Increasing Adoption and Varietal Turnover of Seed—The Role of Producer and Consumer traits

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Abstract

In developing countries, semi-subsistence farmers often play dual roles as both consumers and producers of the same crops. Consequently, decisions regarding crop selection are influenced by a combination of household food security needs and market-oriented considerations. This study assesses the effectiveness of two interventions designed to enhance the adoption of improved maize seed varieties among smallholder farmers in eastern Uganda. A first intervention involves providing farmers with free seed sample packs, allowing them to directly experience the producer related benefits, such as higher yield potential and drought resistance. A second intervention consists of organizing cooking demonstrations and blind tasting sessions to compare maize flour from the improved variety with local varieties, focusing on consumption traits like palatability, texture, and ease of cooking. We find that the seed sample packs significantly enhance farmers' perceptions of the seed's production traits, while the cooking demonstrations improve appreciation for its consumption attributes. There is evidence suggesting that the cooking demonstration intervention increases the adoption of improved seed varieties. However, farmers who received the seed sample packs are more likely to reuse the harvested grain as seed in the subsequent season, essentially crowding out the adoption of fresh seed. We argue that this may be a rational response in the context of positive transaction costs related to the use of improved seed varieties.

Keywords: technology adoption, subsidies, demonstration.

JEL: Q16, H24, O33, D91

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1 Introduction

To sustainably feed a growing global population while mitigating climate change and preserving biodiversity, it is essential to produce more food on less land. Green Revolution technologies, particularly the development of improved planting materials, have been instrumental in achieving higher yields and enhancing resilience to environmental challenges such as drought. Traditionally, breeding programs have prioritized production-related traits, such as yield, drought tolerance, and pest resistance. However, there is a growing focus on consumer-oriented traits, including taste, color, texture, and ease of cooking. Integrating these consumption-oriented attributes alongside production advantages is crucial for driving demand for improved crop varieties, whether among subsistence farmers growing their own food or producers targeting commercial markets.

For new technologies to be widely adopted, it is essential to raise farmers' awareness about beneficial traits. Similar to the historical focus in breeding programs, sensitization efforts often emphasize production traits. A common strategy to encourage farmers to learn about the production traits of a new seed variety is through seed sample packs.[1] These trial packs, typically containing small quantities of seed (e.g., 1 kg), are provided for free, allowing farmers to test them on a small portion of their plot. The goal is to encourage farmers to invest in the seed in subsequent seasons if they find it beneficial.

From a theoretical standpoint, seed sample packs can be viewed as a form of subsidy. Subsidies are often employed to promote adoption and are justified for several reasons. First, resource-constrained farmers may perceive the risk premium of a new product as too high to justify investment. More broadly, even without considering risk premia, farmers may lack the resources to purchase the seed, especially if complementary inputs and effort are required (see Miehe et al., 2023b). A one-off subsidy in the form of a starter kit can help initiate adoption, as supported by the theory of micro poverty traps, which posits that households and individuals remain in chronic poverty because they cannot self-finance investments necessary for high returns (Barrett and Swallow, 2006).[2] Second, it is well known that farmers learn from others when a new technology is introduced (Conley and Udry, 2010; Van Campenhout, 2021) In case where there are positive externalities, subsidies may be justified. Finally, governments may use subsidies to replenish deteriorated seed stocks, enhancing the overall vigor of seeds circulating within society (McGuire and Sperling, 2016).

Surprisingly few studies directly evaluate the effectiveness of seed sample packs in accelerating technology adoption and results are mixed. Emerick et al. (2016) distribute stater kits for seed of a new rice variety in India. They find that seventy-six percent of treatment farmers cultivated the technology in the sec-

[1] One may argue that seed sample packs also enable farmers to discover consumer traits after they harvest the grain obtained from the seed sample pack. However, this would require farmers to keep the grain separate from grain obtained from local seed and consume the grain themselves (as opposed to selling it).

[2] In the context of seed, a sample pack can foster sustained adoption either directly (if the seed is reused in future seasons) or indirectly (if surplus production is sold and the proceeds are used to buy new seed).

ond season following distribution. Biedny et al. (2020) found that in Tanzania, adding sample packs to demonstration plots within the framework of village-based agricultural advisors had no significant impacts on sales, orders received, or learning outcomes. In many studies, the focus is not on the seed packs themselves but on some attribute of the seed, such as its risk reduction potential (eg. Boucher et al., 2021). Morgan, Mason, and Maredia (2020) examined different extension approaches, including the use of sample packs, but their focus was on farmers' willingness to pay, elicited through a Becker-DeGroot-Marschak (BDM) auction, rather than subsequent adoption of the new technology. They found that in the southern highlands of Tanzania, bean farmers' willingness to pay was not influenced by seed sample packs. Most studies on seed sample packs are limited to a single season and primarily investigate the immediate use of the seed sample pack. Subsequent adoption is often assessed by asking farmers about their intention to use the seed in the next season, which can be prone to social desirability bias.

It is even harder to find examples of strategies that emphasize consumption-related traits. This is surprising given that in many contexts where adoption is lacking, farmers consume most of the crops they grow, and there is a large literature that shows that in such settings consumption and production decisions are inseparable. Interventions that focus on demonstrating consumption traits, such as cooking demonstrations and tasting sessions, are typically concerned with nutrition education and rarely examine subsequent adoption in the following season (eg. Olney et al., 2015). One exception is De Brauw et al. (2018), who study the impact of the HarvestPlus' Reaching End Users project (and includes a demand creation component) on the adoption of bio-fortified crops in Mozambique and Uganda.

In this paper, we test to what extent one can accelerate varietal turnover by highlighting both the production and consumption attributes of improved maize varieties to farmers in their roles as producers and consumers. To achieve this, a field experiment is conducted to test the relative effectiveness of two interventions using a cluster randomized control trial with a simple factorial design. The first intervention targets production traits by providing farmers with 1 kg sample packs with seed of an improved variety.[3] Orthogonal to this intervention, a second was introduced that involves cooking demonstrations and tasting sessions. This intervention allows farmers to familiarize themselves with consumption attributes of maize flour derived from the grain grown using improved varieties. Additionally, farmers in this treatment are provided with maize flour samples to further explore consumption traits at home.

The field experiment was conducted in four districts in eastern Uganda among a representative sample of about 1,500 farmers. The area, commonly know as the Busoga Kingdom, is populated with smallholder farmers who pro-

[3] We use the term "improved variety" throughout this paper to refer to both maize hybrids and open pollinated varieties marketed and sold in our study areas, as opposed to farmer-saved seed or seed obtained through farmer-to-farmer exchanges which, in the specific context of maize, may be less effective due to cross pollination and genetic drift over multiple generations, or due to poor seed storage and handling between seasons.

duce for both home consumption and the market. The seed we promoted in this study is a hybrid variety called Bazooka, which, despite being widely available, was relatively new and thus not widely adopted by farmers. The primary production trait of this seed is its potential for increased yield. The study ran over two consecutive agricultural seasons in 2023, with endline data being collected early 2024.

We find that farmers who received a free seed sample are actually less likely to use fresh seed of an improved variety in the next season. This counter intuitive result is caused by the fact that farmers who received Bazooka for free used grain obtained from this seed as planting material in the next season. Since we categorize recycled hybrid seed as local seed, these farmers are considered non-adopters in our analysis. However, we do find that the cooking demonstration and tasting session increased the use of fresh Bazooka, with some indications that this also led to higher maize productivity.

While we expected that increased attention to consumption traits would increase the role of women in the decision making process with respect to seed choice, we do not find this effect. We also test if making consumption traits more salient would increase consumption, but also here we do not find an effect. Moreover, we do not find effects further down the impact pathway in terms of food security or welfare.

Exploring some of the impact pathways, we do find that the cooking demonstration and tasting session increased the share of farmers that rank improved seed varieties higher on a range of consumption attributes such as taste, portions, appearance, and ease of cooking. Again in line with the theory of change, we find that farmers that received the seed sample pack rank improved seed higher in terms of production-related attributes such as yield, abiotic and biotic stress resistance, time to maturity, and germination rate. Interestingly, the seed sample pack also positively affects how farmers think about consumption traits of improved varieties, suggesting farmers consume grain obtained from the seed sample pack and pay close attention to consumption attributes.

