Production and Consumption Traits and the Adoption of Improved Maize Varieties: Evidence from Seed Sample Packs and Cooking Demonstrations

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Abstract

In developing countries, semi-subsistence farmers typically assume dual roles as both consumers and producers of the same crops, which shapes their adoption decisions as they balance household food security with market-driven incentives. This study, conducted in eastern Uganda, employs a field experiment with two intervention arms to assess the relative importance of these factors in farmers' decisions to adopt improved maize seed varieties. The first intervention focuses on production traits, distributing free sample packs of an improved hybrid maize variety to showcase benefits such as higher yields, pest resistance, and drought tolerance. The second intervention emphasizes consumption traits, offering cooking demonstrations and blind taste tests using flour from the same improved maize variety to highlight its taste, texture, and ease of preparation. Our findings reveal that while seed sample packs positively influenced farmers' perceptions of both production and consumption traits, cooking demonstrations primarily affected perceptions of consumption qualities. Moreover, the cooking demonstrations and tasting sessions significantly boosted adoption of the improved maize seed varieties. However, farmers who received seed sample packs tended to recycle the harvested grain as seed in subsequent seasons, thereby crowding out fresh seed purchases. This practice led to productivity losses, suggesting that the seed

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trial packs did not translate into lasting improvements in food security or increased market participation.
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1 Introduction

To sustainably feed a growing global population while addressing climate change and preserving biodiversity, it is essential to produce more food using less land (Tilman et al., 2011). Green Revolution technologies, particularly the development of improved planting materials, have been key to achieving higher yields and enhancing resilience to environmental challenges like drought (Evenson and Gollin, 2003). Traditionally, breeding programs have focused on production-related traits such as yield, drought tolerance, and pest resistance. However, the adoption of new crop varieties equally influenced by consumer-oriented traits—such as taste, color, texture, and ease of cooking. When producing for the market, production traits are often prioritized. Conversely, when producing for self-consumption, consumption traits like taste and cooking ease become more significant. As farmers in developing countries primarily produce for self-consumption, integrating consumption-oriented attributes alongside production advantages is crucial for driving demand for improved crop varieties.

For new technologies to achieve widespread adoption, it is crucial to raise farmers' awareness of their beneficial attributes. Traditionally, much of the focus in breeding programs has been on production traits, often overshadowing the importance of consumption characteristics. A common strategy to encourage farmers to learn about the production traits of a new seed variety is through the distribution of seed sample packs. 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.[1]

Surprisingly few studies directly evaluate the effectiveness of seed sample packs in accelerating technology adoption. Results are also 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 second 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

[1] One may argue that seed sample packs also enable farmers to discover consumption traits after they harvest the grain obtained from the seed sample pack. While this is probably not the primary focus of seed sample packs and assumes farmers keep grain obtained from seed separate and consume it themselves (as opposed to selling), we do find that seed sample packs indeed also affect perceptions of consumption traits—See Section 5.2.1.

(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.

Strategies that emphasize consumption-related traits to increase technology adoption are less common in the literature. This is surprising given that in many contexts where adoption is low, 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 (Singh, Squire, and Strauss, 1986). Interventions that focus on demonstrating consumption traits, such as cooking demonstrations and tasting events, 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 (which includes a demand creation component that focuses on consumption attributes) 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 dual roles as both 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.[2] Orthogonal to this intervention, a second intervention was introduced that involves cooking demonstrations and blind tasting tests. 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 derived from the grain grown using improved varieties to further explore consumption traits at home and potentially convince other household members.

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 produce 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,

[2] 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.

was relatively new and thus not widely adopted by farmers. The primary production trait of this seed is its potential for increased yield, but *Bazooka* also combines a high starch content with mild sweetness. The study ran over two consecutive agricultural seasons in 2023, with endline data being collected early 2024 after the harvest of the second season.

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 can be explained 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 improved varieties, 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. 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 blind tasting 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 explores some of the reasons for the high rates of recycling in the seed sample pack group.

2 Methods

2.1 Experimental Design

We use a field experiment to evaluate the effectiveness of two interventions, which we elaborate on in the subsequent section. The experiment takes the form of 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 to participate in the study.

