Keeping Top-of-Mind: The Impact of Audio Phone Reminders on Kenya Farmers' Knowledge and Uptake of Drought Tolerant (DT) Maize

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Abstract

This study designs and tests two strategies of using information and communication technologies (ICTs) aiming to increase farmers' knowledge and uptake of DT maize. One is a locally-made video, or "participatory" video. Another is a multichannel method that incorporates the same video with timely mobile phone-based audio messages. We conducted a randomized 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, after implementing the interventions in the two sets of communities, farmers in the multichannel group demonstrated higher knowledge about DT maize and its accompanying management practices. They were more likely to report intending to plant DT maize in the next primary season. The effects of both treatments are mainly driven by farmers living in NGO-supported villages who have better access to DT maize seed and related information. 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' to gain knowledge about DT maize and encourage them to try these new seed varieties.

Introduction

Maize contributes forty-five percent of calories to people in Eastern and Southern Africa (ESA) and is a particularly important income source to the poor in this region [1](Shiferaw, 2011). In ESA, the majority of maize is completely rain-fed. Among the most pressing concerns are harvest failures and losses attributable to changing climate conditions, such as drought stress, which increases farmer vulnerability. Such changes affect food production directly through changes in agricultural productivity, and indirectly through reducing agricultural incomes (Fisher et al., 2015). The demand for maize is growing and relatively inelastic. At the current level of productivity growth, accelerating maize demand may exceed maize production in the near future (Shiferaw, 2011). In response to changing rain patterns and climate, scientists have been breeding improved seed, such as drought tolerant (DT) maize seed[2]. Hendrix & Glaser (2007) suggest that planting new varieties alongside improved management practices can reduce yield loss by up to 40%. However, the demand for drought-tolerant maize seed still falls far short of that necessitated by low yields and the productivity variation associated with changing climate conditions in ESA (Fisher et al., 2015). Moreover, farmers' profitability if they decide to grow DT maize 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 varieties to farmers include field demonstrations and field days organized by 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).

[1] Maize currently covers 25 million ha in sub-Saharan African producing 38 million metric tons (Smale et al., 2011)
[2] The Drought Tolerant Maize for Africa (DTMA) project has made release of 160 drought tolerant maize varieties between 2007 and 2013 disseminated to farmers in 13 African countries. In addition to drought tolerance, the varieties have other attractive traits, such as resistance to major disease and high protein content. Seed costs are same as other non-DT commercial varieties. DTMA project is led by International Improved Maize and Wheat Center.

This study assesses how different ICT-based extension approaches associate with farmers' knowledge about DT maize and its complementary practices. One approach is locally made, or "participatory," video that is utilized by extensions and NGOs in developing countries. Another approach is a multichannel method that incorporates the video with mobile phone-based audio messages. The video approach features farmers from the same or a similar community who have adopted DT seed. The video integrates both contextualized social and cultural cues and the technical information about DT varieties and modern practices. The contents entail technical information about DT seed, such as how to select varieties. The video also uses local farmers' narrative stories to inform audiences about the potential risks of growing DT and its risk management practices.

In the second approach, an audio system complements the information in the video by 'pushing' audio message reminders at the appropriate stage in the maize growing season. In total, we sent four messages: one before seed purchase, one before applying basal-dressing fertilizer, one before applying top-dressing fertilizer and one before harvesting. These audio messages are intended as reminders to reinforce the knowledge farmers learned in the video and to encourage adoption. Overall, we compared the marginal impacts of the video only approach with those of the multichannel approach to farmers' knowledge about the seed and management practices and their uptake of DT seed.

We study three research questions. We compare the treatment effects between a video-only group, a multichannel group and a control group. We first study whether farmers in the three groups have different levels of knowledge about DT varieties and about the management practices (RQ1). The second research question asks whether farmers' uptake of DT maize is different between experimental groups (RQ2). Moreover, a local NGO provides services related to DT maize in some villages sampled in the study. Therefore, this current study aims to understand the differential treatment impacts of NGO status on farmers' knowledge and uptake (RQ3). We conducted a study in Machakos and Makueni Counties, Kenya including 581 households to answer these research questions. We found that after implementing the interventions in the two sets of communities, farmers in the multichannel group demonstrated higher knowledge, both about DT maize and its accompanying management practices. They also were more likely to report intending to plant DT maize in the next primary season. Finally, these effects were strongest in those communities supported by an NGO extension provider. This study contributes to a greater understanding of farmers' learning and uptake of DT maize by providing a test of whether the provision of contextualized knowledge about DT maize and the timely reminders can help farmers gain knowledge about DT maize and encourage them to plant the seed.

Literature Review

Drought tolerant (DT) maize in Sub-Saharan Africa (SSA)

Studies have found that farmers use many different strategies to reduce the negative impacts of climate variability and change[3] to their maize production; switching crop varieties is an increasingly used method in this regard (Fisher & Snapp, 2014). Drought tolerant crops are going to play an increasingly important role in coping with climate change and variation (Kassie et al., 2014). Research institutes like International Wheat and Maize Research Institute (CIMMYT) and seed companies have been introducing Drought Tolerant varieties (DT)[4] to the ESA market for about a decade[5]. Between 2007 and 2013, 160 DT varieties were released to ESA market[6]. On-farm trials in ESA found that "DT maize varieties out-yield popular commercial checks by 82-127% (controlled drought), 26-47% (random drought), and 25-56% (optimal rainfall condition)[7]" (unpublished data from Tesdeke 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 lessen yield variability. The authors also speculated that the yield advantage between DT and local

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[3] Other methods include changing in planting date, switching crop species, crop diversification, and soil and water conservation

[4] The scientists used modern conventional method to breed DT. So 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 between 2006 to 2015 by the International Maize and Wheat Improvement Center (CIMMYT), International Institute for Tropical Agriculture (IITA) AND national research/extension institutions of 13 African countries.