The rest of the paper is organized as follows. The next section presents research methods with sub-sections for the experimental layout, the treatments, estimation and inference, and timeline. We then turn to the data and discuss the study context, present balance tables, and look at attrition. The next section presents the findings, starting with adoption. We further look at how the interventions affect decision-making, food security, and well-being. We also study some of the potential underlying mechanisms. A final section concludes.

2 Methods

2.1 Experimental design

In this study, we employ a field experiment to evaluate the effectiveness of two interventions, which we elaborate on in the subsequent section. This evaluation is conducted using a cluster randomized controlled trial (RCT) structured as a 2x2 factorial design. Each factor includes both a control and a treatment level, with interventions clustered at the village level. Within each village, a predetermined number of households were randomly selected.

The first factor pertains to the seed sample pack treatment. Farmers in the treatment villages receive a complimentary sample of a new, improved maize seed variety (bazooka), whereas those in the control villages do not receive this free sample pack.[4]

The second factor involves a cooking demonstration and tasting session. In the treatment villages, farmers are invited to participate in a session where they can taste food prepared with the promoted variety (bazooka) and compare it directly to food made with the local variety. Additionally, all participants receive a free sample of maize flour derived from the improved variety to try at home. In the control villages, these events are not organized.

Treatment assignment is conducted at the village level to ensure that control and treatment conditions are not confounded by proximity. Specifically, this approach prevents a situation where a control farmer, who receives only a bar of soap as a token of gratitude, lives adjacent to a treatment farmer who receives a free bag of maize seed. By assigning treatments at the village level, we also mitigate potential concerns about spillover effects, where benefits or changes experienced by treatment farmers might unintentionally influence control farmers.

2.2 Treatments

The first intervention is straightforward and involves providing a seed sample pack to the household member responsible for most maize cultivation decisions. This sample pack contains an improved variety that is currently available in the market but has not yet been widely adopted by farmers. Specifically, we provided 1 kg bags of bazooka seed, which is sufficient to plant approximately 1/8 of an acre. The control condition for this factor is the absence of a seed sample pack, meaning these households do not receive the pack. However, both the treatment and control groups are informed about the existence and benefits of the improved seed variety. This allows us to isolate the effect of the sample pack from the effects of merely having knowledge about the seeds of the improved variety.

For the second factor, the treatment level consists of a cooking demonstration and tasting event. Here, sampled farmers of the treatment villages are invited to a central place (the village chairperson's residence) for a facilitated meeting. The facilitator starts by asking the group to mention the most commonly grown varieties by farmers in the village. These varieties are grouped into "improved varieties" and "local varieties" on a flip-chart.[5] Farmers are then asked to rank

[4]They do get something of similar value—a so-called token of appreciation—to account for potential income effects

[5]The terms to the seed types in the local language were "Dhuuma Omulongosemu" for "seed of an improved variety" and "Dhuuma Omusoga" for local seed. The latter is clearly derived from the name of the region, Busoga.

the two categories based on ratings of various consumption attributes by a show of hands. To facilitate the discussion, flip charts were pre-filled with the five most common consumption traits: taste, texture, color, aroma, and the degree to which the flour expands during cooking.[6] Farmers can add as many traits as they see fit.

After the rating, we proceed with blind tasting. The facilitator asks a volunteer from the participants to prepare posho, a thick, dense porridge made by mixing maize flour with boiling water until it reaches a dough-like consistency. Two meals are prepared: one using flour obtained from local variety and one using flour derived from Bazooka (the hybrid variety used in the seed sample pack). The cook is unaware of which flour corresponds to which maize type.[7] The resulting dishes are then displayed on a table, and farmers are invited to taste the two varieties, labeled as the variety on the left and the variety on the right. The farmers then rate the two varieties on the various consumption attributes again, indicating which of the two samples is superior for each attribute by a show of hands.

Finally, the results are discussed within the group. Participants are informed that one of the two samples was made from flour obtained from local maize, while the other was from an improved maize type called Bazooka. The facilitator asks the farmers to guess which sample was based on flour from the local variety and which was from the improved variety. After gathering the guesses, the facilitator reveals the correct answers.[8]

2.3 Estimation and inference

We will use Analysis of Covariance (ANCOVA) models to assess the impact of the interventions, focusing specifically on the Intent-to-Treat effect. Given that randomization was conducted at the village level, we will estimate the following equation:

$$Y_{ij} = \alpha + \beta_T T_j^T + \beta_D T_j^D + \beta_I T_j^T T_j^D + \delta Y_{ij}^B + \varepsilon_{ij} \tag{1}$$

[6] These consumption traits were identified through focus group discussions. One notable trait that emerged during these discussions, which was integral to designing the treatment, is the extent to which maize flour expands during cooking, yielding "more food from less flour." This characteristic is linked to the starch content of maize flour, which is a carbohydrate and a natural component of most plants, including fruits, vegetables, and grains. When starch is heated in water, the granules swell and burst, releasing glucose molecules into the water. This expansion property of maize flour was particularly valued by women.

[7] The research team provided all necessary utensils for the session, including a gas stove, pots, aprons, and even a chef's hat. We ensured that the two dishes differed only in terms of the flour used by employing the same cook and starting with identical amounts of flour, measured on a weighing scale. Additionally, the order in which the meals were cooked was randomized across sessions.

[8] During field testing, a large majority of farmers initially stated that the local seed excelled in nearly all dimensions, such as having a sweeter taste, whiter appearance, and better aroma. However, during the tasting, almost all farmers consistently rated the sample made from Bazooka maize as superior. After the tasting, most farmers incorrectly identified the superior sample as being from the local variety, when in fact, it was made from Bazooka maize.

where T_j^T is an indicator variable that is one if village j was randomly assigned to the seed sample pack intervention (and zero otherwise), and T_j^D is an indicator variable that is one if village j was randomly assigned to the cooking demonstration and blind tasting intervention (and zero otherwise). Outcomes are measured at the individual level (Y_{ij}). We also allow for an interaction effect between the two interventions and control for baseline outcomes $\left(Y_{ij}^B\right)$ to improve precision. We will apply a cluster-robust variance estimator with the "bias-reduced linearization" small-sample correction (Imbens and Kolesar, 2016), with standard errors clustered at the level of randomization (village level).

Factorial designs are commonly employed to evaluate multiple treatments within a single experiment. However, combining treatment cells to enhance statistical power can lead to unintended consequences if there is an interaction between the treatments (Muralidharan, Romero, and Wüthrich, 2023). While our design is powered for a complete set of interactions (as in equation 1), we may wish to enhance statistical power by pooling observations across the orthogonal treatments if we find that a treatment effect is smaller than the minimal detectable effect size assumed during power calculations. To achieve this, we will treat the orthogonal treatment as a covariate we want to adjust for, and interact the treatment variable with the demeaned orthogonal treatment (Lin, 2013). This approach provides a more robust and unbiased estimate of the treatment effect:

$$Y_{ij} = \alpha + \beta_M T_i^M + \beta_O \left(T_i^O - \bar{T^O}\right) + \beta_I T_i^M \left(T_i^O - \bar{T^O}\right) + \delta Y_{0ij}^B + \varepsilon_{ij} \tag{2}$$

Where now T_i^M is a dummy for the main treatment (the seed sample pack or the cooking demonstration respectively) and T_i^O is a dummy for the orthogonal treatment (which enters in deviations from its means).

Since we will evaluate treatment effects across a range of outcome measures, it is essential to address the multiple comparisons problem. Following the approach outlined by Anderson (2008), we aggregate various outcome measures within a given family into summary indices. Each index is calculated as a weighted mean of the standardized values of the outcome variables. The weights for this efficient generalized least squares estimator are determined to maximize the information captured by the index, giving less weight to outcomes that are highly correlated with one another. This method of combining outcomes into indices is a widely adopted strategy to mitigate the risk of over-rejecting the null hypothesis due to multiple comparisons.