The first factor in the factorial design pertains to the seed sample pack treatment. Sampled farmers in the treatment villages receive a complimentary sample of a recently introduced improved hybrid maize seed variety (*Bazooka*), whereas those in the control villages do not receive this free sample pack.[3]

The second factor involves a cooking demonstration and tasting session. In the treatment villages, sampled farmers are invited to participate in a session where they can taste food prepared from flour that was obtained from growing the promoted variety (*Bazooka*) and compare it directly to food made with the local variety maize. Additionally, all participants in the treatment group 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 prevent situations where a control farmer, who receives only 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, that is households who do not receive the pack.

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.[4] Farmers are then asked to rank 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.[5] Farmers can add as many traits as

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

[4]The terms for 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.

[5]These consumption traits were identified through focus group discussions held during the design phase of the study. One notable trait that emerged during these discussions was the extent to which maize flour expands during cooking, yielding "more food from less flour." This

they see fit.

After the rating, we proceed with the cooking and blind taste testing. 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 a 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.[6] 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 again 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 sample 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.[7]

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:

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

where T_j^S is an indicator variable that takes the value of 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

characteristic is linked to the starch content of maize flour, a carbohydrate that is a natural component of many plants, including fruits, vegetables, and grains. When starch is heated in water, it absorbs moisture, causing the granules to swell and gelatinize, which results in the flour expanding. This expansion property of maize flour was particularly valued by women.

[6]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.

[7]During field testing this intervention, 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 (which is similar to what Timu et al. (2014) find for Sorghum in neighboring Kenya). However, during the tasting, almost all farmers rated the sample made from *Bazooka* maize as superior. After the tasting, most farmers incorrectly identified the superior sample as being cooked from a local maize variety, when in fact, it was prepared using *Bazooka* maize. This revelation sparked extensive discussions within the group.

$\left(Y_{ij}^B\right)$ to improve precision. We will apply a cluster-robust variance estimator with the bias-reduced linearization (CR2) 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, pooling treatment cells to enhance statistical power can lead to biased estimates of the main treatment effects 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 do so, 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):

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

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).[8]

Since we evaluate treatment effects across a range of outcomes, it is essential to address the multiple comparisons problem. To do so, we follow Anderson (2008) and use two strategies. First, 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. Second, we control the False Discovery Rate (FDR) when conducting multiple hypothesis testing using sharpened two-stage q-values proposed by Benjamini, Krieger, and Yekutieli (2006).

2.4 Timeline

To assess the impact of seed sample packs, we look at two consecutive agricultural seasons. This is because 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 intervention are seed choice in the second season and yield after the second season. This is different for the cooking demonstration and tasting session.

[8] It is important to note that the estimand of the respective treatments in Equation 2 changes. For instance, while the estimand for the seed sample pack treatment in Equation 1 is the effect of the treatment in and on itself, the estimand in Equation 2 is a weighted average of the estimand of the seed sample pack treatment of Equation 1 and the effect of the seed sample pack in the presence of the cooking demonstration and testing treatment.

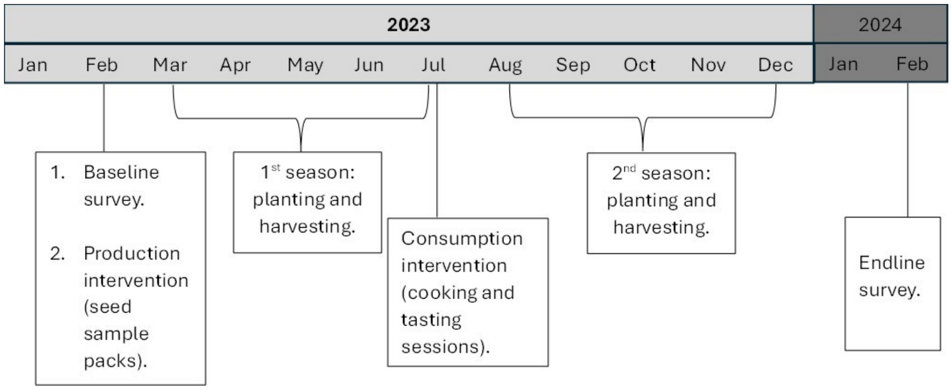

Figure 1: Timeline

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 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 cooking demonstration and blind tasting treatment. Approximately half of the villages in each treatment group (or around 37 villages

