Fear of fraud and willingness to pay for hybrid maize seed in Kenya

Mariam H. Gharib a,1, Leah H. Palm-Forster a,*, Travis J. Lybbert b, Kent D. Messer a

a Department of Applied Economics and Statistics, University of Delaware, 531 S. College Ave., Newark, DE 19716, USA
b Department of Agricultural and Resource Economics, University of California, 2155 Social Sciences and Humanities, Davis, CA, 95616, USA

ARTICLE INFO

Keywords:
Agricultural supply chains
Certification
E-verification
Fake seed
Improved seed
Training

ABSTRACT

Concerns about poor seed quality and outright fraud in seed supply chains can reduce farmers’ willingness to invest in hybrid seeds and in complementary inputs that increase crop yields and improve food security. In Kenya, seed companies have started marketing their seed using novel packaging features to signal product quality and authenticity. We use experimental auctions with smallholder farmers in Kenya’s Nyanza Province to assess (1) farmer willingness to pay (WTP) for hybrid seed from different sources with different packaging features and (2) how WTP is affected by training on best practices for purchasing seed. We elicited demand for two popular types of hybrid maize seed and a familiar local (non-hybrid) seed. For each hybrid, we examined quality and authenticity. We use experimental auctions with smallholder farmers in Kenya

1. Introduction

Policies that foster increased agricultural productivity are essential to reducing food insecurity and poverty in Sub-Saharan Africa. While the introduction of hybrid maize varieties has increased average yields, reduced down-side risk, and contributed to higher annual incomes and greater total asset values (Jones et al., 2012; Mathenge et al., 2012), the adoption of hybrid maize remains low in many Sub-Saharan African countries. Smale et al. (2011) found that improved maize varieties were used on only 44% of the land area under cultivation in Eastern and Southern Africa (not including South Africa). Low rates of adoption have been attributed to several causes, including lack of access to credit (Langyintuo et al., 2010; Ouma and De Groote, 2011), heterogeneous net returns (Suri, 2011), and preferences for maize traits that are typically associated with local varieties (Lunduka et al., 2012). Researchers have called for additional studies to identify policy strategies for increasing adoption of improved hybrid maize varieties.

Among the many barriers that slow adoption of hybrid maize in these settings, a less studied constraint is justifiably receiving increased attention: farmers’ concerns about the authenticity and quality of the hybrid seeds available in local markets. Hybrid seeds cost much more than locally produced open-pollinated varieties (OPVs), but the additional cost should be offset by the hybrids’ superior traits, including drought and pest resistance and early maturation that result in higher yields. Farmers must trust that they will obtain these benefits to justify the additional cost of the seeds. However, Bold et al. (2017) suggest that heterogeneity in seed quality in local markets reduces farmers’ willingness to purchase hybrid seeds because they do not expect a positive rate of return from investing in them. Concerns about the prevalence of low-quality and fraudulent seeds are an emerging problem in Kenya that

https://doi.org/10.1016/j.foodpol.2021.102040
Received 13 July 2020; Received in revised form 13 December 2020; Accepted 27 January 2021
0306-9192/© 2021 Elsevier Ltd. All rights reserved.

Please cite this article as: Mariam H. Gharib, Food Policy, https://doi.org/10.1016/j.foodpol.2021.102040
has limited smallholder farmers’ willingness to pay (WTP) for hybrid seeds (Langyintuo et al., 2010; Odendo et al., 2002; Smale and Olwande, 2014). To address these concerns, seed companies are using novel features to assure farmers of the authenticity and quality of their seed, including certification labeling and scratch cards with e-verification numbers farmers can send by text message to receive confirmation that the seed is authentic. However, little is known about how these features are perceived by farmers and whether they are effective at improving their perception of seed quality, and increasing their demand for the seed and for the complementary inputs needed to achieve the productivity gains possible with hybrids.

In this study, we use a framed field experiment with smallholder farmers in western Kenya to estimate farmers’ WTP for bags of hybrid maize seed from different sources and the discount they apply to bags of seed that have been opened or otherwise tampered with. By design, this experiment focuses on farmers’ perceptions of seed quality based on observable characteristics of retail packaging rather than testing seed quality through germination tests, agronomic trials, or genotyping. We evaluate these perceptions at the point of purchase through incentive-compatible WTP measures. In addition, we investigate the effect of education or extension efforts on farmer perceptions by incorporating a treatment into the experiment in which participants watched a simple video designed to train farmers in how to identify bags of authentic hybrid seeds. To our knowledge, this is the first study to examine the quality signals farmers extract from retail packaging when purchasing maize seeds. Systematic differences in WTP for hybrid seed based on attributes of the bags highlight important issues for agricultural input supply chains. We find that farmers trust the companies selling hybrid seed directly, but their confidence wanes as these bags of hybrid seed are distributed through supply chains and end up in local retail outlets. Education and training in how to inspect seed bags and assess key features used by seed companies to signal quality and protect from fraud and damage increase farmer demand for intact bags of certified seed and increase farmers’ discounts in WTP for compromised bags. Finally, we find preliminary evidence that farmers who express concern about fraud respond differently to compromised packaging and to the training video than those who express concern about seed quality but not fraud in particular.

The policy implications of our results extend beyond Kenya since research suggests that perceptions of fraud limit investments in agricultural inputs in other countries dominated by smallholder agriculture (Ashour et al., 2016; Barriga and Fiala, 2020; Bold et al., 2017; Michelson et al., 2018). Hidden information makes it difficult for farmers to evaluate the quality of inputs offered in the market, including seeds and fertilizers. Governments and the private sector have taken actions designed to assure farmers of product authenticity and quality, but concerns persist. Thus, in addition to more secure supply chains that deliver higher quality inputs to farmers, there may well be a need for additional education and training to ensure that farmers in general, and smallholder farmers in particular, are able to effectively discern the quality signals provided by these upgraded supply chains when purchasing inputs. In product quality signaling, farmers are more likely to use hybrids (Mucioki et al., 2016; Smale and Olwande, 2014).