2.4 Timeline

To assess the impact of seed sample packs, we look at two consecutive agricultural seasons. That is, our main outcome of interest is not whether farmers use the seed trial pack on their fields, but whether the fact that they could experiment with a new seed variety led them to continue using it in subsequent seasons. As such, key outcomes to assess the impact of the seed sample pack

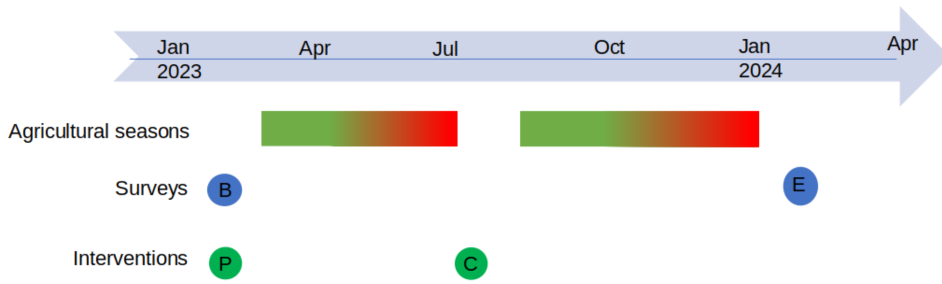

Figure 1: Timeline

seed choice in the second season and yield after the second season. This is different for the cooking demonstration and tasting session. Here, we expect that after having been exposed to the intervention, behavior change can be observed in the agricultural season immediately following the intervention.

Fortunately, the study area experiences two maize growing seasons each calendar year. The first season, locally known as Entoigo, runs from March/April to June/July, while the second season, referred to as Nsambya, extends from August/September to November/December. We distributed the seed sample packs along with baseline data collection a few months before planting commenced for the first agricultural season in 2023. This then allows farmers to experiment with the new seed in the first season of 2023. After the first season and before the start of the second season, the cooking demonstrations and tasting sessions were organized. Endline data was collected in February 2024, after the conclusion of the second season. This timeline is also depicted in Figure 1.

3 Sample

Sample size was determined through a series of power simulations detailed in the pre-registered pre-analysis plan.[9] The simulations resulted in a sample design of 148 villages, with 10 households in each village. In this setup, 74 villages (740 households) would receive a free sample pack, and 74 villages (740 households) would be exposed to the consumption treatment. Approximately half of the villages in each treatment group (or around 37 villages comprising of 370 households))would receive both treatments. To account for attrition, we collected data on 2 more villages in each treatment cell. This leads to a total sample size

[9]The primary outcome used in these simulations is a binary indicator of quality seed of an improved variety use at the farmer level. Data from a previous project, which included 3,450 smallholder maize farmers across 345 villages, was used to estimate the intra-cluster (within-village) correlation for this outcome (Miehe et al., 2023a). We assumed a treatment effect of a 13.5 percentage point increase for both the seed sample treatment and the consumption treatment, and a 23.5 percentage point increase for the interaction effect. The R code used for the simulations is available here. The pre-analysis plan can be accessed here.

of 1,560 households located in 156 villages.

With this design, sample size, and assumptions about outcome variable and minimum detectable effect sizes detailed in the pre-analysis plan, we are not powered to detect both main effects and the interaction simultaneously. Specifically, we can estimate a positive effect for both treatments and their interaction at the 5% significance level in only 68% of cases. However, when we only require one hypothesis to be detected, we achieve power levels in excess of the conventional 80%.

3.1 Context

The study was conducted in Eastern Uganda, specifically in the Busoga Kingdom. We selected our sample from four districts—Bugiri, Iganga, Kamuli, and Mayuge—chosen for their relatively low adoption rates of the improved seed variety (Bazooka) and their well-established network of agro-input dealers, which helps mitigate access issues. These districts were identified based on data from a previous study that matched these criteria.

The study population comprises of smallholder maize farmers. To obtain a representative random sample, villages were selected with probability proportional to the number of households within each village. Within each sampled village, 10 households were randomly chosen to participate in the study.

3.2 Balance test and descriptive statistics

We pre-registered 10 variables to assess balance in our design during baseline data collection. These variables were selected to offer a comprehensive description of a representative farmer in our sample. Half of the variables are characteristics that are unlikely to be influenced by the intervention, while the other five are drawn from the pre-registered primary and secondary endline outcomes.

Table 1 shows sample means in the first column (and standard deviations below). We see that the average household head in our sample was about 49 years old at the time of the baseline survey. About half of household heads had finished primary education. In 20 percent of the households, the household head was a woman. Households in the area are large, with on average about 8 to 9 individuals. The average distance to the nearest agro-input shop where maize seed of an improved variety can be bought is about 4 kilometers.

We first inquired whether farmers had used "quality maize seed, such as an Open Pollinating Variety (OPV) or hybrid seed, on any of their plots during the previous season (Nsambya of 2022)." According to the baseline data, approximately 40 percent of households affirmed using such seeds. Subsequently, we posed a more specific question regarding the exact type of seed used on a randomly selected plot.[10] The seed type of interest was Bazooka, the hybrid seed variety that is also utilized in our experiment. At baseline, only about 7 percent of farmers reported having used Bazooka seed on the randomly selected

[10] See Section 4.1 for more information on the rationale of using of a randomly selected plot.

plot in the previous season. We also asked where the seed used on the randomly selected plot was obtained from. Results indicate that approximately 30 percent of farmers sourced their seed from formal channels, such as agro-input dealers, non-governmental organizations, or the government extension system (Operation Wealth Creation). Conversely, 54 percent of farmers reported reusing seed from previous seasons, with some having used it for more than four seasons. Notably, Open Pollinated Varieties that have been used more than four times tend to lose their yield advantage. Finally, the average farmer harvested about 390 kilograms per acre on the randomly selected plot at baseline.

The table also reports differences between the relevant treatment and control groups, as estimated through the pooled model (Equation 2) as well as the fully interacted model (Equation 1). In particular, the second column in Table 1 corresponds to β_M in Equation 2 for the seed sample treatment (in which case the cooking demonstration and tasting treatment is considered the orthogonal treatment and controlled for). In the third column, this is reversed, showing β_M in Equation 2 for the cooking demonstration and tasting treatment (with the seed sample treatment now considered the orthogonal treatment and controlled for). The fourth, fifth and sixth columns correspond to β_T, β_D and β_I respectively in Equation 1.

The estimates indicate good overall balance. The proportion of male household heads is about 4 percentage points lower in the subsample assigned to the cooking demonstration treatment compared to those not exposed to the intervention, but this difference is only significant at the 10 percent level. Considering that out of 50 comparisons, we would expect 5 outcomes to be significant at the 10 percent level by chance alone, we conclude that the randomization appears to have been effective.

3.3 Attrition and compliance

Attrition was minimal: we successfully located all but four of the 1,560 households interviewed at baseline. However, some of these households could not be interviewed due to circumstances such as burial or illness, or they refused participation, reducing the effective sample size at endline to 1,538.

One of the first questions we asked was whether farmers recalled the treatment, irrespective of their treatment group. This question serves as a useful proxy to assess compliance. For the sample pack treatment, 98 percent of farmers in the treatment group indicated that they received a seed sample pack from us in March 2023. Furthermore, only 8.6 percent of farmers in the control group indicated that they received a seed pack from us, suggesting only limited excess coverage. For the cooking demonstration treatment, 92 percent of farmers in the treatment group recalled being invited to a cooking and tasting demonstration, corresponding to a failure to reach rate of 8 percent. Meanwhile, 96 percent of farmers in the control group did not recall a cooking and tasting demonstration, leading to an excess coverage rate of 4 percent.

