of DT varieties released to all ESA countries. Each country has a smaller number of varieties available to local farmers.

[7] Maize under random drought conditions receives approximately less than 600 mm rainfall per year, and is plagued by pests and disease under rainfed conditions. Maize under optimal rainfall conditions receive more than 750mm per year in a temperature range of 24-33 °C. Under managed drought conditions, maize is grown in the off season and the irrigation interval is calculated based on the crop water balance (Setimela et al, 2017).

We still know little about how farmers adopt DT maize and whether they can profit from growing it, especially because farmers commonly apply insufficient amounts of inputs like fertilizer and labor and use inadequate management practices (e.g. Tambo & Abdoulaye, 2011). Scientists have suggested that growing improved varieties like DT maize requires farmers to use more inputs, especially fertilizer, in comparison to traditional varieties (e.g. Smale, Byerlee & Jayne, 2011), so underutilization of these inputs is potentially a problem for DT maize adoption. Fisher et al. (2015) found that labor constraints did not hinder farmers' adoption of DT maize, but they speculated that it was because farmers currently only grow DT maize at small scales, and the labor shortage may become a salient problem if they decide to expand DT maize production. Seed markets are not well established in ESA, and farmers have limited access to DT seeds in areas where there is no government intervention or development project directly distributing the seeds to farmers (Fisher et al., 2015). Further, Fisher et al. (2015) found in six ESA countries[8] that farmers who were older, owned less land, and had less exposure to information about DT maize were less likely to try DT seed.

Langyintuo et al. (2010) and Fisher et al. (2015) argue that an effective strategy to increase the adoption of improved maize, like DT maize, is to enhance farmers' awareness and knowledge about DT maize. However, most efforts of knowledge provision have mainly targeted farmers who already knew about improved seeds prior to the intervention. Thus, more tailored communication strategies are needed to increase awareness and demand among farmers who are unfamiliar with improved seed. There is also a need to better inform farmers about input requirements and modern cultivation practices associated with improved seed. Access to extension services is vital to raising farmers' awareness of the existence, benefits, and usage of the technology (Kabunga et al.,

[8] This six countries are Ethiopia, Tanzania, Uganda, Malawi, Zambia, and Zimbabwe

2012). However, extension services in ESA, whether publicly or privately funded, are less efficient in boosting adoption, especially where demand for improved seed is low (Muyanga & Jayne, 2008). Seed companies also disseminate information about improved seed through their market networks and other information channels, including seed packs and radio and TV programs. However, there is no evaluation of the effectiveness of these efforts.

2.2. Farmers' Adoption of Improved Seed

Khonje et al. (2015) found that households who grew improved maize saw gains in crop income, consumption expenditure, and food security. However, a substantial portion of maize farmers still plant traditional seeds. In the 2006-07 season, only 44% of total maize area in ESA was planted with improved seed[9] (Abate et al., 2017). An earlier study showed that around 60% of Kenyan farmers used fertilizer and hybrid seed in 2004 (Suri, 2011). Further, farmers who adopted improved maize preferred older improved varieties or jointly planted new and old hybrids in one season ("portfolio selection"). Farmers also grew farm-saved impure seed that farmers kept from previous production using improved seed.[10] Many farmers switched back and forth between traditional and improved seed from season to season (Duflo et al., 2008).

There are several reasons behind the low levels of adoption of improved seeds in ESA, including lack of information about improved varieties and their benefits (e.g. Fisher et al., 2015), lack of knowledge about how to manage new varieties (e.g. Diagne & Demont, 2007), behavioral biases (Duflo et al., 2011), and lack of credit to purchase improved varieties and inputs that complement the technology. Moreover, supply of quality improved seed varieties, such as drought tolerant maize, are unreliable. Seed varieties that are supplied to farmers are often not suitable to

[9] These data exclude South Africa. Improved varieties include open-pollinated varieties (OPVs) and hybrids.
[10] Impure improved seed could lose some improved attributes, such as high yield.

farmers' agro-ecological conditions (personal communication, 2016). Further, in areas like Machakos and Makueni, agro-ecological conditions can vary within a village because of the changing elevations. However, farmers receive little information about how to choose among various improved varieties because that few sources can provide credible recommendations based on their needs and conditions. Fisher et al. believes farmers' lack of knowledge about attributes of improved seeds, such as early maturation or drought tolerance, can explain farmers' reluctance to choose yield-enhancing inputs like improved seeds and intensification cultivation practices (Fisher et al., 2015).

Other studies provide various arguments to explain farmers' slow adoption of improved varieties. One argument claims that farmers are knowledgeable about the technical components of improved seed. However, farmers with a high fixed cost of growing hybrid maize delay their adoption because the return is low (Suri, 2011). Suri (2011) suggests that this high cost is caused by supply and infrastructure constraints. A third argument emphasized the importance of knowledge about complementary practices to effectively cultivate improved seeds. In this case, incomplete knowledge about how to most effectively grow DT maize—such as how to manage maize crops to avoid potential production risks—can lead to low adoption rates (e.g. Diagne & Demont, 2007).

2.3. Videos and Phone Messages in Agricultural Extension

Information communication technologies (ICT), including radio, videos, mobile phones, and computers are increasingly used in provision of agricultural extension services. For example, agricultural training videos have been created to complement and supplement conventional extension trainings. These training videos are lauded for a number of reasons, such as their potential role in improving farmers' knowledge and adoption of agricultural technology (Gandhi et al., 2009; Cai et al., 2015; Nakasone & Torero 2016). One of the most well-known video-based training approaches is developed by Digital Green, an Indian NGO (Gandhi et al., 2009). Digital Green trains grassroots development workers to use low-cost digital cameras and laptops to produce videos. A local moderator screens these videos in their communities. Other efforts that investigate video approach in extension training focus on the video production process (e.g. Van Mele, 2006), dissemination approaches, such as combining the video screening with farmers field school (Ongachi, Onwonga, Nyanganga & Okry, 2017), and video content (e.g. Medhi & Toyama, 2007). The video approach was found to be effective as it can reach populations with lower levels of literacy and education, is cost-effective, can induce behavioral change(Zossou et al., 2009), and helps to bridge gender divides by making information access more equitable across male and female farmers (Bery, 2003; Cai et al., 2015). More recent studies suggest potential for this approach beyond an information transfer tool, such as influencing the psychological well-being of the impoverished by creating aspirations (Bernard et al, 2015) and forward thinking (Bernard & Taffesse, 2014). However, local communities commonly lack video playing devices, and training videos are normally only shown to a community once. The complexity of some agricultural technologies requires intensive training programs that provide relevant information at specific times in order to refresh and remind farmers of training information and to bring farmers' attention to technical details at the right moment.

The mobile phone is another ICT that is used to provide agricultural extension services to farmers. Cole & Fernando (2012) found that voice messages can be effective in helping farmers learn to safely handle pesticides and to improve yield. Text messages (or SMS) is another widely used function to deliver agricultural extension information due to its simplicity and low cost. Whereas studies investigating impacts of the SMS approach show mixed results, the impact of SMS information on knowledge learning and adoption vary depending on the context, content, technology, and delivery strategies. Fafchamps and Minten (2012) investigated a program that provided crop advisory tips and local weather forecasts to farmers through SMS. They found that

SMS had no impact on cultivation practices or harvest losses. The advice provided by the program were rather generic and not tailored to farmers' specific needs. Casaburi et al (2014) designed an intervention in Kenya which sent out SMS to sugarcane growers at individualized moments to remind them to perform certain task. Timing of the messages was based on their harvest cycle and age of their cane. Casaburi et al. (2014) found the program increased yield by 11.5%. A study conducted in Ecuador (Larochelle et al., 2016) tested the impact of SMS as reminders of practices that extension trainers had taught to farmers in formal trainings earlier in the season? . The study found that post-training SMS reminders can improve farmers' knowledge and adoption of integrated pest management (IPM) practices. The authors suggested that impacts of the messages may have been associated with their timing and content, as well as farmers' ability. They also argued that the messages had a positive impact because the information provided through SMS did not provide new information to farmers, but acted as a reminder of the contents that had provided by formal trainings. To conclude, reminders can both increase recipients' recall of certain information and bring farmers' attention to a certain topic. In our study, using mobile phone messages to remind farmers of the information they learned in the video can be effective to help farmers recall important complementary practices that they need to implement several weeks or months after viewing the video. These management practices include proper ways of planting, fertilizer application, and fertilizer micro-dosing, and they need to be implemented at key decision making points during the maize growing cycle.