[9]The primary outcome used in these simulations is a binary indicator for the type of seed used by the farmer (1 if the farmer used fresh seed of an improved variety, 0 otherwise). 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 13.5 percentage point increase (over a baseline adoption percentage of 30 percent) for both the seed sample treatment and the cooking demonstration treatment, and a 23.5 percentage point increase for the interaction effect as minimal detectable effect size. The R code used for the simulations is available here. The pre-analysis plan can be accessed here.

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 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 joint 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 in an area that is also known as 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 (Miehe et al., 2023a).

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 Descriptive Statistics and Baseline Balance

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.

For variables that will be use to assess impact at endline, 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 answered affirmative to this question. 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 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. 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 pack 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 pack treatment now considered the orthogonal treatment and controlled for). The fourth, fifth and sixth columns correspond to β_S, 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: during endline, 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. For the cooking demonstration treatment, 92 percent of farmers in the treatment group recalled being invited

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

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	8.12	-0.02	-0.01	-0.05	-0.03	0.05
	(3.60)	(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. Standared 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).

to a cooking and tasting demonstration. Meanwhile, 96 percent of farmers in the control group did not recall a cooking and tasting demonstration. Given these statistics, we feel a focus on average treatment effects is appropriate.

4 Results

4.1 Adoption

The use of seed of improved varieties by farmers is the primary outcome of interest in this study. Therefore, Table 2 investigates if farmers use seed of improved varieties in general, while Table 3 reports on more detailed outcomes on seed use and practices on a particular (randomly selected) plot within the farm household. As mentioned in Section 2.3, outcomes are combined in a summary index following Anderson (2008).

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 average treatment effect 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 maize seed of an improved variety was used on at least one plot. Furthermore, at baseline, we left it to the farmer to decide what quality seed means; at endline, we define seed of an improved variety as fresh seed of a hybrid variety 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 seed of an improved variety as a result of the cooking demonstration and tasting session.

We define a similar variable to examine the adoption of the specific seed variety 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 addition, we now find that farm 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 maize seed of an improved variety that was used to define the first outcome, we determine the number of plots on which maize seed of an improved variety was planted. However, because the intervention could have changed the total number of plots used for cultivation, we also scale the number of plots on which improved seed was used by the total

Table 2: Adoption

		Pooled model		*Interacted model*			
	mean	sample	demo	sample	demo	interact	nobs
Has used seed of an improved variety 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)	
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	-0.06	-0.18**	0.08	-0.21**	0.06	0.05	1494
	(0.85)	(0.05)	(0.05)	(0.06)	(0.06)	(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 based on sharpened q-values (Benjamini, Krieger, and Yekutieli, 2006). † indicates that baseline outcome was controlled for in the regression.

number of plots. We find that seed of an improved variety was planted on 0.33 plots in the entire sample. The seed sample pack reduced the number of plots on which seed of an improved variety was planted by 0.16 and the share of plots on which improved seed was planted by 13 percentage points. This suggests that total number of plots did not change, but confirms the first result that households that received a seed sample pack actually reduced adoption.

A related outcome is the area planted with maize seed of an improved variety. We find that, on average, households planted about 0.34 acres with seed of an improved variety (again using the definition of the first outcome). However, in households that received a seed sample pack, the area planted with an improved seed variety 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 seed of an improved variety by the total area under cultivation. We observe a reduction in the proportion of the total area planted with seed of an improved variety, suggesting that the intervention led farmers to switch from planting seed of an improved variety to planting local or recycled 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 the seed trial packs lead to lower quantities of seed of an improved variety used, both in absolute terms and when measured per acre.