Table 1: Baseline Balance

		Pooled model		*Interacted model*		
	mean	sample	cons	sample	cons	interact
Age of HH head (in years)	48.62	-0.31	-0.65	-1.53	-1.87	2.45
	(13.58)	(0.85)	(0.85)	(1.31)	(1.22)	(1.69)
HH has finished primary education?	0.51	0.02	0.00	0.00	-0.02	0.04
	(0.50)	(0.03)	(0.03)	(0.05)	(0.04)	(0.06)
Gender of household head (1=male)	0.80	-0.03	-0.04^{+}	-0.03	-0.04	0.00
	(0.40)	(0.03)	(0.03)	(0.03)	(0.03)	(0.05)
Household size	8.24	-0.01	-0.02	-0.05	-0.05	0.07
	(3.91)	(0.03)	(0.03)	(0.04)	(0.04)	(0.06)
Distance of homestead to nearest agro-input shop (km)	4.08	-0.01	0.04	0.01	0.06	-0.05
	(3.54)	(0.10)	(0.10)	(0.14)	(0.15)	(0.19)
Has used quality maize seed on any plot in last season?	0.40	-0.04	-0.02	-0.03	-0.01	-0.02
	(0.49)	(0.03)	(0.03)	(0.05)	(0.04)	(0.07)
Has used the promoted seed (bazooka) on a randomly chosen plot in the last season?	0.07	-0.01	-0.01	0.02	0.02	-0.06
	(0.26)	(0.02)	(0.02)	(0.02)	(0.03)	(0.04)
Seed on random plot was obtained from formal seed source?	0.30	-0.04	0.02	-0.01	0.05	-0.06
	(0.46)	(0.03)	(0.03)	(0.04)	(0.04)	(0.06)
Used seed that is recycled more than 3 seasons on randomly selected plot?	0.54	0.02	0.03	0.00	0.02	0.04
	(0.50)	(0.04)	(0.04)	(0.05)	(0.05)	(0.07)
Maize yields on a randomly chosen plot in last season (kg/acres)	386.76	-0.06	0.00	-0.04	0.02	-0.04
	(299.89)	(0.06)	(0.06)	(0.07)	(0.07)	(0.11)

Note: Column (1) reports sample means at baseline and standard deviations below; columns (2)-(3) report differences between treatment and control groups estimated using the pooled model of Equation 2; (4)-(5) report differences between treatment and control groups estimated using the fully interacted model of Equation 1; column (6) is the interaction effect. Standard errors are below the estimates and are clustered at the level of randomization; **, *, and + denote significance at the 1, 5 and 10% levels. Household size, distance to nearest agro-input shop, and productivity is transformed using the inverse hyperbolic sine transformation (means and standard deviations are in levels).

4 Results

4.1 Adoption

Adoption of improved varieties is the primary outcome of interest in this study. Therefore, Table 2 investigates if farmers use quality seed of improved varieties in general, while Table 3 asks more detailed questions about seed use and practices on a particular (randomly selected) plot within the household. As mentioned in Section 2.3, outcomes are combined in a summary index following Anderson (2008) as a first safeguard to over-rejection due to multiple hypothesis testing.

The structure of Table 2, and all other tables below, is the same as the one used in Table 1. It reports overall sample means (this time at endline; column 1), as well as intent-to-treat estimates for the pooled model in Equation 2 (columns 2 and 3) and the fully interacted model in Table 1 (columns 4 to 6).

Table 2 shows that at enline about 25 percent of farm households used maize seed of an improved variety on at least one plot in the second season of 2023. This is significantly lower than the share reported during baseline (see Table 1). This discrepancy is due to a change in the question used to measure seed use. While at baseline we asked a single, broad question, at endline we inquired about seed use on each plot individually. This detailed information is then used to determine if quality maize seed was used on at least one plot. At baseline, we left it to the farmer to decide what quality seed means; at endline, we defined quality seed as fresh hybrid seed or an OPV recycled a maximum of three times from a trusted source.

We find that the seed sample pack intervention reduced the likelihood of adoption, regardless of the model used. This reduction is substantial, amounting to approximately half of the mean adoption rate. Conversely, we do not observe any change in the use of improved seed as a result of the cooking demonstration and tasting session.

We define a similar variable to examine the adoption of the specific seed used in the experiment, coding this outcome as true only if the seed is fresh and obtained from a trusted source. Overall, about 9 percent of farmers use fresh Bazooka seed on at least one plot. Notably, when considering this outcome, the negative effect of the seed sample pack disappears. In fact, we now find that farmer households exposed to the cooking demonstration intervention are more likely to use fresh Bazooka seed in the season following the intervention.

Next, using the same definition of improved seed as in the first question, we determine the number of plots on which improved seed was planted. However, it could also be that the intervention changes the total number of plots used for cultivation, so we also scale the number of plots on which improved seed was used by the total number of plots. We find that improved seed was planted on 0.33 plots in the entire sample. The seed sample pack reduced the number of plots on which improved seed was planted. We further find that the seed sample pack intervention also reduced the share of plots on which improved seed was planted by 13 to 14 percentage points. This suggests that total number of plots did not change, but that treated households dis-adopted.

Table 2: Adoption

		Pooled model		*Interacted model*			
	mean	sample	demo	sample	demo	interact	nobs
Has used quality maize seed on any plot in last season?	0.25	-0.13**	0.04+	-0.14**	0.03	0.02	1488
	(0.43)	(0.03)	(0.02)	(0.03)	(0.03)	(0.05)	
Has used fresh Bazooka on any plot in last season in last season?	0.09	0.02	0.05**	0.02	0.05*	-0.01	1495
	(0.28)	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)	
Has used Bazooka (fresh or recycled) on any plot in last season in last season?	0.45	0.63**	0.03	0.67**	0.07+	-0.08	1495
	(0.50)	(0.03)	(0.03)	(0.04)	(0.04)	(0.06)	
Number of plots planted with improved seed	0.33	-0.16**	0.05	-0.18**	0.03	0.05	1495
	(0.64)	(0.04)	(0.04)	(0.05)	(0.05)	(0.08)	
Number of plots with improved seed as share of total number of plots	0.23	-0.13**	0.03	-0.13**	0.03	0.01	1494
	(0.41)	(0.03)	(0.03)	(0.03)	(0.03)	(0.05)	
Area planted with improved seed (acres)	0.34	-0.16**	0.04	-0.22**	-0.02	0.12	1495
	(0.81)	(0.05)	(0.05)	(0.06)	(0.06)	(0.10)	
Area planted with improved seed as a share of total maize cultivation area	0.23	-0.13**	0.03	-0.14**	0.03	0.01	1495
	(0.41)	(0.03)	(0.03)	(0.03)	(0.03)	(0.05)	
Index	0.20	0.32**	0.07	0.33**	0.07	-0.02	1494
	(0.74)	(0.05)	(0.05)	(0.06)	(0.07)	(0.09)	

Note: Column (1) reports sample means at baseline and standard deviations below; columns (2)-(3) report differences between treatment and control groups estimated using the pooled model of Equation 2; (4)-(5) report differences between treatment and control groups estimated using the fully interacted model of Equation 1; column (6) is the interaction effect. Standared errors are below the estimates and are clustered at the level of randomization; **, *, and + denote significance at the 1, 5 and 10% levels.

A related outcome is the area planted with improved seed. We find that, on average, households planted about 0.34 acres with improved seed. However, in households that received a seed sample pack, the area planted with improved seed was 0.16 acres less compared to households that did not receive a seed sample pack. To account for potential changes in total acreage due to the intervention, we also scale the area planted with improved seed by the total area under cultivation. We observe a reduction in the proportion of the total area planted with improved seed, suggesting that the intervention led farmers to switch from planting improved seed to planting local seed. Additionally, the summary index confirms a significant and negative impact of the seed sample pack on these adoption outcomes.

We now turn to plot-level outcomes for a more detailed analysis. Instead of collecting data on all plots, we randomly selected one plot per household on which we asked a range of detailed questions. These questions covered not only seed use but also complementary input use and crop management practices. Additionally, we use this data to extrapolate yield estimates.[11]

Table 3 confirms results from Table 2 with negative effects on the adoption of seed of an improved variety for the seed sample pack treatment, but a positive effect on the use of fresh bazooka seed from the cooking demonstration. The table further indicates that reduced adoption leads to lower quantities of improved seed used, both in absolute terms and when measured per acre.

Interestingly, we do not see that the reduced use of improved seed had a negative impact on maize production or productivity. In fact, there are some signs that the cooking demonstration and tasting sessions actually increased production and productivity. In particular, we find a 13 percent increase in maize productivity (as we use log transformations in the regression).

At first glance, the results for the seed sample packs seem counterintuitive. The primary objective of distributing seed sample packs is to increase the adoption of improved seed varieties in subsequent years. However, our findings suggest that a significant portion of farmers in our sample opted to recycle seed from the sample packs rather than purchasing fresh Bazooka seed from agro-input dealers. According to our definition of improved seed, recycled Bazooka seed does not qualify as such. Furthermore, the intervention appears to have inadvertently crowded out the use of fresh improved seed: the high yields experienced with the sample packs led farmers to continue using recycled Bazooka seed. In contrast, farmers in the control group may have been dissatisfied with the local seed they were using. This dissatisfaction could have led them to seek fresh seed or use an Open Pollinated Variety (OPV) that was recycled fewer than four times.