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

[7] Maize under random drought condition receive approximately less than 600 mm rainfall per year and pests and diseases prone locations under rainfed conditions. Maize under optimal rainfall condition receive more than 750mm annum and a temperature range of 24-33 °C. Under managed drought condition, maize grow in the off season and the irrigation interval calculated based on the crop water balance (Setimela et al, 2017) Setimela et al. (2017) On-Farm Yield Gains with Streess-Tolerant Maize in Eastern and Southern Africa. Agronomy Journal Volumn 109, Issue 2.

varieties could be greater when there is a drought. However, the impact of these new DT varieties depends on farmers' level of adoption and their ability to profit from growing them.

We still know little about how farmers adopt DT maize and whether they can profit from growing it, especially because farmers commonly apply deficient amounts of input like fertilizer and labor and use inadequate management practices (e.g. Tambo & Abdoulaye, 2011). Farmers have experienced difficulties accessing new drought tolerant varieties mainly because the seed market is not well established in ESA, and farmers lack access to the seed in areas where no government intervention or development projects directly distribute DT seeds to farmers (Fisher et al., 2015). For example, in Malawi, farmers have mainly received their seed from development projects. Fisher et al. (2015) found that in six ESA countries, older farmers, farmers with less land, and farmers who had less exposure to information about DT maize were less likely to try DT seed. Although their study does not include data collected in Kenya, the results reflect the farmers' perception and adoption status in the ESA area. Fisher et al., (2015) also found that farmers who cultivate land located in low-altitude areas were more likely to grow DT maize due to higher evapotranspiration in these areas when compared to high-altitude farms. Scientists suggested that growing improved varieties like DT varieties require farmers to use more inputs, especially fertilizer, in comparison to traditional varieties (e.g. Smale, Byerlee & Jayne, 2011). Further, Fisher et al. (2015) found 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.

Langyintuo et al. (2010) and Fisher et al. (2015) asserted that an effective strategy to increase the adoption of improved maize seed was to enhance awareness and knowledge about DT maize. However, most efforts mainly targeted farmers who already demonstrated strong demand for improved seed. Thus, more tailored communication strategies are needed to increase awareness and demand among farmers who are unfamiliar with improved seed. Different farmers have specific information needs in order to learn about and adopt a new technology. There is also a need to better inform farmers about needed inpust and modern cultivation practices associated with improved seed. Access to extension services is vital in bringing farmers the information about the existence, benefits and usage of the technology (Kabunga, Dubois & Qaim, 2012). However, the extension services in ESA, regardless of whether they are publicly or privately funded, were found to be less efficient in boosting adoption, especially where demand for improved seed was low (Muyanga & Jayne, 2008). Seed companies also attempt to disseminate information about improved seed through their market network and other information channels including seed packs, and radio and TV programs. Some seed companies found that it was effective to provide small packs of improved seed for farmers to try (Langyintuo et al., 2010).

Below we review literature investigating how farmers' awareness, knowledge and their attitudes towards improved varieties, including DT maize, are associated with their adoption decisions.

Farmers' Adoption of Improved Seed

Studies show that the adoption of improved maize leads to significant poverty reduction. Khonje et al. (2015) found households that grew improved maize had gains in crop incomes, consumption expenditure, and food security. However, a substantial portion of maize farmers still plant traditional seed. In the 2006-07 season, only 44% of maize land in ESA was planted with improved seed[8](Abate et al., 2017). An earlier study showed that around 60% of Kenyan farmers used fertilizer and hybrid seed in 2004 (Suri, 2011). Farmers who adopted improved maize preferred old improved varieties or jointly planted new and old hybrids in one season ("portfolio selection"). Some of the improved seed varieties in Suri's study were released 20 years before the study was conducted. Farmers also grew improved seed using farm-saved impure seed[9]. Many farmers switched back and forth between traditional and improved seed from season to season (Duflo et al., 2008). Fisher, et al (2015) found that some farmers failed to recognize improved seeds' attributes, such as early maturation or drought tolerance in DT maize. They believe this explains farmers' reluctance to choose yield-enhancing inputs, such as DT seed and intensification cultivation practices as their responsive strategies to adapt to changing climate (Fisher, et al. 2015). One argument is that a majority of farmers are not aware of improved seed, which hinders its adoption (e.g. Duflo et al., 2008). Another argument claims that farmers are

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

knowledgeable about the technical components of improved seed. However, they delay their adoption because they do not see the value of adopting improved seed or because the constraints, such as lack of labor, capital and information, foster farmers beliefs that they will be unable to benefit from growing DT maize (e.g. Suri, 2011). A final argument reveals the importance of knowledge-in-practice in farmers' technology adoption. Incomplete knowledge about "how to" grow DT maize—such as how to manage maize crops to avoid potential risks—can lead to low adoption rates (e.g. Diagne & Demont, 2007). The last two arguments call for strategies of promoting new improved varieties that fit local context and farmers' specific situations.

Agricultural Videos and Phone Messages in Agricultural Extension

Information communication technologies (ICT), including radio, video, mobile phone and computers are increasingly used in the provision of agricultural extension services. For example, agricultural training videos have been created to complement and supplement conventional extension training. These training videos are lauded for a number of reasons such as their potential roles 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 has been 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 the same community. However, local communities commonly lack video playing devices, and training videos are normally 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 improve farmers' recall 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 are very effective in helping farmers to safely handle pesticides and to improve yield. 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 are varied according to context, content, technology, and delivery strategies (Fafchamps and Minten, 2012). They 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 (Fafchamps and Minten, 2012). Casaburi et al (2014) designed an intervention in Kenya which sent out SMS to sugar cane growers at individualized moments (harvest cycle and the age of their cane) in order to help them perform certain tasks. The program increased yield by 11.5%. A study conducted in Ecuador found that post-training text message reminders can improve farmers' knowledge about and adoption of integrated pest management (IPM) practices. This study indicated that the impacts of the messages may be associated with their timing, content and farmers' ability. The authors also attributed the positive impacts of the message reminders to farmers' participation in formal trainings with a similar topic (Larochell, Alwang & Travis, 2016). Previous studies on the impact of reminders suggest that reminders can both increase recipients' recall of certain information and also bring farmers' attention to a certain topic. In our study, the complementary practices, including proper ways of planting, fertilizer application and fertilizer micro-dosing need to be implemented at key decision making points during the maize growing cycle. Therefore, four audio messages were sent out to selected farmers aiming to remind them about these practices at least two weeks before the key times.

