Reviving Pulse Production in India: Farm Household Impacts of Pulse Promotion and Extension

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Abstract

While pulses remain a dietary mainstay for Indians, domestic production of pulses has stagnated. In the most agriculturally productive regions, pulse cultivation has retreated in the wake of dramatic productivity gains in staples and cash crops. Concerned about its growing dependence on pulse imports and exposure to global food price shocks and about potential implications for rural diets, the Government of India commissioned an experiment in rural Bihar to test whether an ambitious 'last mile' intervention to revive pulses could reverse this trend. We evaluate the impact of this intervention on the adoption and production of pulses, household profits and food consumption, especially protein intake. The promotion and extension campaign succeeded in getting farmers to cultivate pulses, but these short-term changes were not sustained. While there is some evidence that these production changes increased the storage and consumption of pulses in these households, the production effects were simply too small on average to have a detectable, persistent impact on protein intake. We experimentally test the claim that low and uncertain pulse prices discourage investments in pulse production. We find limited support for this claim, suggesting that productivity breakthroughs in upstream agricultural research may be a prerequisite to reversing Indian farmers' retreat from pulse production.

1 Introduction

Since its onset over 50 years ago, the Green Revolution has unleashed dramatic increases in food supply around the world. While the movement primarily leveraged technological advancements in crop productivity, its penetration in developing countries has relied heavily on local investment in infrastructure, market development, and agricultural extension. In India, these factors combined to raise agricultural output over the second half of the twentieth century. Greater food supply has contributed to dramatic declines in food insecurity and malnutrition, with attendant gains in population health and wellbeing (Deaton, 2008).

Agricultural development in India has historically focused on cereals—primarily rice and wheat—to bolster the availability of calories in a country that faced severe food shortages through the 1960s. However, expansion of these basic staples has displaced traditional crops richer in micronutrients. In particular, farming of pulses, which constitute by far the most common source of protein in the country, has retreated to more marginal and rainfed lands in recent decades to accommodate high-yielding varieties of Green Revolution cereals (Pingali, 2012). As a result, the share of calories from protein consumed in India lags far behind international standards across socioeconomic strata (Sharma et al., 2020). In fact, the divergence in relative crop supply is so stark that per capita protein consumption actually fell in the 1990s and 2000s despite rapid economic growth (Deaton and Drèze, 2009).

In this paper, we evaluate a pilot program to expand the domestic supply of protein by encouraging pulse production using modern technologies among smallholder farmers. The policy couples subsidized inputs with intensive extension services—including local demonstration plots and individualized feedback—over a two-year period to establish pulses as a viable commercial crop. This effort, initiated by NITI-Aayog, the strategic planning arm of the Government of India, was implemented as a randomized controlled trial in five districts in the northeastern state of Bihar, and the pilot was run with the intent to scale up if successful. Farmers in these districts have followed the national trend away from pules toward cereal crops. We track the immediate uptake of pulse farming in response to subsidies and extension as well as secondary effects on household wellbeing and the persistence of changes over the longer term after direct support phases out.

The Government of India's drive to invest in domestic production is motivated by the fact that pulse yields in the country lag farther behind the technological frontier than other crops. In 2010, the average yield for pulses in Bihar was only 10–25% of the estimated potential yield, compared to 40–55% for rice and wheat[1]. uch low productivity stems in part from limited usage of modern seed varieties and input-intensive farming practices that were the hallmark of Green Revolution gains. In our areas of study, pulses are most often grown from traditional seeds on plot borders or other marginal land. This pilot program aimed to shift smallholder farmers to a new production equilibrium with greater investment and higher output.

Long-term production outcomes in this evaluation measure the extent to which experience contributes to path dependence in agricultural technology. Farmers may be hesitant to adopt new production techniques if they are uncertain about the returns or if there is a costly period of learning-by-doing before gains are realized. The policy package in this study was designed to alleviate these barriers by removing adoption costs and providing intensive training on best practices. In effect, it sought to provide farmers with the same level of extension support for pulse cropping as they had received for cereals in years prior. While such a high degree of public investment would be unsustainable as a permanent solution, it may be enough to encourage short-term adoption. We investigate whether the experience gained during a period of a intensive support can stimulate persistent change in production behavior.

