Market Unraveling and Quality Control in Agriculture

Pre-analysis plan

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Abstract

Recent evidence indicates that enhancing agricultural productivity is crucial for reducing poverty and fostering GDP growth. While various technologies exist to achieve this goal, international institutions stress the importance of investing in new crop varieties. These varieties can deliver higher yields, withstand variable climates, and enable farmers to diversify their crop portfolio. If farmers expand their crop portfolio with higher-yielding, climate-resilient crops, they can better endure climate shocks and maintain higher productivity. However, producing high-yield varieties that are *high-quality* is often difficult – prone to issues of moral hazard and adverse selection. We aim to test two interventions that encourage farmers to multiply *high-quality* seeds of improved crop varieties. These methods involve price incentives (offering higher prices to motivate growers) and DNA verification technology (using genotyping to verify genetic purity, a requirement for purchase by seed companies). These approaches aim to address moral hazard and adverse selection in seed markets, ultimately improving local seed quality and increasing the production of high-quality, high-yield varieties.

Keywords: Market Unraveling; Quality verification; Climate change
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1 Introduction

Recent evidence suggests that enhancing agricultural productivity can play a crucial role in reducing poverty and driving GDP growth. While various technologies have been developed to achieve this objective, researchers and international institutions emphasize the importance of investing in new crop varieties. These varieties have the potential to deliver higher yields, withstand more variable climates, and enable farmers to diversify their crop portfolio. These features become increasingly important in the face of climate change, which is hampering agricultural productivity in low-income countries. If farmers can diversify their portfolio with higher yielding varieties that are more resilient to climate change, their ability to withstand climate variability and maintain higher productivity levels will improve. According to the FAO, "producing quality seeds of adapted and improved varieties" is one of the most important technologies for improving crop productivity and food security in low-income countries that are struggling to adapt to a changing climate. Recent research by (Gollin, Worm Hansen, and Wingender, 2021) further supports this claim. By analyzing data from 84 low- and middle-income countries, they find that a 10-percentage point increase in the cultivation of high-yielding varieties (HYVs) leads to a 10-15 percentage point increase in GDP per capita.

Many countries' governments have acknowledged the importance of creating new crop varieties and have launched programs that incentivize their breeding (FAO, 2009). However, the production and adoption of these new varieties is far from universal. What are the challenges that prevent the widespread cultivation of these new crops, and how can they be overcome? After being formally released, the diffusion of a new variety begins with multiplication by seed growers that are contracted by a seed company. The procedures for multiplying seeds can be costly to follow; and require strong regulatory frameworks to verify seed purity. These conditions lead to problems of moral hazard and adverse selection. On the one hand, if it is costly to multiply these seeds, growers may try to cut costs (moral hazard). On the other hand, if the regulatory systems for monitoring quality are not precise enough, falling prices may cause high-quality seed growers to exit the market altogether (adverse selection). When faced with these incentive structures, the markets for multiplying new crop varieties can be tainted by the proliferation of low quality or "impure" seed. This has downstream impacts on the seed market. Farmers may be reluctant to invest in these new crop varieties if they cannot guarantee their quality. Alternatively, for those who do purchase them, managing their crops can be challenging if they believe they are cultivating a high-quality variety that is in fact impure. Indeed, recent evidence from multiple countries shows that farmers often think they are growing a variety that they are not. In extreme cases, these factors can lead markets to collapse. A very similar situation depressed credit markets in low-income countries before the arrival of micro-credit. The lack of robust enforcement mechanisms led to widespread issues of moral hazard and adverse selection, which deterred formal banks from issuing loans.

Governments and international institutions aiming to boost the adoption of new crop varieties must address these problems of adverse selection and moral hazard. They need to encourage skilled farmers to enter the market to produce these seeds, and incentivize them to invest the optimal amount of effort into their cultivation. This is not trivial, and requires changing the incentives that growers face. There are two ways to achieve this. First, organizations can offer higher prices to farmers for multiplying new seeds. Raising prices may incentivize more growers of all types (high and low) to enter the market. The inability of prices to separate growers by type could increase the supply of low-quality seeds, creating financial difficulties for the seed company. Second, is the use of monitoring technologies. This approach has prevented other markets from unraveling: by introducing strict monitoring protocols, micro-credit institutions were successful in mitigating default rates. In the market for new crop varieties, the introduction of DNA verification technologies provides a novel approach to more accurately verify the quality of seeds that growers supply. This type of screening technology increases the payoffs to high-quality growers and increases the costs for low-quality growers, thereby incentivizing the best growers and deterring low-quality ones from entering the market. Importantly, the costs of DNA fingerprinting of crop varieties are rapidly falling.