Growing concerns about fraudulent activity in the supply chain and poor seed quality may reduce investments in hybrid seed, and these concerns are not unique to Kenya. In neighboring Uganda, recent studies have investigated how seed quality changes along the supply chain and tested for evidence of fraudulent activity, like seed faking (i.e., selling bags of seed that do not contain the seed advertised on the label). The outcomes of planting fake or low-quality seeds are similar and include low germination rates and poor yields. Bold et al. (2017) estimated that <50% of the hybrid seed sold in local markets was authentic suggesting that fraudulent activity was rampant; however, more recent research found no evidence of fake seed in the maize supply chain (Barriga and Fiala, 2020). Barriga and Fiala (2020) suggest that mishandling and poor storage practices may explain variation in seed performance. Although they find that average seed quality remains consistent along the supply chain, there is greater variation in performance outcomes when seed is purchased from points lower in the supply chain.

Despite conflicting results on the true prevalence of fake or low-quality seed, concerns about these issues drive farmer behavior and can limit investment in hybrid seeds, especially if farmers lack confidence that they can distinguish between seed of varying quality and authenticity. If fraudulent seeds are sold in bags designed to resemble bags used by genuine producers, consumers may doubt their ability to identify which bags are genuine certified seeds. Furthermore, without knowledge about proper handling protocols, it is difficult to identify other likely causes of low quality such as poor storage, improper handling, and errors in production (Ashour et al., 2016; Bold et al., 2017). Indeed, Bold et al. (2017) find that farmers were not able to differentiate between high-quality and low-quality seeds, creating a disincentive for farmers to purchase a more-costly input that is marketed as being higher quality. Additionally, sellers have few incentives to build and maintain their reputations in the market because farmers are

---

4 The true prevalence of fraud in the seed sector is debated with some sources suggesting that <1% of bags have been tampered with while others suggesting that over 40% of bags are affected. Regardless of the actual prevalence of seed fraud, perceptions of fraud can drive farmer behavior and discourage investment in hybrid seeds.

5 As pointed out by Suri (2011) and others, the actual productivity gains associated with hybrid maize for a given farmer may deviate from the average expected returns. In such a context and wherever they are along the continuum of expected returns to improved seeds, innovations in and improvements to quality seed signals can only help farmers learn more efficiently and make more informed decisions.

6 A study on fertilizer adoption in Tanzania found a similar result (Norton et al., 2020). Despite finding no evidence of inferior fertilizers being sold in regional markets, farmers were willing to pay 46% more for fertilizer that had been tested and was guaranteed to be pure.
not demanding specific actions related to handling and storage of seeds.

Kenya’s government has introduced policies to prevent farmers from purchasing low quality or fraudulent seed and to establish a system by which lots of seed can be traced. For instance, the Kenya Plant Health Inspectorate Service (KEPHIS), in partnership with the Seed Trade Association of Kenya (STAK) a non-government organization of seed companies, has intensified its efforts by introducing e-verification labels for bags of hybrid maize seed weighing up to 10 kilograms (kgs). The labels are embossed with the KEPHIS logo and a specific lot number that allows for identification and verification of purchased seeds (Mahaya and Mburu, 2016). Buyers scratch an area on the label to reveal a 12-digit code they can send to a specified number via a free short message service (SMS), verifying the authenticity of the bag before leaving the point of sale. The SMS message buyers receive in return to such a query, assuming the code is legitimate, provides a host of details, including the seed company name, the cultivator who produced the seed, lot number, seed class, authenticity, and the testing date of the seed. If the 12-digit code has been used previously it reveals the legitimacy of the code, the date the verification code was sent, and part of the phone number of the sender. In the case of an illegitimate verification code, the SMS response requests the sender to verify the numbers, and if all the digits are confirmed, a message cautions the sender that the seed may not be genuine and lists a phone number that can be used to file a complaint.

It is not clear, however, how farmers interpret the presence of the e-verification label. In order for the label to be effective, farmers must be aware of it, use it, and trust in the verification system and in the institutions administering the system. We test the effect of an information treatment that trains farmers to examine key features of seed packaging, including the presence of an e-verification label (and instructions for its use), the condition of packaging, and the source of seed bags. Although farmer demand as encapsulated in their WTP for seed is a summary outcome and does not allow us to parse out in detail the relative importance of specific mediating factors (e.g., trust in the institutions administering the e-verification system), it has the distinct advantage of being both salient and incentive-compatible.

### 3. Experiment design and procedures

A framed field experiment was designed (1) to estimate farmers’ WTP for hybrid maize seed from different sources and in bags in varying conditions and (2) to test the impact of an information treatment meant to train farmers to identify genuine, high-quality hybrid seeds on their WTP. The experiment included both within-subject and between-subject treatments using a 5x2 design as shown in Table 1. We analyze participants’ bids on five 2-kg bags of maize seed (within-subject) and half of the participants received the information treatment prior to bidding (between-subject).