CHAPTER 3. RESEARCH METHOD

We conducted a field experiment in Machakos and Makueni Counties, Kenya and collected baseline information of 615 households in 27 villages in the area. We randomly assigned these villages to one of three groups (see Table 1). Farmers in the first group watched a video that explained the benefits of DT maize and the practices farmers need to use to cultivate DT maize. The technical content of the video was provided by the scientists at CIMMYT who developed germ plants of these DT varieties. Local experts working for FIPS also offered recommendations of modern practices that accompany the growing of DT maize. These practices were tested locally by farmers and were found to be effective. We consulted with experts in both organizations in order to compose recommendations that are suitable for the local agro-ecological and social conditions. Farmers in the second group watched the same video and also received four audio messages before key decision points of a maize growing cycle. The third one was a control group, so no video was screened and no audio message was sent to these villages. In addition to the random variation in the treatment group, we also study whether farmers live in villages with and without FIPS' services associated with the impact of treatments.

The objective is to investigate whether the ICT strategies are associated with greater knowledge about DT seed and modern practices, as well as increased willingness to plant DT maize in the next growing season. In this section, we explain the intervention, study area, experimental design, sampling strategies and sample characteristics, and estimation framework.

3.1. The Interventions

A team of researchers, the FIPS' staff, and the local farmers produced a 30 minute long video. In the video, farmer actors explain the benefits of DT maize, potential risks relating to the type of seed, how to identify and purchase seed, modern cultivation practices, and their personal experiences with cultivating DT maize. We expect the video to provide information about DT seed and the modern practices and to motivate farmers to test the seed. Video screenings were moderated by FIPS. In the video-only group and multichannel group, sampled households were invited to attend a training that included the video screenings and group discussions. We screened the video once in each treatment village around one month prior to the 2016 first maize growing season.

Further, the team created four audio messages with advice and reminders related to seed purchasing and cultivation activities (such as land preparation, planting, and fertilizer application). In the multichannel treatment group, in addition to the same video screening, we sent out four audio messages before the key decision points of a maize growing cycle. The first message was sent a few days after the screening, and it encouraged farmers to purchase DT maize from certified sources. The second and third messages emphasized proper quantity for fertilizer micro-dosing and the application practices. These two messages were sent out a week prior to each fertilizer application. The last message was about post-harvesting practices and was sent during harvesting. The control group received no intervention during the study period. Figure 1 provides a calendar of interventions and data collection activities along with an agricultural calendar.

A pre-screening survey was conducted to obtain production information, such as the maize varieties farmers grew in the previous growing season (2015 second season) and other demographic data about the study area. Then a follow-up survey was implemented after the 2016 first growing season (March –August 2016) to understand farmers' testing and uptake of DT maize after the interventions. The timeline allows us to estimate the impacts of our treatments over the first growing season in 2016 (March to August). This enables us to observe how the treatments associate with farmers' changes overtime. However, due to resource constraints, we are not able to measure the treatment impacts in the 2016 second growing season (primary season). Farmers commonly grow substantially more maize in the second growing season, as rainfall is more consistent and reliable than in the first growing season.

3.2. Study Area

The interventions took place in two counties in the southeastern region of Kenya (Figure 2). These two counties are located in the dry transitional[11] agro-ecological zone and are considered a medium drought-risk zone (20–40% PFS) target areas[12], so there are potential benefits to DT seed(La Rovere et al., 2010). Maize is the primary food and cash crop in both counties.

The majority of the agricultural activities in these two areas are rain-fed and in the small-scale semi-subsistence sector. The soil generally is of low fertility: 97% of the farms had insufficient nitrogen and 40% of the farms had insufficient phosphorus (Barber et al. 1979; NAAIAP, 2014). In the NAAIAP survey, conducted in 2014, in Machakos Sub-County, all the sampled farms had low soil organic matter content, which leads to low water holding capacity and low water infiltration rate. This results in highly erodible soil in the region (NAAIAP, 2014). Poor soil fertility and high erosion has also been found in Makueni County. Maize yield is low compared to the national average. The average production of this zone is generally low, ranging from 300-1,200kg/ha, while the national average is 1,600kg/ha (Muhammad et al., 2010). Most farmers in this area still grow traditional seeds. However, some of them grow both traditional and improved seeds in the same season. The Duma and Pioneer Hybrid seeds are the most common improved maize varieties grown in the study areas. Few farmers grew newer improved varieties. Farming households experience food shortages regularly due to low yields. Farmers sell little, if any output, as most of the harvest is used for home-

[11] This zone includes the lower midland zone (800-1300 MASL) and upper midland zone (1300-1800 MALS). The two areas were included as part of the DTMA's medium drought-risk zone (20-40% probability of failed season) target area.
[12] CIMMYT's Drought Tolerant Maize for Africa (DTMA) project

consumption. The higher variation in rainfall is associated with the fluctuation in maize production in this area (Omoyo et al., 2015). The farmers' adoption of improved seed, including drought tolerant seed, is low, while the dis-adoption rates of the improved seed are high (Muhammad et al., 2010).

Machakos County has a population of 442,930 and a poverty rate[13] of 57%. The population in Makueni County is 253,316, and the poverty rate is 63.8% (Government of Kenya, 2013). These two counties encompass 368.57 thousand hectares of land and mainly consist of hills and small plateaus rising between 700 and 1700 meters above sea level (MASL). The mean elevation is 1,357 MASL in Machakos and 1,047 MASL in Makueni. The capital towns of both counties are less than 100km from Nairobi. The western part of the Machakos area is considered part of the greater Nairobi area. Off-farm employment is prevalent among men, leaving women to take the main responsibility of crop management. The two production seasons are from November to February, and from March to August. Total annual precipitation ranges from 500 to 1,300 mm, depending on altitude and other factors. The majority of farmers produce maize in both seasons, and the primary growing season in this area is associated with the November rains (Hassan, 1998). Jointly with FIPS, we identified two wards for our study. The first one is Kola, located in the southern part of Machakos County. The second one is Kee, located in the northern part of Makueni County. Kola ward has a population of 24,264; and the population of Kee is 20,926 (Government of Kenya, 2013).

3.3. Experimental Design

The local NGO, FIPS has been operating in Kenya for more than 10 years. They are interested in testing different ICT approaches in agricultural knowledge provision in the villages

[13] Defined as households subsisting on under $1.25 per day

where they already work and in villages where they want to expand their operations. They also seek to understand adoption of DT seeds. FIPS provided us with a list of 50 villages located at agro-ecological zones suitable to DT seed adoption and whose yields were greatly affected by recently drought, and which thus had potential demand for DT maize. FIPS was already working in 41 of these villages and planned to cover the remaining 9 villages in the near future, though, in these 9 villages, they had no activities before or during the time of our study. We sampled all 9 villages where they did not operate and randomly selected 18 out of 41 villages where they already operated. Then the 27 villages in our sampling framework were randomly assigned to one of three treatment conditions: eight villages were assigned to the video-only group, eight villages were assigned to the multichannel group, and 11 villages were assigned to the control group (see Table 1). FIPS also provided a list of households in each village. We randomly selected 30 households in each non-FIPS village and 17 households in each FIPS village to include in our study. As the non-FIPS villages are bigger than the FIPS villages, a higher number of households were selected in the non-FIPS village. Our final sample included 615 households in the baseline, and we were able to survey 581 households in the endline (see Table1).