To this end, we ask a simple research question: do price incentives, cheap DNA verification technology, or both, reduce information asymmetries at the very earliest stage of the agricultural value chain? Determining which of these tools matters most could stimulate growth in seed markets for new varieties, which will help farmers adopt high-value crops and diversify their income streams. These outcomes are crucial for farmers to achieve, as the extreme weather conditions they face due to climate change are more regularly threatening their crop yields and productivity. Moreover, by ensuring that high-quality seeds are produced, more farmers may be willing to invest in them and successfully achieve higher yields through proper management.

We expect this study to make three contributions to the literature. First, we contribute to a growing body of literature that highlights quality challenges in agricultural value chains and evaluates interventions aimed at improving quality verification. Research on information asymmetries in agriculture has put more focus on fixing information asymmetries at later stages, particularly at the point of final demand. A related body of work examines how market structure influences product quality. For example, Bold et al. (2022) design a market where higher quality is rewarded with a price premium and document improvements; Macchiavello and Morjaria (2020) explore the role of competition; and Macchiavello and Miquel-Florensa (2019) study the effectiveness of a buyer-led quality upgrading program. A growing number of recent studies also examine the role of providing information to consumers. For example, Bai (2025) show that costly labeling can enhance a vendor's reputation among customers for selling high-quality goods; Hsu and Wambugu (2023) find that giving buyers access to information helps them purchase higher-quality seeds and achieve better agricultural yields; and (Michelson, Magomba, and Maertens, 2025) find that providing farmers with assurances of input quality improves purchases of that input. We aim to contribute to the literature by contrasting two different schemes for improving product quality and comparing how they overcome problems of moral hazard and adverse selection. Moreover, we aim to understand how public institutions can structure different types of contracts—such as price incentives versus quality monitoring versus both —to encourage the provision of higher-quality products.

Second, we contribute to the broader economic literature on the role of monitoring in addressing moral hazard and adverse selection in low-income countries. These information asymmetries have long constrained the private provision of insurance and credit, limiting market development in these contexts (Karlan, 2014; Jensen and Barrett, 2017). Beyond these classic cases, monitoring has proven effective in addressing moral hazard across a range of settings, including education (Duflo, Hanna, and Ryan, 2012), industrial pollution (Duflo et al., 2013), and transportation (Kelley, Lane, and Schönholzer, 2024). Our study builds on this literature by examining a new technology designed to improve the quality of agricultural production inputs. We also aim to disentangle how quality verification affects underlying issues of moral hazard versus adverse selection.

Third, we contribute to a growing literature showing that market frictions can limit effective climate adaptation. While countries frequently exposed to climate shocks show some resilience, adaptation remains limited—especially in low-income settings (Carleton and Hsiang, 2016; Carleton et al., 2022). Recent research suggests this is not due to an optimal cost-benefit tradeoff, but rather to constraints that hinder the adoption of adaptive technologies in areas like agriculture and finance (Dar et al., 2024; Burgess et al., 2017). We add to this work by showing how inefficiencies in the input supply chain can obstruct adaptation.

2 Context

This section describes the setting of our experiment. We use administrative records and data we collected as part of a pilot to describe the status quo of the seed market in Odisha. In doing so, we provide background evidence that the market we study shows signs of unraveling—likely due to unobserved product quality—and that price incentives and quality verification tools may offer an effective solution.

2.1 Market Unraveling

This project is motivated by extensive qualitative and quantitative piloting the team undertook from 2020-2024. First, we had detailed conversations with the Odisha State Seed Corporation (OSSC) to learn about their processes and possible constraints that prevent farmers from growing groundnuts. The difficulty of the Odisha State Seed Corporation (OSSC) to procure enough groundnut seed from seed growers came up repeatedly. OSSC initiates the process by offering production contracts to farmers and registering a designated amount of land for groundnut cultivation. Farmers who participate in the program may receive up to four field inspections from agents of the Odisha State Seed and Organic Products Certification Agency (OSSOPCA) during the growing cycle, though most fields are inspected only once or twice. The primary role of inspectors is to assess whether farmers' fields meet the "Seed Certification Standards" by verifying cultivation status, ensuring the absence of disease, and confirming overall compliance with certain rules such as spacing between plots. If a farmer's field meets these standards, they receive certification for their cultivated area, allowing them to deliver their harvested groundnut seed to OSSC's processing facility.[1] Upon arrival at the processing center, the seeds are assigned a lot number and undergo processing. A final inspection is then conducted to determine the quality of the seeds. OSSC records the quantity of seeds that successfully pass this final inspection, purchases them from the farmers, and distributes them to other farmers through its network of local seed dealers.