The Becker-DeGroot-Marschak (BDM) mechanism (Becker et al., 1964) was used to elicit WTP values for the 2-kg bags of maize seed. This mechanism has been used to reveal participant values in other contexts in Kenya (De Groote et al., 2016; Kimenju et al., 2005), though researchers have noted that the mechanism is difficult to explain and that the order in which products are presented can influence WTP (Morawetz and Kimenju, 2011). We addressed these potential challenges by showing participants a detailed instructional video describing how the BDM mechanism works and conducting a practice session in which participants used the BDM mechanism to purchase candies. To limit order and demand effects, the products were displayed in a random order for each individual, and one of the products was randomly selected as binding at the end of the experiment.

To ensure that farmers were bidding on hybrid seeds they would be interested in buying, they were asked to state which of two popular hybrid seed varieties they preferred: Duma 43 (Seed Co product) and DK 8031 (Monsanto product). Each of the participants then bid on multiple bags of the hybrid seed brand they preferred, but the bags had different characteristics in terms of the source of the seed and the condition of the bags (see Fig. 1). Three bags (Bags A, B and C) had been purchased from local sellers. Bag A was in mint condition with a valid sampling date and an unused e-verification label and no tears in the packaging. Bags B and C were similar to Bag A, but for Bag B the verification label had been scratched off revealing the 12-digit code and Bag C had a torn seal or a torn seal. The fourth bag (Bag D) was purchased directly from the seed company and was in mint condition with the same sampling date and an unused e-verification label and no tears in the packaging. Bags B and C were similar to Bag A, but for Bag B the verification label had been scratched off revealing the 12-digit code and Bag C had a torn seal or a torn seal. The fourth bag (Bag D) was purchased directly from the seed company and was in mint condition with the same packaging features as Bag A. Since all four hybrid seed bags had the e-verification feature, the experiment cannot discern farmers’ perception of the presence of the feature but instead aims to estimate the WTP impact of an intact (unscratched) e-verification feature. In addition to the four bags of hybrid seed, all participants were asked to bid on Bag E, which contained 2 kgs of local seed packaged in an open brown paper bag.

The between-subject treatment involved a control group and a treatment group in which participants watched a video designed to train them in how to recognize and purchase high-quality hybrid maize seed. The video, which was recorded in the local language, Luo, explained...
what farmers should check for when purchasing bags of seed, (2) what features a seed bag should have, and (3) what to do if they suspected the seed was fraudulent. The information communicated via the video was obtained from KEPHIS and from the Constitution of Kenya website (Government of Kenya, 2012).

3.1. Sample selection

We conducted the experiment in two counties in Kenya’s Nyanza Province – Homabay and Siaya. Most farmers begin actively procuring maize seed in February for planting in April, and we conducted the experiment in mid to late January to ensure that farmers had a demand for maize seed. In each county, two sub-locations were randomly selected from the complete list of sub-locations using a random number generator. Then, using the same procedure, we randomly selected two villages from each sub-location for a total of eight villages. From each village, we randomly selected 35 households for each sub-location for a total of eight villages. From each village, we randomly selected 35 households to participate, and village leaders invited a member of each household to participate prior to the experiment date. Village leaders were instructed to invite the member of each household who made most of the agricultural decisions. In total, 264 people participated in the experiment. 8

In each village, we conducted both control and treatment sessions, 9 and no more than seven people participated in each session to allow each person to be paired with an enumerator. All sessions were held in a common meeting area such as a church, school, or open field within or near the village. Our research team worked with village leaders to prevent interaction between the experiment participants and other members of the community. Additionally, to limit discussion between participants in the treatment and control groups, we conducted the control session (no training video) first. Two of the participating villages shared a boundary; therefore, to control spillover, we conducted the control sessions for those villages on the same day and then conducted the treatment sessions the following day.

3.2. Experiment procedures

Each experiment session consisted of three parts: (1) consent, instructions, and practice; (2) the experiment; and (3) a survey. 10 Upon their arrival, each participant was assigned a unique identifier number and paired with an enumerator 11 who spoke the local language (Luo) and/or Swahili (depending on the language preference of the participant). Participants were informed that they would receive 900 Kenyan shillings (KES) for participating in the session (more than 1.5 times the value of the average maize bag) and that the money would be paid using Kenya’s popular mobile banking system, M-Pesa. African rural consumers have low income and participants are provided with 1.5 times to twice the value of the product to cover the expected WTP without inflating bids (De Groote et al., 2016; Morawetz and Kimenju, 2011). As is common with the BDM, if they did not purchase anything, then they would keep the 900 KES; however, if they purchased the good then they

8 Seventeen participants were from households not included in the original sampling frame. These participants were selected by the village leaders to replace people who were not available on the day of the study. Those selected by village leaders are not statistically different from the original sample using variables defined in Table 2.

9 In seven of the villages, five experiment sessions were conducted. Four sessions were conducted in the eighth village. The number of training and control sessions were balanced by sub-location.

10 The experiment instructions and the survey are provided in the appendix.

11 Prior to conducting the first session, the enumerators participated in a rigorous one-day training and conducted a pilot session to make them familiar with the experiment.
would pay the cost from their initial allocation, often at a lower price than they had indicated was their true WTP, a format that has been shown to be demand revealing and incentive compatible (Becker et al., 1964, Irwin 1998, Messer 2010). Before receiving the instructions, participants were asked which hybrid seed brand they preferred Duma 43 or DK 8031. These seed brands were selected as they are the most common and the highest selling hybrid seeds in the area in which we conducted this experiment. A research assistant organized bags for each participant based on their preferences while the enumerators guided participants through the instructions. The initial selection of their preferred seed was designed to ensure that participants were bidding on a product that they actually wanted.

In Part 1 of the experiment, each enumerator read an informed consent script to his or her paired participant. The participants then used a computer tablet and earphones to view a video recording of the instructions to ensure consistency in how the instructions were presented and how the BDM mechanism was explained. The farmers then participated in a practice round.