3.4. Baseline Comparisons

In this section, I show that the randomization process delivered three similar groups: households in the video-only treatment, those in the multichannel treatment, and those in the control group. The baseline characteristics of those in the two treatment groups are compared with those in the control group with the following Ordinary Least Squares (OLS) Regression:

$$Y_i = \alpha_0 + \alpha_1 \, Video_i + \alpha_2 Multichannel_i + \mu_i \qquad (1)$$

Y_i is a characteristic of the ith household at baseline and μ_i is a zero-mean household-specific error term. The coefficients α_1 and α_2 provide estimates of the differences in Y_i of the video-only and the multichannel group relative to the control group, respectively. Additionally, we test whether α_1 and α_2 are statistically different to assess any imbalances between the multichannel and video-only groups. I test whether there are any differences between the video-only, multichannel and control groups along several dimensions, including gender of the household head, the number of people in the household, a livestock index (number of different livestock multiplied by their market values), main income sources (agriculture or non-agriculture), total land size, household distance to the nearest market selling seed, main maize grower's education level, and whether the household was located in a FIPS villages or in a non-FIPS villages.

Sample means of these variable for the video-only, the multichannel, and the control groups – as well as estimates for Equation (1) – are presented in Table 2. The sample is relatively well-balanced in terms of gender of the household head, characteristics of the main maize manager within a household (age, gender, and education), land size, distance to seed markets and trading centers, number of members within a household, wealth (livestock index) and mobile phone ownership. Three dimensions of the baseline comparisons are statistically significant at the 10% level or lower: (a) households in the multichannel group have a higher livestock index than the video-only group; (b) the number of household heads who have no formal education is significantly higher in the video-only group than it is in the multichannel group—though in total, farmers with no education constitute only 6.67% of the total sample; and (c) the proportion of households in the control group who reside in FIPS villages is significantly smaller than it is for both the video-only group and the multichannel group. This is because two non-FIPS villages which were supposed to be assigned to treatment groups were accidently assigned to the control group during the field work implementation (see Table 1). However, these differences are along the lines of what would be expected: out of 36 pairwise comparisons (i.e., three group comparisons along 12 variables), 11% are significant with a p-value of 10% or less. Overall, it does not seem that there are systematic differences between the three groups.

3.5. Empirical Estimation Strategy

The outcome variables we measure in this study include farmers' knowledge about DT maize and about the management practices. We measured knowledge by giving respondents an exam that tested whether they retained various details of DT maize and the complementary practices. This knowledge test has two parts: in the first part, I asked respondents to recall the names of the DT varieties they learned from the video. In the video, seven DT maize varieties that are suitable to the local conditions were mentioned. Therefore, the maximum knowledge score is seven points if we assume the farmers did not receive new information about names of varieties from sources other than the video and audio messages. Farmers earned one point every time they gave correct full name of a DT variety and half of a point for each DT maize name they could partially recall. Two questions were used to test respondents' knowledge about the complementary practices featured in the video. For each correct answer, , they earned one point. Other outcome variables are farmers' willingness to grow DT maize, which is measured both as a dichotomous variable indicating whether they plan to test DT maize or not and a continuous variable capturing the proportion of maize land on which they plan to grow DT maize. We asked farmers to report the total size of cultivated and fallow land their households used to cultivate maize. We then asked what maize varieties they planned to grow in the 2016 primary planting season, followed by size of the plots on which they intended to grow each variety. We added up the total size of plots on which they planned to grow DT maize, if any, in the primary season. If farmers planned to allocate any of their land to grow DT maize, we coded the dichotomous variable "1." If not, we coded it "0." In order to derive the land allocation measure, we divided the quantity of land that farmers planned to allocate to plant DT maize by their total farm size.

Throughout the analysis, I use the following definitions for treatment variables:

Video takes a value of 1 if a household is in a video-only treatment. It takes a value of 0 otherwise.

Multichannel takes a value of 1 if a household is in a multichannel treatment. It takes a value of 0 otherwise. The remaining households (i.e., those with Video=0 and Multichannel =0) are in control villages.

I calculate the impact of the two treatments by comparing households' endline knowledge about DT maize and management practice, and their uptake of DT. Namely, I estimate the following regression:

$$Y_i = \beta_0 + \beta_1\, Video_i + \beta_2 Multichannel_i + \boldsymbol{Z_i}\boldsymbol{\gamma} + \mathcal{E}_i \qquad (2)$$

where Y_i are outcomes including (1) level of knowledge about DT seed (2) knowledge about the complementary practices retained by household *i*, (3) farmers' willingness to plant DT maize, and (4) proportion of land farmers were willing to allocate to DT varieties. Further, we hypothesize that farmers in the multichannel group earned more knowledge and were more willing to grow DT maize than farmers in video-only group. Z_i is a vector of household-level controls, including gender of the household head, household size, a livestock index (number of different livestock multiplied by their market values), the main income sources (agriculture or non-agriculture), total land size, households' distance to the nearest market selling seed, the main maize grower's education level, and whether the households were located in a FIPS village. In this specification, the reference group is the control group. The identification of treatment effects relies on the assumption that the error term $\mathcal{E}_i$ is uncorrelated with the variables of interest, $Video_i$ *and* $Multichannel_i$. In our setting, this is plausible because the treatment was randomly assigned. Equation 2 is based on the original treatment assignment ($Video_i$ *and* $Multichannel_i$) – regardless of whether households actually watched the video or received audio messages – and provides an Intention-to-Treat (ITT) estimate of the intervention. Standard errors are clustered at the village level. Due to the small number of clusters in the study, we follow Cameron et al. (2008) and compute the standard errors using wild cluster bootstrap procedures.

Around half of the households in the video-only group attended the video screenings. In the multichannel group, one third of sampled households watched the video and received the audio messages. There are several reasons that can explain the relatively large number of non-compliers. The project only had resources to screen the video once in each village. Therefore, households did not have the opportunity to watch the video if they missed the scheduled screening in their village. In the multichannel group, we only sent the phone messages to those who attended the video screenings. We were not able to reach some households' phones, mainly because of technical issues, such as phones being turned off or having no reception.[14] None of these reasons seem to be correlated with households' observable characteristics and, overall, there is no reason to suspect that there would be any systematic differences between compliers and non-compliers. We compare the baseline characteristics of the compliers (i.e., those who attended the screening in the video treatment, and those who attended the screening and received the messages in the multichannel group) and non-compliers using Equation (1). There are significant differences between the compliers and non-compliers in two of these characteristics: (a) compliers are younger than the non-compliers, which suggests that younger farmers were more interested in attending the trainings than older farmers, and (b) the proportion of compliers are higher in the non-FIPS villages than in the

[14] The system tried to send the messages to households' phone up to six times within three days.

FIPS villages. We speculate that farmers in the non-FIPS villages appreciated the trainings more than the farmers in the FIPS villages because they rarely receive them. However, these differences are along the lines of what would be expected: out of 24 pairwise comparisons (i.e., two group comparisons along 12 variables), 8% are significant with a p-value of 10% or less. Overall, it does not seem that there are systematic differences between the compliers and non-compliers (see Table 3).