[11] The decision to collect detailed data on only one randomly selected plot per household, rather than on all plots, was based on the generally high correlation between technology use, input use, and management practices within a household. By focusing on a single plot, we aimed to increase the number of farmers included in the sample, thereby enhancing statistical power. While one might be concerned that farmers could use different seeds on different plots, potentially leading to misclassification of adopters if the "wrong" plot is chosen, our data indicates that this is not a significant issue. Adoption outcomes measured at the plot level are virtually identical to those measured across any plot within the household.

Table 3: Adoption on random plot

		Pooled model		*Interacted model*			
	mean	sample	demo	sample	demo	interact	nobs
Has used quality maize seed on randomly selected plot in last season (yes=1)	0.23	-0.12**	0.03	-0.13**	0.02	0.02	1495
	(0.42)	(0.02)	(0.02)	(0.03)	(0.03)	(0.05)	
Has used fresh Bazooka on randomly selected plot in last season (yes=1)	0.07	0.01	0.04*	0.02	0.05**	-0.02	1495
	(0.26)	(0.01)	(0.01)	(0.02)	(0.02)	(0.03)	
Quantity of improved seed used on randomly selected plot (kg)	1.33	-0.89**	-0.13	-1.27**	-0.51+	0.77*	1438
	(3.18)	(0.18)	(0.17)	(0.25)	(0.28)	(0.35)	
Quantity of improved seed used on randomly selected plot (kg/acre)	1.32	-0.78**	-0.05	-1.12**	-0.39	0.67*	1411
	(2.83)	(0.17)	(0.17)	(0.23)	(0.24)	(0.34)	
Maize production	331.20	-0.07	0.11+	-0.09	0.09	0.04	1410
	(340.92)	(0.06)	(0.06)	(0.08)	(0.09)	(0.12)	
Maize productivity	383.50	0.01	0.13*	-0.01	0.11	0.04	1375
	(292.76)	(0.05)	(0.05)	(0.08)	(0.07)	(0)	
Index	-0.07	-0.09*	0.02	-0.16**	-0.05	0.13+	1331
	(0.62)	(0.04)	(0.04)	(0.05)	(0.05)	(0.07)	

Note: Column (1) reports sample means at baseline and standard deviations below; columns (2)-(3) report differences between treatment and control groups estimated using the pooled model of Equation 2; (4)-(5) report differences between treatment and control groups estimated using the fully interacted model of Equation 1; column (6) is the interaction effect. Standared errors are below the estimates and are clustered at the level of randomization; **, *, and + denote significance at the 1, 5 and 10% levels. Production and productivity are log transformed (means and standard deviations are in levels).

4.2 Decision Making and Disposal

We hypothesize that highlighting the consumption traits of improved seed varieties may shift the decision-making role concerning seed selection and the use of harvested maize, potentially increasing the involvement of female co-heads in these decisions. In Uganda, as in many agriculture-based countries with pronounced gender norms, men typically handle production and marketing decisions, while women are more often involved in domestic responsibilities such as cooking. The cooking demonstration and tasting session might increase men's awareness that maize involves more than just yield, potentially creating opportunities for women to participate more in decision-making processes. Consequently, enhancing women's involvement in decision-making is a significant focus of this study.

To explore this, we asked about decision-making within households. Specifically, we inquired who decided which seed to use on the randomly selected plot. We provided a range of response options and combined these into an indicator variable signifying women involvement, which is true if the decision was made solely by the woman, jointly by the woman and the husband, or if the husband made the decision after consulting the woman (as opposed to the husband deciding unilaterally). A similar question was posed regarding decisions about the use of the harvest.

Table 4 reveals that approximately half of the women are involved in decision-making related to seed use and harvest management. Contrary to our expectations, the consumption intervention does not show a significant effect on this involvement. However, there is a positive effect associated with the seed sample pack intervention, observed only in the fully interacted model, with significance at the 10 percent level.

The interventions may also influence the use of maize harvested from the selected plot. We first examined the proportion of the harvest allocated to household consumption. We anticipated that the cooking demonstration and tasting session would increase this share, based on the premise that emphasizing consumption traits would lead to higher consumption. Table 5 shows that approximately three-quarters of the maize is grown for home consumption. However, we did not find a significant effect of either intervention on this outcome.

Maize that is not consumed is usually sold. We thus also look at what share of the harvest is sold. Indeed, Table 5 shows that about 20 percent of seed is sold on average. We do not see any effects of the interventions.

Finally, we examined the amount of maize grain reserved as planting material for the next season. We anticipated a reduction in the quantity of saved seed, given that both interventions aim to promote the adoption of improved maize varieties and encourage varietal turnover. However, we did not observe a significant effect of the interventions on this outcome. This lack of effect may be attributed to the fact that, as discussed in Section 4.1, farmers appear to recycle improved seeds also.

Table 4: Impact on women co-head involvement (random plot)

		Pooled model		*Interacted model*			
	mean	sample	cons	sample	cons	interact	nobs
Woman involved in decision what to plant?	0.47	0.04	0.02	0.09^{+}	0.06	-0.09	1469
	(0.50)	(0.03)	(0.03)	(0.04)	(0.05)	(0.06)	
Women involved in what to do with harvest?	0.46	0.04	-0.01	0.09^{+}	0.04	-0.10	1469
	(0.50)	(0.03)	(0.03)	(0.05)	(0.05)	(0.07)	
Index	0.09	0.08	0.01	0.18^{+}	0.11	-0.20	1469
	(0.98)	(0.06)	(0.06)	(0.09)	(0.09)	(0.13)	

Note: Column (1) reports sample means at baseline and standard deviations below; columns (2)-(3) report differences between treatment and control groups estimated using the pooled model of Equation 2; (4)-(5) report differences between treatment and control groups estimated using the fully interacted model of Equation 1; column (6) is the interaction effect. Standared errors are below the estimates and are clustered at the level of randomization; **, *, and + denote significance at the 1, 5 and 10% levels.

Table 5: Disposal of harvest on random plot

		Pooled model		*Interacted model*			
	mean	sample	cons	sample	cons	interact	nobs
Share kept for consumption	74.24	0.63	-0.72	-1.21	-2.56	3.69	1449
	(30.31)	(2.11)	(2.10)	(3.00)	(2.80)	(4.21)	
Share sold	20.52	-0.74	-0.31	-1.50	-1.07	1.53	1495
	(29.45)	(2.08)	(2.08)	(2.93)	(2.67)	(4.16)	
Maize kept as seed (kg)	4.37	-0.83	-0.48	-0.24	0.11	-1.19	1321
	(8.00)	(0.61)	(0.61)	(0.86)	(0.86)	(1.21)	
Index	0.01	0.06	0.03	0.02	-0.01	0.08	1302
	(0.72)	(0.05)	(0.05)	(0.08)	(0.08)	(0.11)	

Note: Column (1) reports sample means at baseline and standard deviations below; columns (2)-(3) report differences between treatment and control groups estimated using the pooled model of Equation 2; (4)-(5) report differences between treatment and control groups estimated using the fully interacted model of Equation 1; column (6) is the interaction effect. Standared errors are below the estimates and are clustered at the level of randomization; **, *, and + denote significance at the 1, 5 and 10% levels.

4.3 Well-being and food security

Increasing the adoption of improved seed is not an end in itself; ultimately, farmers seek to enhance their food security and overall welfare. Consequently, Table 6 examines the impact of the interventions on various indicators of welfare and food security.

The first two questions assess subjective measures of relative well-being, both within the village and over time. Approximately 35 percent of farm households report that they perceive themselves as better off compared to the average within their village. There is no significant change in this perception following either the seed sample pack or the cooking demonstration and tasting session. Additionally, 42 percent of households believe they are better off than they were six months ago—approximately one agricultural season prior. Notably, there is some indication that farmers in the seed sample pack group are more likely to feel better off compared to those who did not receive a seed sample pack. This may be due to the perceived benefits from the seed sample pack, either through improved harvests or a sense of improvement even if they recycled the sample pack seed rather than adopting new seed (despite yields not showing a significant increase, as detailed in Table 3).