Part 2 of the experiment consisted of formal bidding on bags of maize seed. Before stating their WTP values, participants watched a second instruction video that described how they would submit bids for the bags of maize seed following a process similar to the one they followed in the practice round. Participants in treatment sessions also watched a seed-buying training video that demonstrated best practices when purchasing seeds, including what to look for on the seed packaging before buying a specific bag (i.e., certified seed label, intact e-verification label, quality of the dye on the bag and the seed, quality of bag stitching, the sampling date, and shape and design of the bag). If the farmer suspected the seed to be fraudulent, the video further provided the KEPHIS designated phone numbers they should call and instructed them to keep the bag and receipt as these may be required as evidence.

Participants were presented with a box containing four 2-kg bags of hybrid maize seed (Duma 43 or DK 8031, according to their earlier stated preference) and one 2-kg bag of a local seed in an unlabeled brown paper bag. The enumerators explained that we purchased one of the hybrid bags directly from the seed company and they pointed out which bag that was. They then explained that the other hybrid bags were purchased from local retailers and that the bag of local seed was purchased in the local market. The bags were removed from the box and laid out in any order by the enumerator, and participants were given the opportunity to inspect the bags. After looking at all of the bags, participants were asked to state their maximum WTP for each bag.

Once all of their WTP values were recorded and the participants completed the survey, the seed bag purchase that would be binding was randomly selected. Once the binding bag for the session was known, the price ranging from KES 0 to 899 was randomly determined. The price was set as each participant rolled a 9-sided die marked with numerals 0 through 8 to select the first digit of the price and two 10-sided dice marked with numerals 0 through 9 to select the second and third digits of the random market price of the binding bag of seed, which thus varied from KES 0 to 899.

When a participant’s stated WTP was at least as great as the random price, the participant purchased the binding product at the randomly determined price. Otherwise, the participant did not purchase the bag of seed. The purchase prices were deducted from the KES 900 participation payment and the balance was transferred via M-Pesa. Thus, participants who did not purchase a bag of seed received the full KES 900.

The final part of the experiment, which was conducted immediately after the bidding, consisted of a survey that collected data on the participants’ demographic characteristics, agricultural practices, and awareness and perceptions of the quality of hybrid maize seeds in their local markets and of fraudulent activity. The survey is presented in the appendix. After completing the survey, the participant and the enumerator calculated the amount of their payment. Participants were paid KES 900 plus the M-Pesa withdrawal fee minus the prices of any items that were purchased (candy in the practice round and/or a bag of seed in the experiment).

4. Hypotheses and empirical approach

Our experiment is designed to test three hypotheses. First, we test the null hypothesis that there are no differences between WTP for seed purchased directly from the seed company and seed purchased from local retailers in bags in good condition. This null hypothesis is tested because we do not have a priori information to guide a directional hypothesis. If the farmers believed that fraudulent activity is happening lower in the supply chain, they could place a premium on seed purchased directly from the producer. However, if farmers were not concerned about degradations in quality or fraudulent activity in the supply chain, or believed that the seed company also acted fraudulently, we would not expect them to have different WTP values for the seed bags.

Second, we test the null hypothesis that there are no differences in WTP for intact and tampered bags purchased from multiple local retailers. If the farmers are not closely inspecting the seed bags or do not believe that flawed bags point to quality issues, we do not expect to observe differences in WTP for the intact and flawed bags.

Third, we test for the treatment effect of the training video by estimating differences in WTP for each bag of seed between trained and untrained participants. We hypothesize that training will result in higher WTP for some products, such as seed bags in good condition, and lower WTP for other products, such as damaged bags.

We use a linear random effects model to estimate mean WTP for each bag, the effect of the training video on WTP for each bag, and interaction effects between bag type and the treatment video. Model A is specified as

\[
WTP_{ij} = \alpha + \beta \text{Bag}_i + \delta \text{Training} + \tau (\text{Bag}_i \times \text{Training}) + \phi \text{DK} + \rho_i + \omega_v + \gamma \text{X}_i + u_i + e_{ij}
\]

where \(i = 1, \ldots, N\) represents the participant, \(j = 1, \ldots, 5\) represents the type of seed bag, \(v = 1, \ldots, 8\) represents the village, \(e = 1, \ldots, 7\) represents the enumerator, \(u_i\) is the between-individual error term, and \(e_{ij}\) is the within-individual error term. \(\text{Bag}_i\) is a \(4 \times 1\) vector of binary variables representing Bags B through E (Bag A is the base group), \(\text{Training}\) is a binary variable that equals one when the participant was in the treatment group and zero otherwise, and \((\text{Bag}_i \times \text{Training})\) are a \(4 \times 1\) vector of interaction terms for bag type and training treatment. \(\text{DK}\) is a binary variable that equals one when the participant chose DK 8031 seed and zero when the participant chose Duma 43. We control for village and enumerator fixed effects, which are represented by vectors \(\rho_i\) and \(\omega_v\), respectively. \(\text{X}_i\) is a vector of individual characteristics for participant \(i\) that includes gender and education. Standard errors are clustered at the session level.

The full sample is used to estimate model A. We also analyze how the estimated parameters change when we include only observations from individuals who reported high levels of concern about seed fraud (model B) and seed quality (model C). Models B and C have the same specification presented in eq. (1). Comparing the results of models A, B, and C, the level of censoring does not justify use of a Tobit model (See Table 3). Furthermore, the Tobit model does not capture differential zero-bid responses between the control and treatment groups.