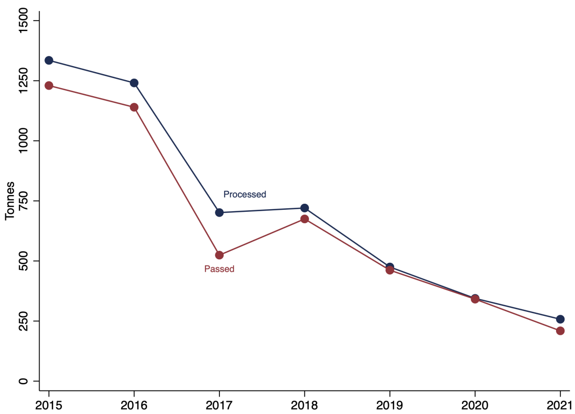
We use two datasets that OSSOPCA makes available on their website to understand trends in the market. The first dataset collected by OSSOPCA details all of the field inspections that OSSOPCA performed with contracted farmers during the growing seasons. It covers 2014-2022 years and includes information on the location of plots, dates of sowing, planting, and harvesting, registered area, inspected area, whether the seed conforms to the standard, certified area, rejected area, reasons for denying certification, and estimated yield from each plot. The second "contract" dataset from OSSOPCA lists all the crops that the government of Odisha sources for certification (including paddy, groudnut, pulses and oth-

[1] In the case of multiple inspections, the most recent inspection determines the certificate status

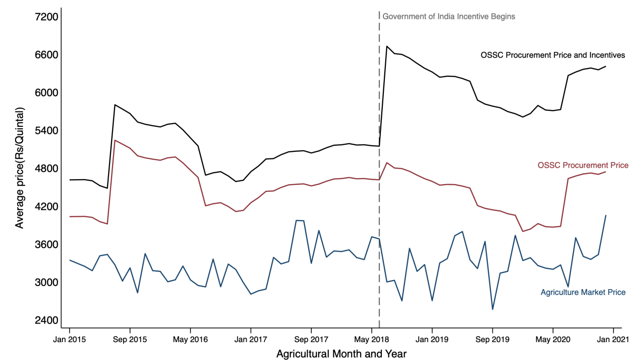
ers). The dataset spans from 2014 to 2022 and includes details on crop type and variety. It records key information similar to the inspection data, such as the registered area, inspected area, certified area, and rejected area. Importantly, it also contains data on outcomes at the processing unit, including the lot number assigned to farmers who bring their seeds to the processing center, the total quantity processed, and the amount that successfully passes the final inspection.

Figure 1 visualizes these data to illustrate key challenges in this market. Panel A shows the total quantity of groundnut seed processed from 2015 to 2021. In 2015, approximately 1,250 tons were produced, but by 2021, this had plummeted to around 250 tons — an 80% decline. While production has sharply decreased, the price incentive for producing seed for OSSC has, if anything, grown over time (Panel B). These incentives consist of two parts: first, the OSSC base price, as shown by the red line, has consistently remained higher than the market price for groundnut. Second, a bonus directly from the state government and, beginning in June 2018, from the central government further adds to the incentive for farmers to participate. This suggests that the steep decline in quantity is not driven by uncompetitive prices for growers.

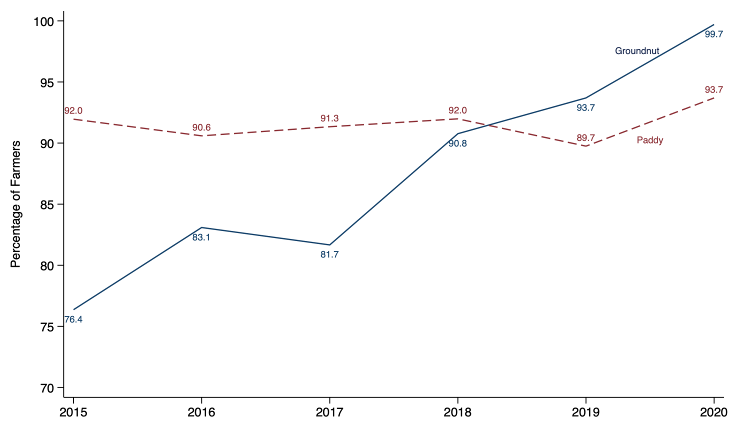
The bottom panel in Figure 1 shows that the percentage of farmers receiving certification has steadily increased in recent years, approaching nearly 100% by 2020. This contrasts with a nearly flat trend in certification given to farmers participating in rice seed multiplication. Given the sharp decline in total groundnut seed production, this trend could have two possible explanations. One possibility is positive selection, where only the most skilled seed producers remain in the system while less skilled producers have exited. Alternatively, as overall production has decreased, certification standards may have loosened, with officials approving more seed to maintain supply. We draw on our pilot data, which reveals low seed purity, to support the argument that certification standards have likely become more lenient—a conclusion we present in the following section.



