KNOWLEDGE, RISK, AND BENEFIT PERCEPTIONS: USING PARTICIPATORY VIDEO AND TAILORED MOBILE MESSAGES TO MOTIVATE FARMERS' UPTAKE OF DROUGHT TOLERANT (DT) MAIZE SEED IN KENYA

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ABSTRACT

KNOWLEDGE, RISK, AND BENEFIT PERCEPTIONS: USING PARTICIPATORY VIDEO AND TAILORED MOBILE MESSAGES TO MOTIVATE FARMERS' UPTAKE OF DROUGHT TOLERANT (DT) MAIZE SEED IN KENYA

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This research documents the design and testing of two strategies for using information and communication technologies (ICTs) to increase farmers' knowledge and uptake of DT maize: (1) locally-made, or "participatory" video, and (2) 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 Kenya. The experiment randomly allocated the two strategies to farmers in the study areas.

It was found that, after implementing these interventions, farmers in the multichannel group demonstrated significantly higher knowledge about DT maize and its accompanying management practices. Further, they were significantly more likely to report purchasing improved seed as well as intending to plant DT maize than the farmers in the video-only and the control groups. Farmers in the video-only group did gain a higher level of knowledge than the farmers in the control group; however, this difference is not statistically significant. Moreover, farmers' perceived risk regarding DT maize was found to be associated with their level of knowledge on the varieties and to which kind of treatments they are exposed. Farmers in the two treatment groups showed lower perceived risk than farmers in the control group, especially in the multichannel group. Mitigating the perceived risk of growing the varieties played a crucial role in motivating farmers to test DT maize. We found risk perception was more likely to decrease

willingness to test DT maize among farmers who retained lower levels of knowledge than the farmers who had higher levels of knowledge.

The results suggest that an ICT strategy integrating multiple ICTs can effectively communicate contextualized knowledge and timely reminders to farmers. This strategy helped farmers gain knowledge about DT maize and induced them to test new seed varieties. This finding contributes to existing theories on the usage of ICTs in agricultural knowledge provision. Previous literature mainly discusses whether single ICTs can improve farmers' knowledge and uptake (e.g. Gandhi, et al., 2009; Cole & Fernando, 2012), while this study investigates how to design ICT-based approaches by integrating various ICTs to make them more effective in innovation diffusion. In this case, those designing ICT strategies should consider farmers' cognitive capacities and the characteristics of agricultural innovations, such as complexity and whether farmers need to practice multiple steps at various points in a growing cycle, as such design can influence farmers' learning and uptake of the innovations. Lastly, this study contributes to a greater understanding of farmers' knowledge and perceptions of DT maize and how they are associated with farmers' uptake decisions.

I dedicate this work to my parents and grandparents

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CHAPTER 1 INTRODUCTION

Maize contributes forty-five percent of calories to people in Eastern and Southern Africa (ESA), and is a particularly important source of income for the poor in this region1 (Shiferaw, 2011). Farmers' most pressing concerns in the region are harvest failures and losses attributed to changing climate conditions, such as drought stress. These changes directly affect food production through changes in agricultural productivity, and indirectly through the reduction of agricultural incomes (Fisher et al., 2015). In response to changing rain patterns and climates, scientists have been breeding improved seeds, some of which are Drought Tolerant (DT)2. Hendrix & Glaser (2007) suggest that planting new varieties alongside improved management practices can reduce yield loss by up to 40 percent. However, although farmers experience prevailing low levels of yield and the productivity variation associated with changing climate conditions in ESA, the demand for DT maize seed still falls far short (Fisher et al., 2015). Moreover, while tests conducted in experimental stations suggest sizeable increases in productivity, farmers' actual profitability of the adoption of DT maize is unknown. The successful diffusion of improved seed in Asia and other regions indicates that technology adoption and impact at scale is due to a combination of innovative technologies and institutional

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 160 D maize varieties between 2007 and 2013, and disseminated 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. The DTMA project is led by International Improved Maize and Wheat Center.

and policy shifts, such as improvements to farmers' access to information, input, output and credit markets (Shiferaw, 2011).

Moreover, scientists have developed new technologies and practices to reduce the risks farmers are likely to encounter in agricultural production. However, Just (2003) points out that adopting these risk-reducing technologies like pesticides and irrigation can also be a risky process for farmers, as they need to invest labor and capital in new technologies that they are not familiar with. Knowledge is also limited in terms of how risk perceptions relate to farmers' perceived benefits and decision to try a technology. Thus, it is important to know how farmers perceive the risks, what factors can alter risk perception and how these perceptions influence farmers' uptake decisions. This information can enable us to understand farmers' mental processes in technology adoption and to develop strategies to help farmers form realistic risk perceptions and facilitate uptake.

Scholars suggest that providing information and training can reduce perceived risk (Wildavsky & Dake,1990; Finucane & Maybery, 1996) and facilitate uptake by helping subjects understand potential risks and form risk perception, as well as offer related risk management methods (Sundblad, Biel & Gärling, 2007). Slovic, Finucane, Peters & MacGregor (2004) propose that, when individuals receive inadequate information, they can develop perceived risks based on speculation rather than an evaluation of facts. In conventional agricultural trainings, farmers generally learn how to practice a technology and its benefits. However, we know little about effective ways to communicate potential risks and relevant risk management practices to farmers. Moreover, we know little in regards to what specific risks farmers perceive about a technology. As such, there is no consensus among scholars as to what types of information can help individuals reduce their perceived risk.

In addition to posters, radio, television, and newspapers, the existing channels for communicating benefits of DT maize 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). Many scholars believe that information and communication technologies (ICTs) can be a partial solution (e.g., Gandhi et al., 2009; Nakasone & Torero, 2014).

This research assesses how different ICT-based extension approaches can improve farmers' knowledge about DT maize and its complementary practices. In particular, we tested two approaches. The first approach includes locally made, or "participatory," videos. This approach is utilized by agricultural extension workers and FIPS' staff in developing countries. These organizations shoot videos that feature farmers from the same or a similar community who have adopted DT seed. The videos integrate both contextualized social and cultural cues, such as how farmers traditionally choose maize seed, and the technical information about DT maize and modern practices. The videos also use local farmers' narrative stories to inform and educate audiences about the potential risks of growing DT and its risk management practices. The second approach is a multichannel method. In addition to the participatory videos, farmers received four audio messages on their mobile phones over the course of a maize growing cycle. A voice system complemented the information in the video by 'pushing' audio messages before key decision points in the maize growing season. These audio messages communicated reminders to reinforce the knowledge farmers learned in the video and to encourage adoption. The initial messages reminded farmers of the timing to purchase DT maize seed. The second and third messages included content that reminded farmers of the proper timing, practices, and quantities of fertilizer micro-dosing. The last message informed farmers about post-harvesting practices for managing DT maize, including how to differentiate between traditional varieties and other improved varieties, and how to improve yield. However, the majority of DT maize are more sensitive to management practices than traditional ones. Therefore, farmers are more likely to receive poor yield if they fail to use these management practices on their improved varieties.

In this study, we partnered with Farm Input Promotions Africa (FIPS), a local NGO, to conduct a field experiment in Machakos and Makueni counties, Kenya. FIPS has worked in the study area for more than 10 years and operated in a variety of villages. Farmers in the FIPS' villages receive sample DT maize seed and can purchase the seed from FIPS, as well as request information and advice from FIPS's village based advisors (VBA). For example, through their VBAs, FIPS provides trainings and demonstrations, distributes free sample seed, and sells inputs. Twenty-seven villages were randomly selected from a list provided by FIPS. The list included villages where FIPS is currently working and villages where FIPS planned to work but had no activity prior to this study. These villages were assigned to one of three groups. Farmers in the first group watched a video, while farmers in the second group watched the same video and received four correlating audio messages. The third group was designated as the control group, in which no video was screened and no audio messages were sent. In total, 615 households were included in the study. The video was produced in the local communities three months prior to the first growing season of 2016 by a team of researchers from a major university in the USA, FIPS' staff, and farmers from local communities. It was screened in the treatment villages, and the four audio messages were then sent to farmers in the multichannel group.

This dissertation is guided by six research questions, all of which are investigated through two studies. The first three research questions are addressed in Study One, and the remaining three are addressed in Study Two. Study One investigates impacts of treatment via a comparison of the treatment effects that occur between a video-only group, a multichannel group, and a control group on farmers' knowledge and uptake. First, we study whether farmers in the three groups have different levels of knowledge about DT maize and management practices (RQ1). We also study the treatment effects of the interventions on farmers' uptake by comparing farmers' probability to purchase improved seed and their willingness to test DT maize in the next primary maize growing season (RQ2). Lastly, we study how the services provided by FIPS related to the treatment effects on farmers in some villages sampled in the study. Therefore, this study aims to understand the differential treatment impacts on farmers' knowledge and uptake when FIPS is active in the village (RQ3).

In Study Two, we explore the pathway from farmers' knowledge and perception of DT maize to their uptake decisions, seeking to understand how the treatments associate with farmers' risk and benefit perception of DT maize. As such, we compare farmers' perceived risk and benefits of DT maize uptake in the video-only group, the multichannel group, and the control group (RQ4). We then explore how the perceived risk and benefit of DT maize uptake are associated with farmers' knowledge of DT maize (RQ5). Lastly, we ask how relationships between knowledge and the perception influences farmers' uptake decisions. (RQ6).

To answer each research question, we test hypotheses that guide treatment effect comparisons between the treatment groups and the control. These hypotheses are presented at the end of the literature review. A field experiment was conducted in Machakos and Makueni counties, Kenya, where 581 households participated in answering these research questions. We found that, after implementing interventions in the both communities, farmers in the multichannel group demonstrated higher-level knowledge about both DT maize and management practices. They were more likely to report purchasing improved seed and more willing to grow DT maize than farmers in the video-only group and control groups. Moreover, households in the FIPS-supported villages mainly drove the impact of treatment.

Additionally, farmers' perceived risk was found to be associated with their level of knowledge about DT maize, as well as with which kind of treatment they were exposed to. Farmers in the two treatment groups—especially the multichannel group—showed a lower level of perceived risk than farmers in the control group. Mitigating the perceived risks of growing the varieties played a crucial role in motivating farmers to test DT maize. This strength of the negative association between perceived risk and uptake is reduced by farmers' levels of knowledge about DT maize.

DT maize is recently introduced to the study area, Machakos and Makueni counties, Kenya. Some DT varieties were introduced to the local market, such as drought Tego, while the majority of DT varieties listed by the International Maize and Wheat Improvement Center (CIMMYT) were absent. The cost of one bag of DT seed (2kg) ranged from Ksh300 to Ksh500, similar to other improved maize varieties in the region. FIPS suggested that farmers need 8kg of maize seed to plant one acre of farm. Research institutions such as CIMMYT and seed companies promote that farmers need to plan different improved varieties based on the characteristics of their differing agro-ecological conditions. Farmers commonly purchased improved seed from local agro-vet dealers in their communities. In the interest of saving money and in situations where farmers found certain seeds were not available in their local markets, some planted improved seed saved from previous seasons. These recycled improved seeds often had poor quality and a yield much lower than the fresh improved seed. Around half of the farmers in our study reported that they had planted improved varieties before the intervention, but few had planted DT maize on a large scale. We found that most farmers commonly planted improved maize seed alongside traditional maize varieties in a same plot. Moreover, farmers were largely unable to distinguish the important differences among the improved varieties in order to select the ones that most suitable to their farms' conditions. We found that farmers commonly planted older improved varieties or any varieties that recommended by agro-vet dealers. Some seed companies listed their varieties' yield, maturation time, and ideal condition on seed packages in English, but few farmers told us that they read and used this information.

This study contributes to exiting theories about the usage of ICTs in agricultural knowledge provision. Previous literature mainly discusses whether single ICTs can improve farmers' knowledge and uptake, while this study investigated how to design ICT-based approaches integrating various ICTs to make them more effective in innovation diffusion. The results suggest the importance of designing ICT strategies based on farmers' cognitive capacities, characteristics of agricultural innovation (such as whether farmers need to practice multiple steps over a long cycle), and the functions of various ICTs. In this study, we sent mobile phone audio messages before key decision points to remind farmers about the contextualized knowledge they learned from the video screenings about DT maize and its management practices over the course of a growing cycle. This multichannel approach was found to be more effective at improving farmers' knowledge than the video-only approach that was shown to the farmers only once before the growing season. Moreover, the knowledge gained from the ICT intervention were shown to help farmers form perceptions of DT maize and to induce behavioral changes. This study also offers a greater understanding of farmers' perceptions of DT maize and how those perceptions are associated with uptake decisions. Moreover, this study generates insights into ICT design strategies for communicating knowledge to farmers about DT maize and its correlating practices.

CHAPTER 2 LITERATURE REVIEW

2.1 Drought Tolerant (DT) maize in the Eastern and Southern Africa (ESA) region

Studies have found that farmers use many different strategies to reduce the negative impacts of climate variability and change[3] on their maize production. Switching crop varieties, in particular, is an increasingly used method in this regard (Fisher & Snapp, 2014). Drought Tolerant crops are likely to play an increasingly important role in coping with climate change and variation (Kassie et al., 2014). Research institutes such as CIMMYT and seed companies have been introducing DT varieties [4] to the ESA market for about a decade[5]. Between 2007 and 2013, 160 DT maize varieties were released to the ESA market[6]. On-farm trials in ESA found that "DT maize varieties out-yield popular commercial checks by 82-127 percent (controlled drought), 26-47 percent (random drought), and 25-56 percent (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 varieties could be greater during droughts. However, the impact of these new DT maize seeds depends on farmers' level of adoption and their ability to profit from growing them.

Yet, scholars 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 inputs,

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

[4] The scientists used modern conventional methods to breed DT maize. So current DT maize seeds in the ESA market are not genetically modified.

[5] Global efforts aiming to develop DT maize germplasm include Drought-Tolerant maize for Africa (DTMA) implemented from 2006 to 2015 by CIMMYT, the International Institute for Tropical Agriculture (IITA) AND national research/extension institutions of 13 African countries.

[6] This is the total number of DT maize 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 600mm 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 conditions, maize grow in the off season and the irrigation interval calculated based on the crop water balance (Setimela et al, 2017).

like fertilizer and labor, and use inadequate management practices (e.g., Tambo & Abdoulaye, 2011). Smallholders have experienced difficulties accessing new DT 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 maize 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 with less exposure to information about DT maize were less likely to try it. Although their study does not include data collected in Kenya, the results reflect farmers' perceptions and adoption statuses in the ESA area. Fisher et al., (2015) also found that, in comparison to high-altitude farms, farmers cultivating land in low-altitude areas were more likely to grow DT maize due to higher evapotranspiration in these areas. Scientists suggest that modern inputs, especially fertilizer, are often a complementary input for improved varieties like DT maize in comparison to traditional varieties, because improved maize has a steeper response curve to fertilizer (e.g., Smale, Byerlee & Jayne, 2011). Indeed, Ertiro et al., (2017) conducted trials on seven inbred DT lines across 11 sites in Kenya. This experiment showed that, in 2014, the grain yield of the seven inbred lines under the low-nitrogen condition was lower than the yield of the same varieties under well-watered and well-fertilized conditions, as well as those under well-fertilized but drought-stressed conditions. However, only a small portion of farmers applied sufficient amounts of chemical fertilizer and used proper approaches to apply it to their improved maize varieties (Smale et al., 2011). It is worth noting that maize response to fertilizer can also be influenced by factors such as the availability of soil organic content (Marenya & Barrett, 2009; Kihara et al., 2016). Fisher et al. (2015) found labor constraints did not hinder farmers' adoption of DT maize, but speculated limited adoption was due to the fact that farmers currently only grow DT maize on small scales. They postulated that the labor shortage may become a salient problem if farmers decide to expand DT maize production.

Langyintuo et al. (2010) and Fisher et al. (2015) asserted that an effective strategy for increasing adoption of improved maize seed is to enhance awareness and knowledge about DT maize. However, most efforts mainly targeted farmers who already demonstrated a strong demand for improved seed, rather than those with no experience of growing the seeds. Such findings point to a need for more tailored communication strategies to increase awareness and demand among farmers who are unfamiliar with improved seed, as different farmers have varying information needs regarding the adoption of new technologies. Similarly, there is a need to better inform farmers about necessary inputs and modern cultivation practices associated with improved seed. Access to extension services is vital to bringing farmers' information about the existence, benefits, and usage of technologies (Kabunga, Dubois & Qaim, 2012). However, 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 attempted 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 it effective to provide small packs of improved seeds for farmers to sample (Langyintuo et al., 2010).