5 Results: Mechanisms

5.1 Knowledge, risk, social learning, and intentions

To explore potential impact pathways, we posed several questions. First, we aimed to assess whether the interventions increased awareness of improved maize seeds, specifically the Bazooka variety. We asked farmers to list as many improved maize seed varieties as they could name, and enumerators recorded the number of varieties mentioned. Second, we directly inquired whether the farmer was familiar with a maize seed variety called "Bazooka."

Table 7 shows a clear impact on seed knowledge resulting from the two interventions. On average, farmers are aware of approximately 2 or 3 different maize seed varieties. Both interventions lead to a substantial increase in the number of seed varieties known by farmers, with the effects being quite similar. Overall, 82 percent of farmers in our sample are familiar with the Bazooka variety. The intervention with the most pronounced impact on this specific knowledge was the seed sample pack, likely because it directly involved the Bazooka variety, with its name prominently displayed on the packaging. In contrast, the cooking and tasting demonstration had a more general focus on the consumption traits of improved seed varieties, which may explain its comparatively lower impact on specific seed recognition.[12]

[12]The more general focus was deliberate as we did not want to be seen as promoting a particular commercial variety. However, we did mention that the maize flour that we used (and also provided a take home sample from) came from Bazooka. This is why the result for the cooking demonstration is small but still significant (at least in the pooled model), and also why we do see that farmers in demo group also adopted more fresh bazooka (see Tables

Table 6: Welfare and food security

		Pooled model		*Interacted model*			
	mean	sample	cons	sample	cons	interact	nobs
Better off than average of village?	0.35	0.02	0.00	0.00	-0.02	0.05	1504
	(0.48)	(0.03)	(0.03)	(0.05)	(0.05)	(0.07)	
Better off than 6 months ago?	0.42	0.12**	-0.02	0.10+	-0.05	0.06	1531
	(0.49)	(0.03)	(0.03)	(0.05)	(0.05)	(0.07)	
Can always eat what they want?	0.49	0.03	0.03	-0.07	-0.07	0.21*	1538
	(0.50)	(0.05)	(0.05)	(0.07)	(0.07)	(0.10)	
Can always eat quantity needed?	0.59	0.08+	-0.04	0.01	-0.10+	0.13	1538
	(0.49)	(0.04)	(0.04)	(0.05)	(0.06)	(0.08)	
Consumption expenditure (*1000 UGX/week)	86145	84	-3175	1875	-1392	-3585	1538
	(46538)	(4062)	(4061)	(5768)	(5717)	(8123)	
Index	0.00	0.08	-0.02	0.01	-0.09	0.14	1502
	(0.61)	(0.05)	(0.05)	(0.07)	(0.07)	(0.10)	

Note: Column (1) reports sample means at baseline and standard deviations below; columns (2)-(3) report differences between treatment and control groups estimated using the pooled model of Equation 2; (4)-(5) report differences between treatment and control groups estimated using the fully interacted model of Equation 1; column (6) is the interaction effect. Standard errors are below the estimates and are clustered at the level of randomization; **, *, and + denote significance at the 1, 5 and 10% levels.

As noted in the introduction, seed sample packs aim to mitigate the perceived risk associated with trying new seed varieties. To assess changes in perceived risk in response to the interventions, we asked farmers to rate how likely they believe it is that using improved seed varieties would result in lower yields compared to local seed. Responses were recorded on a 4-point Likert scale, ranging from "very likely" (improved seed will yield less than local) to "very unlikely" (improved seed will yield more than local). We repeated this question specifically for the seed type used in the study, but only for farmers who reported familiarity with the seed. We constructed an indicator for downside risk, which is set to 1 if the farmer responded with a 1 or 2 on the Likert scale (indicating "very likely" or "somewhat likely" that improved seed will yield less). Our findings reveal that perceived downside risk is generally limited, and neither intervention significantly affected risk perceptions related to improved seed in general nor to the specific seed used in the study.

An additional rationale for subsidizing or providing seed at no cost is to harness potential spillover effects to enhance adoption. To examine whether our interventions influenced social learning, we included questions on whether farmers recommended any improved seed varieties to others. A similar question was posed specifically regarding the seed variety used in the sample pack, but only for those farmers who were familiar with Bazooka.

Our findings indicate that a substantial proportion of farmers recommend improved seed to their peers. Notably, the likelihood of recommending improved seed is significantly higher among those who received the seed sample pack. When focusing specifically on Bazooka, the difference becomes even more pronounced. Receiving a seed sample pack increases the probability of recommending Bazooka by 38 to 44 percentage points, depending on the model used.

Finally, we examined farmers' intentions regarding future use of improved seed. Although a considerable proportion of farmers expressed an intention to use improved seed in the future, we did not observe a significant impact from either the seed sample pack nor the cooking demonstration and tasting session on these intentions. Furthermore, we find that, overall, about 36 percent of farmers indicate that they are very likely to use bazooka in the next season. We see that in the group that received a seed sample pack, the percentage is 16 to 20 percentage points higher than in the group that did not receive a seed sample pack. When summarizing these outcomes into an index, we observe a positive impact from the seed sample pack. In contrast, the effect of the cooking demonstration and tasting session is less convincing.

5.2 Perceptions

5.2.1 Perceptions of consumer traits

Farmers may perceive that maize grown from local seed is tastier than maize from commercial varieties (Pícha, Navrátil, and Švec, 2018). The cooking demonstrations and tasting sessions are intended to alter these perceptions

2 and 3)

Table 7: Knowledge, risk, social learning, and intentions

		Pooled model		*Interacted model*			
	mean	sample	cons	sample	cons	interact	nobs
Knows bazooka (yes=1)	0.82	0.26**	0.06*	0.29**	0.08	0.17**	1538
	(0.38)	(0.03)	(0.03)	(0.04)	(0.05)	(0.02)	
Number of improved seed farmer knows	2.66	0.40**	0.42**	0.48**	0.50**	-0.16	1532
	(1.50)	(0.12)	(0.12)	(0.16)	(0.16)	(0.24)	
Thinks improved seed is risky	0.09	0.00	0.00	0.00	0.01	-0.01	1447
	(0.28)	(0.02)	(0.02)	(0.03)	(0.03)	(0.04)	
Thinks bazooka is risky	0.13	0.01	-0.02	0.03	0.01	-0.05	1207
	(0.34)	(0.04)	(0.04)	(0.05)	(0.06)	(0.08)	
Recommended improved seed to others	0.59	0.29**	0.02	0.29**	0.02	0.01	1538
	(0.49)	(0.04)	(0.04)	(0.06)	(0.05)	(0.07)	
Recommended bazooka to other	0.62	0.38**	0.06	0.44**	0.11+	-0.11	1260
	(0.48)	(0.04)	(0.04)	(0.06)	(0.07)	(0.08)	
Will use improved seed in the future	0.83	0.05	0.01	0.05	0.01	0.00	1461
	(0.38)	(0.03)	(0.03)	(0.05)	(0.05)	(0.07)	
Will use bazooka in the future	0.36	0.16**	0.02	0.20**	0.05	-0.07	1503
	(0.48)	(0.04)	(0.04)	(0.06)	(0.05)	(0.09)	
Index	0.38	0.14**	0.05+	0.16**	0.07	-0.03	1156
	(0.36)	(0.03)	(0.03)	(0.05)	(0.05)	(0.06)	

Note: Column (1) reports sample means at baseline and standard deviations below; columns (2)-(3) report differences between treatment and control groups estimated using the pooled model of Equation 2; (4)-(5) report differences between treatment and control groups estimated using the fully interacted model of Equation 1; column (6) is the interaction effect. Standared errors are below the estimates and are clustered at the level of randomization; **, *, and + denote significance at the 1, 5 and 10% levels.

about the consumption qualities of maize from improved seed varieties. Additionally, if farmers plant the seed sample pack and process and cook the harvest separately, they may revise their preconceived beliefs about the consumer traits of these improved varieties. In Table 8, we examine the effects of the two interventions on perceptions of consumer traits related to the harvest from the seed used in the previous season. Specifically, we assessed whether farmers found the taste of the maize to be better than expected, whether the yield (i.e., the amount of maize that can be prepared from a given quantity) was more satisfactory, whether the appearance was improved (often indicating a whiter posho), and whether the ease of cooking was better.