12 We did not randomly assign maize seeds bags because farmers tend to have strong prior preferences about seed and would likely not treat a randomly imposed hybrid seed seriously in the demand elicitation (Smale and Olwande, 2014). To get the cleanest and most defensible WTP responses from farmers, we allow them to select their preferred seed at the outset of the experiment, as has been done in other field experiments (see Kecinski et al. 2018).

13 The level of censoring does not justify use of a Tobit model (See Table 3).
allows us to investigate whether changes in WTP are related to concerns about seed fraud and/or seed quality. During our field visits, stakeholders suggested that the type of bag may influence farmers’ concerns about fraud and quality. For example, plastic bags, like the packaging used for the DK 8031 bags, are more difficult to copy and are also less likely to tear or open at the seams. To further investigate how the bag type affects WTP, we estimate two models – model D is estimated with WTP data for Duma 43 and model E uses WTP data for DK 8031. Both models are specified as

\[
WTP_{ij} = \alpha + \beta Bag_i + \delta Training_i + \tau(Bag_i \times Training_i) + \theta Fraud\_Concern_i + \phi(Bag_i \times Fraud\_Concern_i) + \rho_i + \omega_i + \epsilon_{ij}
\]

where Fraud\_Concern, is a binary variable that equals one if the participant reported a high level of concern about fraud and zero otherwise. All other parameters are defined the same as in eq. (1).

5. Results

5.1. Sample characteristics

We analyze data from 258 smallholder maize farmers in Kenya’s Nyanza Province. Sample characteristics are described in Table 2. Nearly three-quarters of the participants were household heads, including 58% of the female participants. On average, participants had 7.6 years of education. During the main growing season, participants planted maize on an average of 1.5 acres (0.61 ha). Similar results have been observed in other studies conducted in mid-range moist altitudes that characterize Homabay and Siaya, where, on average, smallholder farmers planted 0.6 ha of maize (De Groote et al., 2016) and had 7.6 years of education (Ouma and De Groote, 2011). Female participants comprised 62% of the sample, which aligns with the proportion of female participants in De Groote et al.’s (2016) study of all major maize growing areas in Kenya, but is generally higher than other similar studies. In Wainaina et al.’s (2016) study of Kenyan farmers, female respondents made up 43% of the sample. The samples used in older studies had a much smaller percentage of female household heads, including 27% in Mathenge et al. (2012) from a 2010 survey and 21% in Smale and Olwande (2014) from a 2007 survey. As shown in Table 2, the participant characteristics for the control and treatment (training) groups were not statistically different.

Survey results indicated that 95% of participants reported planting maize in the preceding year; 52% of those farmers planted hybrid seeds in the long rainy season, and 42% planted hybrid seeds in the short rainy season. The most popular hybrid varieties were Duma 43 from Seed Co and DK 8031 from Monsanto. The other hybrid varieties available accounted for<5% of the seed planted by the sampled farmers. The top three reasons participants chose to use the Seed Co and Monsanto varieties were drought tolerance, high yields, and early maturity, all of which reflect inadequate rainfall experienced in the area. Their four primary sources of seed (hybrid and non-hybrid) were agrodealers, the general market, their own recycled seed, and small traders. <1% of the farmers acquired seed directly from the seed company, and their few purchases were made during the long rainy season (March through August).

The survey collected information on participants’ perceptions and concerns about fraud in the supply chain. Nearly half of the respondents suspected that they had purchased fraudulent seed or they had heard about someone else who had purchased it, and they reported that small traders were the predominant source of fraudulent seed (44% of reported cases). Participants reported that they suspected seed was fraudulent because they observed poor outcomes, including low rates of germination (44% of respondents) and/or low yields (34% of respondents). We note that these outcomes are also expected from seed of low quality due to factors other than fraud and from poor growing conditions that are independent of seed quality. More than half of the participants had not received any information or training on best seed-purchasing practices prior to the study. The most common criterion farmers reported using to assess seed quality was checking for a valid date at the time of purchase (20%). Participants also reported their level of concern, on a scale from 1 to 5, about low-quality and fraudulent seed negatively affecting their agricultural production in the future, and nearly 58% reported a high level of concern (4 or 5) about at least one of these factors. In the discussion and conclusion section, we revisit these findings and discuss their implications for agri-input training programs and policies and outline additional research that is needed to inform those efforts.

5.2. WTP results

Table 3 presents the means and standard deviations of reported WTP values (bids) for each bag of seed for the full sample and for the control and treatment groups, and histograms of bids for each bag type are presented in Fig. 2. Participants were willing to pay KES 403, on average, for the bag in mint condition purchased from local retailers (A). Among the four hybrid seed bags, WTP was highest (KES 462) for the mint condition bag purchased directly from the seed company (D), which reflects a 15% WTP premium, on average, for Bag D relative to Bag A. In the control group (no training), farmers did not discount the bags with a scratched e-verification label (B) or bags with a torn seal or seam (C) relative to the mint condition bags purchased from local retailers (A).

The treatment group that viewed the training video had significantly lower WTP on average for bags with a scratched e-verification label (B) or a torn seal or seam (C), revealing a discount of 12.2% and 13.6%, respectively, relative to the mint condition bag purchased from local retailers (A). As expected, the training treatment had no effect on WTP for the mint condition bag from local retailers (A) or on the bag purchased directly from the seed company (E). Likewise, WTP for local seed (Bag E) was not affected by the training. The results also show that participants in the treatment group were more likely to bid KES 0 (i.e., opt not to buy a given bag) for all of the seed bags that did not come directly from the seed company (D). In the treatment group, 3%, 13%, and 12% of participants bid KES 0 for Bags A, B, and C, respectively. However, <1% of the trained farmers bid zero for Bag D, which was purchased directly from the seed company.