We find evidence that support policies initially encouraged uptake of pulse farming, but these gains dissipate over the life of the program. The fraction of farmers growing pulses was around 50% greater in treatment villages relative to control in the first year when pulse seeds were fully subsidized. However, this difference fell by more than half in the second year with partial subsidies, and by the third year after subsidies expired there was no detectable difference in pulse cultivation between treatment and control. This pattern indicates that whatever learning occurred during the subsidy period did not raise the perceived returns to pulse cultivation enough for pulses to supplant other crops. If anything, evidence suggests that experience confirms farmers' pessimism about the return to investment in pulses, as treated farmers exhibit lower demand for modern variety seeds relative to control in a revealed-preference demand elicitation after two years of intervention.

Measures of household wellbeing are consistent with low returns to investment for pulse crops. We find no evidence of increased revenue or lower production costs among treated households despite the fact that the intervention included heavy input subsidies. One potential explanation for this fact is that total volume remained small, even among those induced to grow pulses by the program, so most production was retained for household consumption rather than market sales. However, we also find no statistically significant program impact on household diet, food stores, or protein consumption. Across a range of measures, there is scant evidence that modernizing pulse production techniques, even with heavily subsidized inputs, would lead households to be better off.

In a supplementary evaluation, we explore the potential for output price supports to bolster local production. Among villages that received extension services, we subsidized the sale price for a random subset in the year after the input intervention expired. Support took the form of either a flat per unit subsidy or a minimum price guarantee matching India's Minimum Support Price (MSP) policy, announced ahead of the planting season so farmers could adjust accordingly. These two arms separately test the role of expected returns and price risk (see Goyal, 2010; Donovan, 2020) in adoption decisions. We find evidence that sale of outputs responds to price signals, with greater market sales when the price is subsidized. However, the operative margin seems to be in selling versus home consumption, and there is little impact of output support on cultivation practices. This behavior once again confirms that farmers do not consider pulses to be sufficiently profitable at current market prices.

Taken together, our results suggest that lack of knowledge or experience is not a primary constraining factor for pulse farming in India. While the crop may not have benefited from the same level of investment and extension during India's Green Revolution, this underinvestment alone cannot explain the low prevalence of modern varieties and practices in the sector today. Our evaluation demonstrates that even under ideal conditions with substantial outside investment, pulses would struggle to compete with other crops in terms of profitability. Therefore, low yields would likely persist in the presence of nationwide extension efforts, and

[1]As reported in the FAO's GAEZ database.

farmers would continue to prioritize more lucrative alternatives.

This work contributes to a flurry of research in recent years aimed at better understanding India's pulse dilemma after the Government of India sounded the alarms about stagnant domestic pulse production nearly a decade ago. ADD CITATIONS and brief discussion here (to be expanded in greater detail in Background section). This study offers novel and rigorous insights about the viability of local initiatives to incentivize local pulse production. Indeed, this paper tests many of the suggestions that emerged from initial diagnoses of the pulse problem (CITE), including implementing a procurement mechanism to operationalize the stated MSP for pulse crops, which otherwise may simply facilitate collusion among intermediaries in the market (CITE). Although our experimental procurement mechanism is not without its limitations, as a prototype it provides a unique test of the common claim that lack of procurement at MSP is the central problem given the current access farmers have to such favorable prices for competing crops. Taken as a whole and when seen in this broader context, our results suggest that reviving pulse production among Indian farmers who long since turned to more remunerative crops will likely demand productivity breakthroughs in upstream research that allow promising new pulse varieties to hold their own in on-farm crop portfolios. Such breakthroughs are never quick-win propositions, however, and require specific, sustained and long-term commitments to public R&D support. Last-mile access to the best available technologies is necessary, but it is not sufficient when best available is just not good enough.

Our study also contributes to the large body of research on technology adoption in agriculture (see de Janvry et al., 2017). Extension work is frequently motivated by the assumption that lack of knowledge or training prevents the uptake of new technologies (Waddington and White, 2014). However, experimental evidence indicates that farmer training alone is insufficient to change farm practices (Fabregas et al., 2017; Kondylis et al., 2017; Maertens et al., 2021). In contrast, programs that augment training with hands-on demonstration and experience have shown greater success (Maertens et al., 2021; Aker and Jack, 2021; Emerick and Dar, 2021), highlighting the importance of either learning-by-doing or learning about the returns to technology (see Magruder, 2018). Results from our primary input experiment, which closely resembles Emerick and Dar (2021) in its use of field visits and demonstration plots, diverge from this prior work. Our study indicates that in the case of pulses in Bihar, lack of knowledge is not the main constraining factor causing low yields.