2.2 Farmers' Adoption of Improved Seed

This section presents different assessments from recent literature that analyze farmers' awareness and knowledge about improved seed varieties and adoption, including that of DT maize. One argument asserts 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 aware of improved seed, but delay adoption due to a focus on constraints such as lack of labor and capital, which further fosters farmers' beliefs that they will be unable to benefit from growing DT maize (e.g., Suri, 2011). A final argument asserts the importance of knowledge-in-practice in farmers' technology adoption. However, incomplete knowledge about "how to"—such as how to manage maize crop to avoid potential risks—has been shown to lead to low adoption rates (e.g., Diagne & Demont, 2007). The last two arguments, in particular, call for strategies to promote new improved seed varieties that fit local contexts and farmers' specific situations.

2.2.1 The Myths of Low Adoption and Dis-Adoption of Improved Varieties

Studies show that the adoption of improved maize leads to significant poverty reduction. Khonje et al. (2015) found households that grew improved maize exhibited gains in crop incomes, consumption expenditures, and food security. However, a substantial portion of maize farmers still planted traditional seed. In the 2006-07 season, only 44 percent of maize land in ESA grew improved seed[8] (Abate et al., 2017). An earlier study showed that around 60 percent 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, so these older improved varieties do not have characteristics of new and improved seed, such as drought tolerance. 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).

[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.

Extant literature cites limited access to information as a main adoption constraint, which leads to low awareness of new seed availabiliy (Duflo et al., 2008; Fisher et al., 2015; Kabunga, Dubois & Qaim, 2012). Heterogeneous populations do not have equal access to information about improved seed, including its attributes and performance; this contributes to the lower adoption rates among disadvantaged households lacking capital, labor and access to input and output markets (Foster & Rosenzweig, 2010). Similarly, Shiferaw et al. (2015) found that factors such as access to seed and capital, together with limited access to information, hinder DT maize adoption. Fisher, et al. (2015) also 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 maize and intensification cultivation practices, as their responsive strategies to adapt to changing climates (Fisher, et al. 2015).

While some research points to a general lack of awareness among farmers in cases where improved seeds are rejected, some research argues that farmers are very aware of improved seed due to decades of exposure in their local markets. In such cases, farmers' decisions to adopt or not adopt improved seed are based on the kinds of information farmers choose to accept and how they internalize that information. Some farmers chose not to adopt or dis-adopt improved seed as they came to believe improved seed was not efficacious (Foster & Rosenzweig, 2010). Duflo et al. (2011) found that farmers' behavioral biases, such as being myopic mindedness, limited their investment in fertilizer even when they noticed the apparent values of applying it to their fields. Suri (2011) indicated that farmers who received low or even negative net returns from improved seed tended to not adopt it, even when gross returns were high. When farmers had zero net returns from growing hybridized maize, they tended to switch their adoption decisions from period to period and were subject to shocks, such as the changing of input and availability of seed. Suri (2011) ovbserved that the cost and return of hybrid seed varied by farmers, but that farmers knew and understood the net return well before planting. Overall, this argument assumes that farmers possess complete knowledge about improved seed, and that no cost and return differences exist between varieties of improved seed.

Return to improved seed is sensitive in terms of how it is planted and managed. To distinguish between farmers' awareness of improved seed and their profound knowledge about how to use them more efficiently, Duguid (2005) and Diagne & Demont (2007) argued that knowledge-in-practice may better predict farmers' adoption. Cultivating improved seed varieties requires farmers to use a package of technologies beyond seed itself. For example, some seed varieties are more sensitive to soil conditions than traditional varieties, so farmers need to apply complementary inputs, such as organic or chemical fertilizer to achieve ideal yield (Byerlee & Heisey, 1996; Foster & Rosenzweig, 2010), otherwise the return to adoption can be negative or insignificant. Foster & Rosenzweig (1995) argue that, as long as farmers were aware of improved varieties, they could learn the importance of complementary inputs and identify the optimal labor and input to invest in by learning through doing or learning from their peers. However, other studies show that this is not the case (e.g., Fisher & Snapp, 2014). Increasingly, studies have recognized that farmers need to experiment with seed selection and the implementation of improved cultivation practices[10] to intensify production; these studies imply that farmers need time and effort to discover how to maximize net returns from using improved seed such as DT (Shiferaw et al., 2011; Foster and Rosenzweig, 2010). Moreover, the provision

[10] The improved practices include increased plant density, line planting, place spacing, weeding and post harvesting (Byerlee & Heisey, 1996)

of the information about seed selection and management practices could escalate farmers' uptake of knowledge-in-practice. However, knowledge about complementary inputs or improved cultivation practices and the reasons why farmers need them are rarely communicated to farmers together with efforts to promote improved seed.

2.2.2 Step-wise adoption of improved seed

To reduce uptake risks, farmers test and adopt new technologies in a step-wise manner, by allocating parts of their resources, such as land, to testing new technologies at an early stage of learning. Smale, Just & Leathers (1994) found that farmers intended to reduce the risks of uptake by growing both new and traditional maize varieties in the same season to prevent harvesting failure. Farmers seemed to believe that, if one variety failed, they could still harvest enough from the other. Another type of step-wise adoption is *partial adoption*, which occurs if components in a technology package can be separable. Byerlee and Polanco (1986) found that farmers adopted individual components in a technology package sequentially. They found farmers delayed the adoption of some package components when they perceived the components as too risky (e.g., Abate et al., 2017). However, studies commonly treat adoption as a dichotomous variable. That is, all respondents "either adopt completely or not at all" (Samel, Just & Leathers, 1994, p.536). Yet, this assumption hardly reflects farmers' adoption behaviors in the real world (Byerlee & Polanco, 1986, p.519). As such, I employ two outcome variables in this study to measure farmers' decisions after receiving the intervention: (1) farmers' probability of paying for maize seed, and (2) the proportion of land farmers are willing to allocate to DT maize.

In the next section, I use previous literature on individuals' perceived risk, perceived benefit, and behavior detail to outline the conceptual framework of this study.

2.3 Risky Decision-Making

In this section, I review literature investigating individuals' perceived risk, perceived benefit, and adoption of new agricultural technologies. Slovic (2000) argued that, in general, high levels of perceived risk were negatively associated with perceived benefit. Although a risky object may entail the "potential for gains as well as potential for losses" (Coombs & Lehner, 1981, p. 318), individuals may not expect positive outcomes from this object if they perceive it to be too risky (Sarin & Weber, 1993). Fischhoff, Slovic & Lichtenstein (1978) identified this particular tradeoff as a societal dilemma because risk reductions commonly accompany a decrease of societal benefits. It is also suggested that individuals' perceived risk may not be rational due to reasons such as lack of adequate information (Slovic, 2000; Sundblad, Biel & Gärling, 2007).

However, few studies seek to specifically understand farmers' risk and benefit perceptions regarding improved seeds (Fisher & Snapp, 2014). Indeed, a substantial number of studies focused on people's perception of societal-level risk of new technologies (e.g., Slovic et al., 1982), but little literature exists focused on people's perception of how new technologies can harm individuals, as well as how this risk perception is linked to technology adoption. Moreover, few studies investigate proper approaches to help farmers form rational risk perceptions. Thus, my study investigates how provision of contextualized knowledge and individualized reminders intervened with farmers' risk perception, benefit perception of DT maize, and their uptake of DT maize. I draw findings from broader disciplines including ICT and development (ICTD), media studies, psychology, management, and agricultural and behavioral economics to develop my conceptual framework. In this chapter, I review the mechanism between constructs including perceived risk, perceived benefit, and risky decision-making.

2.3.1 Perceived Risk

Perceived risk has been commonly cited as a crucial factor that decreases farmers' adoption of new agricultural technologies (e.g., O'Mara, 1980; Smale, Just & Leathers, 1994; Byerlee & Polanco, 1986). However, few studies investigate ways to reduce its impact on technology adoption (Marra, Pannel & Ghadim, 2003). People's perceived risk has multiple dimensions and is regarded by scholars either as a rational judgment or as an emotional response (e.g., "feelings") (Loewenstein et al., 2001; Slovic et al., 2004). The basic assumption of risk perception theories is that, at the same level of return, individuals dislike objects with more perceived risk over fewer (von Neumann & Morgenstern, 1947). Risk perception studies do not directly deal with actual risks, or potential risks likely to be encountered. Instead, they have considered perceived risk as individuals' subjective impressions of the risks of a technology (Bauer, 1960).

Extant literature defines perceived risk in various ways. Bauer (1960) defined it as a two-aspect construct that entails individuals' expected uncertainty and expected negative consequences of failure. He argued that "consumer behavior involves risk in the sense that any action of a consumer will produce consequences which he cannot anticipate with anything approximating certainty, and some of which at least are likely to be unpleasant" (p. 24). Cunningham (1967, p.37) advanced this definition by defining perceived risk as: "the amount that would be lost (i.e. that which is at stake) if the consequences of an act were not favorable, and the individual's subjective feeling of certainty that the consequences will be unfavorable." Other perceived risk definitions include outcome variance of an activity (Sarin & Weber, 1993) and subjective "evaluations of variation in the distribution of possible outcomes their likelihoods and their subjective values" (Shapira, 1995, p.167).

Slovic (2000) suggested that perceived risk is a social construct. He and other scholars have investigated perceived risk as affects, emotions, and feelings (e.g., Slovic, 2004; Loewenstain et al., 2001). Further, scholars argued that individuals' negative consequences of perceived risk have diverse dimensions. Jacoby and Kaphlan (1972) proposed four dimensions including financial, performance, physical, and psychological and social risk. Fischhoff et al. (1978) suggested perceived risk is a qualitative construct, while Gregory and Mendelsohn (1992) listed nine dimensions of risks and dread perceptions such as voluntariness of taking a risk, immediacy of effect, newness, catastrophe, equity, future generations, economic benefits, etc.[11] They attempted to quantify these qualitative dimensions using a psychometric paradigm. Slovic (1987) later narrowed these dimensions down to three: dread, familiarity, and number of people exposed.

My study focuses on farmers' perceived risk about a new agricultural technology which use Bauer's (1960) two-aspect definition to investigate farmers' perceived risk, including uncertainty and expected negative consequences of growing DT maize.. I define *perceived risk* as individuals' subjective judgments of a risky I measure farmers' subjective assessments on four dimensions of the negative consequences (these four dimensions are listed in the operational section in the method chapter).

2.3.2 Perceived Benefit and Its Relationship with Perceived Risk

Previous studies have various definition of perceived benefits. Starr (1969) defined perceived benefit as the average contribution that a technology makes to individuals' annual

[11] They listed nine characteristics of perceived risk entailing voluntariness of risk, immediacy of effect, knowledge, common-dread, newness, catastrophic potential, controllability, equity and risk to future generations.

income. Snoj et al. (2004) defined perceived benefit as bundles of attributes that together produce a level of benefits, thereby providing utility to customers. These are tangible benefits that individuals can directly observe or obtain by using the technology. My study aims to understand how farmers rate specific benefits of DT maize. According to scientists, these benefits include early maturing and good yield during drought (Fisher et al., 2015). Both benefits were explicitly mentioned in the intervention this is tested for the study.

There are various arguments about relationship between perceived risks and perceived benefits. Cognitive consistency theories state that people exhibit strong desires to hold consistent judgments, so individuals tend to rate an object less beneficial if they perceive it to be risky (Heider, 1946). Relatedly, Starr (1969) found individuals were more likely to tolerate perceived risk when they perceived higher benefit of an object. He found that tolerance to risks was conditioned by individuals' judgments on the voluntariness of taking the risk and others' perception of risks, like familiarity and catastrophic potential. Fischhoff et al. (1978) criticized Starr's findings, suggesting they were based on a small number of technologies. They found the relationship between perceived risk and perceived benefit of 30 different technologies and activities were varied and inconsistent. However, Alhakami and Slovic (1994) found an overall inverse relationship between perceived risk and benefits. Their findings were based on the respondents' risk and benefit perceptions of 40 different technologies like herbicides, X-rays, air-travel and police work. They speculated that, when perceived risk was salient, it hindered the recall of perceived benefit. Similar inverse relationships were found by later studies investigating single technologies, such as genetically modified canola (Mauro & McLachlan, 2008) and nanotechnology (Cobb & Macoubrie, 2004). Siegrist & Cvetkovich (2008) found that individuals who perceived more benefits of nanotechnology, such as food materials and food packaging, perceived fewer risks compared to those who perceived fewer benefits.

Moreover, individuals' knowledge levels about a technology can alter the relationship between perceived risk and benefit. Finucane & Maybery (1996) found that participants perceived fewer risks of a technology when exposed to information about its benefits. In the same study, information about risks was also found to relate to the change in benefit perception. Wildavsky and Dake (1990) suggested that respondents who rated their knowledge of technologies as high also tended to perceive greater benefits associated with technologies than those who rated their knowledge as low; similarly, the perceived risks were lower when self-rated knowledge was higher. However, we know little about whether individuals' actual knowledge levels are associated with their perceived benefit and perceived risk of an unfamiliar technology.

2.3.3 Perceived risk and risky behavior

Brewer et al. (2004) proposed three relationships between perceived risk and individuals' risky behavior. The first relationship argues farmers' perceived risk is associated with their engagement in risky behavior. The second proposes that higher perceived risk leads to preventative behavior. The last argument of Brewer et al. (2004) is that individuals reduce their perceived risk of the action in which they choose to engage because those individuals tend to justify their decisions as low risk to validate said decisions. The last argument is similar to Fischhoff et al.'s findings (1978) that individuals' perception of risk and benefit vary by the degree of voluntariness of a risky behavior. Weber & Milliman (1997) suggested that reducing individuals' risk perception can be a driving force behind actions under risks.

The current study adapted a risk-value framework instead of an expected utility (EU) framework. The EU framework is widely used by previous literature to study risk and risky behavior. Sarin & Weber (1993) suggested that a risk-value framework could more effectively reflect individuals' real world choices than the expected utility models because their framework required that choices "depend on the riskiness of the gamble and its value" (Sarin and Weber, 1993, p.148).

The expected utility (EU) framework was widely used with the expectation that individuals choose less risky objects to achieve profit maximization. The EU framework uses individuals' risk preferences—that is, whether an individual is risk averse or risk seeking—to explain their choices (e.g., Binswanger, 1980). However the EU framework fails to invoke the notion of individuals' risk judgments in the model; such an absence makes it hard to explore realistic human behavior in diverse application areas (e.g., King & Robison, 1981; Sarin & Weber, 1993). In the EU framework, risk preference cannot be directly captured in a lab setting or controlled environment by deriving individuals' choices during a gamble or lottery (Binswanger, 1980; Weber & Milliman, 1997). King and Robins (1981) found that participants' perceptions of specific risks are more important in explaining adoption than their risk preferences because individuals employ a set of mental strategies or heuristics to make decisions in an uncertain world (Slovic, 1987).

One approach to reducing perceived risk is through assisting individuals' cognitive processes by providing information that aims to communicate an innovation's values to individuals, as well as its potential risks and risk reducing practices to help individuals better manage perceived risk (Sundblad, Biel & Gärling, 2007). For example, Fisher, Arnold & Gibbs (1996) showed that effective information, such as performance of the innovation in a local garden, is vital to farmers' adoption of wheat varieties. In their study, farmers mainly obtained quality information by trying a new wheat variety over time by themselves. Sundblad, Biel & Gärling (2007) argued that knowledge can indirectly affect individuals' behaviors via risk perception. They suggested that diverse components of individuals' knowledge about climate change, including knowledge about consequences and causes of climate change, can have different impacts on individuals' risk perception and behavior. Verbeke et al. (2007) suggested that individuals were willing to spend more money to obtain information about potential risks than on information about the benefits of a technology.