Research Method

This study conducts a randomized field experiment in Machakos and Makueni Counties, Kenya. The experiment randomly allocated the video approach and a multimedia approach, including both audio mobile phone messages and the video, to farmers in the study areas. The interventions provide the study with exogenous variation in access to knowledge about DT seed and modern practices among similar households. The object is to investigate whether the interventions a aressociated with greater knowledge about DT seed and modern practices and willingness to plant DT maize in the next season. In this section, we explain the intervention, study area, experimental design, sampling strategies and sample characteristics, and identification strategies.

The Interventions

A team of researchers, NGO staff, and local farmers produced the video in December 2015. In the video, farmer actors explain the benefits of drought tolerant maize, potential risks related to the type of seed, how to identify and purchase seed, modern cultivation practices, and their personal stories about planting. The team created four audio messages that deliver advice and reminders related to seed purchasing and cultivation activities, such as land preparation, planting and fertilizer application. We expect the video to provide knowledge about the DT and the modern practices, and motivate farmers to test the seed. Video screenings were moderated by the local NGO. Households in two treatment groups participated in the video screenings in February 2016. Households in multichannel group then received four different audio messages between March and July 2016 (long-rain reason), throughout the period during which they grew maize. We used this approach to reinforce knowledge about DT seed because people have limited memory capacity and attention to varied characteristics of a technology. The interventions provide the study with exogenous variation in access to knowledge about DT seed and modern practices among similar households. The objective was to investigate whether the interventions are associated with more knowledge about DT seed and uptake of the seed. Figure 1 provides a calendar of interventions and data collection activities along with an agricultural calendar.

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 (DT)[10] Agro-ecological zone (AEZ) and are considered as a medium drought risk zone (20–40% PFS) target area[11], where drought risks are high and DT seed could have potential benefits (La Rovere et al., 2010). Maize is the critical 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, and many soils are highly erodible (Barber, Thomas, and Moore 1979). The maize yield is low comparing with the national average. Most farmers in this area still grow the traditional seed, and some of them grow both traditional and improved seed in the same season. The Duma series and seed from Pioneer Hybrids are the most common improved maize varieties grown in the study areas. Few farmers grew newer improved varieties. Farming households experience food shortage regularly due to the low yield. 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). Farmers have no or only a small amount of output for sale as the majority of harvest is used for domestic consumption. The higher variation in rainfall was found to associate with the fluctuation in maize production in this area (Omoyo, Wakhungu & Otengi, 2015). The farmers' adoption of improved seed, including drought tolerance seed, are low, while the dis-adoption rates of the improved seed are high (Muhammad et al., 2010).

Machakos County has a population of 442,930 with a poverty rate[12] 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 the sea level (MASL). The mean elevation is 1,357 MASL in Machakos and 1,047 MASL in Makueni. More than 60 per cent of the region contains very erodible, relatively shallow, sticky, red, black, and brown clay soil with variable fertility, on steep slopes; 20 per cent has poorly drained, shallow,

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[10] Including lower midland zone (800-1300 MASL) and upper midland zone (1300-1800 MALS). And the two areas were included as part of the DTMA's medium drought risk zone (20-40% probability of failed season) target area.
[11] CIMMYT's Drought Tolerant Maize for Africa (DTMA) project
[12] Population below $1.25 per day

stony soils of low fertility (Bernard, Campbell, and Thom 1989, based on findings in Jaetzold and Schmidt 1983). The capital towns of both counties are less than 100km from Nairobi. The western part of the Machakos area is considered as part of the greater Nairobi area. Off-farm employment is prevalent among men, leaving women to take the main responsibility for crop management. The two production seasons are between November and February, and between March to August. Total annual precipitation ranges from 500 to 1300 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).

Experiment Design

We designed two treatment groups and one control group in this study (see Figure 3). Households in the video only treatment group watched a video about the DT maize. In the multichannel treatment group, in addition to participating in the video screening, households also received four audio messages sent to their mobile phone. The control group received no intervention from the study. In additional to the random variation in the treatment groups, we also included an NGO condition for a subset of the treatment and the control groups in a cross-cutting experiment. Farmers in NGO and non-NGO villages can be different in diverse ways. The NGO provides services and sells inputs through its village based advisers (VBA). Farmers in NGO villages receive sample maize seed for free (25g per sample bag) and can purchase regular seed packages (2kg) at the retail price from the VBAs. The NGO trains their VBAs on new varieties and the complementary technologies and practices. These advisors work as small agro-dealers who supply inputs, such as the DT seed and provide management advice based on farmers' requests. Some VBAs manage a small demonstration plot in the villages and organize "baraza", community meetings to distribute sample seed, including the DT varieties.

Farmers in the non-NGO villages do not receive these services. Therefore, in the NGO villages, the interventions are not the only information sources relating to the DT varieties. We expected that households in NGO villages would receive services from the NGOs in addition to interventions in both the treatment group and the control group as compared to those households in the non-NGO groups villages.

A pre-test survey was conducted before the video screenings to obtain production information, such as the maize varieties farmers grew in previous growing season (November 2015), and other demographic data about the study area. Then a post-test was implemented after the 2016 first growing season (March – August 2016) to understand farmers' testing and uptake of DT maize after the interventions.