(a) Total Quantity of Groundnut Seed Processed



(b) Monthly Modal Real Price for Groundnut



(c) Farmers Receiving a Seed Certificate

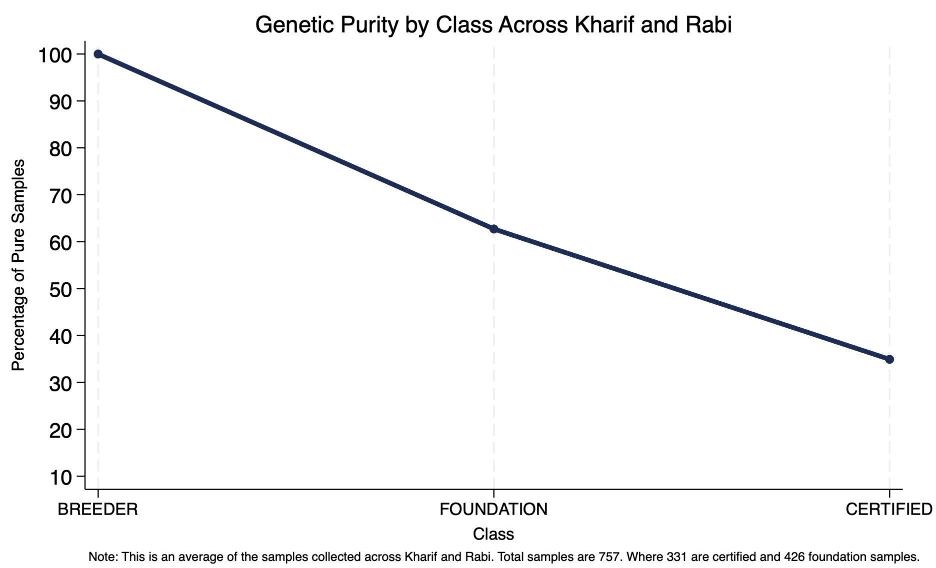
Figure 1

2.2 Purity Concerns

We conducted two field pilots across consecutive agricultural seasons (Kharif 2022, and Rabi 2023). During the first pilot in Kharif 2022 we worked with 105 growers in 4 districts. We ran a field survey after the harvest period to understand the challenges farmers faced breeding groundnut. Our sample is comprised of 1) farmers who were contracted by OSSC to multiply foundation seed, which is the output from multiplying material directly from the plant breeder (i.e. the research station), and 2) farmers who were contracted by OSSC to multiply certified seeds, which is the output from multiplying foundation seeds that were produced by other farmers. For the 34 farmers who submitted their groundnut to the seed certification agency's processing plant, we took 10 samples of their groundnut (each sample is a small bag of peanuts), and we sent them to a lab for DNA testing. During the second pilot in Rabi 2023, we worked with 45 farmers and collected 10 samples of their groundnut seeds at the time of harvest, and again when they took their seeds to the processing plant.

We consistently find evidence that seed growers provide groundnuts that do not correspond to the variety they were contracted to supply. Figure 2 shows results for 757 samples (from both Kharif 2022 and Rabi 2023). A total of 428 of the samples are foundation seed, which is the output from multiplying material directly from the plant breeder, i.e. the research station. After harvesting, foundation seeds are provided to seed growers for multiplication into certified seeds. Another 331 of the samples are for certified seed, which are then sold to other farmers for cultivation. Strikingly, although breeder seed starts at 100% purity, 35% of the foundation seed samples we collected from farmers were not the correct variety. This issue worsens over time, as impure foundation seeds are further multiplied in subsequent seasons. Figure 2 shows that 65% of certified seed samples also fail to match the intended variety.

Figure 2: Genetic Purity of Certified and Foundation Pre-Seed



Our pilot survey also included interviews with farmers who were contracted to sell seeds to OSSC but ended up not doing so. Approximately 90% stated that they chose to sell their seeds to local traders instead, citing the higher prices offered in the open market as their primary motivation. While this response may be surprising given that administrative data shows higher prices offered by OSSC over the full sample, focus groups reveal that farmers do not always receive the bonuses offered by the state and national governments. Payment delays were also mentioned frequently by farmers dealing with OSSC, which may contribute to the perception that the open market offers better prices. Additionally, the survey asked farmers about factors that would lead them to consider selling to OSSC in the future. Approximately 95% of farmers identified higher prices as the decisive factor, while 59% indicated that lower rejection rates by OSSOPCA field inspectors would convince them to switch.

Finally, in July and August 2024, we conducted a qualitative data collection exercise in Odisha. The objective was to conduct in-depth interviews with groundnut producers to understand their experiences multiplying seeds for OSSC and to investigate why they might submit impure seeds. We identified several reasons for this: during sowing, farmers have little incentive to separate different seed varieties, and during harvest, production losses may drive them to mix crops. Some farmers even directly mentioned mixing varieties after harvesting.