Wildavsky & Dake (1990) asserted that knowledge of a technology can help individuals form risk perceptions of real dangers. In other words, individuals lacking knowledge of a technology can form perceptions of said technology that are not rational and tend to be anxious about risks that do not exist. Slovic (1982) proposed that perceived risk due to inadequate information can be reduced by education. This is because effective information helped reduce uncertainty of an innovation. Moreover, Slovic's (1982) study found that individuals can more effectively prepare to deal with potential risks by gaining more knowledge about an innovation. Marra et al. (2003) added that, in order to reduce farmers' perceived risk, it is important to develop relevant risk management skills by learning from their own experience. Weber & Milliman (1997) suggested the importance of situational factors in facilitating individuals' decision-making under risks. These factors include times or different contexts at which an innovation is offered.

2.4 Participatory Videos and Phone Messages in Agricultural Extension

Scholars and practitioners have tested participatory video in different contexts, such as agricultural training, to achieve diverse goals like information provision and inducing behavioral change. In contrast to non-participatory video, participatory video aims to involve farmers in video production and distribution and to communicate contextualized information to farmers. Early research on participatory video mainly focused on documenting locals' participation in video production processes and how this approach allows locals' voices to be heard by outsiders, like policy makers. To this effect, Kindon (2003) worked with locals to produce a video about a tribe's history. More recent examples include an approach developed by Digital Green, an Indian NGO, which implements the participatory video approach in agricultural extension training. These examples adapt some elements of participatory video steps, such as producing videos with locals (e.g., Gandhi et al., 2009; Stassart, Mathieu & Mélard, 2011; Cai et al., 2017). Their aim is to use video to facilitate participatory learning among communities. These efforts allow communities to view, discuss and learn from the videos as well as from one another. The videos are lauded for a number of reasons, including their potential roles in improving farmers' knowledge and adoption of agricultural technologies (Gandhi et al., 2009). Other studies (e.g., Cai et al., 2017) investigated an approach to producing participatory videos that features both situated technical content (similar to Digital Green's video), and social and cultural content related to learning and the adoption of an agricultural innovation, all in the form of local farmers' narrative stories. Further, this video initiates a participatory learning process within the same communities where the video was produced. For example, Cai et al. (2017) found farmers' personal stories rendered to video can motivate farmers to discuss the challenges that are imposed by social norms, power relationships, and out-of-dated mindsets in adopting new technologies. As such, farmers' participatory learning provokes them to overcome challenges and their own biases by encouraging them to actively test the innovation.

However, local communities commonly lack video playing devices, and training videos are normally only shown once to a community. 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. Although this phenomenon is not documented in the previous literature on participatory video, studies investigating other approaches used to provision knowledge to rural communities have elicited the drawback of approaches that only provide information one time to individuals (Casaburi & Kremer, 2014). Due to humans' inattention and memory failure, these approaches can be ineffective at informing farmers about complex innovations that require them to practice different steps at a variety of times. Sending reminders to farmers can be a plausible approach to overcoming this drawback (Taubinsky, 2014).

The mobile phone is another ICT commonly used to provide agricultural extension services to farmers. Cole & Fernando (2012) found that voice messages to be effective in helping farmers safely handle pesticides and improve yield. Short Messages Service (SMS) is another widely used function to deliver agricultural extension information due to its simplicity and low cost. Whereas studies investigating the impacts of the SMS approach showed mixed results, the impact information transmitted through SMS on knowledge learning and adoption vary according to context, content, technology, and delivery strategies (Fafchamps and Minten, 2012). Fafchamps & Minten (2012) investigated a program providing crop advisory tips and local weather forecasts to farmers through SMS. They found SMS had no impact on cultivation practices or harvest losses. Alternately, Casaburi & Kremer (2014) designed an intervention in Kenya that sent out SMS information to sugar cane growers at individualized moments (harvest cycle and age of their cane) to help them perform certain tasks. The program increased yield by 11.5 percent (Casaburi & Kremer, 2014). Similarly, 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 (Larochelle, Alwang & Travis, 2016). This study indicated that the impacts of the messages may be associated with their timing, content, and farmers' capacities of applying the information. The authors also attributed the positive impacts of message reminders to farmers' participation in formal trainings on a similar topic. Previous studies on the impact of text reminders suggest that reminders can both increase recipients' recall of certain information and bring individuals' attention to a certain topic (Casaburi & Kremer, 2014; Taubinsky, 2014; Larochelle et al., 2016). Given the general success of SMS in agricultural extension services, I chose to implement this approach in my study. The complementary practices—including proper 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 to remind them about these practices at least two weeks before the key times.

Using the approaches of participatory video and SMS messaging synthesized in the literature review, I test the following hypotheses. These hypotheses are organized by research questions:

In Study One, I compare the treatment effects of farmers' knowledge and uptake between a video-only group, a multichannel group, and a control group.

RQ1: Do farmers in the three groups have different levels of knowledge about DT maize and management practices?

H1: Farmers in the video-only group retain more knowledge about DT maize than farmers in the control group.

H2: Farmers in the multichannel group, which include both the participatory video and mobile phone reminders retain more knowledge about DT maize than farmers in the video-only and control groups.

H3: Farmers in the video-only group retain more knowledge about management practices than farmers in the control group.

H4: Farmers in the multichannel group retain more knowledge about management practices than farmers in the video-only group and control groups.

RQ2: What are the treatment effects on farmers' uptake as measured by their probability to purchase improved seed and their willingness to test DT maize in the next primary maize-growing season?

H5: Farmers in the video-only group are more willing to test DT maize than farmers in the control group.

H6: Farmers in the multichannel group are more willing to test DT maize than farmers in the video-only and control groups.

H7: Farmers in the video-only group are more likely to purchase DT maize than farmers in the control group.

H8: Farmers in the multichannel group are more likely to purchase DT maize than farmers in the video-only and control groups.

RQ3: What are the differential treatment impacts on farmers' knowledge and uptake in terms of whether or not they reside in FIPS villages?

H9: The treatment effects on farmers' knowledge about DT maize and management practices differ between those residing in FIPS *villages and those residing in non-* FIPS *villages.*

H10: The treatment effects on farmers' willingness to test DT maize differ between those who reside in FIPS *villages and those who reside in non-* FIPS *villages.*

H11: The treatment effects on farmers' likelihood to purchase DT maize differ between those who reside FIPS *villages and those who reside in non-* FIPS *villages.*

In Study Two, I intend to explore how the treatments associate with farmers' risk and benefit perceptions of DT maize, and how those perceptions associate with farmers' uptake decisions.

RQ4: What is the difference between farmers' perceived risk and benefit of DT maize in the video-only group, the multichannel group, and the control group?

H12: Risk perception differs between farmers in the treatment groups and the control.

H13: Benefit perception differs between farmers in the treatment groups and the control.

RQ5: How are the perceived risks and the perceived benefits of DT associated with farmers' knowledge about DT maize?

H14: Association between risk perception and farmers' knowledge differs between farmers in the treatment groups and the control.

H15: Association between benefit perception and farmers' knowledge differs between farmers in the treatment groups and the control.

RQ6: How does the knowledge-perception relationship influence farmers' uptake decisions?

CHAPTER 3 RESEARCH METHOD

In this study, we conducted a randomized field experiment in Machakos and Makueni counties in Kenya. The experiment randomly allocated the video training and a multichannel approach, including both audio mobile phone messages and video, to farmers in the study areas. Through the video, farmer actors explain the benefits of DT maize, potential risks related to seed type, how to identify and purchase seed, modern cultivation practices, and their personal stories about uptake. Audio messages deliver advice and reminders on cultivation activities, such as land preparation, planting, and fertilizer application. The intervention provides the study with exogenous variation in access to knowledge about DT maize and modern practices among similar households. The objective was to investigate whether the interventions are associated with greater knowledge about DT maize and modern practices, differential risk and benefit perceptions of DT maize, and uptake of DT maize. In this chapter, I explain the interventions, study area, experimental design, sampling strategies, sample characteristics, operational measures, questionnaire design, and identification strategies.

3.1 The Intervention

A team of researchers, FIPS staff, and local farmers produced the video in December 2015. In the video, farmer actors explained the benefits of DT maize, potential risks related to seed type, 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. In February 2016, 341 households in two treatment groups were invited to participate in the video screenings. Between March and August 2016 (long-rain reason), the period during which they grew maize, 169 households in the multichannel group are sent four different audio messages. Here is an example of the phone message received by farmers in the multichannel group a few weeks prior to application of top dressing fertilizer to maize:

> *"Hello this is Faith Kilonzo. I am calling to remind you this is the time to apply top dressing. You apply the top dressing when the maize has 8 leaves. Apply a bottle cap full of fertilizer 5 centimeters from the base of the maize and cover with soil. This is also the time to do the second weeding. Thank you."*

The intervention provides the study with exogenous variation in access to knowledge about DT maize and modern practices among similar households. The objective was to investigate whether the intervention is associated with more knowledge about and uptake of DT maize. Figure 1 provides a calendar of intervention and data collection activities along with an agricultural calendar. It is important to note that there are two annual growing seasons in the study region: the "short-rains" season from September to February, and the "long-rains" season from March to August. Although rains in the "short-rains" seasons are shorter, they are typically more consistent than rains in "long-rains" seasons. Therefore, farmers tend to grow more maize, the main staple crop, in the "short-rains" seasons than in the "long-rains" seasons. They are also more likely to store the maize they harvest in the "short-rains" season as food for future consumption.

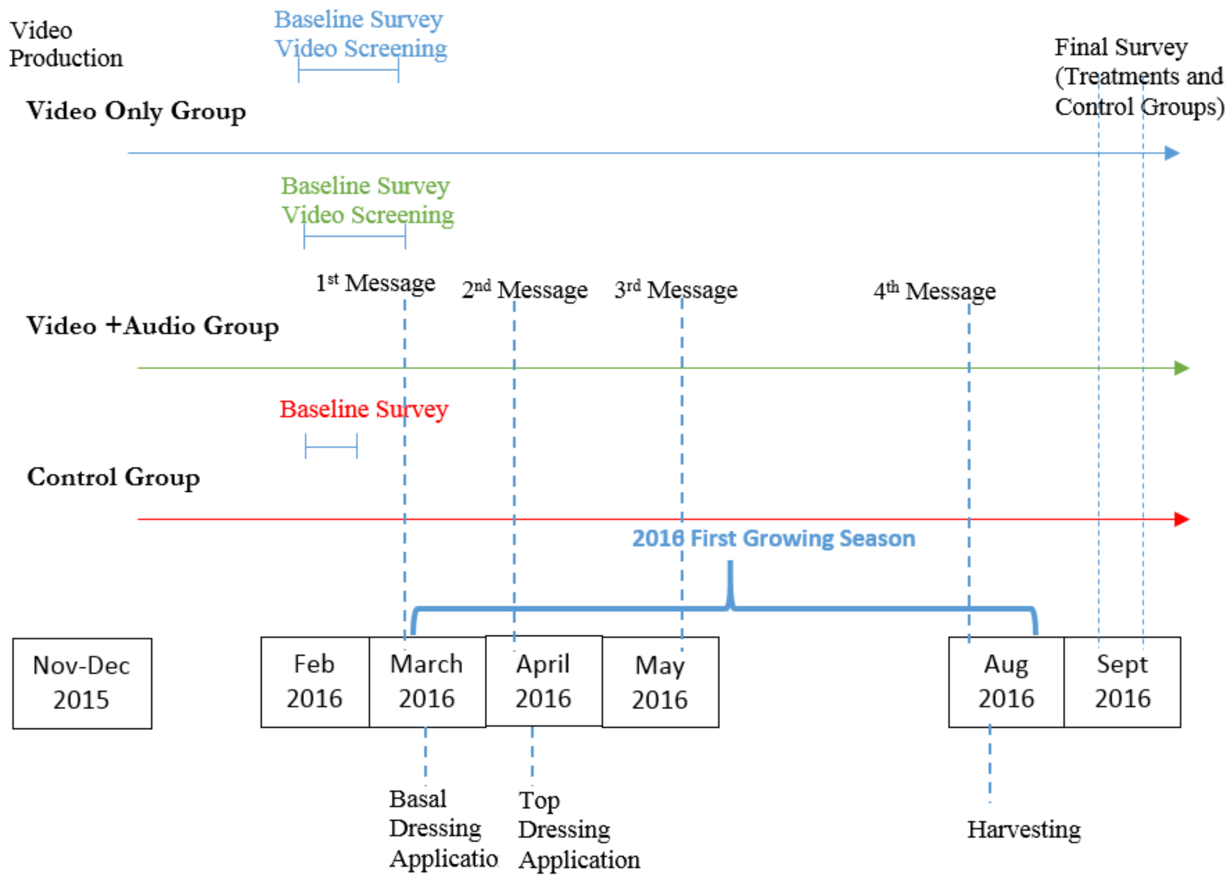


Figure 1:Timeline of the Intervention

3.2 Study Area

The intervention took place in two counties in the southeastern region of Kenya (Figure 2). These counties are located in the dry transitional (DT)[12] agro-ecological zone (AEZ) and are considered medium drought risk zones (20–40 percent PFS) target areas[13], where drought risks are high and DT maize can 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 is generally of low fertility, and many soils are highly erodible (Barber, Thomas, and Moore 1979). The maize yield is low compared to the national average. Most farmers in this area still grow the traditional seed, and some 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 be associated with the fluctuation in maize production in

[12] Other methods include changing planting dates, switching crop species, crop diversification, and soil and water conservation.
[12] The scientists used modern conventional methods to breed DT maize. So current DT maize seed in the ESA market are not genetically modified
[13] 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.

this area (Omoyo, Wakhungu & Otengi, 2015). Farmers' adoption of improved seed, including DT seed, is low, while the dis-adoption rates of improved seed is high (Muhammad et al., 2010).

Machakos County has a population of 442,930 with a poverty rate[14] of 57 percent. The population in Makueni County is 253,316, with a poverty rate of 63.8 percent (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 1,700 meters above sea level (MASL). The mean elevation is 1,357 MASL in Machakos and 1,047 MASL in Makueni. More than 60 percent of the region contains very erodible, relatively shallow, sticky, red, black, and brown clay soil with variable fertility on steep slopes; 20 percent has poorly drained, shallow, stony soils of low fertility (Bernard, Campbell, and Thom, 1989; based on findings by Jaetzold and Schmidt, 1983). The capital towns of both counties are less than 200 km 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 responsibility for crop management.

As previously noted, the two production seasons are between September and February, and between March and 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 short-rains season (Hassan, 1998).

Further, farmers use traditional knowledge passed from parents to children to select the seed. For example, farmers often pick maize cobs that have more rows of kernels to use them as

[14] Population below $1.25 per day

seed. In our survey prior to the intervention, few farmers mentioned taste of maize as a major concern because they were unable to tell the taste difference in varieties of maize. Some farmers mentioned that they observed improved maize to be more vulnerable to pests than traditional varieties.

As these study areas are close to Nairobi, the biggest city in Kenya, many male household members work as laborers in the city. Therefore, in over 70 percent of the households sampled in this study, women farmers made the decisions regarding which maize varieties to plant, and managed the maize throughout the growing season. However, their decisions were influenced by their male family members' support, such as the provision of remittances and information in regards to new improved seed varieties. Around four-fifths of farmers reported fertilizer application to their maize, although we found that the majority of farmers did not apply sufficient amounts of fertilizer. Moreover, farmers lacked knowledge about agricultural practices that could improve the efficiency of using fertilizer, such as fertilizer micro-dosing. A small portion of farmers in these study areas received subsidized fertilizer from the government, while the majority of farmers reported purchasing fertilizer from their local market. The costs of a 50kg bag of fertilizer ranges from $25 to $35 in the local market.