Sampling Strategy

Two wards, Kola and Kee were selected together with a local NGO[13]. Kola is located in the southern part of Machachos County and Kee is in the northern part of Makueni County. The Kola ward has a population of 24,264; and the population of Kee is 20,926 (Government of Kenya, 2013). Summary statistics are presented in Table 1.

This study implemented a cluster-randomized field experiment where 27 villages were randomly assigned to a control group (*n =11*) or one of two treatment groups (*n = 8 each*). The 27 villages[14] were selected among villages within a local NGO's current or future operating area. We used a two-stage sampling strategy to select households. The NGO offered a list of villages (n=50). In this list, the NGO had no activities in nine out of 50 villages. We included all nine non-NGO villages in the study and randomly allocated them to two treatments and the control group. The NGO had no activities in these villages during the study. We randomly selected 18 villages from the remaining 41 villages where the NGO had activities prior and during the study. Then we randomly allocated these 18 NGO villages to the two treatments and the control group. Control villages were randomly selected from the same sampling frame in order to preserve comparability to the treatment villages. The NGO also provided a list of households in each village. We randomly selected 30 households in each non-NGO village and 17 households in each NGO village to include in our study.

Baseline Comparisons

[13] This local NGO assist the project to implement the field work
[14] The NGO identified these villages have potential demand for DT varieties as these villages located at agro-ecological zones suitable to DT varieties, and the yield was largely affected by recently drought.

In this section, we show that the randomization process delivered three similar groups: those households in the video only treatment, those in the multichannel treatment, and those in the control group. We compare the baseline characteristics of those who were in the two treatment groups and in the control with the following Ordinary Least Squares (OLS) Regression:

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

Y_i is a characteristic of the ith household before the interventions 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 and the multichannel group relative to the control group. Sample means of the video, the multichannel and the control group – as well as estimates for Equation (1) – are presented in Table 2. The sample is relatively well balanced in terms of gender of household head, characteristics of the main maize manager within a household (age, gender, education), land, distances to seed and trading center, number of members within a household, wealth (livestock index) and mobile phone ownership. Households in the multichannel group are richer (higher livestock index) than the video group. Further, more maize managers in the video only group are illiterate in comparison to both the multichannel group and the control group, while the overall illiterate rate in the sample is less than 7%.

Identification Strategies

We analyze whether the two treatments increased households' level of knowledge and willingness to test the DT varieties. For this purpose, we compare level of knowledge, willingness to plant DT maize and proportion of maize land that households allocated to DT, and the probability of paying for improved seed of those who were assigned to the treatments compared with those who were in the control. Additionally, we test for the presence of NGO effects within the treatment groups by comparing the outcomes of households in NGO villages with those of households who were in the non-NGO villages.

Throughout the analysis, we use the following operationalization for treatment variables:
Video takes a value of 1 if a household is in a video only treatment. It takes a value of zero otherwise.
Multichannel takes a value of 1 if a household is in a multichannel treatment. It takes a value of zero otherwise.

The remaining households (i.e. those with Video=0 and Multichannel =0) are those in control villages.

We calculate the impact of two treatments by comparing households' post-test knowledge about DT maize and management practice, and their willingness to plant DT. Namely, we estimate the following regression:

$$Y_{ij} = \beta_1 \, Video_{ij} + \beta_2 Multichannel_{ij} + \gamma \, \boldsymbol{Z_{ij}} + \varepsilon_{ij} \qquad (2)$$

Where Y_{ij} are outcomes including (1) level of knowledge on DT seed and the complementary practices which household *i* retained, and (2) farmers' willingness to plant DT maize and proportion of land farmers were willing to allocate to the varieties. The subscripts denote household *i* residing in villages *j*. Z_{ij} is a vector of household-level controls, including gender of household head, number of people in households, a livestock index, the main income sources (agriculture or non-agriculture), total land size, households' distance to the nearest market selling seed, the main maize growers' education level, whether households received information about DT seed from other information sources such as radio, and whether households lived in the NGO villages. In this specification, our reference group is the control group. Additionally, the error term ε_{ij} is uncorrelated with other explanatory variables as we assigned households to treatment randomly. Equation 2 is based on the original treatment assignment ($Video_{ij}$ *and* $Multichannel_{ij}$) – regardless of whether households actually watched the video or received audio messages – and provides an Intention-to-Treat (ITT) estimate of the intervention.

Around half of the households in the video only treatment villages attended the video screenings. In the multichannel villages, one third of sampled households watched the video and received the audio messages. We compare the baseline characteristics of those who actually received the treatments (compliers) and those who did not receive the treatments (non-compliers) using (1). We found no significant difference between the compliers and non-compliers in these characteristics. There are several reasons that can explain the relatively large number of non-compliers (compliance rate). The project only had resources to screen the video once in each village. Therefore, households did not have opportunities 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[15].

We also estimate Local Average Treatment Effects (LATE) using the treatment assignment as instruments for compliance. In particular, we estimate the following system of equations:

$$Y_{ij} = \varphi_0 + \varphi_1 video_{ij} + \varphi_2 multichannel_{ij} + \boldsymbol{\theta X_j} + \varepsilon_{ij} \quad (3)$$

$$Watch_{ij} = \delta_0 + \delta_1 video_{ij} + \boldsymbol{\rho X_j} + \omega_{ij} \quad (3a)$$

$$ReceiveWatch_{ij} = \delta_0 + \delta_1 multichannel_{ij} + \boldsymbol{\sigma X_j} + \eta_{ij} \quad (3b)$$

where $Watch_{ij}$ and $ReceiveWatch_{ij}$ are indicator variables for whether the households are compliers in the video treatment and in the multichannel treatment respectively, and Y_{ij} are the outcome variables including knowledge about the DT seed, knowledge about the practices and the uptake of the DT, and φ is the LATE on those who are compliers in the two assigned treatment groups.