Beyond knowledge and training, past research has identified uncertainty about inputs (Bold et al., 2017; Hasanain et al., 2022) and lack of credit (Magruder, 2018) as further barriers to agricultural technology adoption. This project resolves the former concern by sourcing high-quality inputs from reputable vendors and distributing locally through trusted organizations with strong community ties. This distribution network, which was not experimentally evaluated, remains in place after the intervention period. The study population consists of established farmers with access to credit for agriculture.

Promotion of new technologies and modern cropping practices represent supply-side initiatives to increase agricultural productivity. A complementary approach focuses on demand-side interventions that raise the returns to investment and quality (see Bold et al., 2022; Rao and Shenoy, 2022 for experimental evaluations and Bellemare and Bloem, 2018 for a comprehensive review). Related demand-side factors include contract design (Goodhue et al., 2010; Saenger et al., 2013), market competition (Bernard et al., 2017; Macchiavello and Morjaria, 2021), and quality verification (Saenger et al., 2014; Bai, 2021).

A few experimental evaluations couple supply- and demand-side interventions simultaneously. Macchiavello and Miquel-Florensa (2019); Park et al. (2022) find that training induces greater technology upgrading when farmers are connected with output markets to sell their crop. Our research attempts to simulate the to returns market expansion with price supports, with little success. It remains an open question whether a more sustained commitment to higher output prices could generate greater pulse cultivation and productivity in the long run.

Raising agricultural productivity is a crucial component of economic development because 75% of the world's poor live in rural areas reliant on agriculture (World Bank, 2007; Castañeda et al., 2016). Across countries, the difference in productivity between rich and poor tends to be greater in agriculture than in other sectors (Caselli, 2005), and the productivity gap between agriculture and non-agriculture is greatest at the bottom of the income distribution (Gollin et al., 2014). Adamopoulos and Restuccia (2021) decompose agricultural productivity to show that crop selection and input use, rather than land endowments, account for the overwhelming majority of differences between rich and poor countries. (McArthur and McCord, 2017) argue that improved use of inputs was a fundamental driver of growth in cereals during the Green

Revolution.

2 Background

This paper reports results from an evaluation of a pilot led by the Government of India to promote the small-scale production of pulses in Bihar. The initiative was motivated by recent rises in pulse prices driven by demand growth outpacing supply. The pilot program tests the capacity for technological upgrading to raise domestic production in the pulse sector. In this section we provide background on pulses in India and a more detailed description of pilot efforts.

2.1 Pulses in India

India is simultaneously the largest producer, consumer, and importer of pulses in the world. The country produces around 25% and consumes around 27% of the world's pulse crop. Accordingly, pulses make up an integral part of Indian diets, and are a key ingredient in traditional cuisines around the country.

Despite the high volume, local production has lagged behind demand in recent years. From 1995 to 2016, consumption of pulses in India increased at an average annual rate of 2.3%, outpacing the growth in domestic production of around 1%.While imports from Canada, Myanmar, and other nations increased to fill the gap, the pulse sector has still seen steady price increases.

Pulse accessibility is particularly important in the country because pulses represent a key source of protein for Indian households. Pulses account for nearly a quarter of non-cereal protein consumption on average, and are the largest protein source outside of cereals for poor households in both rural and urban areas (Rampal, 2018). Protecting this source of consumption is especially vital in a country where the protein content of diets lags well behind international standards across geographic and socioeconomic strata (Sharma et al., 2020). Pulse prices also play a role in political stability, as unexpected price spikes have forced administrative resignations and induced turnover among elected officials[2].

To stabilize the national market, the Government of India is exploring policy solutions to bolster supply. In this paper, we evaluate one such initiative aimed at promoting pulse production in the state of Bihar. This policy is motivated by the fact that pulse cultivation in the region typically uses low inputs and traditional cropping methods. As a result, yields lag farther behind the technological frontier than more commercial crops: pulse plots achieve only 10–25% of their theoretical maximum on average compared to 40–55% for plots devoted to rice or wheat[3]. The interventions we study follow from the hypothesis that this technological sluggishness is path-dependent, such that a one-time investment by the government could raise yields by inducing local producers to adopt modern techniques and increase their use of inputs.

2.2 Policy Design and Implementation

The pulses program in this study was developed as a joint initiative between the Government of India and local non-governmental organizations (NGOs). NITI Aayog, the economic steering arm of the Indian government, coordinated with the Aga Khan Foundation (AKF) and four local NGOs in Bihar to develop a policy package to provide the most favorable conditions possible for pulse cultivation. The package was then implemented by the local partners over a three-year period, with the intent of scaling up successful components into a state- or nation-wide policy. Funding for the pilot project was provided by the Bill and Melinda Gates Foundation, and implementation oversight was managed locally by AKF.