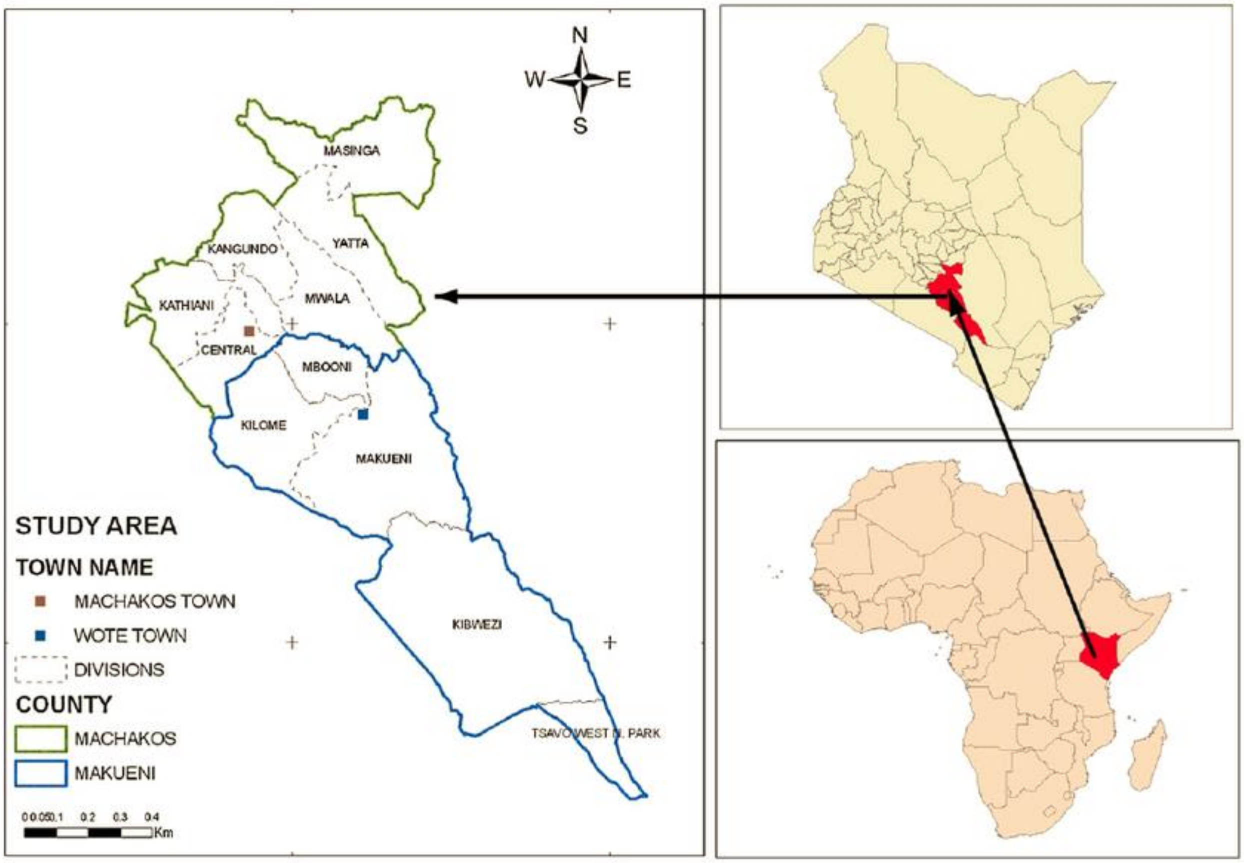


Figure 2:The Study Area

3.3 Experiment Design

In order to answer the research questions, I designed two treatment groups and one control group in this study (Table 1). Households in the video-only treatment group watched a video about DT maize. The video focused on introducing basic knowledge-in-practice, such as where to purchase seed, and how to engage in modern management practices. We expected the video to provide knowledge about DT (H1) and its associated modern practices (H3), and to motivate farmers to test the seed (H5). Video screenings were moderated by a local FIPS. In addition to participating in the video screening, households in the multichannel treatment group also received four audio messages to their mobile phones. This approach was intended to reinforce knowledge about DT maize (H2) and its management practices (H4), and to induce farmers to test composting (H6) because humans have limited memory capacity and limited attention to various characteristics of a technology. The study's control group received no intervention. It was expected that farmers in the multichannel and video-only groups would be more likely to purchase DT seed than farmers in the control group (H7 and H8).

In addition to the random variation in the treatment group, the FIPS condition was also included as a subset of the treatment and control groups in a cross-cutting experiment. Farmers residing in FIPS and non- FIPS villages can be different in diverse ways. These differences include that, FIPS provide services and sell inputs through its village-based advisers (VBA). Farmers residing in FIPS villages receive sample maize seed for free (25g per sample bag) and can purchase regular seed packages (2kg) at retail price from the VBAs. The FIPS trains their VBAs on new varieties and their complementary technologies and practices. These advisors work as small agro-dealers supplying inputs, such as DT maize, 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 DT maize.

Farmers residing in the non- FIPS villages do not receive these services. Therefore, in the FIPS villages, the intervention is not the only information source associated with DT maize. It was expected that households would receive services from FIPS in addition to interventions in both the treatment and the control groups in comparison to those households in the non- FIPS villages. Therefore, differences in knowledge improvement and increased uptake between farmers residing in the FIPS villages and those who did not were expected (H9, H10 & H11).

This experimental design also enabled me to test how treatments associate with farmers' risk and benefit perceptions of DT maize uptake, and how these perceptions associate with their uptake decisions. Farmers in two treatment groups and the control are expected to have different levels of perceived risks (H12) and perceived benefits (H13). Further, it is expected that the association between farmers' perception and knowledge will vary between the treatment groups (H14 & H15). Lastly, I explore whether farmers' uptake decisions relate to the association between their knowledge about DT maize and their perceptions of its varieties (RQ6).

To obtain production information, a pre-test survey was conducted prior to the video screenings in order to determine what maize varieties farmers grew in the previous growing season (November 2015); other demographic data about the study area were also collected through this survey. Then, a post-test was implemented after the first 2016 growing season (March–August 2016) in an effort to understand farmers' testing and perceptions of DT maize after the intervention. Qualitative research methods like focus groups, key informant interviews, and field observation were utilized to attain a deep understanding of how farmers' risk and benefit perceptions associate with their choice to grow or not grow DT maize.

Table 1: Experimental Design

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

3.4 Sampling Strategy

Two wards, Kola and Kee, were selected together with FIPS. Kola is located in the southern part of Machachos County and Kee is located in the northern part of Makueni County. The Kola ward has a population of 24,264; while the Kee ward has a population of 20,926 (GOK, 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[15] were selected among villages within a local FIPS's current or future operating area. A two-stage sampling strategy was used to select households for the study. FIPS offered a list of villages (n=50) to this effect. The list showed that FIPS had no activities in nine out of the 50 villages. All nine non- FIPS villages were included in the study and were randomly allocated to two treatment groups and the control. FIPS continued to have no activities in these villages during the study. 18 villages were randomly selected from the remaining 41 where FIPS had activities prior to and during the study. These 18 FIPS villages were then randomly allocated to the two treatment groups and the control. Control villages were randomly selected from the same

[15] This is the total number of DT maize

sampling frame to preserve comparability to the treatment villages. FIPS also provided a list of households in each village, of which 30 households in each non- FIPS village and 17 households in each FIPS village were randomly selected for inclusion in the study. A larger number of households in the non- FIPS villages were selected, as there more households resided in the non-FIPS villages than in the FIPS villages in the selected study areas.

3.5 Baseline Comparisons

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

$$Y_i = \alpha_1\, Video_i + \alpha_2 Multichannel_i + \mu_i \tag{1}$$

Y_i is a characteristic of the ith household before intervention 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 multichannel groups 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 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 were richer (higher livestock index) than those in the video group. Further, more maize managers in the video-only group were illiterate in comparison to both the multichannel and control groups, while the overall number of people with no formal education in the sample was less than 7 percent.

Table 2: Household Characteristics in Baseline by Treatment Groups[2]

	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 members 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 members	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 FIPS 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

1. For the first three columns, 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.
2. We also compare baseline characteristics between households residing in and out of FIPS villages. Please see Appendix 4.
Standard errors in parentheses. Significance levels of the differences between the two treatment groups and control denoted by *** 99%, ** 95%, * 90%.

3.6 Operational Measures

3.6.1 Perceived risk and perceived benefit

In extant literature, perceived risk and perceived benefit have been measured in various ways, producing different findings and various conclusions about the relationship between perceived risk and perceived benefit, and the relationship between perceived risk and risky behavior (Fausti & Gillespie, 2006; Binder et al., 2011). One main ongoing debate focuses on whether scholars should use a single-item measurement, which captures global risk and benefit assessment, or a multi-item measurement, which captures individuals' perceptions of the specific risks and benefits of an innovation. Another debate focuses on whether perceived risk and perceived benefit should be measured separately or together[16]. In line with the latter strand of research, this study uses two sets of questions to measure perceived risk and perceived benefit separately. This measurement includes multiple items for both constructs.

Coombs & Lehner (1981) created and tested a single item measurement of risk perception asking one question: how risky is the prospect? Several studies tested this scale and asserted that the single-item measurement can accurately reflect individuals' judgments of risk. Weber et al. (1992) found this single item measurement correlated strongly "with standard features of risky prospects that are useful in making decisions" (e.g., Weber, Anderson & Birnbaum, 1992). Cobb and Macoubrie (2004) suggested that a single-item question was useful for measuring risk perception in situations where the public still viewed nanotechnology as an abstract idea. In contrast, Fishoff, Slovic & Lichtenstein (1978) proposed a multi-item measurement using a psychometric procedure to elicit quantitative judgments of the risks and benefits of various activities and technologies. Further, they measured individuals' estimation of

[16] Risk and benefit are the two extrema in one scale

likelihood that each risk and benefit would influence them or the public. Fishoff (1978) et al. argued that this likelihood measurement presents relative magnitude of impact of perceived risk and perceived benefit.

Binder et al. (2011) compared a single-item with a multi-item measurement of individuals' perceived risk and perceived benefit of two new technologies. They found the single-item performed poorer than the multi-item measurement in capturing perceptions (p.14). Binder et al (2011) criticized the single item measurement because it can capture biased responses, as it is less robust in terms of controlling for random errors captured by the measurement. Moreover, they suggested that the multi-item measurement delivered more "descriptive" assessments of perceived risk and perceived benefit than the single-item measurement.

Sitkin & Weingart (1995) tested a multi-item measurement to study perceived benefit and perceived risk together as a single construct. They examined the relationship between risk perception and risky decision-making. Sitkin & Weingart's (1995) measurement entails four instruments that aim to capture information about individuals' overall evaluation of a risky decision. The first three items answered the question: "how would you characterize the decision?" The three seven-point Likert type items are: threat—opportunities, potential for loss—potential for gains, and positive situation to negative situation. The fourth item measures participants' estimation of likelihood that a risky decision can be successful (Sitkin & Weingart 1995). Other researchers criticized similar multi-item measurements for being incapable of adequately distinguishing between perceived risk and perceived benefit, as well as for the lack of clarity regarding the instrument's face validity (Binder et al., 2011).

I adapted Sitkin & Weingart's (1995) multiple items to measure risks and benefits. However, in this study, risk and benefit were measured separately due to their qualitative differences in the context of this study. The decisions regarding whether or not to grow DT maize can be more complex than decisions made in lab settings about the lottery or gambling, as they includes aspects beyond mere monetary trade-off. Furthermore, rather than engage a global evaluation, I intend to understand the specific risks and benefits farmers perceived to be associated with DT maize. All specific perceived risks and perceived benefits were tailored to regional conditions and to the technology. Four dimensions of the perceived risk of DT maize include: (1) *having a poor yield*, (2) *losing the money spent on the seeds,* (3) *losing spent on growing the maize, and* (4) *not having food in the next season*. Each dimension was comprised of two items: (1) *likelihood of the negative impact of the risks* and (2) *frequency of the risks*. Two dimensions of perceived benefit of DT maize include (1) *fast maturation* and (2) *drought tolerance*. Each dimension of perceived benefit was comprised of two items: (1) *likelihood of positive impact of DT maize and* (2) *beliefs in the positive impact of DT maize*. Participants rated each item on a 7-point scale. These dimensions of perceived risk and perceived benefit were derived from previous literature (e.g., Smale, Just and Leathers, 1994) and findings from qualitative studies conducted by other project members[17].

[17] Three other team members who worked in the same project conducted this qualitative study summer 2015 in the study areas.

Below are the questions used to measure perceived risk and perceived benefit[18]:

Perceived risk	Perceived benefit
Dimensions of perceived risk:	Dimensions of perceived benefit:
a. having a poor yield	a. fast maturation
b. losing the money spent on seeds	b. drought tolerant
c. losing the time spent on growing the maize	
d. do not have food in the next season	*Measurement items:*
	i. To what extent would any of these benefits positively affect you and your family?
Measurement items:	ii. How important are these benefits to your family?
i. How likely is it that any of these problems would actually happen to John and Mary if they planted DT maize?	
ii. How likely is it that each of these three concerns would negatively influence you and your family?	

3.6.2 Knowledge Scores

Knowledge was measured by giving respondents an exam that tested whether they retained key details of DT maize and its complementary practices. 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. Appendix 1 details the test questions and acceptable answers. This knowledge test had two parts: in the first part, respondents were asked to list what they knew about DT

[18] A full list of question can be found in Appendix 1

maize; in the second part, 11 questions were used to test respondents' knowledge about the complementary practices featured in the video.

3.6.3 Behaviors and Behavioral Intention

The video was screened in the treatment groups several weeks before the 2016 secondary planting season (March to August), when the majority of farmers had not yet purchased maize seed to plant for the season. The first audio message was sent to farmers in the multichannel groups within a week after the screenings and encouraged farmers to purchase DT maize seed from reliable sources, such as FIPS or valid input shops.

The measurement used by Smale, Just & Leathers (1994) was adapted for this study to implement the proportions of land allocated to new varieties. This was the first variable used in this study to measure farmers' uptake of DT. Farmers were first asked to report total farm size in their households. They were then asked what maize varieties they planned to grow in the 2016 primary planting season (September 2016 to February 2017) followed by the size of the plot in which they intended to grow each variety. The total size of the farm on which they planned to grow DT maize in the primary season was summed. In order to measure farmers' willingness to plant DT maize in the primary season, I used farm size that farmers were going to allocate to plant DT maize to divide their total farm size. This measurement was believed to be a reliable proxy for capturing farmers' actual uptake decisions because we asked farmers to estimate their land allocation to DT in the post-test. This test was conducted two to three weeks prior to purchasing the seed in the 2016 primary season when all the intervention were implemented. This variable captured the impact of both the video and all four audio messages, as farmers were asked to give their responses to the question after the interventions were implemented in the communities (see Figure 1).

The second variable used to measure the impact of treatment on farmers' behavior is whether they purchased DT maize seed. Farmers were asked what maize varieties they planted in the 2016 secondary maize season and how much they paid for the seed. Then a dichotomous variable was created to determine farmers' willingness to purchase the seed, in which the variable "1" was coded if farmers paid for the seed, and the variable "0" was coded if they did not. This variable captured an aspect of farmers' responses following the video screening and the first audio message, which both occurred prior to farmers' seed purchases in the 2016 secondary maize season (see Figure 1).

3.6.4 Indirect Questioning and Visual Aids

People tend to show their best side and hide their negative side during interactions with others (Fisher, 1993). This tendency is called *social desirability bias*. It can substantially distort the information gathered through self-reported measurement across almost all social science disciplines. The bias can be fraught as it leads to spurious theoretical and practical conclusions (Mensch & Denise, 1988).

As such, an indirect questioning technique is widely used by researchers to minimize the impacts of social desirability bias (e.g., Gregson, Zhuwau, Ndlovu, 2002). It is a projective technique through which study subjects respond to structured questions from another person's or group's angles. Indirect questioning can reduce social desirability bias and offer reliable measurement (Gregson et al., 2002). Thus, it can give respondents a context to report information from the external world that is similar to them rather than of themselves directly. A typical way to enact indirect questioning is to ask a respondent to guess "what would other people would do?" instead of "what would I do?"

Despite the advantages of using indirect questioning, the limitations of this measurement approach (e.g., Hofmann & Schmitt, 2008) include that it is not suitable for all kinds of behavior, and its reliability and validity can be lower than those of more direct measures. Further, scholars need to be cautious when they use the data collected from indirect questioning (Bishop & Heberlein, 1979).