We use a linear random effects model that accounts for participant-level covariates to estimate differences in WTP among people with differing demographic characteristics, village locations, assigned enumerators, and levels of concern about fraud and seed quality. Table 4 presents the results for the full sample (model A, n = 258) and for subsets of participants who were “very concerned” about seed fraud (model B, n = 83) and about seed quality (model C, n = 65).

The results for the full sample show that the average WTP premium for the mint condition bag purchased directly from the seed company is KES 61, which is 15% greater than their WTP premium for the mint

---

To gather this information, participants were asked the following question: “On a scale from 1 to 5, how concerned are you about the following issues affecting maize farming?” Respondents stated their level of concern about ‘low quality seed’ and ‘fraudulent and counterfeit seeds’ in addition to other potential threats to maize agriculture, including ‘fall armyworm,’ ‘maize lethal necrosis disease,’ ‘too much rainfall,’ ‘too little rainfall,’ and ‘severe weather.’
condition bag purchased from local retailers. Participants who did not receive training were willing to pay a relatively small premium (about one-third the premium they were willing to pay for the bag purchased directly from the seed company) for the bag with the scratched e-verification label (Bag B). It is not clear what motivated their greater WTP for that bag. One may speculate that, without knowledge about the purpose of the e-verification label, farmers may have assumed that its mere presence was a signal of quality and they may have inferred value from seeing the e-verification code displayed; however, more research is needed to understand how farmers interpreted the information. The training treatment had no effect on the premium participants were willing to pay for bags purchased directly from the seed company (D) but led to significant discounts in their WTP for bags that were not in good condition: KES 69 and KES 67 for Bags B and C, respectively.

The hybrid seed brand that the participant selected (Duma 43 or DK 8031) had no effect on WTP, nor did gender, years of education, or Table 2

**Characteristics of experiment participants, N = 258.**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Control Group (n = 126)</th>
<th>Training Group (n = 132)</th>
<th>All participants (N = 258)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Std. dev.</td>
<td>Mean</td>
<td>Std. dev.</td>
</tr>
<tr>
<td>Gender</td>
<td>0.61</td>
<td>0.49</td>
<td>0.62</td>
<td>0.49</td>
</tr>
<tr>
<td>Head of household</td>
<td>0.71</td>
<td>0.46</td>
<td>0.73</td>
<td>0.44</td>
</tr>
<tr>
<td>Education</td>
<td>8.09</td>
<td>3.32</td>
<td>7.19</td>
<td>3.62</td>
</tr>
<tr>
<td>Maize Acres</td>
<td>1.70</td>
<td>2.56</td>
<td>1.40</td>
<td>1.43</td>
</tr>
<tr>
<td>Concern Fraud</td>
<td>2.65</td>
<td>1.33</td>
<td>2.69</td>
<td>1.48</td>
</tr>
<tr>
<td>Concern Quality</td>
<td>2.58</td>
<td>1.26</td>
<td>2.46</td>
<td>1.22</td>
</tr>
</tbody>
</table>

Note: *There are no statistically significant differences between characteristics of participants in the control and treatment (training) groups.

<table>
<thead>
<tr>
<th>Description (Bag Code)</th>
<th>Control Group (n = 126)</th>
<th>Treatment Group (n = 132)</th>
<th>All participants (N = 258)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mint condition bag from local retailers (A)</td>
<td>401.01 (152.98)</td>
<td>&lt;1%</td>
<td>405.77 (178.95)</td>
</tr>
<tr>
<td>Scratched e-verification label from local retailers (B)</td>
<td>420.36 (153.78)</td>
<td>&lt;1%</td>
<td>356.31 (204.76)</td>
</tr>
<tr>
<td>Torn bag seal or seam from local retailers (C)</td>
<td>412.92 (151.80)</td>
<td>&lt;1%</td>
<td>350.70 (200.93)</td>
</tr>
<tr>
<td>Mint condition bag from the seed company (D)</td>
<td>461.79 (157.38)</td>
<td>0%</td>
<td>463.00 (178.46)</td>
</tr>
<tr>
<td>Local seed variety (E)</td>
<td>111.42 (77.20)</td>
<td>5%</td>
<td>108.90 (75.45)</td>
</tr>
</tbody>
</table>

Note: Mean WTP values marked with the same superscript are not statistically different at the 5% level.
assigned enumerator (p > 0.10). One characteristic that seemed to influence WTP was the village of the participants, as bids from two of the villages were significantly higher and lower overall than bids from the other villages; however, the explanation for this finding is not clear.

Model B in Table 4 presents the results of restricting our analysis to observations from participants who indicated that they were highly concerned about fraud in the seed supply chain (n = 83, 32% of the full sample). The results indicate that these individuals were willing to pay more than other individuals in the sample for seed directly from the seed company (D). Their average WTP premium for Bag D is KES 97, 23% greater than their WTP premium for the mint condition bag purchased from local retailers (A). The training treatment also had a greater impact on these participants, reducing their WTP for Bags B and C, by KES 84 overall and KES 100, respectively, relative to their WTP for Bag A. These discounts are 21% to 49% greater than the average discount for these bags for the full sample.

Participants’ variations in WTP could be driven by a broad concern about seed quality rather than a specific concern about fraudulent activity in the supply chain. To further analyze the results for model B, we estimated a third model (C) in which we restricted the observations to ones from participants who reported a high level of concern about seed quality (n = 65, 25% of the full sample) and report the results in Table 4. Comparing the coefficients from these models suggests that the WTP premium for seed directly from the seed company (WTP for Bag D relative to Bag A) is larger in the fraud-concerned group (model B) relative to the quality-concerned group (model C). Participants in the treatment group that reported high levels of concern about fraud indicated higher WTP discounts for bags with torn packaging (Bag C).