We designed the interventions to assess whether training messages about the new DT seed and the complementary practices can increase households' knowledge and uptake of DT varieties. However, we are also interested in investigating if the treatment effects are relatively homogeneous between households who live in the NGO villages and those who do not. We estimate the following variation of Equation (4) to calculate the ITT effect on households with different NGO status:

$$Y_{ij} = \beta_1\ Video_{ij} + \beta_2 Multichannle_{ij} + \beta_3 Video_{ij}\ W_{ij} + \beta_4 Multichannle_{ij}\ W_{ij} + \gamma\ Z_{ij} + \mu_{ij} \quad (4)$$

where W_{ij} is NGO status (i.e., live in an NGO village and lived in a non-NGO village). The NGO works through their village based advisors (VBAs); farmers who are from the villages and are elected by community members.

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

In the next chapter, we present the results into two sections based on our research questions. We present results answering questions about the treatment impacts on farmers' knowledge and uptake of DT maize.

Results

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

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

Results of the treatments effects on respondents' knowledge scores are reported in Table 3. We estimate impact of the treatments on farmers' knowledge about on the DT seed (Column 1-4) as well as two management practices: proper ways to apply fertilizer (Column 5-8) and the recommended amount of fertilizer (Column 9-12). We include knowledge measurement of these two practices because the video featured these two practices, and the phone audio messages reinforced them. Therefore, these measurements can indicate the impact of reminders on households' knowledge about the practices. Columns (1), (2), (5), (6), (9) and (10) show intent-to-treat (ITT) effects of treatments using simple OLS regressions.

As shown in column (1), although households retained a low level of knowledge on the DT seed, on average, households in the multichannel group have three percentage points higher knowledge level on the DT maize than households in the control condition. These differences are quantitatively small but statistically significant. Households in the video only group earned nearly the same knowledge score as the control group. The difference of the knowledge score is not significantly higher in the multichannel group than it is in the video only group. Since some households in the treatment groups did not comply with the intervention and thus are not treated, we used the randomly assigned treatments as instrumental variables for treatment received to solve this compliance problem. The compliance rate in the video treatment is 47.82% and the compliance rate in the multichannel group is 37.04%. The results in column (3) suggest that there were sizeable impacts of the multichannel treatment on households' level of knowledge on the DT seed and complementary practices if the households received the treatment. Column (3) shows households who received both video and four audio messages earned knowledge scores on DT that were 8.6 percentage points higher than households in the control group and 7.8 percentage points higher than households in the video only group. The difference between the multichannel and the control is statistically significant.

We found similar results of the households' knowledge score on the two management practices[16]. Column (5) in Table 3 shows that the multichannel treatment increased the probability of giving correct answers to questions about the correct methods of fertilizer application by 13 %, and the video only treatment increased the probability by six percent. Column (9) in the same table shows that the impact of the two treatments on household *i*'s knowledge about the recommended quantity of fertilizer is close to zero. The coefficients in both column (5) and (9) are statistically insignificant. Lastly, we find similar treatment effects as the ITT when we use the LATE to estimate farmers' knowledge about the proper method of fertilizer application and the recommended quantity of fertilizer farmers should use.

These results indicate that multichannel treatment can significantly increase households' knowledge about DT maize seed compared to the video only treatment and the control. 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 the knowledge about DT maize. In this framework, all the standardized errors are estimated using Wild Cluster Bootstrapping due to a small number of clusters in this study.

The Effect of Treatment on Willingness to grow DT maize

[16]We use the linear probability models to estimate households' knowledge score on the proper ways of applying the fertilizer and the recommended amount of fertilizer because these two knowledge measurements are binomial and take value of one if household *i* gives correct answers to the knowledge test questions, and zero otherwise. The coefficients estimated by the linear probability model are quantitative similar to the Probit estimation.

Uptake of DT maize is modeled as a function of the treatment conditions and households' socio-economic characteristics. The same variables as in the knowledge regressions are included, plus a variable that measures households' intended uptake of DT maize a season after the intervention. Due to the project schedule, the post data collection was carried out in September 2016. This schedule made it not possible to capture the households' actual uptake of DT maize in the primary maize growing season in the study area, which is from September to February. Therefore, we capture households' post-intervention intention to grow DT maize in the next primary season, and use it as a proxy to measure households' uptake of DT maize and proportion of land they were willing to allocate to grow the DT.

Columns 1 and 2 in Table 4 show that the multichannel treatment has a positive and significant impact on households' intention to plant DT maize in the next primary planting season. The multichannel treatment increases the probability of uptake by 14%. The video only treatment has a positive but insignificant impact on this intention. It increases the willingness to plant DT maize by three percent. The LATE estimation reported by column 3 and 4 in Table 4 suggests that the multichannel treatment increases the probability of uptake by 38%, and the video only treatment increases it by 7%.

Households in the multichannel group are more likely to plant DT maize than the households in the control and in the video only condition. The analysis shows that although the reminders do not increase households' knowledge on the practices, they help to reinforce households' knowledge about DT maize and effectively bring their attention to the new varieties of maize seed. We speculate these impacts of the reminders associate with households' willingness to try the seed.

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 will grow the varieties in the next primary season or not and (2) a continuous variable measuring the proportion of land farmers are willing to allocate DT maize ranging from 0 to 1. We only present regression analysis using the dichotomous variable in Table 4 as the analysis using the continuous outcome variable shows similar results.

In sum, households in the multichannel treatment group are more willing to grow DT maize in the next primary maize planting season than the households in the control group and in the video only treatment group. The analysis shows that the multichannel treatment increases households' knowledge about the complementary practices, and it helps to reinforce households' knowledge on the DT seed and their willingness to try DT seed.