While cautious of these potential limitations, the current study uses this indirect questioning technique in order to increase validity of the measurement. For instance, when measuring farmers' perceived risk, farmers were asked to respond to "what do farmers John and Mary need to worry about with DT maize if they plan to grow them next season?" Here is the question:

> *Farmer John and Mary, they are husband and wife. They have three kids and live in your neighboring village. They have some land and grow maize every year. They only grow traditional maize and Duma 43, so they don't know anything about DT maize. They come to you and ask your suggestions. What things do John and Mary need to worry about if they are going to grow DT next year?*

Most of the participants in this study have low-level literacy skills. They also have little experience answering survey questions that ask them to weigh the importance, agreement, and likelihood of statements or situations (Bernard & Taffesse, 2014). Chachamovich, Flech & Power (2009) suggested that illiterate respondents failed to distinguish a five-point scale (extremely high – extremely low) and a three point scale (low, medium, high). The use of visual scales can prevent this difficulty. In addition, (Reid, Maag & Vasa, 1994) found visual scales can reduce social desirability bias. As such, the visual scales featured in Gore & Kahler (2015) were adapted to this study in self-report questions, such as perceived risk, perceived benefit, and expected outcome. One example is:

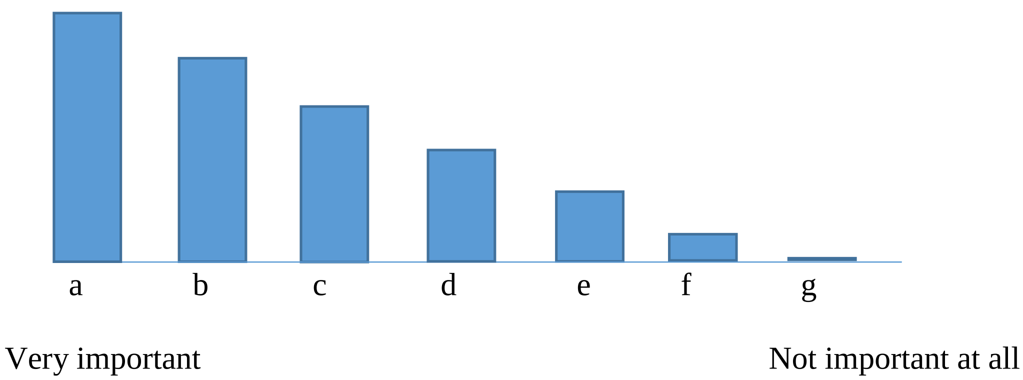


Figure 3: How important is using chemical fertilizer to get good DT maize yield?

All questions in the questionnaire, including the indirect questions and visual scales, were tested before the actual survey. A pilot study was conducted with the enumerators in a Kamba community to ensure that wording and measurements, including perceived risk, perceived benefits, and expected outcomes, were appropriate to the local context.

3.7 Questionnaire Design

The pretest survey was used to gather the following information: basic household demographics and households' maize production information of all types of maize[19], including size, seed varieties, productivity, etc. These questionnaires collected information on up to four maize varieties that households planted in the secondary planting season as well as what they intended to plant in the 2016 primary season. Other modules in the questionnaire included experience of drought, seed and other input access, information sources regarding maize production, household GPS, and distance to the nearest market.

In the post-test survey, the following information was collected: households' maize production information of up to four types of maize, size of land for growing certain maize varieties, seed varieties, costs of seed, usage of modern practices, and what maize varieties farmers intended to plant in the next primary season. Similarly, the post-test questionnaire includes farmers' knowledge about DT and modern practices, risk perception, benefit perception, experience of drought, seed, and access to the input and output market.

The schedules of both surveys as well as the interventions are presented above in Figure 1.

3.8 Estimation Strategies

3.8.1 Aggregated Indices

Several studies combined the value of perceived risk and perceived benefit as a single variable by subtracting perceived benefit from perceived risk. According to Binder et al. (2010), the disadvantage of this analysis method is that it potentially loses valuable information, such as

[19] Including improved and traditional seed

the distinct influences of risk and benefit perception to an individual's risky choices. They invoked further studies focusing on how risk and benefit perception converge and diverge. Relatedly, this study aggregates perceived risk and perceived benefit indices separately. Clearly, aggregation still leads to loss of information for each of the specific dimensions, however, can also reduce errors by cancelling out some of the random noise inherent in self-reporting measurements. In this case, the aggregation across the dimensions of each construct can offer a useful measurement (Bernard & Taffesse, 2014).

As previously mentioned, for each dimension of perceived risk and perceived benefit, two items were included to measure the likelihood of a risk dimension and the severity of its impact. To obtain the aggregated perceived risk where PR below is perceived risks, two items were multiplied for each perception dimension. Then the four dimensions of perceived risk were summed and divide by the number of perceived risks:

$$PR = \sum_{i=1\ j=1}^{I_{PR}} likelihood_{ij} * severity_{ij}$$

where, PR is perceived risk.

Similarly, to obtain the aggregated perceived benefits, we sum the two dimensions of perceived benefit, the likelihood of positive impact of DT maize and beliefs in its positive impact, and divide it by number of the perceived benefits:

$$PB = \sum_{i=1}^{I_{PB}} likelihood_{ij} * belief_{ij}$$

where, PB is perceived benefit.

The same wording and scale (seven-point Likert scale) was used for the questions measuring a given construct. To analyze the constructs together in a model, respondents' ratings for the questions of each construct were summed.

3.8.2 Estimation of Treatment Impacts

A key goal of this study was to analyze whether the two treatments increased households' level of knowledge and willingness to test DT maize. As such, the following factors in treatment groups were compared with those of the control group: level of knowledge, proportion of maize land that households allocated to DT, the probability of paying for improved seed, and the perception of DT maize. Additionally, the presence of FIPS effects within the treatment groups was tested by comparing the outcomes of households in FIPS villages with those of households in non-FIPS 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 in control villages.

The impact of the two treatments was calculated by comparing: households' post-test knowledge scores, whether or not they purchased improved seed, the proportion of land they were willing to allocate to DT, and the perceived risk and perceived benefit of DT maize uptake. Namely, I estimated the following regression:

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

Where Y_i were outcomes including: (1) level of knowledge about DT maize and its complementary practices, which household *i* retained, (2) whether the household purchased improved maize, (3) farmers' willingness to plant DT maize and the proportion of land farmers were willing to allocate to the varieties, and (4) farmers' risk and benefit perceptions. Z_i is a vector of household-level controls, including gender of household head, number of people in household, livestock index (number of livestock multiplied with each type's market price), 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 maize from other information sources such as radio, and whether households lived in the FIPS villages. In this specification, the reference group was the control group. Additionally, the error term $_i\mathcal{E}_i$ was uncorrelated with other explanatory variables as households were randomly assigned to treatments. 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 provided 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. The baseline characteristics of those who actually received the treatments in the treatment groups and those who did not receive treatment in the control group (compliers) were compared with those who did not receive treatments in the treatment groups and those who received treatment in the control group (non-compliers) using formula (1), see Appendix 3. Two significant differences between the compliers and non-compliers were found in accordance with the following characteristics: (a) compliers were younger than non-compliers and (b) more compliers were in the non- FIPS villages than in the FIPS villages. There are several reasons that can explain the relatively large number of non-compliers (compliance rate). One reason is that 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 screenings in their village. In the multichannel group, phone messages were only sent to those who attended the video screenings, as we were not able to reach some households' phones due to technical issues, such as phones being turned off or having no reception[20].

The Local Average Treatment Effects (LATE) were estimated using the treatment assignment, $video_i$ and $multichannel_i$ as instruments for compliance (Gerber & Green, 2012). In particular, we estimated the following system of equations:

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

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

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

Using these equations, we predicted the likelihood of households attending the video screening ($Watch_i$) and the likelihood of households attending the video screening and receiving the audio messages ($ReceiveWatch_i$). In other words, we were able to obtain predicted values of the likelihood that households were compliers in the video treatment and in the multichannel treatment respectively, and Y_i were the outcome variables that included knowledge about DT maize, knowledge about maize management practices, and DT uptake. φ was the LATE on those

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

who were compliers in the two assigned treatment groups. In Appendix 3, I present the comparison of baseline characteristics between households who received the treatments and those who did not.

The following variation of Equation (4) was estimated to calculate the ITT effect on households with different NGO statuses:

$$Y_i = \beta_1\, Video_{ij} + \beta_2 Multichannel_{ij} + \beta_3 Video_{ij}\, W_{\mathrm{j}} + \beta_4 Multichannel_{ij}\, W_{\mathrm{j}} + \gamma\, Z_{ij} + \mu_{ij} \qquad (4)$$

where W_j is NGO status (i.e., lived in an FIPS village or lived in a non-FIPS village) or main income source (i.e., agricultural activities and non-agricultural activities).

CHAPTER 4 RESULTS

In the next chapter, I present the results in two sections based on the research questions. For Study One, the present results answer questions about the interventions' treatment impacts on farmers' knowledge and uptake of DT maize. For Study Two, the treatments are investigated in terms of how they associate with farmers' perceived risks and benefits, and how these perceptions relate to farmers' uptake of DT maize.

4.1 Study One

In this study, I present the impact of treatments on: farmers' levels of knowledge regarding DT maize and its complementary management practices, farmers' probability of purchasing improved maize seed, and farmers' willingness to plant these seed varieties in the next primary growing season. I also present results of the heterogeneous treatment effects between farmers who received FIPS services and farmers who did not.

4.1.1 The Impacts of Treatments on Knowledge about DT Maize and Management Practices

Results of the treatment effects on respondents' knowledge scores are reported in Table 3. Impact of the treatments on farmers' knowledge about DT maize are estimated in columns 1-4, and impact of the treatments on farmers' management practices are estimated in columns 5-8. Measurement of management practices includes proper planting and fertilizer application. The video featured characteristics of DT maize and its management practices, and the phone audio messages reinforced them. Therefore, both knowledge measurements can indicate the impact of reminders on households' knowledge about the practices. Columns (1), (2), (5) and (6) 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 about DT maize, households in the multichannel group, on average, showed a 0.19 higher knowledge score on DT maize than households in the control group. This difference accounts for three percentage points of the total knowledge score and are quantitatively small, but statistically significant. Households in the video group gained nearly the same knowledge score as the control group. This difference in knowledge score is not significantly higher in the multichannel group than it is in the video-group.

The proportion of farmers who watched video in the video treatment group is 47.82 percent, and in the multichannel treatment, 37.04 percent of the farmers watched the video and received the audio messages. To solve this compliance problem, the random treatment assignments were used as instrumental variables for treatments received. The results in column (3) suggest sizeable impacts of the multichannel treatment on households' level of knowledge about DT maize and its complementary practices in cases where the households received the treatments. Column (3) shows households who received both video and the four audio messages earned knowledge scores on DT that were 0.52 higher than households in the control group and 0.47 higher than households in the video-only group. The multichannel treatment increased households' knowledge of DT maize by 8.6 percentage points of the total knowledge score, and the video-only treatment increased it by 7.8 percentage points. The difference between the multichannel group and the control group is statistically significant.

Similar results were found for the households' knowledge score on DT maize management practices. Column (5) in Table 3 shows that the multichannel treatment increased farmers' level of knowledge by 0.4 over farmers in the control and the video-only groups. These differences are around 3.6 percentage points of the total knowledge score of DT maize. Column

(7) presents the LATE estimation showing farmers in multichannel treatment groups retaining eight percentage points more knowledge about DT maize management practices than farmers in the control group, and six percentage points more than farmers in the video-only group. All of these reported differences are statistically significant.

Overall, these results indicate that multichannel treatment can significantly increase households' knowledge about DT maize compared to the video-only treatment and the control. Further, the reminders about DT maize management practices sent out to the multichannel treatment group significantly improved households' knowledge about the complementary practices of growing DT maize, which were demonstrated in the video and reinforced in the audio message reminders.

Table 3: Knowledge Scores [4] Regression by Treatment Groups[1]

	Knowledge about DT [4]				Knowledge about the management practices			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Video (1)	0.02	0.02			0.01	-0.05		
	(0.09)	(0.09)			(0.15)	(0.16)		
Multichannel (2)	0.19*	0.14			0.40**	0.31*		
	(0.10)	(0.09)			(0.15)	(0.16)		
Video Complier			0.05	0.02			0.20	0.11
			(0.21)	(0.16)			(0.23)	(0.24)
Multichannel Complier			0.52**	0.40*			0.88***	0.77***
			(0.25)	(0.24)			(0.29)	(0.30)
Additional baseline controls [2]	N	Y	N	Y	N	Y	N	Y
Observations	582	582	582	582	582	582	582	582
Mean Knowledge scores in the Control	0.55	0.55	0.55	0.55	7.19	7.19	7.19	7.19
households in the video only group watched the video [3]			0.48	0.48			0.48	0.48
			(0.02)	(0.02)			(0.02)	(0.02)
households in the multichannel group watched the video and received the messages [3]			0.37	0.37			0.37	0.37
			(0.04)	(0.04)			(0.04)	(0.04)
F-test values for Video only = Multichannel	1.89	1.32	2.30	2.12	5.22**	4.54**	5.95**	5.45**

1. Column 1, 2, 5 & 6 report the Intend-to-Treat (ITT) estimates of the intervention. Column 3, 4, 7 & 8 report the Average Treatment Effect or Local Average Treatment Effects (LATE) estimates using the treatment assignments as instruments for the compliers in each treatment group.

2. Additional baseline controls in columns 2, 4, 6 & 8 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, residence in FIPS villages or not, and total amount of fertilizer applied in the 2016 long rain season.

3. Predicted value of the likelihood for households in two treatment groups to participate in the intervention. For the multichannel group, 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 knowledge about DT is 0-6, measured in increments of 0.5 as a unit. The knowledge measurement of DTmanagement practices is 0-11 with 1 as a unit.

Standard errors in parentheses. Significance levels of the differences between the two treatment groups and control group denoted by *** 99%, ** 95%, * 90%.

4.1.2 The Impacts of Treatment on Willingness to grow DT maize

Uptake of DT maize is modeled as a function of the treatment groups and households' socio-economic characteristics. The same variables from the earlier 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-test data collection was carried out in September 2016. As such, it was not possible to capture the households' actual uptake of DT in the primary maize growing season, which occurs from September to February. Therefore, I captured the households' post-intervention intention to grow DT maize in the next primary season, and used it as a proxy to measure households' uptake of DT maize.

Table 4 shows that the multichannel treatment had a positive and significant impact on households' intention to plant DT maize in the next primary planting season. The multichannel treatment increased the probability of uptake by 14 percent. The video-only treatment, however, had a positive but insignificant impact on this intention. It increased farmers' willingness to plant DT by three percent. This evidence is consistent with a behavioral model of inattention; in other words, the audio message probably had a reminder effect on households' uptake of DT maize. The LATE estimation reported in Table 4 suggests that the multichannel treatment increased the probability of DT uptake by 38 percent, and the video-only treatment increased it by 7 percent.

Two outcome variables were used to measure farmers' willingness to grow DT maize in the 2016 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 were willing to allocate to DT maize that ranged from 0 to 1. Only the regression analysis using the dichotomous variable as the outcome variable in Table 4 is presented, as the analysis using the continuous outcome variable showed similar results.

Table 4: Marginal Impacts of Treatments on Households' Intention to Grow DT Maize in the Next Primary Season [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)
Additional baseline controls [1]	N	Y	N	Y
Observations	582	582	582	582
Mean adoption rate of control group	0.37	0.37	0.37	0.37
Households in the video only group watched the video			0.48	0.48
			(0.02)	(0.02)
Households in the multichannel group watched the video and received the messages			0.37	0.37
			(0.04)	(0.04)
F-test values for Video-only = Multichannel	2.12	3.23*	2.60*	6.04**

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, main maize growers' education level, residence in FIPS villages or not, and total amount of fertilizer applied in the 2016 long rain season.
2. Columns 1 & 2 report the Intent-to-Treat (ITT) estimates of the intervention. Columns 3 & 4 report the Average Treatment Effect or Local Average Treatment Effects (LATE) estimates using the treatment assignments as instruments for the compliers in the treatment groups.
3. These analyses are based on a linear specification; note that other non-linear models—such as random effects Probits—yielded similar coefficient magnitudes (not reported).
4. The indicator variable for households in two treatment groups participated in the intervention. For the multichannel group, 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 in parentheses. Significance levels of the differences between the two treatment groups and control group are denoted by *** 99%, ** 95%, * 90%.