Interestingly, we do not see that the reduced use of improved seed as a result of the seed sample pack had a negative impact on maize production or productivity. What is more, we find that the cooking demonstration and tasting sessions actually increased production and productivity, albeit only in the pooled model and only at the 10 and 5 percent significant levels respectively. In particular, we find a 13 percent increase in maize productivity (as we use log transformations in the regression).

At first glance, the results of distributing seed sample packs may seem counter-intuitive. The intervention aimed to increase the adoption of improved

[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 of technology use, input use, and management practices between plots 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 seed varieties 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.

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)	(0.11)	
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 based on sharpened q-values (Benjamini, Krieger, and Yekutieli, 2006). Production and productivity are log transformed; means and standard deviations are in levels. All regressions include baseline outcome as control.

seeds in future planting seasons, yet instead, we observe a decline. This can be explained by the fact that many farmers who received the *Bazooka* seed sample packs chose to reuse the harvested grain as seed rather than purchasing fresh Bazooka seeds from agro-input suppliers, NGOs, or government programs. According to our definition of seed of improved varieties, only fresh *Bazooka* seed obtained from a credible source qualifies as an improved variety, while recycled *Bazooka* is classified as local seed. However, if we redefine adoption to include reused *Bazooka* seeds, we find that over 60% of farmers who received the sample pack continued growing Bazooka in the next season.

What is more, the fact that we observe an overall decline in fresh improved seed use—along with the insignificant effect of the sample pack on fresh Bazooka purchases—indicates that OPVs and other (non-*Bazooka*) hybrid seed varieties were likely crowded out. This is probably because farmers, encouraged by the high yields from the trial pack, opted to continue using recycled Bazooka rather than investing in fresh hybrids or recent OPVs. Meanwhile, farmers in the control group, potentially dissatisfied with their local seeds, were more likely to seek out fresh hybrids or use OPVs that are recycled a maximum of three times. However, they tended to opt for cheaper alternatives rather than purchasing Bazooka.

4.2 Decision Making

We hypothesize that highlighting the consumption traits of improved seed varieties—domains where it is more culturally acceptable for women to make decisions—may shift the decision-making role concerning seed selection and the use of harvested maize, potentially increasing the involvement of female coheads in these decisions (Kramer and Trachtman, 2024). 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, women's involvement in decision-making is a key outcome in 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 indicates that women are already highly engaged in decision-making regarding seed use and harvest management. Contrary to our expectations, the consumption intervention does not increase women involvement. In fact, judged by the index, we find that the seed sample pack increases women involvement in

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?	0.85	0.04	-0.03	0.01	-0.06	0.05	1098
	(0.36)	(0.03)	(0.03)	(0.04)	(0.04)	(0.05)	
Women involved in what to do with harvest?	0.86	0.05	-0.04	0.02	-0.07	0.05	1098
	(0.35)	(0.03)	(0.03)	(0.04)	(0.04)	(0.05)	
Index	-0.02	0.12^{+}	-0.11	0.05	-0.18	0.15	1098
	(0.96)	(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 based on sharpened q-values (Benjamini, Krieger, and Yekutieli, 2006). All regressions include baseline outcome as control.

decision making. However, the effect is significant only at the 10 percent level.

4.3 Well-being and Food Security

Increasing the adoption of improved seed varieties is a means to an end, as farmers ultimately aim to improve their food security and overall well-being. Therefore, Table 5 evaluates the interventions' effects on key welfare and food security indicators.

The first two indicators assess subjective measures of relative well-being, both within the village and over time. In particular, we asked if the respondent felt that their household was better off, about the same, or worse off in terms of income and consumption than the average households in the community, and convert this to an outcome that is true if the respondent answered that they were better off. Similarly, we asked if the respondent felt that their household was better off, about the same, or worse off in terms of income and consumption than six months earlier, and convert this to an outcome that is true if the respondent answered that they are now better off.

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 nor 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 that their well-being improved over time 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).