The first two years of program implementation focused on input support. Project partners first created a local market for insecticide-treated, modern-variety pulse seeds, which had previously been difficult to purchase in the area of study. They offered these seeds at a subsidized cost for two years, and provided substantial extension support to program farmers over this period. After the second year, project partners continued to make seeds available at the market price. This portion of the study tests whether an intensive, short-term investment in technological upgrading can induce enough adoption to create sustained demand for seed purchases and output sales over the longer term.

[2]e.g. *The Hindu*, 2015, October 21, "Finally, pulse price is a poll issue in Bihar".

[3]As reported in the FAO's GAEZ database.

In the third year, program activities shifted to marketing of output. Implementers assisted farmers in forming Farmer Producer Companies (FPCs) to negotiate bulk sales with traders and processors. The program also experimented with offering price supports and backstopping the sale price with a floor set to match India's national Minimum Support Price (MSP). The MSP, which had previously been enforced for cereal crops but not for pulses in Bihar, represents an effort by the government to insure agricultural households against income loss driven by unexpected price fluctuations at the time of harvest. This portion of the study tests the elasticity of local pulse supply to increases in the sale price.

Program evaluation takes place in five districts in the Indian state of Bihar, depicted in Figure 1. Pulses, especially pigeon peas, are a staple of food consumption in this region, but local production remains limited. Landowners commonly grow small quantities of pulses for household consumption, typically as a border crop to delineate between plots or on other marginal land. Nearly all farm households supplement home production with market purchases despite being net sellers of the other crops in their portfolio.

[Figure 1 about here.]

The region of study follows a two-season cropping cycle. In the main Kharif crop season, which runs from May through October, farmers typically grow rice for commercial sale. The pulses program promoted replacing a portion of the rice crop with either pigeon peas or black gram during this period. In the secondary Rabi season, which runs from November through February, farmers typically grow wheat, maize, and vegetables for commercial sale. The pulses program focused on green lentils during this season, but implementers provided support for a number of other pulse crops as well. It should be noted that pigeon peas are a longer duration crop, so that fields devoted to pigeon peas in the Kharif season would remain occupied through Rabi as well.

3 Research Design

We evaluate two interrelated experiments to measure the effect of input and output market support on farmers' adoption and production of pulses. The primary experiment focuses on input support and takes place over two years, spanning four cropping seasons in total. The secondary experiment, focused on output support, takes place in treated villages from the primary experiment in the year after input support has expired. In this section we describe the interventions in each experiment, the randomization design, and the data used for evaluation.

3.1 Theory of Change

We first present a simplified model to describe the motivation behind this evaluation. Consider a farmer that can produce using either a traditional (L) or modern (H) production technology. In a given cropping season, the farmer chooses a technology $T \in \{L, H\}$ and a level of inputs x, and then produces output $f_T(x)$. Under the traditional technology, let $f_L(0) = 0$, and let $f_L(x)$ be increasing and concave when $x > 0$. The modern technology requires up-front investment (e.g. for hybrid seeds), so that $f_H(x) = 0$ when inputs fall below some threshold $x \leq \underline{X}$. Let $f_H(x)$ also be increasing and concave above the minimum threshold when $x > \underline{X}$. Further, let there be a crossover point $\overline{X}$ below which $f_L(x) \geq f_H(x)$ and above which $f_L(x) \leq f_H(x)$. That is, at low levels of investment, the traditional technology produces more, but once inputs are sufficiently high, output from the modern technology dominates.

Figure 2a represents the pre-intervention equilibrium with low technology adoption. Farm profits can be written as revenue minus cost, that is $\pi(x) = pf(x) - x$. For each production technology, farmers will maximize profits by choosing inputs so that the slope of the production function equals the (inverse of) market price. Farmers will choose whichever technology delivers higher profits at this price, which in this case is the traditional technology.

The primary intervention lowers the required level of investment $\underline{X}$ for the modern technology by subsidizing the cost of modern inputs. This treatment, which effectively shifts the farmer's modern production function to $f_H(x + s)$ for a subsidy value s, is depicted in Figure 2b. The policy package is designed to provide a high enough level of support that adoption becomes profitable.