3 Experimental design

Our administrative data and field piloting document evidence of a market failure: farmers are not multiplying enough groundnut seed, and they are not producing the seed they were contracted to supply. In addition, they demonstrate that DNA fingerprinting technologies are workable and have the potential to rapidly identify the type and quality of the seed. Our experiment builds on these two to test different ways of addressing this market failure.

3.1 Experimental Design

We will explore the use of two possible levers to improve seed quantity and quality: higher prices (incentives to growers) and DNA testing. These two interventions have the potential to deal with problems of moral hazard and adverse selection they may be causing this market to unravel. Higher incentives may be necessary to offset the costs growers incur when multiplying seed and to attract higher-quality producers back into the market, helping to mitigate problems of adverse selection in these markets. However, even high-quality growers may decide not to bear the costs of producing pure seeds if there is little risk that inspectors will reject their output. In this case, implementing DNA testing may be necessary to ensure compliance with best practices and overcome problems of moral hazard.

To formally test which strategies are most effective at improving the quality of seeds that growers supply, we will run an RCT across 408 villages with 4 farmers in each village. Each village will be assigned to one of three treatment arms and a control group:

1. Control (C - 100): We will offer farmers discounted groundnut seeds and inform them

that we will return at harvest. If they follow a simple set of best practices that don't require DNA verification—such as maintaining a minimum distance between plots—we will guarantee a 10% premium for each kilogram they produce. We consider this to be a business-as-usual scenario because seed grower currently receive prices that exceed the market.

2. Incentive (T1 - 100): We will offer farmers discounted groundnut seeds and inform them that we will return at harvest. If they follow a simple set of best practices that don't require DNA verification—such as maintaining a minimum distance between plots—we will guarantee a 30% premium for each kilogram they produce.

3. DNA testing (T2 - 100): We will provide farmers with discounted groundnut seeds and inform them that we will return at harvest to collect DNA samples from their crops. If the DNA verification confirms that the seeds are genetically pure, we will guarantee a 10% premium for each kilogram they produce.

    - Surprise: We will subsequently inform 50% of the sample who agrees to this contract that we will not in fact be using DNA verification technology (they will be told this is due to capacity constraints) to validate their samples are genetically pure.

4. Incentive and DNA testing (T3 - 100): We will provide farmers with discounted groundnut seeds and inform them that we will return at harvest to collect DNA samples from their crops. If the DNA verification confirms that the seeds are genetically pure, we will guarantee a 30% premium for each kilogram they produce.

    - Surprise: We will subsequently inform 50% of the sample who agrees to this contract that we will not in fact be using DNA verification technology to validate their samples are genetically pure.

Higher incentives are likely to influence which farmers choose to accept the contract (adverse selection) but do not directly affect their compliance with best practices (moral hazard). In contrast, DNA testing is expected to impact *both* the selection of participants (adverse selection) and their adherence to best practices (moral hazard). To distinguish between these effects, we implement the unexpected removal of DNA testing after contract acceptance in the treatment arms that offer DNA testing (T2 and T3). By comparing the behavior of farmers who accept a contract with DNA testing but are later exempt from testing to those whose samples are actually tested, we can distinguish between the effects of adverse selection and moral hazard in influencing seed quality when DNA testing is implemented. We provide details on the exact test we will conduct in the analysis section.[2]

3.2 Sampling

We use two data sources to select our villages. The first is CROPGRIDS, a global dataset that maps the area of 173 crops at a 5.6 km resolution for the year 2020, offering a detailed view of crop distribution worldwide. The second is data collected by ICRISAT, which provides district-wise yearly area, yield and production for 20 crops across India. Using these dataset we plot the total production of groundut across the state of Odisha. Figure 3 compares groundnut production distribution from the two data sources: CROPGRIDS (red bars) and ICRISAT (blue bars). We shared the top 10 districts with ICRISAT officials familiar with the local context, and based on their recommendations, we selected Bargah, Mayurbanj, and Anugul as our focus areas.