As I do not find major differences between compliers and non-compliers, we can estimate Local Average Treatment Effects (LATE) using the treatment assignments as instruments for compliance. In particular, I estimate the following system of equations:

$$Y_i = \varphi_0 + \varphi_1 video_i + \varphi_2 multichannel_i + \boldsymbol{X_i \theta} + \varepsilon_i \qquad (3)$$

$$Watch_i = \delta_0 + \delta_1 video_i + \delta_2 multichannel_i + \boldsymbol{X_i \rho} + \omega_i \qquad (3a)$$

$$ReceiveWatch_i = \lambda_0 + \lambda_1 multichannel_i + \lambda_2 video_i + \boldsymbol{X_i \sigma} + \eta_i \qquad (3b)$$

where $Watch_i$ and $ReceiveWatch_i$ are indicator variables for whether the households are compliers in the video-only group and in the multichannel group, respectively, and Y_i is a vector of outcome variables, including knowledge about DT seed, knowledge about the practices and the uptake of DT, and φ_1 and φ_2 are the LATE estimates on those who are compliers in the two assigned treatment groups.

We designed the interventions to assess whether communication strategies providing information about the new DT seed and the complementary practices can increase households' knowledge and uptake of DT maize. However, we are also interested in investigating if the treatment effects are relatively homogeneous between households who live in the FIPS villages and those who do not. In other words, we intend to test whether the treatments can be a stand-alone approach that increases farmers' knowledge and willingness to grow the DT maize. Farmers in FIPS and non-FIPS villages can be different in diverse ways. For example, FIPS, through their village-based advisors (VBAs), provides trainings and demonstrations, distributes free sample seed, and sells inputs. FIPS trains their VBAs on new maize varieties and complementary practices. Some VBAs manage a small demonstration plot in the villages and organize "baraza," (community meetings) to distribute sample seed, including DT maize seed. Moreover, these advisors work as small agro-dealers who supply inputs, such as DT seed, and provide management advice based on farmers' requests. Farmers in the non-FIPS villages do not receive these services. Therefore, in the FIPS villages, the interventions are not the only information sources relating to DT maize. I test for the presence of FIPS effects within the treatment groups by comparing the outcome variables of households in FIPS villages with those of households in the non-FIPS villages. We expected that households in FIPS villages would receive services from FIPS in addition to the interventions in the treatment groups. Therefore, farmers in FIPS villages could gain more knowledge about DT maize and be more willing to grow it.

I estimate the following variation of Equation (4) to calculate the ITT effect on households who resided in FIPS village versus those who did not:

$$Y_{ij} = \beta_1\, Video_{ij} + \beta_2 Multichannel_{ij} + \beta_3 Video_{ij}\, W_j + \beta_4 Multichannel_{ij}\, W_j + \beta_5 W_j + \gamma\, Z_{ij} + \mu_{ij} \qquad (4)$$

where W_j is NGO status (i.e., live in an FIPS village and lived in a non-FIPS village).

CHAPTER 4. RESULTS

In this section, we present the impact of the treatments on farmers' level of knowledge about DT maize and the management practices, on the probability of purchasing improved maize seed, and on farmers' willingness to plant the varieties in the next primary growing season. We also present results of heterogeneous treatment effects between farmers who are with the FIPS services and those who are not.

4.1. The Effect of Treatments on Knowledge about DT Maize and Management Practices

Results of the treatments effects on respondents' knowledge about DT seed and the management practices are reported in Table 4. We used two outcome variables to measure farmers' knowledge: (1) a continuous variable measuring farmers' knowledge about DT maize with a range from 0 to 6 in increments of 0.5, and (2) a continuous variable measuring farmers' knowledge about the management practices with range from 0 to 11 in increments of 1. Estimates of the impacts of the treatments on farmers' knowledge about DT seed are in columns 1-4, on their knowledge about proper ways to apply fertilizer are in columns 5-8, and on their knowledge of the recommended amount of fertilizer are in columns 9-12. Knowledge measurement of these two practices are included because they were featured in the video and reinforced in the audio messages. Therefore, these measurements can indicate the impact of reminders on households' knowledge about the practices. Columns (1), (2), (5), (6), (9) and (10) in Table 4 show ITT effects of treatments. Columns (3), (4), (7), (8), (11), (12) show the LATE estimation of treatment effects, which I will discuss below.

As shown in column (1), on average, farmers in the multichannel group earned knowledge score of DT maize that was 0.72 points, or 34.5% higher than those in the control group. These differences are statistically significant. Farmers in the video-only group earned nearly the same knowledge score as the control group, and the difference is not statistically significant.. Although the percentage differences of knowledge about DT maize between treatment groups is relatively high, the actual difference is relatively small. This is because farmers in the control group, which we used as the reference to compare with farmers in the treatment groups, retained a substantially lower level of knowledge about DT maize. For example, only one third of farmers could recall one or more varieties of DT maize. This fact should be considered when interpreting the differences of knowledge about DT maize.

Since some farms in the treatment groups did not comply with the intervention, we used the random assignment of the treatments as instrumental variables for compliance. The compliance rate in the video treatment is 47.8%, and the compliance rate in the multichannel group is 37%. The results in Table 4, column (3) suggest that there were sizeable impacts of the multichannel treatment on farmers' level of knowledge on DT seed and the complementary practices if the farmers received the treatment. Column (3) shows that farmers who received both the video and four audio messages earned knowledge scores on DT that were 94.5% higher than farmers in the control group and 86.7% higher than farmers in the video-only group. Both differences are statistically significant.

However, the difference in knowledge on the two management practices[15] between the multichannel group and the control group is not statistically significant, regardless of the estimation strategies. Column (5) in Table 4 shows the ITT estimation on the probability of giving correct answers to questions about the methods of fertilizer application among those in the multichannel group. We find an ITT effect of 13 percentage points in the multichannel group, and an ITT effect

[15] Households' knowledge score on the proper ways of applying the fertilizer and the recommended amount of fertilizer are binary variables and take a value of 1 if household *i* gives correct answers to the knowledge test questions and 0 otherwise. I used a linear probability model to estimate the effects on these variables. However, the coefficients estimated by the linear probability model are quantitatively similar to those from the Probit model. .

of 6 percentage points in the video-only group. Column (9) in the same table shows that the ITT estimation of the impact of the two treatments on household *i*'s knowledge about the recommended quantity of fertilizer is close to zero.

These results indicate that the multichannel treatment can significantly increase households' knowledge about DT maize seed compared with the control. Although the video-only approach increased farmers' knowledge, the difference in the score between farmers in the treatment group and those in the control group is not statistically significant. Reminders about the management practices sent out to the multichannel treatment group did not improve households' knowledge about the two fertilizer application practices as much as they did knowledge about DT maize.

4.2. The Effect of Treatment on Willingness to Grow DT maize

Farmers' willingness to grow DT maize is modeled as a function of the treatment conditions and households' socio-economic characteristics, which include the same variables as in the regressions of knowledge scores and a new variable that measures households' uptake of DT maize in the 2016 first planting season. Due to the project schedule, the endline was collected in September 2016. Therefore, I use it as a proxy to measure households' uptake of DT.

We used two outcome variables to measure farmers' willingness to grow DT maize in the next primary season: (1) a dichotomous variable measuring whether farmers planned to grow the varieties in the next primary season or not, and (2) a continuous variable ranging from 0 to 1 measuring the proportion of land farmers were willing to allocate to grow DT maize. Regression results from analysis using the dichotomous variable are presented in Table 5, while results from using the continuous outcome variable are similar and are thus excluded.

Columns 1 and 2 in Table 5 show that the multichannel treatment had a positive and significant impact on farmers' intention to plant DT maize in the next primary planting season. Farmers in the multichannel group were more likely to plant DT maize than the farmers in the control and in the video-only groups. The ITT estimation shows that farmers in the multichannel treatment were 14 percentage points more willing to test DT maize than were those in the control group. This difference is statistically significant at 10% level. The video-only treatment had a positive but insignificant impact on farmers' willingness to test DT maize. It increased the willingness to plant DT maize by 3 percentage points. The LATE estimation reported by column 3 and 4 in Table 5 suggests that the multichannel treatment increased the willingness of uptake by 38 percentage points, and the video-only treatment increased it by 7 percentage points.