Next, we use two questions from the The Household Food Insecurity Access Scale (HFIAS), one that aligns with the "food preference" dimension, which assesses whether people had to compromise on their preferred diet due to financial or food constraints and one that captures "reducing quantity", a more severe form of food insecurity where people eat smaller portions or skip meals due to lack of resources (Coates, Swindale, and Bilinsky, 2007).[12] Table 5 show that 49 percent of households indicate that in the past month they were always able to eat what they wanted, whereas 59 percent of households indicate that in the past month they always had the desired quantities of food that they wanted. We do not find any impact of the interventions on these outcomes.

Finally, we approximate consumption expenditure by asking farmers to report how much money was spent in the week prior to the survey on 14 of the most consumed items in the area (maize, sorghum, millet, rice, cassava, sweet potatoes, beans, groundnuts, fruits, vegetables, sugar, cooking oil, soap, and

[12] In our analysis, as we want to focus on positive outcomes, we take the inverse and measure food security instead of insecurity.

airtime). On average, a household spent about UGX84905, which at the time of the survey corresponds to about USD24. We also do not find that our treatments affected consumption expenditure.

Judging by the index, we similarly find no effects from the treatments on overall welfare and food security. However, most of the interaction effects are positive and as a result, there is some evidence that farmers that received both treatments did see welfare increase, albeit only at a 10 percent significance level.

5 Mechanisms

In this section, we explore various secondary and intermediary outcomes to investigate potential impact pathways. We start by looking at changes in knowledge, risk perceptions, social learning and intentions. We also have a separate section that looks at the impact on perceptions related to consumption and production traits of improved varieties.

5.1 Knowledge, Risk, Social Learning, and Intentions

We start by testing if the interventions increased awareness of improved maize seed varieties, specifically *Bazooka*. 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 variety called "*Bazooka*."

Table 6 shows a clear impact on seed knowledge resulting from the two interventions. On average, farmers are aware of approximately 2 to 3 different maize varieties. Both interventions lead to a substantial and similar increase in the number of seed varieties known by farmers. Overall, 82 percent of farmers in our sample are familiar with the *Bazooka* variety. The intervention with the most pronounced effect on this specific type of 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 varieties, which may explain its comparatively lower effect on specific variety knowledge.[13]

One of the reasons why seed sample packs are distributed for free is to mitigate the perceived risk associated with trying out new 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 varieties would result in lower yields compared to local varieties. Responses were recorded on a 4-point Likert scale, ranging from "very likely" (improved varieties will yield less than

[13]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 2 and 3)

Table 5: 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)	84905	-2050	-2742	-1795	-2488	-510	1507
	(42299)	(3657)	(3659)	(5253)	(5379)	(7315)	
Index	-0.01	0.05	-0.02	-0.02	-0.10	0.15+	1471
	(0.59)	(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. Standard errors are below the estimates and are clustered at the level of randomization; **, *, and + denote significance at the 1, 5 and 10% levels based on sharpened q-values (Benjamini, Krieger, and Yekutieli, 2006).

local) to "very unlikely" (improved varieties will yield more than local). We repeated this question specifically for *Bazooka* as well, but only for farmers who reported familiarity with the variety. 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 variety will yield less). Our findings reveal that perceived downside risk is generally limited, and neither intervention significantly affected risk perceptions related to improved varieties in general, nor the specific variety used in the study.

An additional rationale for subsidizing or providing seed at no cost is to harness potential spillover effects to enhance adoption, as it is well known that farmers learn form others when new a technology is introduced (Conley and Udry, 2010; Van Campenhout, 2021). To examine whether our interventions influenced peer learning, we included questions on whether farmers recommended any improved varieties to others. A similar question was posed specifically regarding *Bazooka*, but only for those farmers who were familiar with this variety.

Our findings indicate that a substantial proportion of farmers recommended improved varieties to their peers. Notably, the likelihood of recommending improved varieties 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 increased the probability of recommending *Bazooka* by 38 to 44 percentage points, depending on the model used.

Finally, we examine farmers' intentions regarding future use of improved varieties. Although a considerable proportion of farmers expressed an intention to use improved varieties 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 appears to be less robust.