Differential Impacts of the Interventions

We found the treatment effects were relatively heterogeneous between households who live in the NGO villages and who do not. Table 5 shows that the impact of both treatments on households' knowledge about the DT seed was mostly driven by households living in the NGO villages. Households who live in the NGO villages and were assigned to one of the two treatments gained higher knowledge scores on the DT seed than the households who received the treatments but live in the non-NGO villages. Households who are assigned to the multichannel treatment group and live in the NGO villages retained four percentage points more knowledge scores on the DT seed than households in control group without the NGO's services. This difference is quantitatively small but statistically significant. Households living in the NGO villages and were in the video treatment retained two percentage points higher knowledge score on DT than the households in the control group. This difference is not statistically significant.

Households in both the video treatment group and the multichannel treatment group have higher willingness to plant DT maize in the next primary season if they live in the NGO villages than the households who live in villages with no services from the NGO. In the control group, the differences in willingness to plant DT maize is similar between households who reside in the NGO villages or not. Comparing with the control group, the multichannel treatment increases the probability of uptake by 20% when a household lives in an NGO-supported village, and the video only treatment increases the willingness to plant the DT by 13% if a household resides in an NGO-supported villages. Both impacts are statistically significant. VBAs in the villages mainly serve as seed suppliers, so these households in the NGO villages have easier access to the DT seed than the households in the non-NGO villages. We speculate this makes the uptake more likely.

We found that farmers in multichannel group retained more knowledge about DT maize and the management practices, and they are more willing to grow DT seed in the next primary season than the farmers in the video only group and the control group. Moreover, the availability of seed and services in NGO villages enhance the multichannel treatment effect, which suggests that factors such as easy access to DT seed complement the information provision including trainings and reminders in the multichannel group.

Discussion and Conclusion

We examined the effect of audio message reminders and participatory video in enhancing farmers' knowledge about the DT maize and the practices and uptake of DT maize. The findings provide insights that can inform the design of ICT strategies aimed at communicating knowledge about DT maize and the complementary practices to farmers. To our knowledge, few studies explore strategies to reinforce participatory video trainings by combining the video with other approaches. 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 is more effective than the video-only treatment in communicating relatively complex agricultural technologies with multiple steps.

Digital Green, an Indian NGO discussed in the literature review, has developed the well-known participatory video training approach, which has been adopted by various organizations in India. Its quick expansion depends on a substantial number of skilled frontline extension workers who consistently work with communities to help them learn from the training videos and follow-up with them to resolve issues that impede adoption. It also builds on India's fast-growing technology sector, which has been producing affordable and quality technologies, such as low cost digital devices. However, due to the absence of these two conditions, the impact of the Digital Green's video training approach can be limited in other parts of the world. For example, in most SSA countries including this study area, the community lacks video playing devices, and training videos are normally shown to a community once due to the lack of proficient personnel to handle video playing devices, to moderate screening sessions, and to follow up with farmers after the screenings. Therefore, there is a need to re-evaluate the video approach based on the local context in order to develop feasible and applicable strategies, such as the combination of the video approach with mobile phone reminders.

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. This finding corroborates the conclusion by Larochell, Alwang & Travis (2016) in Northern Ecuador that reminders could reduce inattention, especially when farmers need to make complex decisions. This result 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).

This study presents recent evidence of an impact evaluation of two communication strategies created to increase farmers' knowledge and uptake of DT maize. One approach is a locally-made video, or "participatory" video. Another approach is a multichannel method that incorporates the same video with mobile phone-based audio messages. These messages were sent out before key-decision points during a maize growing circle to remind them about practical practices. Both the video only treatment and the multichannel treatment had impact on increasing farmers' knowledge about DT maize. Further, we found that farmers in the multichannel group have higher knowledge about DT maize and its accompanying management practices than the video only treatment and the control. They are more likely to plant DT maize in the next primary season than the other two groups. The effects of the treatments are mainly driven by farmers who live in NGO villages.

These results reveal the potential benefits of integrating different ICT approaches on reinforcing farmers' knowledge, sustaining their attention to DT maize overtime and motivating them to test the new varieties. The impact of video training with contextualized content (e.g. Gandhi et al., 2009) and timely reminders (e.g. Larochell et al., 2016) have clearly been demonstrated. This study contributes to this discussion of using ICTs in farmers' learning and adoption of new agricultural technologies. The findings show an alternative but effective design strategy which creates a synergy of the two ICT approaches to enable farmers' learning and uptake of a relatively complex technology involving multiple steps overtime. Future studies on this and others relevant issues should test this "package" of strategies to increase farmers' adoption of improved seed and the complementary practices, and to leverage the productivities.