This finding shows that the multichannel treatment increases farmers' knowledge about DT seed and that it helps to reinforce farmers' knowledge about complementary practices and increases their willingness to try DT seed, relative to farmers in the control group and in the video-only group. This multichannel treatment helps to reinforce farmers' knowledge about DT maize and effectively bring their attention to the new varieties of maize seed. These reminders appear to be positively associated with farmers' willingness to try the seed.

4.3. Differential Impacts of the Interventions

The treatment effects were relatively heterogeneous between households who live in the FIPS villages and those who do not. Table 6

shows the ITT effects of both treatments on households' knowledge and potential adoption of DT seed by these households' NGO status. My results show that the impact of the intervention was mostly driven by households living in FIPS villages. Households who live in FIPS villages and were assigned to one of the two treatments gained higher knowledge scores on DT maize than did households who received the treatments but live in non-FIPS villages. Households who were assigned to the multichannel treatment group and live in FIPS villages retained a 47.3% higher knowledge score on DT seed than households in the control group without the FIPS' services. This difference is statistically significant at 1% level. Households living in FIPS villages that were in the video treatment retained 27.3% higher knowledge scores on DT than did households in the control group. This difference is not statistically significant.

Households in both the video-only group and the multichannel group had a higher willingness to plant DT maize in the next primary season if they live in FIPS villages than their counterparts who received the same treatments and live in villages with no service from FIPS. Relative to the control group, the multichannel treatment increased the probability of uptake by 20 percentage points when a household lived in a FIPS-supported village, and the video-only treatment increased the willingness to plant DT by 13 percentage points if a household resided in a FIPS-supported village. Both impacts are statistically significant at 5% level. FIPS distributes free sample DT maize seed to farmers, and VBAs sell seed to communities and provide trainings and demonstrations about DT maize and modern management practices, so households in FIPS villages have better access to DT seed and related information than do households in non-FIPS villages. We speculate these makes the uptake more likely.

To conclude, we found that farmers in the multichannel group retained more knowledge about DT maize and the management practices, and they were more willing to grow DT maize in the next primary season than the farmers in the video-only group and the control group. Moreover, FIPS, the local NGO, increases availability of seed and provides services that advise farmers about management practices, and these follow-up activities enhance the multichannel treatment effects.

CHAPTER 5. DISCUSSION AND CONCLUSION

I examined the effect of participatory videos and audio message reminders in enhancing farmers' knowledge about DT maize and complementary practices and their willingness to grow DT maize. This study finds that timely audio messages reinforced the video training content and reminded farmers about the management practices based on the maize growing stages. The multichannel treatment that included both video and audio reminders was more effective than the video-only treatment in communicating relatively complex agricultural technologies with multiple steps. The video content provided local context of the technical messages that enable farmers to understand the benefits of the new varieties and the management practices. The demonstration in the video also provided visual guidelines to farmers about steps to plant and manage DT maize. Moreover, the short audio messages that were sent out prior to key decision-making points in the growing season reminded farmers about the management practices at proper times. For example, two audio messages reminded farmers of the need to engage in fertilizer micro-dosing more than a month after the video screenings, a topic the farmers learned about and viewed during the video screening. Hence, one explanation for the heightened effectiveness of the multichannel treatment is that the audio messages reminded farmers of the video content at appropriate times over a relatively long growing season. Further, although we did not include a group that received audio reminders only, we speculate that the impact of a reminders-only approach would be less than the synergy created by the multichannel strategy tested in this study.

If the above interpretation is correct, it has a number of implications for the external validity of these findings. The findings provide insights for the design of ICT strategies aimed at communicating knowledge to farmers about new agricultural technologies and practices. These insights include selection and the arrangement of ICTs and other agricultural extension approaches within a strategy to create a synergy. Moreover, how best to design these strategies is based on farmers' cognitive abilities and local context.

Farmers commonly need to understand multiple steps and various components in order to adopt new agricultural technologies. Therefore, they need consistent information and coaching to learn and to reinforce the new knowledge. For example, Digital Green, an Indian NGO discussed in the literature review, has developed the participatory video training approach, which has been adopted by various organizations in India to provide information to farmers. The success of this approach depends on a substantial number of skilled frontline extension workers who consistently work with communities to help them learn from the training videos and resolve issues that impede adoption. However, in the majority of Sub Saharan African countries (including our study area), training videos are normally only shown to a community once, due to the lack of video playing devices and proficient personnel to handle these devices and to moderate screening sessions. Further, due to a deficiency of skilled extension workers and other training resources in the majority of Sub Saharan African countries, extension workers are not able to provide frequent follow-up to enhance farmers' knowledge about a technology after the video screening. The multichannel strategy we tested in this study creates a synergy between various ICT extension approaches to provide farmers contextualized information using the video approach. Without engaging with extension workers, the audio messages remind farmers about the content of the video before key decision points in the maize growing season. Therefore, the audio reminders in this study enhanced the video approach based on the local context to compensate for the deficiencies of knowledge reinforcement after the video screening.

The importance of the reminders has become more widely recognized by scholars and practitioners because of its impact on the reinforcement of knowledge and capacity for nudging behavior in areas such as agricultural production. In our study, we found that the reminders improved farmers' knowledge about DT maize seed and the management practices and increased farmers' willingness to grow the DT maize after the video screenings. This finding corroborates the conclusion by Larochelle et al. (2016) in Northern Ecuador that reminders could reduce inattention, especially when farmers need to make complex decisions. The result of this study suggests that tailored reminders sent out before decision-making points to encourage farmers' specific behavior are effective, a suggestion similarly made by Cole & Fernando (2012).

Although this study area has more than a 90% mobile phone subscription rate, we experienced several challenges in delivering the audio mobile phone reminders to farmers. We delivered the audio messages by making automated phone calls with an audio recordings in the local language. This is different from studies (e.g., Larochelle et al. 2016) that sending SMS to farmers because previous research among rural farmers in Kenya had found low mobile phone literacy and limited ability to read SMS among this population (Wyche & Steinfield 2016). Despite our use of audio recordings, however, we still encountered difficulties in getting messages delivered. The main challenges we faced were network failures and phone numbers that were not functioning. Additionally, in the focus group discussions, some farmers told us that they did not pick up the calls because they were busy and did not expect to receive the messages. We suggest that in any future attempts to use this approach, hints should be sent to farmers prior to sending out the messages to inform farmers about the scheduled call. It is also possible to convert from a "push" strategy to a "pull" strategy, where farmers can trigger a system to send the messages based on their demand. Lastly, although we found some farmers were able to recall the content in the audio messages, it was impossible for them to revisit these audio messages when they wished. Therefore, it would be useful to provide a means of allowing farmers to re-listen to the messages or to provide information in a reviewable form such as in a handout containing the information in the audio messages.

A number of other limitations should be kept in mind when interpreting our results and planning for future studies. Due to resource constraints, this study is not able to measure farmers' actual uptake of DT maize and the management practices in their primary growing season. Future studies should plan a longer-term assessment of this multichannel approach to understand its impact on farmers' knowledge and uptake over time. Further, this current study design does not include a treatment which only sends out audio reminders without videos. Future studies can incorporate this treatment to understand the marginal impact of the participatory videos on farmers' knowledge and uptake of agricultural innovation in this multichannel approach. More studies should focus on investigating what types of reminders are more likely to work and when to send them to farmers, and how to design different multichannel approaches that can match the characteristics of various agricultural innovations, as well as farmers' needs and cognitive capacity.