Table 4
Results of linear random effects estimation of farmers’ WTP for seed bags.

<table>
<thead>
<tr>
<th>Dependent variable: WTP (KES)</th>
<th>Coefficient</th>
<th>Robust std. error</th>
<th>Coefficient</th>
<th>Robust std. error</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A) Full sample</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mint condition bag from local retailers (A)</td>
<td>Base group</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scratched e-verification label from local retailers (B)</td>
<td>19.35**</td>
<td>7.57</td>
<td>21.35</td>
<td>14.02</td>
</tr>
<tr>
<td>Torn bag seam or seal from multiple retailers (C)</td>
<td>11.91</td>
<td>8.52</td>
<td>18.92</td>
<td>15.53</td>
</tr>
<tr>
<td>Mint condition bag from the seed company (D)</td>
<td>60.79***</td>
<td>11.82</td>
<td>96.86***</td>
<td>23.93</td>
</tr>
<tr>
<td>Local seed variety (E)</td>
<td>–289.59***</td>
<td>15.56</td>
<td>–295.41***</td>
<td>34.01</td>
</tr>
<tr>
<td>Training</td>
<td>9.80</td>
<td>17.15</td>
<td>15.77</td>
<td>38.60</td>
</tr>
<tr>
<td>Training × Bag B</td>
<td>–68.81***</td>
<td>13.50</td>
<td>–83.53***</td>
<td>24.11</td>
</tr>
<tr>
<td>Training × Bag D</td>
<td>–3.50</td>
<td>16.89</td>
<td>–18.78</td>
<td>32.03</td>
</tr>
<tr>
<td>Training × Bag E</td>
<td>–7.28</td>
<td>22.21</td>
<td>0.91</td>
<td>48.10</td>
</tr>
<tr>
<td>DK 8031</td>
<td>26.79</td>
<td>16.46</td>
<td>–5.00</td>
<td>32.43</td>
</tr>
<tr>
<td>Constant</td>
<td>380.94***</td>
<td>44.88</td>
<td>417.21***</td>
<td>65.92</td>
</tr>
<tr>
<td>Number of observations (individuals)</td>
<td>1,290 (258)</td>
<td>415 (83)</td>
<td>325 (65)</td>
<td></td>
</tr>
<tr>
<td>Overall R²</td>
<td>0.4249</td>
<td>0.4746</td>
<td>0.6325</td>
<td></td>
</tr>
</tbody>
</table>

Note: ***, **, and * indicate significance at the 0.01, 0.05, and 0.10 levels, respectively. The regression controls for village, enumerator, gender, and years of education. Standard errors are clustered at the session level.

Table 5
Results of linear random effects estimation of farmers’ WTP split by brand of seed.

<table>
<thead>
<tr>
<th>Dependent variable: WTP (KES)</th>
<th>Coefficient</th>
<th>Robust std. error</th>
<th>Coefficient</th>
<th>Robust std. error</th>
</tr>
</thead>
<tbody>
<tr>
<td>(D) Sample selecting</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mint condition bag from local retailers (A)</td>
<td>Base group</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scratched e-verification label from local retailers (B)</td>
<td>29.08**</td>
<td>11.91</td>
<td>–9.32</td>
<td>17.62</td>
</tr>
<tr>
<td>Torn bag seam or seal from local retailers (C)</td>
<td>22.59**</td>
<td>12.06</td>
<td>–10.42</td>
<td>11.59</td>
</tr>
<tr>
<td>Mint condition bag from the seed company (D)</td>
<td>50.41***</td>
<td>13.91</td>
<td>44.93</td>
<td>28.21</td>
</tr>
<tr>
<td>Local seed variety (E)</td>
<td>–273.40***</td>
<td>16.89</td>
<td>–357.96***</td>
<td>31.67</td>
</tr>
<tr>
<td>Training</td>
<td>20.05</td>
<td>19.27</td>
<td>–18.89</td>
<td>33.90</td>
</tr>
<tr>
<td>Training × Bag B</td>
<td>–78.58***</td>
<td>18.05</td>
<td>–21.47</td>
<td>23.55</td>
</tr>
<tr>
<td>Training × Bag C</td>
<td>–76.46***</td>
<td>23.52</td>
<td>–14.46</td>
<td>19.47</td>
</tr>
<tr>
<td>Training × Bag D</td>
<td>–11.87</td>
<td>20.63</td>
<td>17.30</td>
<td>33.34</td>
</tr>
<tr>
<td>Training × Bag E</td>
<td>–19.37</td>
<td>24.66</td>
<td>41.34</td>
<td>41.54</td>
</tr>
<tr>
<td>High Fraud Concern</td>
<td>–26.01</td>
<td>39.34</td>
<td>–26.68</td>
<td>38.65</td>
</tr>
<tr>
<td>High Fraud Concern × Bag B</td>
<td>–17.40</td>
<td>23.30</td>
<td>24.22</td>
<td>22.96</td>
</tr>
<tr>
<td>High Fraud Concern × Bag C</td>
<td>–30.48</td>
<td>23.64</td>
<td>33.58***</td>
<td>16.69</td>
</tr>
<tr>
<td>High Fraud Concern × Bag D</td>
<td>49.22***</td>
<td>23.11</td>
<td>12.09</td>
<td>32.16</td>
</tr>
<tr>
<td>High Fraud Concern × Bag E</td>
<td>–10.66</td>
<td>31.58</td>
<td>44.69</td>
<td>53.99</td>
</tr>
<tr>
<td>Constant</td>
<td>403.35***</td>
<td>44.88</td>
<td>393.32***</td>
<td>65.92</td>
</tr>
<tr>
<td>Number of observations (individuals)</td>
<td>1,045 (209)</td>
<td>245 (49)</td>
<td>325 (65)</td>
<td></td>
</tr>
<tr>
<td>Overall R²</td>
<td>0.4057</td>
<td>0.4746</td>
<td>0.6325</td>
<td></td>
</tr>
</tbody>
</table>

Note: ***, **, and * indicate significance at the 0.01, 0.05, and 0.10 levels, respectively. The regression controls for village, enumerator, gender, and years of education. Standard errors are clustered at the session level.