Results show that 72 percent of farmers indicate that the maize flour obtained from the randomly selected plot tasted better or much better than what they expected expected. A slightly lower share of farmers, 65 percent, indicated that portions obtained from the maize turn out larger (or much larger) than expected. A similar proportion of farmers reported that the appearance of the maize, typically indicated by its whiteness, was either better or much better than expected. Additionally, just over half of the farmers found that the maize grain from the randomly selected plot was (much) easier to cook than they had anticipated.

We observe that the seed sample intervention resulted in significant improvements across all these measures. The treatment effects are approximately 20 percentage points, indicating a substantial impact. In contrast, we find no significant effect from the cooking demonstration and tasting session.

The results in Table 8 are for the seed that was used by the farmer, only some of which may be using improved seed varieties. Therefore, we also included a module in the questionnaire asking farmers to compare maize from improved seed varieties (such as Longe5 or Bazooka) with maize from local seed across the same four consumption traits. In other words, this module directly compares the consumption attributes of improved seed with those of local seed.

Results are summarized in Table 9. As in Table 8, the overall satisfaction with the consumption traits of improved seed is high across the sample. Furthermore, the seed sample pack intervention significantly increased the proportion of farmers who perceive improved seed as superior to local seed across various consumption attributes. Notably, we now also observe that the cooking demonstration and tasting session has influenced consumer perceptions, demonstrating its effectiveness in altering views on the quality of improved seed.

The differences between Table 9 and 8 align with the findings reported in Tables 2 and 3. Specifically, the negative impact on adoption observed with the seed sample pack can be attributed to a significant proportion of farmers recycling the sample seed. These farmers are more likely to report that the grain from the sample seed exceeded their expectations. Conversely, farmers in the cooking demonstration group increased their adoption of bazooka seed. Although this effect is statistically significant, it is economically modest, with an increase of only five percentage points in adoption. These farmers primarily grew local seed, resulting in consumption traits aligning with their expectations. However, when asked to compare consumption traits of improved seed varieties,

Table 8: Impact on Consumption traits of seed used

		Pooled model		*Interacted model*			
	mean	sample	cons	sample	cons	interact	nobs
Taste	0.72	0.17**	0.01	0.19**	0.03	-0.04	1452
	(0.45)	(0.04)	(0.04)	(0.05)	(0.06)	(0.07)	
Portions	0.65	0.19**	-0.01	0.18**	-0.02	0.02	1400
	(0.48)	(0.04)	(0.04)	(0.06)	(0.05)	(0.08)	
Appearance	0.65	0.24**	0.05	0.25**	0.06	-0.02	1447
	(0.48)	(0.04)	(0.04)	(0.06)	(0.05)	(0.07)	
Ease of cooking	0.56	0.22**	0.03	0.24**	0.05	-0.04	1387
	(0.50)	(0.04)	(0.04)	(0.06)	(0.06)	(0.09)	
Index	0.24	0.41**	0.03	0.43**	0.05	-0.04	1345
	(0.75)	(0.07)	(0.07)	(0.10)	(0.10)	(0.13)	

Note: Column (1) reports sample means at baseline and standard deviations below; columns (2)-(3) report differences between treatment and control groups estimated using the pooled model of Equation 2; (4)-(5) report differences between treatment and control groups estimated using the fully interacted model of Equation 1; column (6) is the interaction effect. Standard errors are below the estimates and are clustered at the level of randomization; **, *, and + denote significance at the 1, 5 and 10% levels.

Table 9: Impact on Consumption traits - improved seed compared to local

		Pooled model		*Interacted model*			
	mean	sample	cons	sample	cons	interact	nobs
Taste	0.70	0.21**	0.09*	0.27**	0.15*	-0.11	1424
	(0.46)	(0.04)	(0.04)	(0.06)	(0.06)	(0.08)	
Portions	0.81	0.10**	0.10**	0.14**	0.15**	-0.08	1360
	(0.40)	(0.03)	(0.03)	(0.04)	(0.05)	(0.06)	
Appearance	0.85	0.05+	0.09**	0.06	0.10*	-0.02	1421
	(0.36)	(0.03)	(0.03)	(0.05)	(0.04)	(0.05)	
Ease of cooking	0.71	0.14**	0.13**	0.19**	0.18**	-0.10	1316
	(0.45)	(0.04)	(0.04)	(0.06)	(0.06)	(0.08)	
Index	0.32	0.23**	0.20**	0.29**	0.26**	-0.12	1248
	(0.60)	(0.05)	(0.05)	(0.09)	(0.09)	(0.11)	

Note: Column (1) reports sample means at baseline and standard deviations below; columns (2)-(3) report differences between treatment and control groups estimated using the pooled model of Equation 2; (4)-(5) report differences between treatment and control groups estimated using the fully interacted model of Equation 1; column (6) is the interaction effect. Standared errors are below the estimates and are clustered at the level of randomization; **, *, and + denote significance at the 1, 5 and 10% levels.

such as bazooka, to local seed, the cooking demonstration and tasting session effectively altered perceptions, as expected.

5.2.2 Perceptions of producer traits

The seed sample pack is also designed to address preconceived notions farmers may have about the production-related traits of improved seed. For example, qualitative fieldwork conducted during the study's preparation revealed that some farmers believed improved seed varieties might offer higher yields but were less resistant to fall armyworm (*Spodoptera frugiperda*) infestations. Others, having been disappointed in the past, might no longer believe in the yield advantages of improved seeds (Miehe et al., 2023b). Providing free seed sample packs can be an effective way to alter these perceptions, as it allows farmers to directly experience the production traits of new technology on their own fields (Foster and Rosenzweig, 1995).

In Table 10, we therefore examine the effects of the two interventions on perceptions regarding the production-related characteristics of the seed used by farmers in the previous season. Specifically, we assess whether farmers perceived the following aspects as exceeding their expectations: yield, tolerance to abiotic stresses (such as drought and heat), tolerance to biotic stresses (such as pests, diseases, and weeds), germination rates, and time to maturity.

Overall, farmers appear to be more critical regarding the production traits of the seed used on the randomly selected plot. For instance, only approximately 24 percent of farmers reported that the yield from the seed on the randomly selected plot was (much) higher than what they had anticipated.

As with consumer traits, the seed sample pack significantly impacts all production-related traits. Specifically, a notably higher proportion of farmers who received the seed sample pack report that the yield exceeded their expectations compared to those who did not receive the sample pack. Conversely, we do not observe any significant impact from the cooking demonstration and tasting session on production traits, which aligns with our expectations.

As for consumption traits above, the results in Table 10 are for the seed that was used by the farmer, only some of which may be using improved seed varieties. Therefore, we also include a module in the questionnaire where we ask farmers to compare seed of an improved variety to local seed on the same five production traits. Results are summarized in Table 9.

Overall averages indicate that most farmers perceive improved seed varieties to be superior in several production traits. For example, 92 percent of farmers acknowledge that improved seed yields more or much more than local seed varieties. Similarly, a high proportion of farmers appreciate the shorter time to maturity and better germination rates of improved seed. However, farmers are somewhat less convinced about the improved seed's resistance to biotic stressors. This skepticism aligns with the perception that improved seed may be less resistant to fall army-worm infestation, a significant issue in the region.

When farmers compare improved seed directly to local seed, the summary index indicates a significantly positive impact from the seed sample pack. Farmers

Table 10: Impact on Production traits of seed used

		Pooled model		*Interacted model*			
	mean	sample	cons	sample	cons	interact	nobs
Yield	0.24	0.14**	0.05	0.13**	0.04	0.02	1462
	(0.43)	(0.03)	(0.03)	(0.04)	(0.03)	(0.06)	
Abiotic stresses	0.43	0.11*	0.00	0.15*	0.04	-0.07	968
	(0.49)	(0.04)	(0.04)	(0.07)	(0.05)	(0.09)	
Biotic stresses	0.39	0.17**	0.03	0.24**	0.10*	-0.14*	1381
	(0.49)	(0.03)	(0.03)	(0.05)	(0.04)	(0.07)	
Time to maturity	0.65	0.26**	0.02	0.28**	0.04	-0.05	1446
	(0.48)	(0.03)	(0.03)	(0.05)	(0.05)	(0.07)	
Germination Rate	0.70	0.17**	0.03	0.21**	0.06	-0.07	1465
	(0.46)	(0.04)	(0.04)	(0.06)	(0.06)	(0.08)	
Index	0.25	0.39**	0.07	0.45**	0.13	-0.12	941
	(0.70)	(0.07)	(0.07)	(0.11)	(0.08)	(0.13)	

Note: Column (1) reports sample means at baseline and standard deviations below; columns (2)-(3) report differences between treatment and control groups estimated using the pooled model of Equation 2; (4)-(5) report differences between treatment and control groups estimated using the fully interacted model of Equation 1; column (6) is the interaction effect. Standared errors are below the estimates and are clustered at the level of randomization; **, *, and + denote significance at the 1, 5 and 10% levels.