4.1.3 The Impacts of Treatment on Probability to Purchase Improved Maize Seed

I found the multichannel treatment tended to increase farmers' probability of purchasing fresh improved maize seed more than the video only treatment in cases where farmers decided to grow DT maize and other improved maize varieties. Farmers were informed about the importance of planting fresh improved maize seed in the video and the first audio message. This information was sent out to farmers a few weeks before it was time to purchase the maize seed. A little more than half of the participants who reported growing maize in the first maize season of 2016purchased improved seed (n = 280). On average, they spent 230Ksh on one KG of the maize seed, which is similar to the average price of improved maize seed (median = 225 & SD = 45, range 140-500Ksh). Farmers' probability of purchasing the maize seed is modeled as a function of the treatment groups and households' socio-economic characteristics. In total, around half of the farmers purchased maize seed after the intervention in the first planting season of 2016. Table 5 shows that all farmers in the multichannel group, regardless of whether or not they received the treatments, were six percent more likely to pay for improved maize seed than farmers in the control group. The difference was 15 percent among farmers who actually received the treatment, which is significant at 0.05 level. Moreover, around one fifth of the farmers reported that they purchased DT maize seed in the first planting season of 2016. Among them, farmers in the multichannel group were nine percent more likely to pay for DT maize seed than farmers in the control. This difference is significant at the 0.1 level among farmers who are compliers.

In sum, households in the multichannel treatment group were more likely to purchase improved maize seed and more willing to grow DT maize in the next primary maize planting season than the households in the control and video-only treatment groups. The analysis shows that although the multichannel treatment did not increase households' knowledge about DT maize practices, it reinforce households' knowledge about DT maize, and correspondingly reinforced farmers' likelihood to purchase improved maize seed and their willingness to try DT maize.

Table 5: Marginal Impacts of Treatments on Purchasing Maize Seed by Treatment Groups

	Purchased Improved Maize				Purchased DT Maize			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Video (1)	-0.03	-0.01			0.04	0.03		
	(0.05)	(0.05)			(0.04)	(0.04)		
Multichannel (2)	0.09*	0.09*			0.06*	0.04		
	(0.05)	(0.05)			(0.04)	(0.04)		
Video Complier			-0.07	-0.03			0.09	0.08
			(0.08)	(0.08)			(0.06)	(0.06)
Multichannel Complier			0.20**	0.19**			0.15*	0.13
			(0.10)	(0.10)			(0.15)	(0.08)
Additional baseline controls [2]	N	Y	N	Y	N	Y	Y	Y
Observations	582	582	582	582	582	582	582	582
Likelihood of purchasing seed in the control group	0.49	0.49	0.49	0.49	0.17	0.17	0.17	0.17
Households in the video-only group watched the video [3]			0.48	0.48				0.48
			(0.02)	(0.02)				(0.02)
Households in the multichannel group watched the video and received the messages [3]			0.37	0.37				0.37
			(0.04)	(0.04)				(0.04)
F-test values for Video only = Multichannel	4.72**	3.71*	8.03***	6.17**	0.25	0.56	0.56	0.38

1. Columns 1, 2, 5 & 6 report the Intend-to-Treat (ITT) estimate of the intervention. Columns 3, 4, 7 & 8 report the Average Treatment Effect or Local Average Treatment Effects (LATE) estimate using the treatment assignments as instruments for the compliers in each treatment group.

2. Additional baseline controls in columns 2, 4, 6 & 8 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, residence in FIPS villages or not, and total amount of fertilizer applied in the 2016 long rain season. In Columns 6 & 8, households in FIPS villages who have higher asset indexes are more likely to purchase DT maize seed. In Columns 2 & 4, male-headed households and households located further away from the seed market were more likely to purchase improved maize seed.

3. Indicator variable for households in two treatment groups participated in the intervention. For the multichannel group, 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 in parentheses. Significance levels of the differences between the two treatment groups and control group are denoted by *** 99%, ** 95%, * 90%.

4.1.4 Differential Impacts of the Intervention

I found that the treatment effects were relatively heterogeneous between households residing in the FIPS villages and households who did not. Table 6 shows that the impact of both treatments on households' knowledge about DT maize was mostly driven by those residing in the FIPS villages. Households residing in the FIPS villages who were assigned to one of the two treatments gained higher knowledge scores on DT maize than the households who received the treatments but were located in the non-FIPS villages. Households assigned to the multichannel treatment group who lived in the FIPS villages scored 0.26 points higher on index measuring knowledge about DT maize than households in the control group that without the FIPS' services. This difference accounts for four percentage points of the total knowledge score on DT maize; it is quantitatively small, but statistically significant. Households assigned to the video treatment who lived in the FIPS villages scored 0.15 points higher on the index measuring knowledge about DT maize than households in the control group. This difference is not statistically significant. However, it is worth noting that, in the control group, there were no significant differences in knowledge about DT maize between the farmers living in the FIPS villages and those in the non-FIPS villages. This suggests that the FIPS' efforts became important only when paired with the treatments.

Table 6 shows that the treatment effects on farmers' knowledge about management practices were significantly higher among farmers in the multichannel group who resided in the non-FIPS villages. These farmers scored 0.53 points higher on the index measuring knowledge about DT maize management practices than farmers in the control outside the FIPS-supported area. This difference constitutes nine percentage points of the total knowledge score on management practices. I did not observe similar significant differences in knowledge about practices between the farmers in the video-only treatment group who resided in the non-FIPS villages, and those in the control group who did not reside in the FIPS-supported area. Further, farmers in the FIPS villages retained less knowledge than farmers in non-FIPS villages in both the video-only group and the multichannel group; however, this difference is not significant. This might be because the FIPS already provided farmers with training regarding management practices prior to the video screenings. These farmers may have thus learned less about the management practices from the treatments than farmers in the same treatment groups who did not have experience working with the FIPS.

I found that farmers living in the FIPS villages who received the multichannel treatment were more likely to purchase improved seed in the first planting season of 2016 after watching the video and receiving the audio message reminders compared to farmers who in the video-only group and control groups, regardless of whether they lived in the FIPS villages or not. Moreover, farmers' likelihood of purchasing improved seed was also higher in the video-only treatment group if they lived in the FIPS villages. In the control group, farmers living in the FIPS villages were less likely to purchase improved seed than farmers in the non-FIPS villages. This may be because the FIPS offers their farmers sample maize seed, including DT maize, for free. The two treatments, especially the multichannel one, motivated farmers living in the FIPS village to invest more than farmers in the non- FIPS villages in improved maize seed, instead of depending on the free sample seed, which is normally small in quantity (25g per bag). The multichannel treatment increased the probability of farmers' purchasing improved seed by 18 percent when a household was located in the FIPS villages compared to farmers who lived in the non- FIPS villages but were assigned to the control. Compared to households in the FIPS villages who were assigned to the control group, the video-only treatment increased percentage of farmers who are willing to purchase improved seed by 12 percent if a household resided in the FIPS villages.

Households in the video treatment and multichannel treatment groups had higher willingness to plant DT maize in the next primary season if they lived in the FIPS villages as opposed to households who lived in villages with no FIPS services (see Table 7). In the control group, the differences in willingness to plant DT maize were similar between households residing in the FIPS villages and those who did not. Compared to the control group, the multichannel treatment increased the probability of uptake by 20 percent when a household lived in the FIPS villages, and the video-only treatment increased willingness to plant DT by 13 percent if a household resided in the FIPS villages. Both impacts are statistically significant. VBAs in the villages mainly serve as seed suppliers, so the households in the FIPS villages have easier access to DT maize than the households in the non- FIPS villages. I speculate this makes the uptake more likely. In Appendix 3, I present the comparison of baseline characteristics between households living in FIPS villages and those living in non- FIPS villages.

In Study One, I found that farmers in the multichannel group retained more knowledge about DT maize and its management practices, and that they were more likely to purchase improved seed and more willing to grow DT maize in the next primary season than farmers in the video-only and control groups. Therefore, H2, H4, H6 and H8 are supported in this study. Further, there is not a significant difference in knowledge and uptake between farmers in the video-only group and control groups; therefore, this study fails to support H1, H3, H5 and H7. Moreover, the services provided in FIPS villages enhanced the multichannel treatment effect on farmers’ knowledge about DT maize and uptake, which suggests that factors such as easy access to DT maize complement the information provision via trainings and reminders in the multichannel group. However, farmers' knowledge scores of DT maize management practices were higher in the non- FIPS villages than farmers in the FIPS villages in both treatment groups, though this difference is not statistically significant. Thus, these findings partially support H9, H10 and H11.

Table 6: Differential Impacts of Treatments on knowledge about DT by NGO Status (ITT)[1]

	Knowledge about DT maize		Knowledge about DT management practices	
	(1)	(2)	(3)	(4)
Video (β_1)	-0.17	-0.13	0.15	0.18
	(0.22)	(0.19)	(0.23)	(0.23)
Multichannel (β_2)	0.09	0.06	0.53**	0.46**
	(0.17)	(0.12)	(0.23)	(0.23)
Video treatment x FIPS (β_3)	0.32	0.27	-0.40	-0.45
	(0.23)	(0.20)	(0.31)	(0.31)
Multichannel treatment x FIPS (β_4)	0.16	0.16	-0.40	-0.32
	(0.24)	(0.21)	(0.31)	(0.32)
Farmers assigned to video treatment residing in FIPS villages [2]	0.15	0.16	-0.25	-0.27
	(0.12)	(0.10)	(0.22)	(0.22)
Farmers assigned to multichannel treatment residing in FIPS villages [2]	0.26***	0.25***	0.14	0.14
	(0.08)	(0.09)	(0.22)	(0.22)
Additional baseline controls	N	Y	N	Y
Observations	582	582	582	582
Knowledge score in control group (FIPS)	0.55	0.55	7.49	7.49
Knowledge score in control group (non-FIPS)	0.54	0.54	7.00	7.00

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, main maize growers' education level, residence in the FIPS villages or not, and total amount of fertilizer applied in the 2016 long rain season.

2. The coefficients are a sum of the main effects and the interaction effects.

Standard errors in parentheses. Significance levels of the differences between the two treatment groups and control group are denoted by *** 99%, ** 95%, * 90%.

Table 7: Differential Impacts of the Treatments on Households' Probability of Purchasing Improved Maize Seed and Intention to Grow DT Maize in the Next Season by NGO Status[2]

	Purchased Improved Maize		Intention To Grow DT Maize[2]	
	(1)	(2)	(3) [2]	(4)
Video (β_1)	-0.18**	-0.15	-0.12*	-0.11*
	(0.07)	(0.07)	(0.05)	(0.06)
Multichannel (β_2)	0.03	0.03	0.05	0.02
	(0.07)	(0.07)	(0.06)	(0.05)
Video treatment x FIPS (β_3)	0.29**	0.27	0.24***	0.23**
	(0.10)	(0.10)	(0.08)	(0.09)
Multichannel treatment x FIPS (β_4)	0.14	0.14	0.15	0.17*
	(0.10)	(0.10)	(0.11)	(0.11)
Farmers assigned to video treatment residing in FIPS villages [3]	0.12*	0.12*	0.13**	0.12*
	(0.07)	(0.07)	(0.06)	(0.07)
Farmers assigned to multichannel treatment residing in FIPS villages [3]	0.18**	0.17	0.20**	0.19**
	(0.07)	(0.07)	(0.09)	(0.09)
Additional baseline controls [1]	N	Y	N	Y
Observations	582	582	582	582
Control Mean (FIPS villages)	0.41	0.41	0.38	0.38
Control Mean (non-FIPS villages)	0.54	0.54	0.37	0.37

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, main maize growers' education level, residence in FIPS villages or not, and total amount of fertilizer applied in the 2016 long rain season. In column 2, gender of household head and house's distance to the nearest seed market are significant baseline predictors to whether farmers purchased improved seed after the intervention. In column 4, the number of livestock is the only significant predictor to farmers' willingness to plant DT in the next season.

2. 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).

3. The coefficients are a sum of the main effects and the interaction effects.

Standard errors in parentheses. Significance levels of the differences between the two treatment groups and control group are denoted by *** 99%, ** 95%, * 90%.

4.2 Study Two

I found that farmers' uptake of DT maize was mainly attributed to the perceived risk of growing these varieties, which were mitigated by the knowledge farmers gained from attending the video screening and receiving the audio messages. Farmers in the multichannel treatment had the lowest perceived risk among the three treatment groups. They were more likely to test DT maize if they had lower perceived risk. Farmers' knowledge about DT maize moderated the relationship between perceived risk and willingness to test DT maize. In fact, for farmers with little to no knowledge about the varieties, perceived risk was more likely to reduce farmers' willingness to grow the seed. Whereas, for farmers who had higher knowledge levels, perceived risk was less likely to associate with farmers' willingness to grow DT maize. Further, I found that farmers who perceived lower risk were more likely to purchase DT maize seed and other improved maize seed. However, perceived benefit was not significantly associated with probability to purchase the seed, nor with farmers' willingness to grow the seed in the next primary season. As DT maize was a new technology for the farmers in this study, helping them increase their knowledge about the varieties and reduce their perceived risk of the seed by helping them tackle potential risks tended to motivate farmers to test DT maize. Therefore, future efforts to communicate information on DT maize should be geared toward knowledge improvement and risk mitigation.

4.2.1 Perceived Risk and Perceived Benefit by Treatment Groups

As shown in Figure 3, farmers in the multichannel group perceived lower risk in all four dimensions. The same figure displays farmers' perception of the four risk perception items that constituted the perceived risk index in this study. Indeed, farmers were less likely to perceive that growing DT maize would reduce their yield, waste the money they spent on the inputs(such as DT maize), and time they used to grow the seed. However, only the perceived risk of food security was significantly lower in the multichannel group than in the control group. Further, when integrating the four risk dimensions together into the perceived risk index, Table 8 shows farmers in the multichannel group had lower perceived risk of DT than farmers in the control group, while farmers in the video-only group perceived similar amounts of risks as farmers in the control. These differences are not statistically significant when using the Intent-to-Treat estimation, which includes all sampled farmers in the analysis. Moreover, around half of the households in the video-only treatment attended the video screenings, and one third of sampled households in the multichannel treatment group watched the video and received the audio messages. Therefore, the Local Average Treatment Effect (LATE) was measured using the treatment assignments as the instruments for compliance in order to estimate the treatment effects on households who received the treatments. Treated farmers in the multichannel group had 4.37 points lower perceived risk than farmers' in the control group and 3.24 points lower than treated farmers in the video-only group. Both differences are statistically significant.