APPENDICES

APPENDIX 1. QUESTIONNAIRE: FARMERS' KNOWLEDGE REGARDING IMPROVED MAIZE SEED AND MANAGEMENT PRACTICES

How many Drought Tolerant varieties are you aware of? Ni mithemba yiana ya mbeu wisi ila itonya kumiisya

sua? _____varieties *(if never heard, put "0", skip E.3)*

1. Please name all of the Drought Tolerant varieties that you know (Kwa ndaia ndavya mtihemba yonthe ya mbeu ila wisi itonya kumiisya sua ___. (*Enumerator*: *Write down all the names the farmers can remember, remember to include all numbers and letters)*

IF A15=1 OR A22=1 *[Enumerator: this is the instruction for the farmers who watched the video] Now I'm going to ask you how much you know about ways of growing maize showed in the video and the audio messages*

IF A15=2 AND A22=2 *[Enumerator: this is the instruction for the farmers who did not watch video]*

Now I'm going to ask you how much you know about ways of growing maize recommended by extension workers or experters from NGOs. You can also just tell us good ways you know about growing maize

2. How many seeds to plant per planting hole? Ni mbeke syiana sya kuvanda kwa kila yiima? ________seed(s)
3. What is the distance between each hole within a row? Utaaniu wa yiima na yingi mustalini wiana ata? ______ (feet)
4. What is the distance between each row? Utaaniu wa mustalli na ungi wiana ata?______ (unit_____ feet)
5. How many times fertilizer is applied during a growing season? Ni mavinda meana vatalisa wikiawa ivindani yila liu ukwiana? ______times *(if farmers think no need to apply, write "0")*
6. What is the method to apply fertilizer during planting ? IS IT READ OPTION Mwikiile wa atalisa ni wiva? [enumerator: read options]

a. mix the fertiliser and the seed <u>together</u> (ikia vatalisa mbekeni) (yes/ no)

b. Separate the seeds from the fertliser when applying fertilizer (ikia vatalisa utee wa mbeke) (yes/ no)

7. Do you need to cover the fertilizer you applied with soil? Niwailite kuvwika vatalisa ula weekia na muthanga?

   a. yes (yii) b. no (Aiee)

8. How much fertilizer is applied? Ni vatalisa wiana ata wikiawa? <u>(visual aid4)</u>

   a. Less than half a bottle top
   b. half a bottle top
   c. One a bottle top
   d. Two bottle tops
   e. Two or more bottle top
   f. Don't know

9. When is the time to do the first fertilizer application? Ni ivinda yiva yailite kwikia vatalisa yambee?
   a. during planting (yila unuuvanda)
   b. when maize is germinated (yila mbemba yamea)
   c. 1-2 weeks after maize is germinated (katikati wa kyumwa 1-2 kana itna wa mbemba kumea)
   d. 3-4 weeks after maize is germinated(katikati wa kyumwa kya 3-4 itina wa mbemba kumea)
   e. more than a month after maize is germinated
   f. Don't know

10. When is the time to do the second fertilizer application? Ni indii yila vailite kwikia vatalisa yakeli?
   a. during planting(yila unuuvanda
   b. when maize is germinated(yila mbemba yamea
   c. 1-2 weeks after maize is germinated (katikati wa kyumwa kya katatu na kya kana itina wa mbemba kumea)
   d. 3-4 weeks after maize is germinated (katikati wa kyumwa kya thanthatu na muonza itina wa mbemba kumea)
   e. more than a month after maize is germinated
   f. Don't know