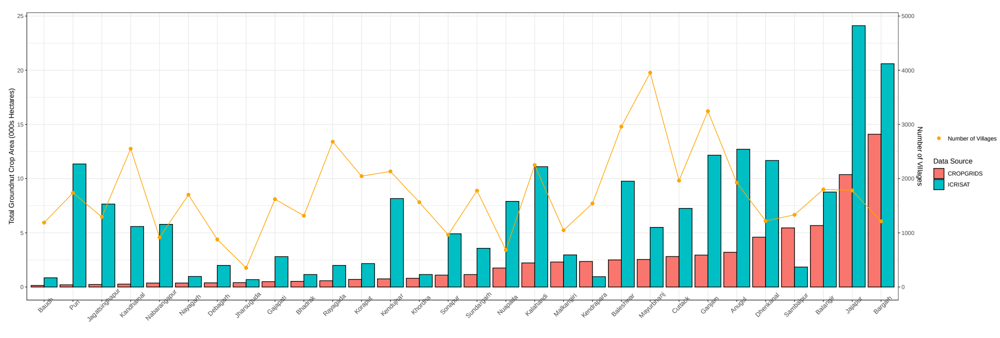


Figure 3: Distribution of Groundnut

Within these three districts, we use CROPGRIDS data to calculate the area-normalized groundnut production for each village. We then select two blocks per district that contain the highest number of villages with above-median groundnut production. Finally, we randomly select 68 villages per block (and 8 backup villages), ensuring that only villages with above-average area-normalized groundnut production are included in the sample. This results in a total sample size of 408 villages. We randomize villages into our four groups (3 treatment arms and 1 control), stratifying by block. We will work with 4 households per village for a total sample size of 1,632 households. In villages assigned to T3 and T4, two households will be randomly selected from the four to receive the 'surprise experiment'.

[2]We will not conduct a surprise experiment comparing low prices to high prices within the price group, as we are not focused on distinguishing between selection and moral hazard in this group. Our primary goal is for the price group to serve as a benchmark for comparing DNA testing results.

3.3 Implementation

Seed purchases We partner with ICRISAT to source the seeds we distribute to farmers, which ICRISAT acquires directly from breeders. To ensure quality, we conduct genetic purity tests on a random sample of these seeds. Additionally, we collaborate with ICRISAT to develop a reference library of prominent groundnut varieties, providing a standardized benchmark for comparing the genetic traits of farmers' groundnut that we obtain at harvest. We will provide 20kg of groundnut seed to each farmer (which can be used to sow 1 plot of approximately 0.4 acres).

DNA testing We will adopt a bulked sample genotyping method to assess the purity of groundnut grown in farmer fields. Our team will collect groundnut pods directly from farmers plots at an estimated cost of $13 per farmer. Using the bulked approach, the samples will be shelled to produce 100 grams of groundnut seed. These will be packaged in labeled plastic sample bags and shipped to ICRISAT genomics laboratory in Hyderabad for sample processing. At ICRISAT, the groundnut seed samples will be ground to fine powder, plated in 96 well plates, and a sample tracking file will be generated. ICRISAT has confirmed that they have the capacity to process these samples at an estimated cost of $12 per farmer.

Finally, the samples will be shipped to Intertek Sweden for DNA extraction and genotyping with a low-density panel of markers comprising 50 informative SNPs. The markers are a subset of SNPs previously tested across a diverse array of groundnut genotypes and are suitable for testing varietal purity. Two approaches will be used to analyze received genotype data. First, a comparative assessment of alleles in each locus will be done to deduce the similarity of each sample to the reference. Second, genetic distances will be computed for each sample to measure their divergence from the reference. Samples will be determined to be pure if they have $> 90\%$ locus similarity and $< 5\%$ genetic distance from the reference. We received a quote from Intertek for approximately $14 per farmer (the quote also includes a buffer for testing the foundation seed samples provided to farmers).

We estimate the total cost per farmer will not exceed $40, a conservative estimate that is likely to decrease with a larger sample size. This approach is actually much cheaper than other schemes aimed at encouraging groundnut farmers to produce high-quality seed. Since 2018, the OSSC has consistently offered a total incentive of $20 per quintal, with farmers producing an average of 4.89 quintals per acre—resulting in a total incentive of $98 per farmer per acre.[3] In contrast, our DNA testing method is cheaper by 77%.[4]

[3] Note this incentive amount represents a lower bound. In 2018, the Government of India introduced an additional bonus of INR 1875 or $21.7 per quintal. This brings the total incentive to $41.7 per quintal, or $204 per farmer per acre

[4] 4.89 quintals per acre in the upper bound of average yield from our qualitative survey. We also use the

Incentives The OSSC has consistently provided a total incentive of \$20 (1700 INR) per quintal. Our comparison group will receive an incentive of \$4.50 per quintal, which is approximately 22% of the OSSC's incentive. Our treatment group will receive an incentive of \$17 per quintal, which is approximately in line with the OSSC incentive. Since farmers can receive up to \$50 per quintal as the base price on the open market, our offer of \$4.50 per quintal represents a 10% incentive for the comparison group, and an 30% incentive for the treatment group. These incentives will be paid directly to farmers using bank transfers.

4 Data Collection

We will focus on a select set of key outcomes described below. In June 2025, we will conduct a baseline survey, distribute seeds, and record contract acceptance. At harvest in November 2025, we will return to collect seed samples for genetic testing and administer the endline survey.