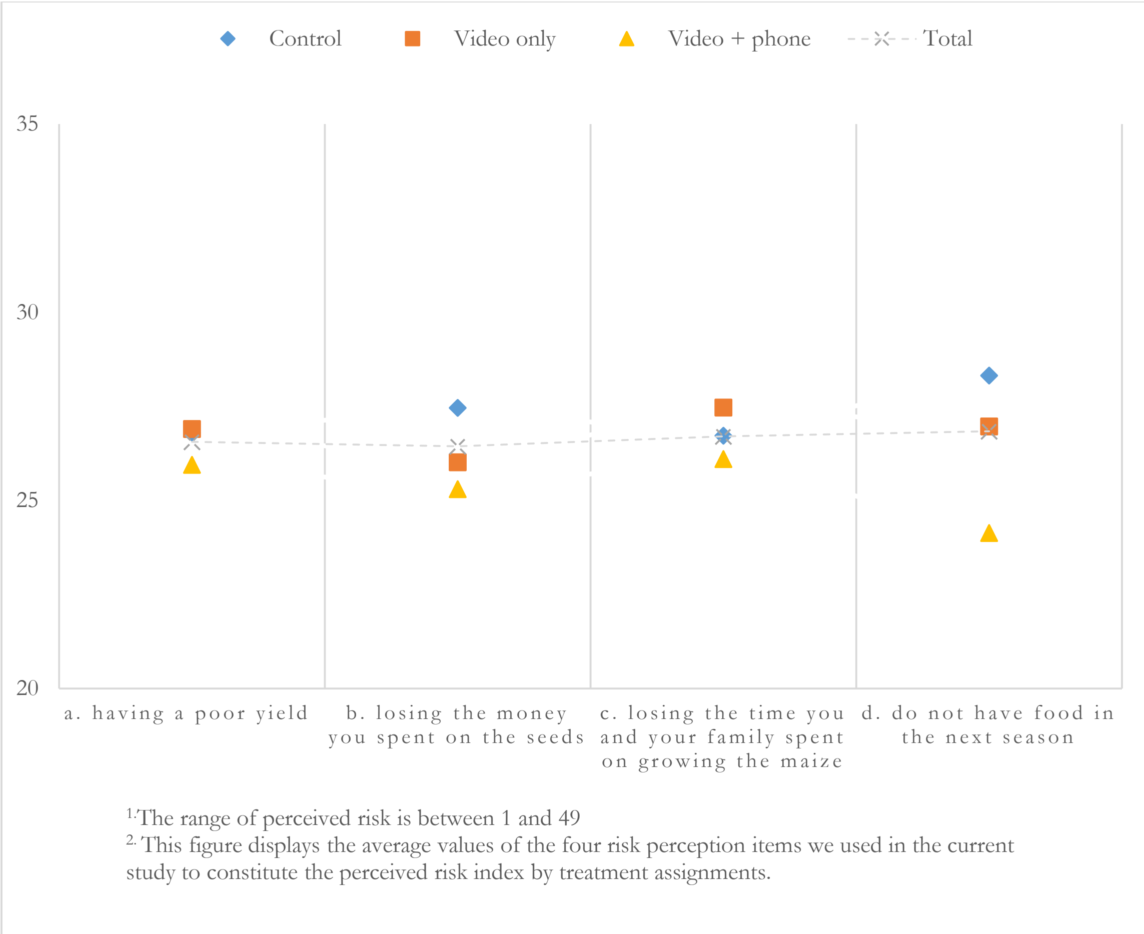
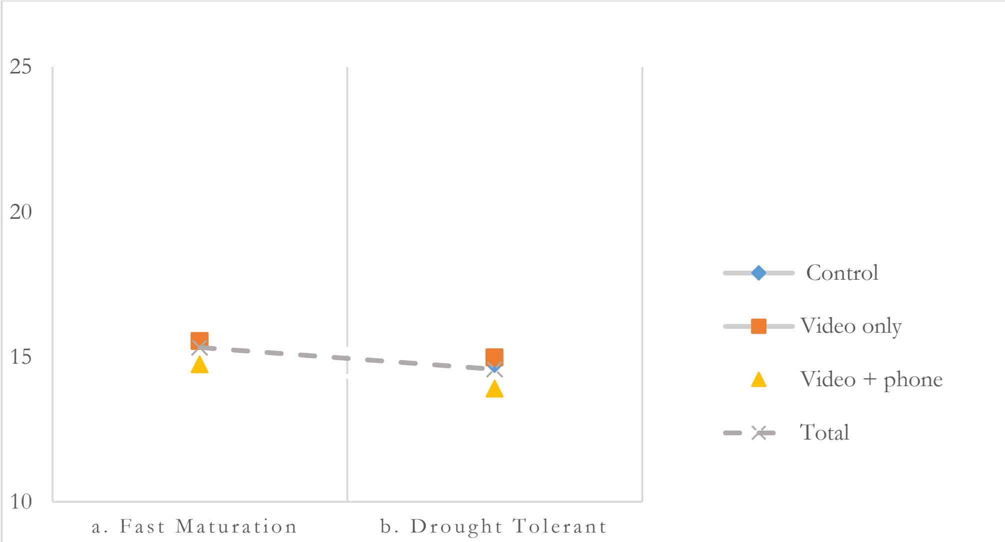


Figure 4: Perceived Risk of Growing DT Maize by treatment groups

The treatments presented to farmers regarding the two main characteristics of DT maize are early maturation and drought resistance. The scientists who developed DT maize state that these two characteristics can benefit farmers' production by increasing farmers' maize production and by helping farmers to reduce harvest failure due to drought (Abate et al., 2017). Figure 4 shows that farmers in the multichannel group had a lower level of perceived benefit in regards to the two characteristics than farmers in the control. Further, as Table 8 shows, when integrating the two perceived benefit dimensions together into an index, farmers in the multichannel group reported less perceived benefit of DT maize than farmers in the video-only and control groups,. These differences are not statistically significant.



[1.]The range of perceived benefit is between 1 and 49
[2.] This figure displays the average values of the two benefit perception items used to constitue the perceived benefit index by treatment assignments.

Figure 5: Perceived Benefit of Growing DT Maize by Treatment Groups

Table 8: Farmers' Perceptions of DT Maize by Treatment Groups[1]

	Perceived Risk				Perceived Benefit			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Video (1)	0.14	-0.23			0.23	0.58		
	(1.03)	(1.06)			(1.54)	(1.56)		
Multichannel (2)	-1.46	-1.63			-1.65	-1.23		
	(1.03)	(1.06)			(1.54)	(1.56)		
Video Complier			-0.92	-1.69			1.36	2.23
			(1.61)	(1.63)			(2.40)	(2.39)
Multichannel Complier			-4.37**	-4.49**			-1.28	-0.96
			(2.00)	(2.04)			(2.97)	(2.98)
Additional baseline controls [2]	N	Y	N	Y	N	Y	N	Y
Observations	582	582	582	582	582	582	582	582
Farmers' perception in the control group [3]	27.81	27.81	27.81	27.81	30.29	30.29	30.29	30.29
Households in the video-only group watched the video [4]			0.48	0.48			0.48	0.48
			(0.02)	(0.02)			(0.02)	(0.02)
Households in the multichannel group watched the video and received the messages [4]			0.37	0.37			0.37	0.37
			(0.04)	(0.04)			(0.04)	(0.04)
F-test values for Video only = Multichannel	1.96	1.46	3.24*	2.09	1.21	1.13	0.86	1.26

1. Columns 1, 2, 5 & 6 report the Intend-to-Treat (ITT) estimate of the intervention. Columns 3, 4, 7 & 8 report the Local Average Treatment Effects (LATE) estimate using the treatment assignments as instruments for the compliers in each treatment group.
2. Additional baseline controls in columns 2, 4, 6 & 8 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, residence in the FIPS villages or not, and total amount of fertilizer applied in the 2016 long rain season.
3. The range of the perceived risk is 1-49, and the range of perceived benefit is 1-.
4. 49 Indicator variable for households in two treatment groups participated in the intervention. For the multichannel group, 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 in parentheses. Significance levels of the differences between the two treatment groups and control group are denoted by *** 99%, ** 95%, * 90%.

These results demonstrate that the multichannel treatment was associated with farmers' lower risk perception of DT maize, but farmers in the treatment group reported lower perceived benefits than farmers assigned to the video-only group and control groups.

4.2.2 Knowledge, Farmers' Perceptions, and Willingness to Grow DT Maize

Farmers' knowledge about DT maize was found to be associated with their risk and benefit perceptions. Further, knowledge moderated the relationship between farmers' risk perception and reported willingness to plant DT maize the next season. Table 9 shows that, after controlling for the treatments and demographic variables, farmers who gained more knowledge about DT maize perceived significantly less risk of DT maize.

Table 9: Regression of Farmers' Perceived Benefit and Perceived Risk as a Function of Knowledge Level, Treatments, and Baseline Control Variables

	Perceived Risk		Perceived Benefit	
	(1)	(2)	(3)	(4)
Video-only	0.19	-0.24	0.15	0.64
	(1.03)	(1.05)	(1.51)	(1.52)
Multichannel	-0.97	-1.24	-2.83*	-2.19
	(1.04)	(1.06)	(1.52)	(1.54)
Knowledge about DT	-1.90***	-1.92***	2.88***	3.11***
	(0.72)	(0.74)	(1.06)	(1.07)
Knowledge about the management practices	-0.32	-0.33*	1.59***	1.61***
	(0.28)	(0.28)	(0.41)	(0.41)
Additional baseline controls [1]	N	Y	N	Y
Observations	582	582	582	582
Control Mean [2]	30.73	30.73	15.17	15.17

1. Additional baseline controls in columns 2 & 4 include treatment groups, 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, residence in the FIPS villages or not, and total amount of fertilizer applied in the 2016 long rain season. In column 4, the coefficient for distance from the households to the nearest seed market is positive and significant.

2. The range of the perceived risk and perceived benefit is 1-49, and the range of the knowledge of DT maize is 0-6 measured in increments of 0.5 as a unit.

Standard errors in parentheses. Significance levels of the differences between the two treatment groups and control group are denoted by *** 99%, ** 95%, * 90%.

Farmers who perceived fewer risks of DT maize reported that a greater willingness to grow DT maize in the next primary season. Figure 5 and Table 10 show a significant interaction effect between farmers' perceived risk and level of knowledge about DT maize to farmers' willingness to plant DT maize. For farmers with little to no knowledge about DT maize, perceived risk was negatively associated with their willingness to plant DT maize in the next season. Whereas farmers who retained more knowledge about DT showed risk perception was less likely to be associated with their willingness to grow DT maize. For example, for farmers who received the treatments (compliers) and scored zero or 0.5 points on the DT maize knowledge test following the intervention, there was a significant negative relationship between perceived risks and willingness to test DT in the next primary season. However, among farmers with higher knowledge about DT maize, perceived risk was not significantly associated with their uptake decisions. These conclusions are valid even when the baseline control is included in the regression.

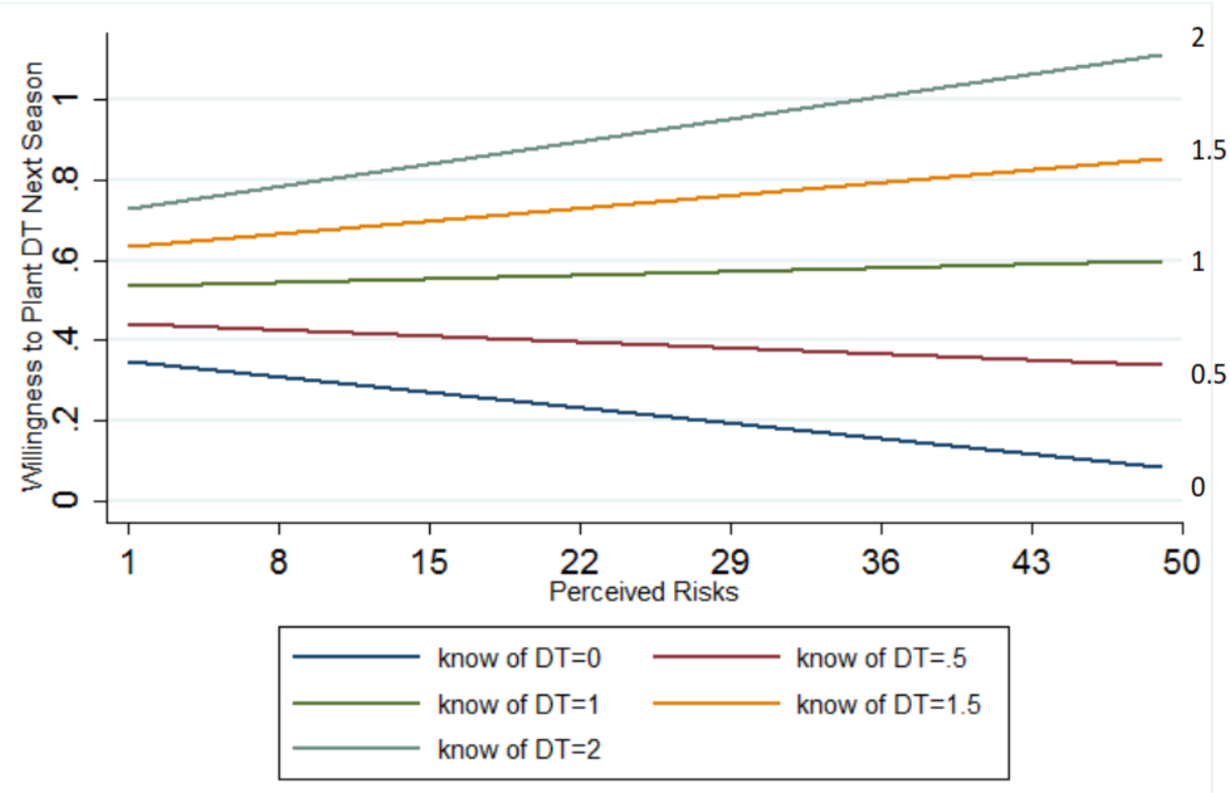


Figure 6: The Interaction Effect between Perceived Risk and Knowledge of DT Maize on Farmers'' Willing to Grow DT Maize

Table 10: Differential Impacts of Risk Perception on Households' Intention to Grow DT Maize in the Next Season by Level of Knowledge about the Varieties

	Total Sample		Compliers	
	(1)	(2)	(3)	(4)
Perceived Risk (β_1)	-0.003*	-0.003*	-0.006***	-0.006***
	(0.002)	(0.001)	(0.002)	(0.002)
Knowledge of DT (β_2)	0.10**	0.11***	0.09**	0.07
	(0.04)	(0.04)	(0.05)	(0.05)
Perceived Risk x Knowledge of DT (β_3)	0.002*	0.002*	0.003*	0.004**
	(0.001)	(0.001)	(0.002)	(0.002)
β_1+β_3 (Knowledge of DT = 0)	-0.03	-0.03*	-0.006***	-0.006***
	(0.002)	(0.001)	(0.002)	(0.002)
β_1+β_3 (Knowledge of DT = 0.5)	-0.001	-0.002	-0.004**	-0.004**
	(0.001)	(0.001)	(0.002)	(0.002)
β_1+β_3 (Knowledge of DT = 1)	-0.0002	-0.0006	-0.002	-0.002
	(0.001)	(0.001)	(0.002)	(0.002)
β_1+β_3 (Knowledge of DT = 1.5)	0.001	0.0004	0.0001	0.0001
	(0.002)	(0.001)	(0.002)	(0.002)
β_1+β_3 (Knowledge of DT = 2)	0.002	0.001	0.002	0.002
	(0.004)	(0.002)	(0.003)	(0.003)
Additional baseline controls [1]	N	Y	N	Y
Observations	582	582	347	347
Risk perception in the control group	0.16	0.16	0.14	0.14

[1.] Additional baseline controls in columns 2 & 4 include treatment groups, 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, residence in the FIPS villages or not, and total amount of fertilizer applied in the 2016 long rain season. The coefficient for size of land is negative and significant.
[2.] The range of the perceived risk is 1-49, and the range of knowledge of DT maize is measured in increments of 0.5 as a unit.

Standard errors in parentheses. Significance levels of the differences between the two treatment groups and control group are denoted by *** 99%, ** 95%, * 90%.

Lastly, farmers who perceived larger benefits in regards to DT maize retained more knowledge about DT maize and its management practices. This may be because farmers with knowledge about DT maize management practices had higher levels of confidence that their family could benefit from producing DT maize. However, perceived benefit was not associated with willingness to plant DT maize in the next season (see Appendix 13).

In sum, I found that mitigating the perceived risk of growing DT maize played a crucial role in motivating farmers to test the varieties. Farmers in the two treatment groups, especially the multichannel group, had lower perceived risk than farmers in the control group. Farmers' perceived risk was associated with their level of knowledge about DT maize and to which kind of treatment they were exposed. These findings support H12 and H14. The strength of the association between perceived risk and uptake was lessened by farmers' increasing of knowledge about DT maize over time. This finding answers RQ6. However, no relationship was found between perceived benefits, treatment assignment, and knowledge level. Therefore, H13 and H15 are not supported by this study.

CHAPTER 5 DISCUSSION

Study One examined the impacts of participatory video and audio message reminders in both enhancing farmers' knowledge about DT maize regarding awareness of DT seed varieties as and agricultural practices, and keeping farmers' attention on DT maize after attending the video screening and discussion. The findings thus provide insights that can inform the design of ICT strategies aimed at communicating knowledge about DT maize and its complementary agricultural practices to farmers. To my knowledge, few studies have explored strategies to reinforce participatory video trainings by combining video with other approaches. This study found audio messages reinforced video training content and reminded farmers about agricultural 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. I found farmers in the video-only and multichannel groups retained more knowledge about DT maize and its management practices than farmers in the control group. However, only the difference between the multichannel group and the control group is significant. This result suggests that a multichannel approach including both video and audio messages is a more effective design than the video only treatment. The video provided contextualized knowledge about DT maize and its associated agricultural management practices. The participatory content provides important context complemented by the short audio messages at appropriate times in the growing season. For example, two audio messages reminded farmers to engage in fertilizer micro-dosing, a topic the farmers learned about and viewed during the video screening, more than a month after the video screenings. Hence, one explanation for the heightened effectiveness of the multichannel treatment is that the audio messages reminded farmers of the video content at key times over the course of a relatively long growing season.