11. How many times crops are weeded? Liu uimiawa keana? ________times

APPENDIX 2. FIGURES AND TABLES

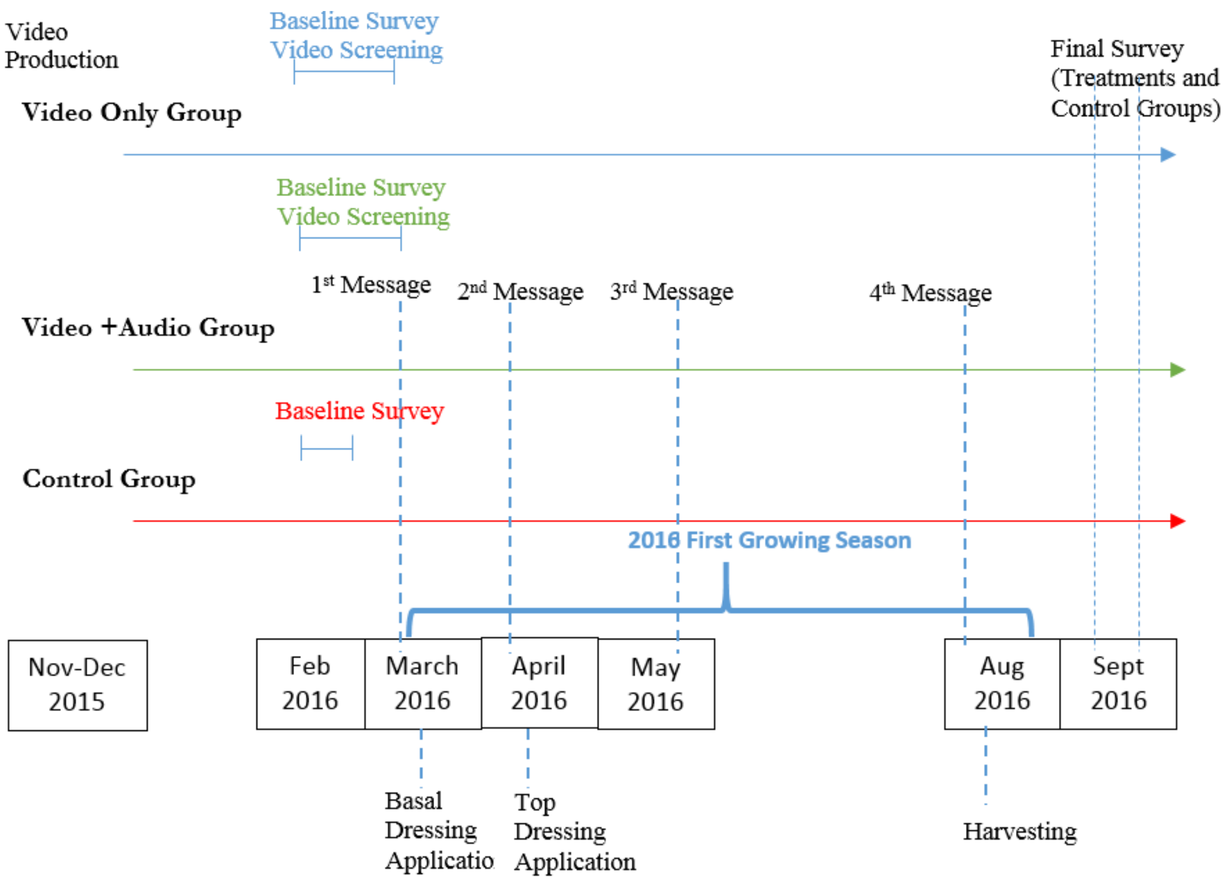

Figure 1. Timeline of the Study

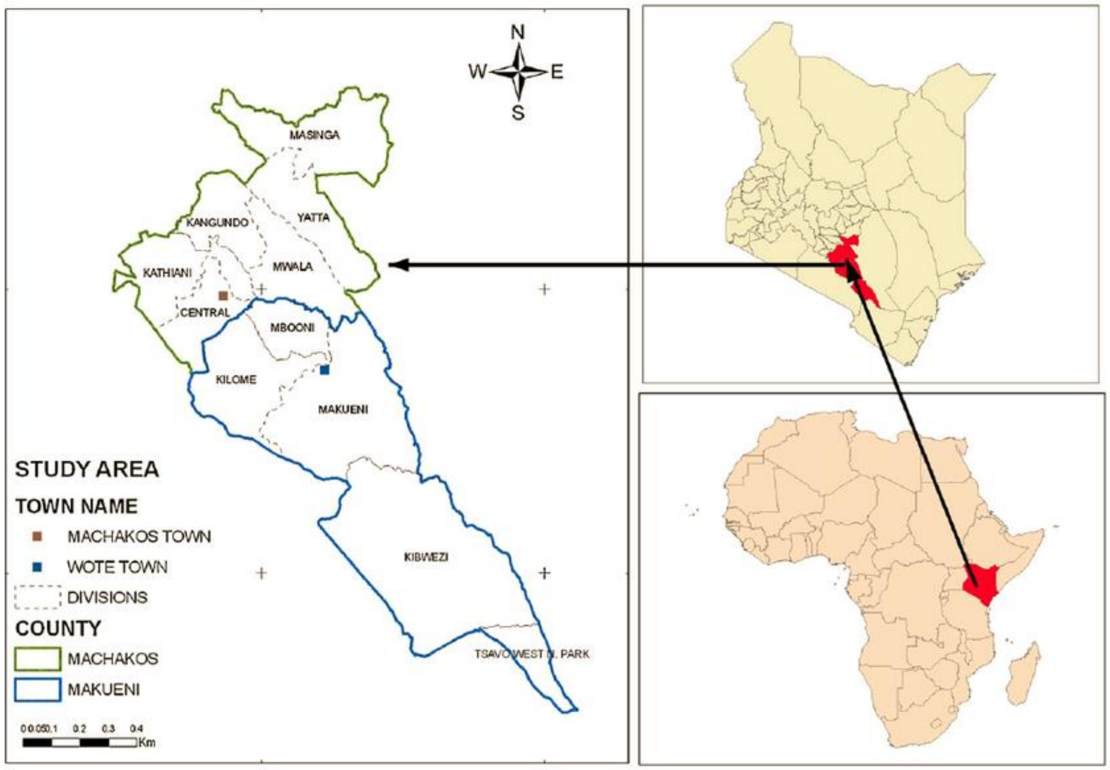

Figure 2. The Study Area

Table 1: Experimental Design

	Treatments	Number of villages (original assignment)	Number of villages (final assignment)	Number of households at the baseline	Number of household in the post test
FIPS	Video only	6	6	104	97
	Multichannel	6	6	102	99
	Control	6	6	100	100
Non-FIPS	Video only	3	2	68	64
	Multichannel	3	2	67	63
	Control	3	5	169	159

Table 2: Household Characteristics in Baseline by Treatment Groups

	Overall Mean	Control	Video	Multichannel	Mean Differences		
		(C)	(V)	(M)	(C)-(V)	(C)-(M)	(V)-(M)
Age of household head	49.9	48.464	51.017	50.686	-2.554	-2.223	0.331
	(15.97)	(0.91)	(1.31)	(1.29)	(1.55)	(1.54)	(1.83)
Number of household members ages 15-65	3.11	3.117	3.174	3.036	-0.058	0.081	0.139
	(1.7)	(0.10)	(0.13)	(0.13)	(0.17)	(0.16)	(0.19)
Number of household members	5.481	5.595	5.401	5.379	0.194	0.216	0.022
	(2.64)	(0.16)	(0.21)	(0.20)	(0.26)	(0.25)	(0.29)
Household's distance to nearest market selling seed (km?)	6.791	9.02	8.1	7.56	0.92	1.46	0.54
	(8.00)	(0.67)	(0.77)	(0.62)	(1.04)	(0.98)	(0.99)
Household's distance to nearest trading center (km?)	6.783	6.34	6.827	7.486	-0.488	-1.146	-0.658
	(8.05)	(0.43)	(0.58)	(0.75)	(0.71)	(0.80)	(0.94)
Landholdings (acres)	3.27	3.769	3.619	4.195	0.151	-0.425	-0.576
	(2.67)	(0.27)	(0.30)	(0.45)	(0.41)	(0.49)	(0.54)
Livestock index	177.78	176.394	157.483	198.852	18.912	-22.458	-41.37*
	(170.04)	(10.02)	(12.54)	(13.77)	(16.09)	(16.73)	(18.62)
Female headed household (1=yes)	0.236	0.212	0.297	0.201	-0.085	0.01	0.095
	-	(0.03)	(0.04)	(0.03)	(0.04)	(0.04)	(0.05)
Own mobile phone (1=yes)	0.929	0.964	0.936	0.964	0.027	-0.001	-0.028
	-	(0.01)	(0.02)	(0.01)	(0.02)	(0.02)	(0.02)
Household head with no formal education (1=yes)	0.067	0.055	0.116	0.036	-0.062**	0.019	0.081**
	-	(0.01)	(0.03)	(0.01)	(0.03)	(0.02)	(0.03)
Household head with secondary education or higher (1=yes)	0.020	0.168	0.174	0.136	-0.007	0.032	0.038
	-	(0.02)	(0.03)	(0.03)	(0.04)	(0.04)	(0.04)
Household in FIPS village (1=yes)	0.506	0.386	0.64	0.515	-0.254***	-0.129***	0.125
	-	(0.03)	(0.04)	(0.04)	(0.05)	(0.05)	(0.05)
N	615	274	172	169	446	443	341

Note [1]. For the first three columns, the means and standard deviations of each variable in the control, video-only and multichannel groups are reported. In the last three columns, the differences were calculated using the following regression: $Y_i = \alpha_1 \; Video_i + \alpha_2 Multichannle_i + \mu_i$. .

Standard errors clustered at the village level (right?) and in parentheses below. Significance levels of the differences between the two treatment groups and control group denoted by *** 99%, ** 95%, * 90%.

Table 3: Household Characteristics in Baseline by Compliance with Treatments

	Non- Complier	Complier	Mean Difference
Age of household head	51.737	49.041	2.696*
	(1.31)	(0.75)	(1.42)
Number of household members ages 15-65	3.07	3.139	-0.069
	(0.13)	(0.08)	(0.15)
Number of household members	5.301	5.59	-0.289
	(0.20)	(0.13)	(0.24)
Household's distance to nearest market selling seed (km?)	7.27	6.589	0.682
	(0.66)	(0.37)	(0.71)
Household's distance to trading center (km?)	7.269	6.57	0.699
	(0.66)	(0.38)	(0.71)
Landholdings (acres)	4.189	3.706	0.483
	(0.43)	(0.21)	(0.43)
Livestock index	181.43	176.056	5.374
	(12.56)	(8.54)	(15.13)
Female headed household (1=yes)	0.247	0.23	0.017
	(0.03)	(0.02)	(0.04)
Own mobile phone (1=yes)	0.941	0.965	-0.024
	(0.02)	(0.01)	(0.02)
Household head with no formal education (1=yes)	0.081	0.058	0.022
	(0.02)	(0.01)	(0.02)
Household with secondary education or higher (1=yes)	0.129	0.175	-0.046
	(0.03)	(0.02)	(0.03)
Household in FIPS village (1=yes)	0.602	0.466	0.136*
	(0.04)	(0.03)	(0.04)
N	186	395	581

Note: The second column reports the means and standard deviations of each variable among farmers who did not received the treatments in the treatment villages and those who received the treatment in the control villages (Non-Compliers). The third column reports who received the treatments in the treatment villages and who did not receive the treatment in the control (compliers), . In the last column, the differences were calculated using the following regression: $Y_i = \alpha_1 \text{ Complier}_i + \mu_i$.
Standard errors clustered at the village level and in parentheses below. Significance levels of the differences between the two treatment groups and control group denoted by *** 99%, ** 95%, * 90%.