Table 11: Impact on Production traits - improved seed compared to local

		Pooled model		*Interacted model*			
	mean	sample	cons	sample	cons	interact	nobs
Yield	0.92	0.03	0.00	0.03	0.01	-0.02	1464
	(0.27)	(0.02)	(0.02)	(0.03)	(0.03)	(0.04)	
Abiotic stresses	0.72	0.06^{+}	-0.03	0.10^{+}	0.00	-0.06	1336
	(0.45)	(0.04)	(0.04)	(0.05)	(0.06)	(0.08)	
Biotic stresses	0.58	0.09^{*}	-0.01	0.12^{+}	0.02	-0.05	1391
	(0.49)	(0.04)	(0.04)	(0.06)	(0.06)	(0.09)	
Time to maturity	0.93	0.01	0.00	-0.01	-0.02	0.05	1446
	(0.25)	(0.02)	(0.02)	(0.03)	(0.02)	(0.04)	
Germination Rate	0.84	0.08^{**}	0.05^{+}	0.09^{+}	0.06	-0.02	1439
	(0.36)	(0.03)	(0.03)	(0.05)	(0.04)	(0.06)	
Index	0.10	0.11^{*}	0.03	0.13^{+}	0.05	-0.04	1273
	(0.58)	(0.05)	(0.05)	(0.08)	(0.07)	(0.10)	

Note: Column (1) reports sample means at baseline and standard deviations below; columns (2)-(3) report differences between treatment and control groups estimated using the pooled model of Equation 2; (4)-(5) report differences between treatment and control groups estimated using the fully interacted model of Equation 1; column (6) is the interaction effect. Standard errors are below the estimates and are clustered at the level of randomization; **, *, and + denote significance at the 1, 5 and 10% levels.

who received the seed sample pack updated their beliefs most notably regarding germination rates. Interestingly, these farmers also revised their previously pessimistic views on biotic stress resistance. Although the effects on other attributes are positive, the statistical power may be limited due to already high baseline perceptions of improved seed varieties. No significant impact was observed from the cooking demonstration and tasting session, which aligns with our expectations.

5.2.3 Perceptions on post-harvest traits

We also examine perceptions of post-harvest traits that could influence adoption decisions and might be affected by our interventions. Specifically, we assess perceptions related to marketability (e.g., whether the seed fetches a high price, is easy to sell), biomass or crop residues (e.g., maize stalks and maize bran for use as organic fertilizer or animal feed), and processing ease (e.g., shelling, milling). These traits are considered separately as they straddle the line between production and consumer traits. They relate to the utilization of the product obtained from the seed, but we anticipate an impact primarily from the intervention targeting production-related traits.

Table 12 shows results for perceptions related to post harvest characteristics of the seed used in the randomly selected plot, while Table 13 presents direct comparison between improved seed varieties and local seed. We find weak evidence that farmers in the group that received the seed trail pack rate the seed they used on the randomly selected plot higher on a range of post harvest traits than those that did not get a seed sample pack. We come to a similar conclusion when farmers are asked to directly compare improved seed to local seed. As expected, we find no impact of the cooking demonstration and tasting session.

6 Conclusion

In this study, we conduct a field experiment to evaluate the effectiveness of two interventions aimed at increasing the adoption of improved maize seed varieties among smallholder farmers in eastern Uganda. The first intervention provides free seed sample packs, allowing farmers to assess the production-related attributes of the new variety, including its yield potential, pest tolerance, and germination rate. The second intervention consists of a cooking demonstration and tasting session designed to emphasize the consumption-related attributes of the new variety, such as taste, texture, and color of the food produced from the new seed.

The interventions are tested using a cluster randomized controlled trial involving 1,560 maize farmers. The trial is clustered at the village level, with 10 households randomly selected from each village, and villages are assigned to treatments according to a 2x2 factorial design.

Our findings indicate that the seed sample pack intervention has an unintended effect: it reduces the likelihood of adopting improved seed in the subse-

Table 12: Impact on post harvest traits of seed used

		Pooled model		*Interacted model*			
	mean	sample	cons	sample	cons	interact	nobs
Marketability	0.55	0.12*	0.01	0.14+	0.03	-0.05	1021
	(0.50)	(0.06)	(0.06)	(0.08)	(0.07)	(0.11)	
Biomass	0.33	0.00	0.08*	0.02	0.10*	-0.05	1395
	(0.47)	(0.03)	(0.03)	(0.05)	(0.04)	(0.07)	
Easy to process	0.55	0.13**	-0.02	0.10	-0.05	0.07	1245
	(0.50)	(0.05)	(0.05)	(0.07)	(0.07)	(0.10)	
Index	0.14	0.15+	0.02	0.19	0.07	-0.09	856
	(0.69)	(0.08)	(0.08)	(0.12)	(0.12)	(0.16)	

Note: Column (1) reports sample means at baseline and standard deviations below; columns (2)-(3) report differences between treatment and control groups estimated using the pooled model of Equation 2; (4)-(5) report differences between treatment and control groups estimated using the fully interacted model of Equation 1; column (6) is the interaction effect. Standared errors are below the estimates and are clustered at the level of randomization; **, *, and + denote significance at the 1, 5 and 10% levels.

Table 13: Impact on post harvest traits - improved seed compared to local

		Pooled model		*Interacted model*			
	mean	sample	cons	sample	cons	interact	nobs
Marketability	0.52	0.09^{+}	0.04	0.15^{*}	0.10	-0.11	1344
	(0.50)	(0.05)	(0.05)	(0.06)	(0.07)	(0.09)	
Biomass	0.37	-0.01	0.00	0.02	0.03	-0.05	1351
	(0.48)	(0.04)	(0.04)	(0.06)	(0.06)	(0.08)	
Easy to process	0.70	0.06	-0.01	0.08	0.02	-0.04	1236
	(0.46)	(0.05)	(0.05)	(0.07)	(0.07)	(0.09)	
Index	0.12	0.09	0.00	0.17^{+}	0.08	-0.16	1097
	(0.68)	(0.07)	(0.07)	(0.10)	(0.11)	(0.14)	

Note: Column (1) reports sample means at baseline and standard deviations below; columns (2)-(3) report differences between treatment and control groups estimated using the pooled model of Equation 2; (4)-(5) report differences between treatment and control groups estimated using the fully interacted model of Equation 1; column (6) is the interaction effect. Standared errors are below the estimates and are clustered at the level of randomization; **, *, and + denote significance at the 1, 5 and 10% levels.

quent season. This counterintuitive result arises because farmers who received the sample pack are more inclined to recycle the seed from the sample pack, rather than purchase fresh seed. Notably, recycled seed from the sample pack is not categorized as "improved seed" in our analysis.

Despite the unexpected outcome concerning seed adoption, the intermediary variables align with our expectations and indicate that the interventions achieved their intended effects. Specifically, the seed sample pack improves perceptions of production-related traits, while the cooking demonstration and tasting session enhance perceptions of consumption traits.

Interestingly, the seed sample pack intervention also positively influences perceptions of consumption-related traits, in addition to production traits. From a cost-efficiency standpoint, and assuming comparable costs for both interventions, the seed sample pack appears to be a more effective approach.

The main lesson from the seed sample pack experiment is the necessity of addressing additional constraints. While the sample pack positively impacts farmer perceptions and intentions, the observed preference for recycling old seed over purchasing fresh seed suggests issues related to seed access. Potential barriers include the unavailability of improved seed at local agro-input shops or high seed prices. Ultimately, addressing these access issues alongside intervention strategies will be crucial for maximizing the impact of improved seed adoption and enhancing overall agricultural productivity in the region.

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