This study contributes to extant literature on participatory video by adapting this approach to integrate contextualized content into learning materials such as training videos. The video and all four audio messages were developed by working closely with local farmers and inviting them to share their personal stories about: how DT seed can benefit local farmers like them, the risks they encountered, and how they can mitigate the risks using modern practices of maize management. In focus group discussions following the post test, farmers explained that this situated content, such as a scene showing actors selecting various seeds in a local seed shop, aided their learning, particularly in regards to the difference between improved seed varieties and modern management practices like fertilizer micro-dosing. In the pre-test, we found that the majority of farmers only planted or heard about older improved varieties, such as Duma43. Few knew about newer improved varieties like DT maize or the difference between Duma43 and DT maize. Therefore, farmers believed that they could just grow the older improved varieties in lieu of newer ones because they assumed the performance would be the same. Farmers told us that they had heard something about improved varieties through sources such as agriculture programs on the radio, roadside advertising, demonstration plots, relatives living in cities, and directly from seed company agents. However, they further explained that the video screening and discussion was the first time they learned about the many improved seed varieties and how they might choose the appropriate varieties for their farm.

In this study, the video screenings were moderated by two FIPS experts from the local communities who were knowledgeable on DT maize . We observed that, during the screenings, these moderators were essential to engaging farmers in watching and discussing the videos, as well as to addressing farmers' questions immediately after screening. Much as was found in Wyche et al. (2016), we doubt that simply showing a short video alone would be sufficient for teaching farmers about new agricultural technologies. Wyche et al. (2016) found farmers needed moderators to explain the video content during and after viewings. Farmers also benefited from participating in a group, as they could help each other learn and resolve questions.

However, the study extends the Wyche et al. (2016) research of questioning the effectiveness of video-only approaches to educating rural farmers by showing a need to further complement video-based informational strategies, even those deeply rooted in the local context, with additional communication strategies; in this case, with mobile phone reminders to supplement the video-only training. 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 its capacity for nudging behavior in areas such as agricultural production. This finding corroborates Larochelle, Alwang & Travis (2016) conclusion in Northern Ecuador that reminders can reduce inattention, especially when farmers need to make complex decisions. Further, the first reminder sent out after the video screening in this study encouraged more farmers to purchase improved maize seed compared to farmers who did not receive the message. This result suggests that tailored reminders sent out at key decision-making points to encourage specific behavior in farmers' can be effective, a suggestion similarly made by Cole & Fernando (2012).

Larochelle et al. (2016) argued that reminders had greater impact on simple tasks or farmers' non-purchase-reliant behaviors. On the contrary, this study found that farmers in the multichannel group were significantly more likely to purchase improved seed comparing with the video-only and the control group, while there is no difference in fertilizer application to improved maize varieties between the treatment groups and the control. In this study, farmers generally purchased a small amount of improved seed. On average, farmers purchased 4kg of improved seed, and one kg of the seed costs around 200KSh (slightly less than 2 USD). Farmers tended to purchase a small quantity of seed for testing rather than purchasing larger scale maize production, and it is likely that the low cost did not substantially hinder farmers' decisions to purchase maize seed. The labor of planting was also less likely to impede farmers' seed purchasing decisions than the labor of fertilizer application. However, fertilizer application can involve a relatively larger investment in capital and labor. One bag of fertilizer costs $25 to $35 per bag (50kg) in the local market, depending on the fertilizer variety. For the farmers, the prohibitively-high investment for fertilizers reduced the impact of treatment on the farmers' decisions to purchase fertilizer.

Study Two shows that, in order to increase farmers' willingness to plant DT maize, it is important to understand farmers' perceptions of DT maize and the relationship between these perceptions and other impacts of treatments like improving knowledge and adoption. Study Two tests a pathway from the treatments to farmers' knowledge about DT maize and management practices to farmers' risk and benefit perception of the varieties and to their uptake decisions. If farmers have inadequate or inaccurate knowledge about DT maize, their perception of risk can be higher than those who have sufficient knowledge. Moreover, the association between perceived risk and farmers' risk-taking behavior can differ between farmers with varied levels of knowledge. I do not intend to reduce the actual risks of growing DT because it is beyond the scope of this study. Instead, this study tests strategies aimed at helping farmers form perceptions of DT maize based on facts and knowledge and to improve farmers' knowledge about management practices in order to reduce the potential risks of growing DT maize.

Study Two was designed based on a premise by Weber & Milliman (1997) that situational factors like proper timing can help individuals form proper risk perceptions. The informed risk perception in turn facilitates decision-making. Sundblad, Biel & Gärling (2007) suggested perceived risk can be properly mitigated by facilitating individuals' cognitive processes. Fisher et al. (1996) found that providing information to farmers communicating potential risks of an innovation can mitigate their perceived risk.

I found that, if farmers had less or no knowledge of DT maize, their higher risk perception was associated with a lower willingness to test DT maize; this result is consistent with previous literature, which found a negative relationship between individuals' perceived risk and risk-taking behavior (Brewer et al., 2004). However, if farmers had higher knowledge about DT maize, perceived risk had no impact on their willingness to plant DT maize in the next primary season. This may be because farmers' willingness to take risks can be conditioned by their level of knowledge about an innovation and risk reducing practices. For example, a farmer might report that the risk of growing DT maize is high because the maize may not perform well if he or she chose the wrong variety of DT maize, or if no complementary practices were used to manage the maize. However, they were also aware that the risks of growing DT maize could be reduced if they chose corrected DT maize and used timely practices to manage the crop. In contrast, another farmer might say his perceived risk of growing DT maize was high because he does not know about DT maize and its management practices. Therefore, although the two farmers might have similar levels of perceived risk, the first farmer is more likely to plant DT maize than the second. As such, risk perception can predict future behavior differently. Thus, two people with the same responses to a risk question—"Is growing DT maize risky?"—can have very different degrees of interest in DT maize. Level of knowledge about the innovation and about practices that can reduce risks moderate the relationship between perceived risks and uptake (Brewer et al., 2004). These findings support Sundblad, Biel & Gärling's (2007) study, which argued that knowledge can indirectly effect individuals' behavior via risk perception.

Another explanation for the finding that level of knowledge moderates the relationship between perceived risks and uptake is due to the indirect questioning measures used to capture farmers' risk and benefit perception of DT maize in this study. Surveyed households were asked about their perceptions of DT maize through invitations to evaluate what other farmers like them might perceive the risks and benefits of DT maize to be in order to reduce potential social desirable biases. The purpose of the indirect questioning measure was to avoid the social desirability biases among farmers. This measure, however, can lead to third person bias (Gunther & Mundy, 1993) or the phenomenon that people who are more knowledgeable tend to see themselves as more resistant to risks when compared to others. That is to say, farmers with higher levels of knowledge about DT maize choose to plant it even when they perceive other farmers like them might experience higher risks of growing DT maize. Although this study does not include data about farmers' perception of risks on their own production and how this risk perception relates to their uptake of DT maize, we speculate that farmers' knowledge of DT maize was a primary factor leading to their willingness to test DT maize.

Additionally, the current study found that the treatments did not increase farmers' perceptions of the benefits of DT maize. The perceived benefit was not shown to be associated with farmers' willingness to grow DT maize, which differs from the relationship between perceived risks and the risky behavior. One explanation for this is that perceived risks are more likely to affect farmers' uptake decisions than perceived benefits, even when farmers are convinced of the potential benefits. *Prospect theory,* as described by Kahneman & Tversky (1979), can explain this finding, as it suggests people's behavior is conditioned by their evaluation of losses and gains. However, people tend to be loss averse, thus, their perceived risk has a larger influence on their behavior than perceived benefit. Another explanation is that farmers can form their benefit perception by means other than the information provided by the intervention; examples of this include their personal observations of a new technology's benefits and the profitability of the seed. Therefore, the farmers' evaluation of the benefits can be differ from the assessments made of the same object by scientists (Lee, 1981). This suggests that other efforts are needed to help farmers understand whether and how DT maize can benefit their households' production, such as farmers' own experimentation. Moreover, farmers can perceive a new technology differently from the scientists and technicians who developed the technology. Therefore, more studies are needed to help scholars understand farmers' perceptions of DT maize, how they align with or diverge from the creators' initial intentions, and what content should be included in interventions aiming to increase adoption.

CHAPTER 6 LIMITATIONS AND FUTURE WORK

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

Although the study area had more than a 90 percent mobile phone subscription rate, we experienced several challenges in delivering the audio mobile phone reminders to farmers. The audio messages were delivered by making automated phone calls with audio recordings in the local language. This approach differs from those taken in other studies (e.g., Larochelle et al., 2017) where text messages were sent to farmers. Our approach intentionally diverged from this text-based approach because previous research among rural farmers in Kenya found low mobile phone literacy among this population and limited abilities to read text messages (Wyche & Steinfield, 2016). Despite our use of audio recordings, however, we still encountered difficulties delivering messages. The main challenges were network failures and non-functioning phone numbers. Additionally, in the focus group discussions, some farmers told us they did not pick up the calls because they were busy and did not expect to receive the messages. Thus, we suggest that future attempts to use this approach should consider implementing the sending of hints prior to sending out the audio messages to inform farmers of the scheduled calls. 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, useful revisions to this design for future studies include providing a means for farmers to re-listen to the messages and providing the information in a reviewable form, such as in a handout.

We also found that the lack of supply of DT maize in local markets undermined treatment impacts. For example, we found that, in a village where a local agricultural input shop supplied a few DT maize varieties, more farmers were willing to try DT seed after the intervention than those in villages where DT varieties were hard to find. Farmers living in the former village told us that they asked the owners to supply the DT seed they learned about from the video. This owner was originally from the village, worked full time in the county agriculture office, and operated this local input shop as a part-time job. We learned that this owner had access to supply channels through which he obtained the seed varieties requested by farmers, and therefore was able to supply the seed directly to his community. Farmers in other villages who did not report requesting DT maize seed from an input shop may have not been able to do this due to the lack of an input supplier in the village, or because they did not have a trusted relationship with the seed suppliers located there.

Finally, in this study, we mainly used a randomized controlled trial (RCT) approach and focus group discussions as methodologies to evaluate the impact of the video and multichannel strategies. The former methodology is widely used in development studies to measure the effects of specific developmental interventions. Although we were able to use this methodology to capture the overall impact of the interventions, it did not allow us to fully capture the heterogeneity of the treatment impacts on various households in the study (Barrett & Carter, 2010). Moreover, it did not fully reveal the mechanics of how the two communication strategies, particularly the multichannel approach, changed farmers' knowledge and willingness to test DT maize. Therefore, we encourage future studies to implement a more mixed-method approach by incorporating participatory research methods to complement the RCT and develop a more in-depth understanding of the treatment impact.

CHAPTER 7 CONCLUSION

Overall, this study designs and tests two communication strategies created to increase farmers' knowledge and uptake of DT maize, locally-made "participatory" video and a multichannel method that incorporates the participatory video with a series of mobile phone-based audio messages. Study One found that farmers in the multichannel group had higher levels of knowledge about DT maize and its accompanying management practices. They were shown to be more likely to purchase improved seeds after the treatment, and were more willing to plant DT maize in the next primary season. The effects of both treatments were largely driven by farmers living in villages supported by FIPS that provided trained village-based advisors to perform informational assistance and access to inputs. The second study found that farmers in the multichannel group had lower levels of perceived risk and lower levels of perceived benefit in regards to planting DT maize than farmers in the video-only and control groups. Perceived risk was more likely to reduce farmers' willingness to test DT if they retained little knowledge about DT maize. On the other hand, among farmers who had higher levels of knowledge about DT maize, perceived risk was less likely to be associated with willingness to grow DT maize. As such, it appears that the multichannel treatment reduced farmers' perceived risk in regards to growing DT maize, which in turn encouraged them to plant DT maize.

These findings suggest that providing timely reminders and contextualized video content can increase farmers' knowledge about an agricultural innovation and reduce the negative impact of perceived risk on uptake. Moreover, mitigating farmers' perceived risk by increasing their knowledge about an innovation can effectively increase their willingness to try the innovation.

Furthermore, this study investigated how to design ICT-based approaches to make them more effective in innovation diffusion, which contributes to current literature on ICT usage in agricultural knowledge provision. Such literature has mainly focused on testing whether ICTs can be effective in improving farmers' knowledge and uptake. This study demonstrates that the design of ICT approaches depends on farmers' cognitive capacities, characteristics of the agricultural innovation (such as whether farmers need to practice multiple steps over a long cycle), and the functions of various ICTs. Thus, this research can motivate implementation and examination of knowledge learning and risk perception theories in ICTD research and practices. This study will hopefully encourage ICTD researchers and practitioners to use these theories to guide their own design, testing, and evaluation of ICT strategies in agricultural training and rural development.

APPENDICES

Appendix 1 Summary Statistics

Table 11: Summary Statistics

Variable	Mean	SD	Min	Max	N
Knowledge Scores					
% of correct answers on DT maize	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 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 (15-65 yrs)	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

Appendix 2 Household Characteristics in Baseline by Compliance with Treatments

Table 12: Household Characteristics in Baseline by Compliance with Treatments

	non- Complier	Complier	Mean Difference
Age of household	51.737	49.041	2.696*
	(1.31)	(0.75)	(1.42)
Number of household members between 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 market selling seed	7.27	6.589	0.682
	(0.66)	(0.37)	(0.71)
Household's distance to trading center	7.269	6.57	0.699
	(0.66)	(0.38)	(0.71)
Size of land (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)
Women headed household	0.247	0.23	0.017
	(0.03)	(0.02)	(0.04)
Own mobile phone	0.941	0.965	-0.024
	(0.02)	(0.01)	(0.02)
Household with no education	0.081	0.058	0.022
	(0.02)	(0.01)	(0.02)
Household with secondary education or higher	0.129	0.175	-0.046
	(0.03)	(0.02)	(0.03)
Household in FIPS villages	0.602	0.466	0.136*
	(0.04)	(0.03)	(0.04)
N	186	395	581

[1.] For the first three columns, the means and standard deviations of each variable among farmers receiving the treatments in the treatment villages who did not receive the treatment in the control (complier), those who did not receive treatments in the treatment villages, and those who received treatment in the control villages (non-Complier) are reported. In the last three columns, the differences were calculated using the following regression: $Y_i = \alpha_1$ Complier$_i + \mu_i$. Regression standard errors are reported in parentheses.
Standard errors in parentheses. Significance levels of the differences between the two treatment groups and control group are denoted by *** 99%, ** 95%, * 90%.

Appendix 3 Household Characteristics in Baseline by NGO status[1]

Table 13: Household Characteristics in Baseline by NGO status1

	Non-FIPS	FIPS	Mean Differences
Age of household	50.989	48.858	2.131*
	(0.97)	(0.90)	(1.32)
Number of household members between 15-65	3.218	3.02	0.197
	(0.10)	(0.10)	(0.14)
Number of household members	5.439	5.554	-0.115
	(0.15)	(0.16)	(0.22)
Household's distance to market selling seed	9.275	4.431	4.844***
	(0.60)	(0.23)	(0.63)
Household's distance to trading center	10.16	7.027	3.134***
	(0.61)	(0.45)	(0.76)
Size of land (acres)	3.919	3.804	0.115
	(0.31)	(0.26)	(0.40)
Livestock index	168.267	186.932	-18.666
	(9.64)	(10.27)	(14.10)
Women headed household	0.214	0.257	-0.043
	(0.02)	(0.03)	(0.04)
Own mobile phone	1.965	1.949	0.016
	(0.01)	(0.01)	(0.02)
Household head with no education	0.074	0.057	0.016
	(0.02)	(0.01)	(0.02)
Household head with secondary education or higher	0.172	0.149	0.023
	(0.02)	(0.02)	(0.03)
N	234	347	581

[1.] For the first three columns, the means and standard deviations of each variable in the FIPS and non- FIPS villages are reported. In the last three columns, the differences were calculated using the following regression: $Y_i = \alpha_1 \text{ FIPS}_i + \mu_i$. Regression standard errors are reported in parentheses.

Standard errors in parentheses. Significance levels of the differences between the two treatment groups and control group are denoted by *** 99%, ** 95%, * 90%.

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