Contract Acceptance We observe directly which farmers accept the contract. This amounts to a binary outcome variable equal to 1 if the farmer agrees to multiply seeds.

Genetic match We will collect groundnut samples from each farmer's field for DNA verification. The local field team will monitor crop maturation and determine the best time to collect samples. All samples will be sent to a laboratory for genetic purity assessment, and the results will be shared with select farmers in T2 and T3. This means the for every farmer that agrees to the contract, we will observe an indicator variable equal to 1 if their output was a genetic match to the contracted variety.

Contract Success This is the product of the binary variables for the take-up and genetically matched seeds (previous two outcomes). It is a main outcome of interest because it indicates that the contract was taken up and the farmer produced genetically pure seeds, which is the ultimate goal of OSSC.

Delivered Quantity Growers may respond on the intensive margin. In addition to the binary outcomes, we will include a continuous outcome of the amount of kilograms returned by the farmer. This will be 0 for farmers that did not take up the contract. We include the continuous outcome as well as it's product with the genetic match indicator. We do

administrative data available from OSSC, which gives an average of 3.12 quintals per acre.

this because farmers may mix in quantities of other varieties. Verification could reduce this leading to smaller but more pure amounts returned by growers.

Production Processes and Effort We will collect information from farmers on each plot they cultivated, including their GPS coordinates, the crops and varieties grown, the quantity of seeds sown (in kg), the area allocated to each crop, and the timing of sowing. Additionally, we will gather details on input applications and expenditures (fertilizer, irrigation). We are particularly interested in investigating inputs that are particularly effective at improving seed quality, which include: distance between plots, harvest timing; hired versus family labor, difference in days between harvest of groundnut plots, and labor after harvesting[5].

Production Amount/Sales We will collect information from farmers about the area and amount of each crop that was harvested. We will also ask about the amount sold, and the price received, who they sold to (local trader, at the market), the date of the sale and where the sale took place.

Satisfaction with contract Fourth, we will ask farmers how satisfied they were with the contract and its execution, and if they would be interested in this type of contract in the future.

5 Hypotheses and analysis

5.1 Take-up

We will conduct our analysis in three stages. First, we estimate the effect of the different treatments on contract acceptance with the following specification:

$$Y_{ivb} = \beta_0 + \beta_1 Incentives_{vb} + \beta_2 DNA_{vb} + \beta_3 Both_{vb} + \rho_b + X_{ivb}\beta + \varepsilon_{ivb}$$

where Y_{ivb} is a binary indicator for contract acceptance for person i in village v and in block b. $Incentives_{ivb}$ is an indicator for the incentive treatment, DNA_{ivb} is an indicator for the DNA testing treatment, and $Both_{ivb}$ is the is an indicator for receiving both higher incentives and DNA testing. We include block (ρ_b) fixed effects and X_{ivb} is a vector of socio-demographic

[5] Our qualitative work suggested that laborers sometimes mix varieties after harvesting, so supervising effort by farmers after harvest is an important outcome for understanding whether the treatments trigger greater effort

controls selected via double-selection LASSO, while ε_{ivb} is the error term which we cluster at the village level. We test the following hypotheses:

1. Comparing T0 to T1 ($\beta_1 \neq 0$) will test the degree to which higher incentives encourage more participation. We expect this to be positive.

2. Comparing T0 to T2 ($\beta_2 \neq 0$) will test if DNA testing changes incentives to participate. The direction of this effect is ex-ante ambiguous. If DNA testing decreases the perceived likelihood of low-quality seeds being accepted, fewer farmers may be willing to join the program. However, if DNA testing reduces the perceived risk of false rejections, it may encourage more high-quality growers to participate.

3. Comparing T0 to T3 ($\beta_3 \neq 0$) tests how a combination of both incentives and DNA test changes participation. As before, the direction of this effect is ambiguous.

4. To assess complementarity, we will test the hypothesis that $\beta_3 = \beta_1 + \beta_2$.

5.2 Production Processes/Amount and Quality

Second, we will analyze how our treatments impact farming practices, seed production, and objectively measured quality. For this analysis, we will focus only on individuals who were not unexpectedly excluded from DNA testing. We use the following specification as above:

$$Y_{ivb} = \theta_0 + \theta_1 Incentives_{vb} + \theta_2 DNA_{vb} + \theta_3 Both_{vb} + \rho_b + X_{ivb}\beta + \varepsilon_{ivb}$$

where Y_{ivb} is now a farming practice or seed production outcome, including the dummy variable for genetic matches, contract success, and the continuous variables for quantities and pure quantities. The definitions of all other variables remain as above. We test the following hypotheses:

1. Comparing T0 to T1 ($\theta_1 \neq 0$) allows us to assess the impact of offering higher incentives to farmers. Higher prices could encourage both high- and low-quality growers to enter the market, thereby affecting production processes, quantities, and quality.