Table 4: Knowledge Scores Regression by Treatment Groups[1]

	Knowledge on DT [4]				Knowledge on fertilizer application [4]				Knowledge on fertilizer quantity [4]			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Video only (1)	0.02	0.02			0.06	0.05			0.004	0.01		
	(0.09)	(0.09)			(0.13)	(0.18)			(0.003)	(0.02)		
Multichannel (2)	0.19	0.14			0.13	0.12			0.02	0.02		
	(0.10)*	(0.09)			(0.17)	(0.28)			(0.04)	(0.07)		
Video Complier			0.05	0.02			0.12	0.11			0.01	0.03
			(0.21)	(0.16)			(0.12)	(0.11)			(0.08)	(0.07)
Multichannel Complier			0.52	0.40			0.36	0.32			0.06	0.06
			(0.25)**	(0.24)*			(0.25)	(0.25)			(0.16)	(0.15)
Additional baseline controls [2]	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y
Observations	582	582	582	582	582	582	582	582	582	582	582	582
Control Mean	0.55	0.55	0.55	0.55	0.35	0.35	0.35	0.35	0.22	0.22	0.22	0.22
Share of compliers in the video-only group [3]			0.48	0.48			0.48	0.48			0.48	0.48
			(0.02)	(0.02)			(0.02)	(0.02)			(0.02)	(0.02)
Share of compliers in the multichannel group [3]			0.37	0.37			0.37	0.37			0.37	0.37
			(0.04)	(0.04)			(0.04)	(0.04)			(0.04)	(0.04)
P-values for Video only = Multichannel	0.17	0.28	0.13	0.14	0.30	0.39	0.36	0.39	0.93	0.91	0.73	0.82

Note [1.] Columns 1, 2, 5, 6, 9 & 10 report the ITT estimate of the interventions. Columns 3, 4, 7, 8, 11 & 12 report the Average Treatment Effect or Local Average Treatment Effect (LATE) estimates using the treatment assignment as an instrument for the compliers in each treatment condition.

[2.] Additional baseline controls in columns 2, 4, 6, 8, 10 & 12 include gender of household head, number of people in the household, livestock index, main income sources (agriculture or non-agriculture), total land size, household distance to the nearest market selling seed main maize, grower's education level, and whether the household was located in a FIPS village

[3.] Indicator variable for whether the households in the two treatment conditions participated in the interventions. For the multichannel condition, households both watched the video and received the phone messages. The results are the first stage of the Instrumental Variable Regression (following equation 3)

[4.] The range of the knowledge on DT is 0-6 in increments of 0.5. The knowledge measurement of two practices is binomial and take the value of 1 if household *i* gives correct answers to the knowledge test questions and 0 otherwise.

[5.] The standard errors of the ITT coefficients are estimated by using the Wild Cluster Bootstrap (Cameron et al., 2008).

Standard errors clustered at the village level and in parentheses below. Significance levels of the differences between the two treatment conditions and control conditions denoted by *** 99%, ** 95%, * 90%.

Table 5: Households' Intention to Grow DT Maize in the Next Season by Treatment Groups[3]

	(1) [2]	(2)	(3) [2]	(4)
Video (1)	0.03	-0.01		
	(0.06)[4]	(0.04)		
Multichannel (2)	0.14	0.10		
	(0.08)**	(0.05)*		
Video Complier			0.07	-0.02
			(0.14)	(0.09)
Multichannel Complier			0.38	0.28
			(0.18)**	(0.13)**
Share of compliers in the video group [5]			0.48	0.48
			(0.02)	(0.02)
Share of compliers in the multichannel group [5]			0.37	0.37
			(0.04)	(0.04)
Additional baseline controls [1]	N	Y	N	Y
Observations	582	582	582	582
Control Mean	0.37	0.37	0.37	0.37
P-values for Video only = Multichannel	0.140	0.061	0.107	0.017

Note [1]. Additional baseline controls in columns 2 & 4 include gender of household head, number of people in the household, livestock index, main income sources (agriculture or non-agriculture), total land size, household distance to the nearest market selling seed, current year's uptake of DT maize and main maize grower's education level.
[2]. Columns 1 & 2 report the ITT estimate of the interventions. Columns 3 & 4 report the Average Treatment Effect or Local Average Treatment Effects (LATE) estimates using the treatment assignment as an instrument for the compliers in each treatment condition.
[3]. These analyses are based on a linear specification; note that other non-linear models— such as random effects Probits— yield similar coefficient magnitudes (not reported).
[4]. The standard errors of the ITT coefficients are estimated by using the Wild Cluster Bootstrap (Cameron et al., 2008).
[5]. Indicator variable for whether households in the two treatment conditions participated in the interventions. For the multichannel condition, households both watched the video and received the phone messages. The results are the first stage of the Instrumental Variable Regression (following equation 3)

Standard errors clustered at the village level and in parentheses below. Significance levels of the differences between the two treatment conditions and control conditions denoted by *** 99%, ** 95%, * 90%.

Table 6: Differential Impacts of the Treatment on Knowledge about DT maize by NGO Status[1]

	Knowledge about DT [2, 3]				Willingness to try [3]	
	(1) [4]	(2)	(3)	(4)	(5) [4]	(6)
Video (β_1)	-0.17	-0.13			-0.12	-0.11
	(0.22)	(0.19)			(0.05)*	(0.06)*
Multichannel (β_2)	0.09	0.06			0.05	0.02
	(0.17)	(0.12)			(0.06)	(0.05)
Video treatment x FIPS (β_3)	0.32	0.27			0.24	0.23
	(0.23)	(0.20)			(0.08)***	(0.09)**
Multichannel treatment x FIPS (β_4)	0.16	0.16			0.15	0.17
	(0.24)	(0.21)			(0.11)	(0.11)*
Video Complier (β_5)			-0.30	-0.24		
			(0.20)	(0.19)		
Multichannel Complier (β_6)			0.34	0.23		
			(0.69)	(0.55)		
Video Complier x FIPS (β_7)			0.65	0.56		
			(0.33)*	(0.29)*		
Multichannel Complier x FIPS (β_8)			0.25	0.30		
			(0.73)	(0.60)		
Combination of coefficients						
$\beta_1 + \beta_3$	0.15	0.16			0.13	0.12
	(0.12)	(0.10)			(0.06)**	(0.07)*
$\beta_2 + \beta_4$	0.26	0.25			0.20	0.19
	(0.08)***	(0.90)***			(0.09)**	(0.09)**
$\beta_5 + \beta_7$ [5]			0.35	0.32		
			(0.24)	(0.23)		
$\beta_6 + \beta_8$ [5]			0.59	0.52		
			(0.22)***	(0.22)***		
Additional baseline controls	N	Y	N	Y	N	Y
Observations	582	582	582	582	582	582
Control Mean	0.55	0.55	0.55	0.55	0.37	0.37

Note [1]. Additional baseline controls in columns 2, 4 & 6 include gender of household head, number of people in household, livestock index, main income sources (agriculture or non-agriculture), total land size, household distance to the nearest market selling seed and main maize grower's education level.

[2]. The range of the knowledge about DT maize is 0-6 in increments of 0.5.

[3]. The coefficients are estimated in the regression $Y_i = \beta_1 Video_i + \beta_2 Multichannle_i + \beta_3 Video_i W_i + \beta_4 Multichannle_i W_i + \gamma Z_i + \mu_i$ where W_i is a binary variable that indicates whether household is in a FIPS or non-FIPS village. We use the treatment assignments and their interaction with W_i as instruments.

[4]. Columns 1-4 present the impact of the treatments on knowledge about DT: 1 & 2 use the ITT estimation and 3 & 4 use the LATE estimation. Columns 5 & 6 present the impact of the treatments on willingness to grow DT.

[5]. Indicator variable for households who received the interventions. For the multichannel condition, households both watched the video and received the phone messages. The results are the first stage of the Instrumental Variable Regression (following equation 3).

Standard errors clustered at the village level and in parentheses below. Significance levels of the differences between the two treatment conditions and control conditions denoted by *** 99%, ** 95%, * 90%.

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