5.2 Perceptions

5.2.1 Perceptions of Consumption Traits

Farmers may perceive that crops grown from local varieties are tastier than crops grown from improved varieties (Pícha, Navrátil, and Švec, 2018; Timu et al., 2014). The cooking demonstrations and tasting sessions are designed to alter these potentially biased perceptions about the consumption qualities of maize from improved varieties. Additionally, if farmers plant the seed sample pack and process and cook the harvest separately and then consume it themselves, they may revise their preconceived beliefs about the consumption traits of these improved varieties as well.

Table 6: 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 based on sharpened q-values (Benjamini, Krieger, and Yekutieli, 2006). † indicates that baseline outcome was used as control in regression.

To test if our interventions alter perceptions of consumption traits of maize of improved varieties, we included a module in the questionnaire asking farmers to compare maize from improved seed varieties (such as *Longe5* or *Bazooka*) with maize from local varieties across four consumption traits—taste, portions, appearance, and ease of cooking.

Results are summarized in Table 7. The overall satisfaction with the consumption traits of improved seed is high across the sample. Both the seed sample pack intervention and the cooking demonstration and blind tasting sessions significantly increased the proportion of farmers who perceive improved varieties as superior to local varieties across all four consumption attributes. Interestingly, the results show that the seed trial pack is equally, if not more, effective in changing biased perceptions.

5.2.2 Perceptions of Production Traits

The seed sample pack is primarily designed to address preconceived notions farmers may have about the production-related traits of improved varieties. For example, qualitative fieldwork conducted during the study's preparation revealed that some farmers believe that 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).

To test if our interventions alter perceptions of production traits of maize of improved varieties, we also include a module in the questionnaire where we ask farmers to compare seed of an improved variety to local seed on five production traits—yield, abiotic stress resistance such as drought or heat resistance, biotic stress resistance such as pests and weed resistance, time to maturity, and germination rates.

Results are summarized in Table 7. When farmers compare improved varieties directly to local varieties, the summary index indicates a significantly positive impact from the seed sample pack. Farmers who received the seed sample pack updated their beliefs most notably regarding germination rates. Although the effects on the other production 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 expectations.

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

Table 7: 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. Standard errors are below the estimates and are clustered at the level of randomization; **, *, and + denote significance at the 1, 5 and 10% levels based on sharpened q-values (Benjamini, Krieger, and Yekutieli, 2006).

Table 8: 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 based on sharpened q-values (Benjamini, Krieger, and Yekutieli, 2006).

free seed sample packs, allowing farmers to assess production-related attributes of the improved variety, including its yield potential, pest tolerance, and germination rate. The second intervention consists of a cooking demonstration and blind tasting session designed to emphasize the consumption-related attributes of the improved variety, such as taste, texture, and color of the food produced from the variety.

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 that farmers adopt quality seed of improved varieties in the subsequent 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 purchasing fresh seed, and recycled seed from the sample pack is not categorized as "improved" in our analysis, given that the widely accepted recommendation is to not reuse seed of hybrid varieties. The cooking demonstration and tasting session did increase adoption, albeit only moderately.

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. What is more, the seed sample pack intervention also positively influences perceptions of consumption-related traits, in addition to production traits.

There are various reasons why farmers recycle seed instead of purchasing fresh seed. For instance, it could be that farmers are unaware that there is a yield penalty from recycling hybrid seed. Alternatively, the seed may not be available at reasonable cost, or farmer may not trust seed suppliers (Miehe et al., 2023a; Barriga and Fiala, 2020; Bold et al., 2017).

When we presented our finding to farmers during focus group discussions, the general impression was that farmers are typically aware of the yield penalty of recycling and that seed was also available, but that some level of recycling is a rational response give that the yield reduction is gradual. Our data suggests that planting fresh *Bazooka* seed leads to an average yield of about 535 kilograms of maize per acre. In the subset of farmers that use local seed (but excluding recycled *Bazooka*), average yield is only 323 kilograms of maize per acre. In the subset of farmers that recycled Bazooka from the seed trial pack, average yield is 375 kilograms per acre. To plant one acre with *Bazooka*, one needs about 8 kilograms. As one kilogram of Bazooka costs UGX12,000, the cost of one acre of *Bazooka* maize is UGX96,000. We further assume that the cost of local seed, as well a recycling *Bazooka*, is negligible.