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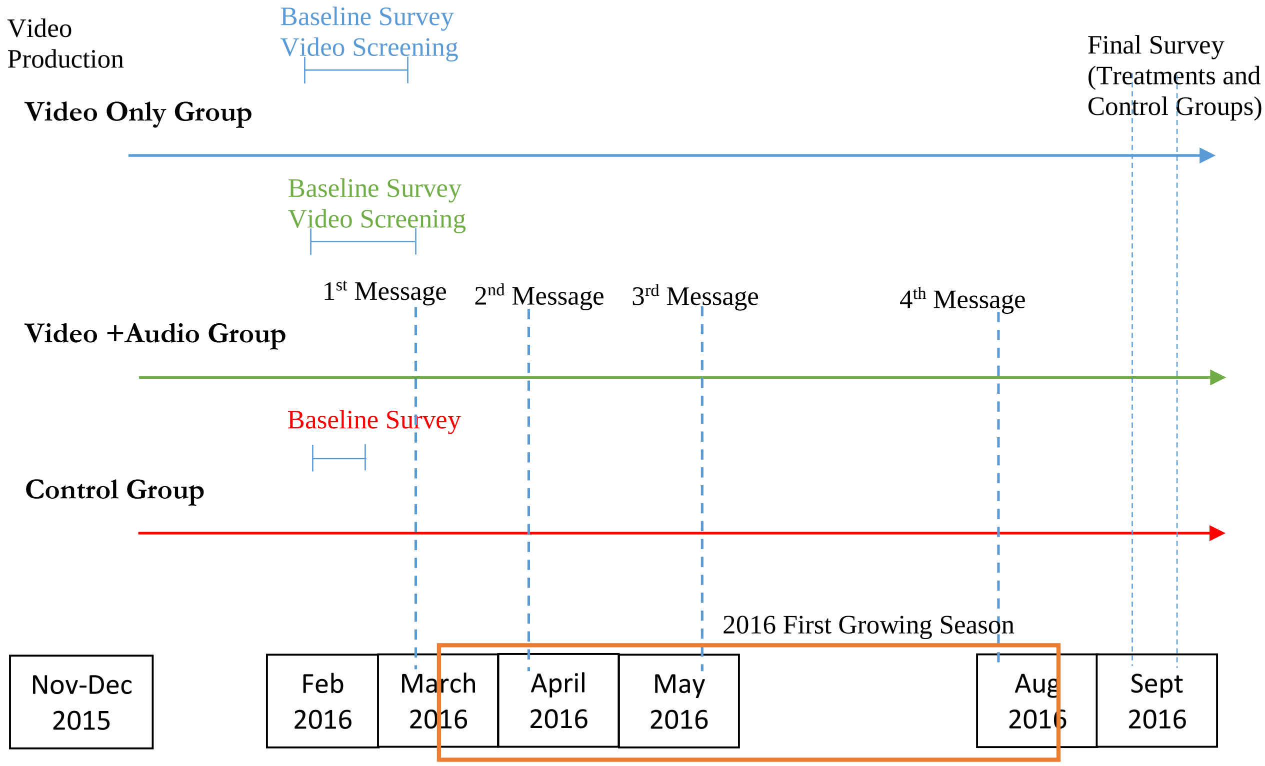