The regression controls for village, enumerator, gender, and years of education. Standard errors are clustered at the session level.
compared to treated participants reporting concern about seed quality. We acknowledge that the estimates from models B and C are based on a relatively small number of observations, thus limiting the statistical power of our estimation. This part of the analysis was exploratory since our experiment was not intended to model the mechanisms that drive differences in WTP. However, these results suggest that concerns about fraud may affect WTP differently than concerns about seed quality generally. Additional research is needed to identify the mechanisms driving these differences.

In Table 5, we show the results of models D (n = 209) and E (n = 49), for which the specification was presented in Eq (2). The premium placed on bags purchased directly from the seed company (Bag D) are only statistically significant for bags of Duma 43 relative to DK 8031. We also find that the premium for purchasing Duma 43 directly from the seed company was significantly higher among participants who reported high levels of concern about fraud. Additionally, participants bidding on bags purchased directly from Duma 43 who received training placed larger discounts on bags B and C, which were damaged. Due to the small number of participants selecting DK 8031 (n = 49, 19% of the full sample), we are cautious in our interpretation of these results, but they suggest that the brand of seed and/or packaging may affect concerns about fraud and the premiums and discounts that farmers place on bags based on its source and other bag attributes.

6. Discussion and conclusion

Investing in hybrid maize seed can increase smallholders’ productivity and reduce their down-side risks. But to justify the higher cost of such seed relative to local varieties, farmers want to know that the bags of hybrid seed available for purchase are genuine and of high quality. Seed companies are beginning to label their bags with specific information about packing dates, germination testing, and proof of certification to assure farmers that they are buying genuine, high-quality seed. However, it is unclear whether farmers value these features. Using an economic field experiment with smallholder farmers in Kenya’s Nyanza Province, we analyzed farmers’ WTP for hybrid seed in bags from different sources and with different physical attributes indicating potential tampering and mishandling. We also tested the impact of training farmers to recognize genuine seed bags and certifications on their WTP for the bags.

We find that farmers in the control (no training) and training treatment groups were willing to pay a premium for seed purchased directly from the seed company and that the highest premium came from farmers who reported significant concern about fraud in the seed supply chain. Farmers who reported significant concern about the quality of seed in the supply chain also were willing to pay a premium (albeit smaller) for purchasing seed directly from the supplier. This finding suggests that participants’ concerns about fraudulent activity and deteriorations in quality are associated with actors lower in the supply chain (e.g., sellers in local markets). More research is needed to determine the prevalence of fraudulent activity at these levels; however, regardless of the actual occurrence of fraud, we find that perceptions of fraud influence farmer behavior, specifically their WTP for hybrid seed.

Finding ways to assure farmers of high seed quality throughout the supply chain has been challenging for seed companies and government agencies, and our results indicate that their current efforts aimed at assessing the quality and authenticity of seeds in the marketplace. Training to determine if bags of seed are high-quality and authentic is especially

---

16 While purchasing the seeds for our experiment, we observed limited differences in prices and the differences were not related to the quality of the bags, but we were unique buyers and we were buying large quantities of seeds. Individual transactions for smaller quantities of seeds likely involve more negotiation between buyers and sellers, and studying these transactions may reveal relationships between prices and packing attributes that we did not observe when making seed purchases for this experiment.
important when the seed companies introduce new features on the bags. Farmers would also benefit from a better understanding of what information on the bags means. For example, they may not know that seed should be used within one year of the “sampling date” to ensure full yield performance. Making these label features clearer, e.g., using “best by” or “use by” dates, would more directly inform farmers and enable better seed management on their part. Additionally, the seed bag labels should include instructions about how to test the verification code, including a note that there is no charge for the test and what to do when the e-verification label is already scratched or the code is invalid.

Such specific, simple labeling improvements and others may be needed to translate recent packaging innovations in agroinputs into real productivity gains. These gains could be especially important among smallholder farmers who may have trouble deciphering the message contained in these features and who are more hesitant to invest in complementary inputs. In this context, building consumer confidence in the quality of the improved seeds available from agro-dealers could generate a double productivity dividend by directly enhancing yield and simultaneously inducing greater investment in fertilizer and other inputs.

Funding: This work was supported by the Borel Global Fellows Program and by the University of Delaware’s College of Agriculture and Natural Resources Seed Grant Program.

Credit authorship contribution statement

MARIAM H. GHARIB: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Writing - original draft. LEAH H. PALM: Conceptualization, Methodology, Investigation, Formal analysis, Writing - original draft. TRAVIS J. LYBBERT: Conceptualization, Methodology, Writing - review & editing. KENT D. MESNER: Conceptualization, Methodology, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

Acknowledgments

We thank our dedicated research team in Kenya for their assistance with data collection. For their helpful feedback and guidance, we thank Hugo De Groote, Naureen Karachwila, Hope Michel, Emilia Tjernström and Randy Wisser. We also thank Jim and Marcia Borel for their generous endowment to support the Borel Global Fellows Program at the University of Delaware.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.foodpol.2021.102040.

References