Figure 2 plots out profits as a function of the value of the harvest (proxied by the price at which a 100 kg bag of maize is sold). The graph shows that profits from recycling *Bazooka* are generally higher than using fresh *Bazooka*; only if

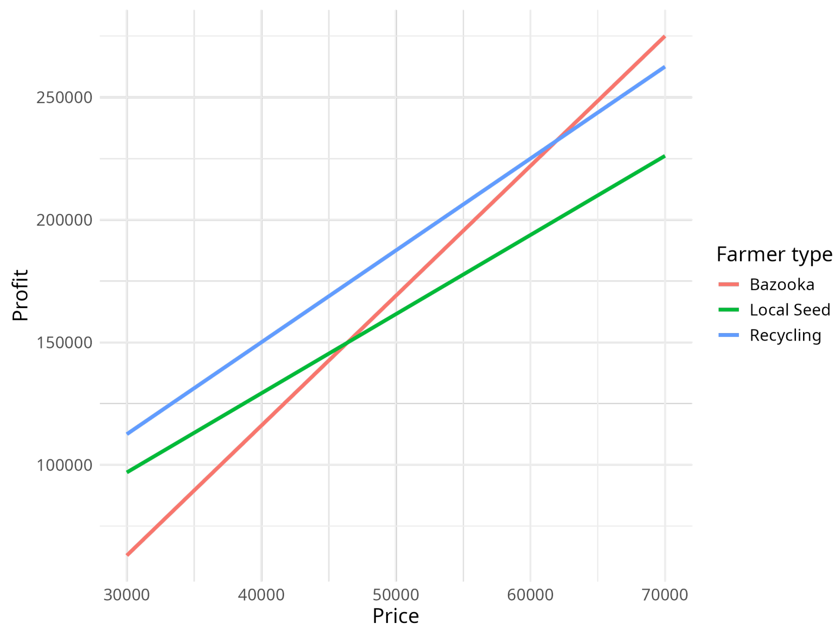

Figure 2: Profits as a Function of Sales Price

prices at which *Bazooka* is sold become larger than about UGX62,000 per bag, buying fresh *Bazooka* becomes more profitable than recycling. For our sample with median sales price of UGX60,000 per bag, this means that recycling would be the rational response to the seed trial pack.[14]

The main lessons we draw from this research is that farmers can be encouraged to adopt new varieties even by simply highlighting consumption-related traits, without having to grow the variety for themselves. However, the sample packs are more effective, likely because an increase in adoption mainly comes from farmers either experiencing the production traits, and from having produced grain that can be recycled as seed. Despite inseparability of consumption-production decisions in this context, constraints in accessing seeds (especially the higher prices of Bazooka seed) may well be limiting the effectiveness of the consumer intervention.

These findings highlight the complex decision-making processes that farmers navigate when adopting improved seed varieties. While the seed sample pack intervention successfully increased farmers' awareness and appreciation of the improved variety's production and consumption traits, its unintended consequence—encouraging seed recycling—suggests that adoption is influenced

[14]Consistent with this, we also find that within the subsample of farmers that received the seed trial pack, farmers that report to have been selling maize at prices higher than UGX62,000 are significantly more likely to use fresh Bazooka seed as opposed to farmers that sold at low prices.

not only by knowledge but also by heterogeneous benefits and costs of the technologies (Suri, 2011). Given the gradual yield decline from recycling and the relatively low maize prices faced by the majority of farmers in our sample, many farmers appear to weigh the costs and benefits and opt for seed reuse as a cost-effective strategy.

This underscores the need for complementary interventions that address economic constraints alongside knowledge dissemination interventions such as seed sample packs and cooking demonstrations and tasting sessions. This includes policies that improve farmers' access to reliable and affordable seed, potentially in the from of credit. Additionally, interventions that enhance market linkages and ensure that quality maize fetches premium prices may help shift the cost-benefit calculation in favor of purchasing fresh seed. Future research should explore these avenues to design more effective strategies for improving seed adoption and enhancing smallholder productivity in a sustainable manner.

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