Figure 1: Timeline of this study

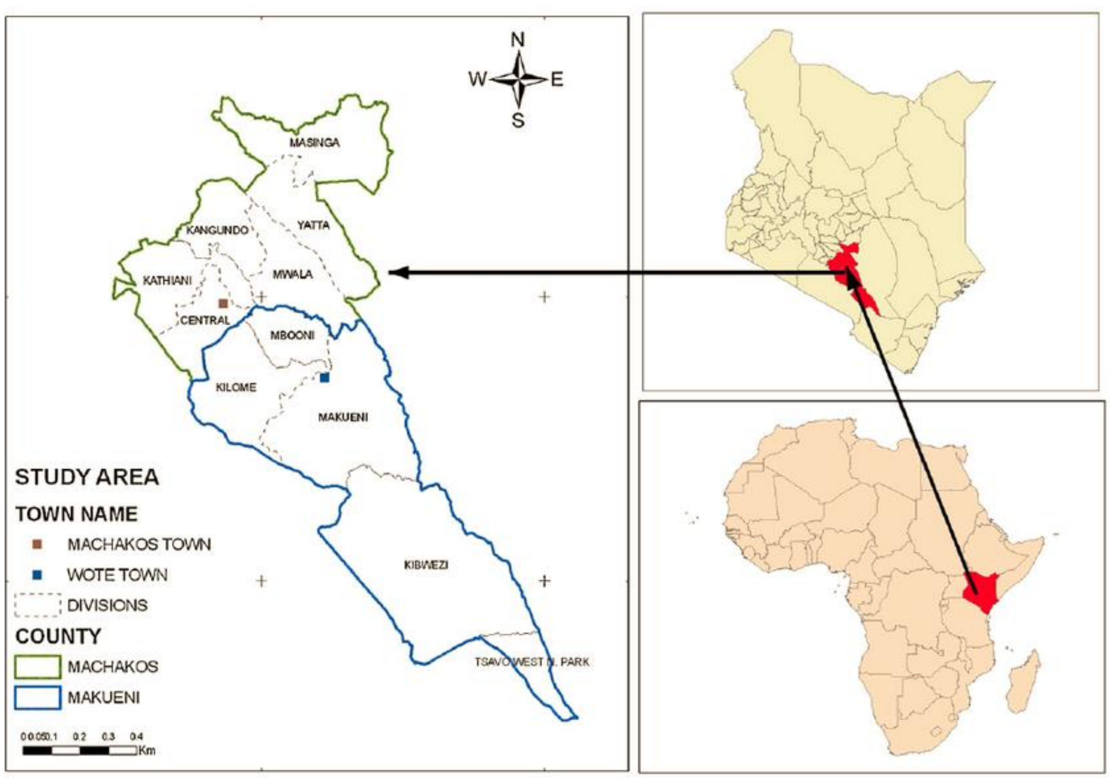

Figure 2: The study area

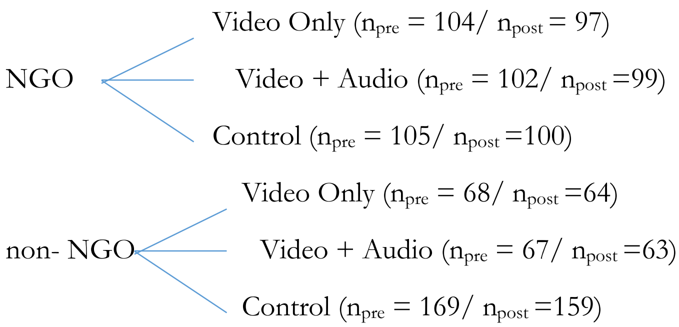

Figure 3: Experimental design

Table 1: Summary Statistics

Variable	**Mean**	**SD**	**Min**	**Max**	**N**
Knowledge Scores					
% of correct answers on the DT varieties	10.1	0.1	0	91.67	582
% of correct answers on the complementary practices	66.45	0.11	18.18	100	582
% of correct answers of all knowledge questions	46.53	0.08	11.76	79.41	582
% of maize land allocated to plant the DT					
Maize grower's characteristics					
Education Level					
no formal education	6.67				
did not complete primary	21.63				
completed primary	34.31				
did not complete secondary	17.24				
completed secondary or higher	20.17				
Age	49.9	15.97	18	95	582
Household characteristics					
Number of household members (15-65yrs)	3.11	1.7	0	12	582
Kilometers to main seed source	8.60	9.28	0	50	582
Gender of household head	23.58	42.49	0	1	582
Assets and income					
Size of farmland (acre)	3.27	2.67	0	17	582
Livestock index	177.78	170.04	0	782	582
Agriculture as primary source of income	55.94	49.69	0	1	582
Own mobile phone	92.94	25.63	0	1	582

Table 2: Household Characteristics in Baseline by Treatment Groups

	Control	Video	Multichannel	Mean Differences		
	(C)	(V)	(M)	(C)-(V)	(C)-(M)	(V)-(M)
Age of household	48.464	51.017	50.686	-2.554	-2.223	0.331
	(0.91)	(1.31)	(1.29)	(1.55)	(1.54)	(1.83)
Number of household member between 15-65	3.117	3.174	3.036	-0.058	0.081	0.139
	(0.10)	(0.13)	(0.13)	(0.17)	(0.16)	(0.19)
Number of household member	5.595	5.401	5.379	0.194	0.216	0.022
	(0.16)	(0.21)	(0.20)	(0.26)	(0.25)	(0.29)
Household's distance to market selling seed	9.02	8.1	7.56	0.92	1.46	0.54
	(0.67)	(0.77)	(0.62)	(1.04)	(0.98)	(0.99)
Household's distance to trading center	6.34	6.827	7.486	-0.488	-1.146	-0.658
	(0.43)	(0.58)	(0.75)	(0.71)	(0.80)	(0.94)
Size of land (acres)	3.769	3.619	4.195	0.151	-0.425	-0.576
	(0.27)	(0.30)	(0.45)	(0.41)	(0.49)	(0.54)
Livestock index	176.394	157.483	198.852	18.912	-22.458	-41.37*
	(10.02)	(12.54)	(13.77)	(16.09)	(16.73)	(18.62)
Women headed household	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	1.964	1.936	1.964	0.027	-0.001	-0.028
	(0.01)	(0.02)	(0.01)	(0.02)	(0.02)	(0.02)
Household with no education	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 with secondary education or higher	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 NGO villages	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	274	172	169	446	443	341

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

Standard errors in parentheses. Significance levels of the differences between the two treatment groups and control group denoted by *** 1%, ** 5%, * 10%.

Table 3: Knowledge Scores [4] 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 (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
households in (1) were compliers [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)
households in (2) were compliers [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	1.89	1.32	2.30	2.12	1.27	0.97	0.85	0.74	0.08	0.09	0.12	0.05

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

[2.] Additional baseline controls in columns 2, 4, 6, 8, 10 & 12 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 main maize growers' education level and lived in the NGO villages

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

[4.] The range of the knowledge on the DT is 0-6 with 0.5 as a unit. The knowledge measurement of two practices are binomial and take value of one if household i gives correct answers to the knowledge test questions, and zero otherwise.

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

Standard errors in parentheses. Significance levels of the differences between the two treatment conditions and control conditions denoted by *** 1%, ** 5%, * 10%.

Table 4: Marginal Effects of Treatment Conditions on Households' Intention to Grow DT Varieties in the Next Season by Treatment Groups[3]

	(1) [2]	(2)	(3) [2]	(4)
Video (1)	0.03	-0.02		
	(0.06)	(0.07)		
Multichannel (2)	0.14	0.12		
	(0.08)**	(0.09)*		
Video Complier			0.07	-0.02
			(0.14)	(0.09)
Multichannel Complier			0.38	0.28
			(0.18)**	(0.13)**
households in (1) were compliers [5]			0.48	0.48
			(0.02)	(0.02)
households in (2) were compliers [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

Note [1]. Additional baseline controls in columns 2 & 4 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, current year's uptake of DT maize and main maize growers' education level.

[2]. Column 1 & 2 report the Intend-to-Treat (ITT) estimate of the interventions. Column 3 & 4 report the Average Treatment Effect or Local Average Treatment Effects (LATE) estimate using the treatment assignment as an instrument for the compliers in each treatment conditions.

[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, Gelbach & Miller, 2008).

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

Standard errors in parentheses. Significance levels of the differences between the two treatment conditions and control conditions denoted by *** 1%, ** 5%, * 10%.

Table 5: 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 NGO (β_3)	0.32	0.27			0.24	0.23
	(0.23)	(0.20)			(0.08)***	(0.09)**
Multichannel treatment x NGO (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 NGO (β_7)			0.65	0.56		
			(0.33)*	(0.29)*		
Multichannel Complier x NGO (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 growers' education level.

[2]. The range of the knowledge about DT maize is 0-6 with 0.5 as a unit.

[3]. The coefficients are estimated in the regression $Y_{ij} = \beta_1 Video_{ij} + \beta_2 Multichannle_{ij} + \beta_3 Video_{ij} W_{ij} + \beta_4 Multichannle_{ij} W_{ij} + \gamma Z_{ij} + \mu_{ij}$ where W_{ij} is a binary variable that indicates whether household i in a NGO or non-NGO villages. We use the treatment assignments and their interaction with W_{ij} as instruments.

[4]. Column 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. Column 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 first stage of the Instrumental Variable Regression (following equation 3).

Standard errors in parentheses. Significance levels of the differences between the two treatment conditions and control conditions denoted by *** 1%, ** 5%, * 10%.