2. Comparing T0 to T2 ($\theta_2 \neq 0$) reveals the impact of providing better certification to farmers. As mentioned above, DNA testing could address both adverse selection and moral hazard. First, reducing the probability of false rejections may encourage more high-quality farmers to enter the market while prompting low-quality farmers to exit. This is because lower rejection risk decreases the cost of seed multiplication for high-quality farmers, whereas low-quality farmers may find it harder to pass inspection.

Moreover, DNA testing may incentivize farmers to invest more effort and reduce the likelihood of cutting corners, as the chances of detecting impure seeds are higher. However, if the offered prices are too low to cover the costs of producing pure seeds, even high-quality growers may choose not to participate. These dynamics will also affect production processes, production amount, and seed quality.

3. Comparing T0 and T3 ($\theta_3 \neq 0$) informs us about the potential value of the combined intervention. The combination of higher prices and DNA verification is designed to induce more high-quality types to opt into producing these seeds. Indeed, the DNA technology reduces the probability of false rejections which is appealing to high-quality types, and the price increase makes the costs of investing the effort more manageable. In other words, the combined intervention overcomes the limitations associated with offering each one on its own. Higher prices on their own attracts good types, but may also attract bad types. DNA testing on its own helps crowd out bad types but may also crowd out good types if the offer prices are too low to warrant the effort that producing these seeds requires. Offering both potentially overcomes the full set of constraints. This will affect production processes, production amount, and seed quality.

4. To assess complementarity, we will test the hypothesis that $\theta_3 = \theta_1 + \theta_2$.

5.3 Moral Hazard/Adverse selection

The final step of our analysis will examine the effect of the surprise removal of DNA testing. For this step, we will limit the sample to only those villages assigned to treatment arms with DNA testing (T2 or T3). The specification is:

$$Y_{ivb} = \gamma_0 + \gamma_1 Surprise_{ivb} + \gamma_2 Incentive_{vb} + \gamma_3 Surprise \times Incentives_{vb} + \rho_b + X_{ivb}\beta + \varepsilon_{ivb}$$

where Y_{ivb} is a seed outcomes, $Surprise_{ivb}$ is an indicator for receiving the surprise removal of DNA testing, and $Incentive_{ivb}$ is an indicator for being in the high incentive group (T3 only). All else is the same as above, except we do not cluster the error term ε_{ivb}, as the surprise treatment is assigned at the individual level.

1. Comparing "surprised" households to not surprised households in the DNA (T2) group ($\gamma_1 \neq 0$) allows us to test whether moral hazard specifically played a role in any production effect. If we find that DNA testing improves seed quality, it could be due to one of two reasons: 1) only high-quality producers accept the contract (meaning DNA testing screened out low-quality individuals), or 2) those who might have performed

poorly are motivated to try harder. The surprise group allows us to differentiate between these two scenarios. If we observe that those who did not undergo testing but agreed to it (the surprise group) produce quality on par with those who did receive testing, it suggests that the threat of DNA testing screens out low-quality individuals (indicating adverse selection as the primary problem in the market, as those likely to under-perform declined the contract). Conversely, if we find that those who did not undergo testing but agreed to it (the surprise group) produce worse quality seed than those who receive testing, it suggests that DNA testing motivates farmers to invest more effort into producing high-quality seeds (indicating moral hazard).

2. Comparing "surprised" households to not surprised households in the Both (T3) group ($\gamma_3 \neq 0$) allows us to conduct the same test as above, but among a differently selected sub-group: those who accept the contract with a higher incentive. Given that the higher incentive could attract a different type of farmer, it is possible that moral hazard problems could be different among this sub-sample.

5.4 Heterogeneity

All of our heterogeneity analyses will be exploratory. We will examine variations across several factors, including prior experience with OSSC and whether farmers have above- or below-median years of experience in groundnut production.

5.5 Multiple hypothesis testing

Our primary analysis a core set of outcomes (contract, production processes/ amount, quality), each assessed through specific targeted questions. However within each outcome category we will account for multiple hypotheses by computing False Discovery Rate (FDR) q-values.

5.6 Power

It is important to note that we are likely to be better powered than most agricultural experiments because most of our main outcomes are precisely measured binary variables (did the farmer agree to multiply the seed, did they ultimately multiply the seed (and how much). We compute that with 100 clusters in each treatment arm, four farmers in each cluster, an inter-cluster correlation of 0.1 and 80% power, the standardized minimum detectable effect is 0.2 standard deviations. This effect size is of a reasonable magnitude - this is roughly a 6-percentage point increase in acceptance of the peanut growing contract.

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