In this experiment, we test the hypothesis that past experience raises the return to inputs in the modern technology. This can most straightforwardly be attributed to learning-by-doing. If there are returns to experience in production techniques, then a one-time policy that provides the impetus for initial adoption can raise profitability to sustain modern practices in the long run. This effect can be described conceptually as a post-intervention production function of $f'_H(x) > f_H(x)$ in the range $x > \underline{X}$, as depicted in Figure 2c. We test this hypothesis against the alternative that post-subsidy production returns to the equilibrium in 2a.

A related possibility is that experience resolves uncertainty about returns. If farmers are risk-averse and heterogeneous in their ability, then uncertainty about their private returns to a new technology can lower the expected utility of adoption. Even if experience does not alter the distribution of productivity in the population, it can induce greater adoption on average if it gives individuals more precise information about where they fall in that distribution. Unfortunately, without an independent measure of farmer ability, our research design does not allow us to differentiate between these mechanisms. Nevertheless, both theories generate the same prediction that a short-term intervention to promote adoption of a new technology can induce a persistent increase in that technology's utilization.

The secondary experiment complements the primary intervention by evaluating the additional impact of price supports. Raising the output price leads to flatter isoprofit curves, and if the price is sufficiently high then the modern technology becomes optimal as depicted in Figure 2d. In this case, we explicitly design the experiment to test the role of risk relative to expected return by varying whether the price support is applied uniformly across the distribution of possible outcomes or selectively insures only against very low price realizations in the form of a price floor.

[Figure 2 about here.]

3.2 Description of Interventions

We evaluate two sets of policies intended to increase pulse production in our areas of study. The primary intervention aims to trigger permanent change in cropping practices with an intensive package of short-term input support. The secondary intervention tests whether changes in cropping practices can be sustained through subsidies to the sale of outputs.

3.2.1 Primary Intervention: Pulse Promotion and Support

The primary intervention consists of input subsidies combined with extension support for a two-year period spanning four cropping seasons. For this project, implementers sourced insecticide-treated seeds for high-yielding varieties of pulses from a seed bank and made them available at harvest time. In the Kharif season, the intervention included seeds for pigeon peas and black gram, and in the Rabi season offered seeds for green lentils. Local agronomists provided specialized extension support for the promoted crops as well as additional guidance on other pulse crops, most commonly fava beans and green peas.

In treated villages, all input support activities were channeled through a village farmer group. Farmers planning to cultivate pulses joined the farmer group, and the group was responsible for delivering subsidized seeds, announcing extension visits by agronomists, and all other pulse-related activities. No such group was formed specifically for pulses in control villages, but farmer groups for other crops and investments existed in the region throughout the duration of the experiment.

In the first year, pulse farmer group members had the option to receive pulse seeds for free, under the soft conditionality that they plant what they receive and not resell. In the second year, subsidies were scaled back to 50%, and from the third year onward seeds were sold at market price. The subsidies temporarily lowered the cost of adopting modern pulse varieties. Through the life of the experiment, farmers in control villages had the option to purchase project seeds at market price as well. Therefore, the intervention tests the marginal effect of temporary subsidies and extension while holding market access to input quality constant across treatment and control arms.

Input subsidies were combined with agricultural extension. In the first year of study, the intensity of extension in treated villages varied experimentally. In villages receiving the highest intensity extension package, implementers set up a demonstration plot to showcase best-practices and made two visits per month to provide individualized feedback and support. A second subset of villages received medium-intensity extension that consisted of two agronomist visits per cropping season without local demonstration plots. In a final subset of low-intensity villages, seeds were offered with no complementary extension at all. In the second year, all villages receiving the input package were treated with the highest intensity extension, so that all treated farmers had seen a demonstration plot and received individualized feedback by the end of the intervention.[4]

Extension services focused on best practices for pulse cultivation. Agronomists provided detailed guidance on row planting, spacing, appropriate use and timing of irrigation and fertilizer, and other techniques to maximize yield. In our areas of study, such practices are already commonly used in the cultivation of rice, wheat, and other commercial crops. However, pulses tend to be grown along plot borders or on other marginal land using low-quality seeds and low-intensity agricultural techniques. Therefore, the highest intensity intervention package was designed to maximize the potential for learning-by-doing among adopters.

3.2.2 Secondary Intervention: Output Price Support

The secondary intervention measures the elasticity of pulse supply to output prices by offering price supports to producers. Price supports take the form of either a per-unit subsidy or a guaranteed price floor, matching India's MSP program, to separately identify farmers' sensitivity to expected returns and to risk (see Donovan, 2020).

This intervention was implemented exclusively within treated villages from the primary intervention, and took place in year three during the two cropping seasons after the primary intervention had concluded. At the end of the two input support years, implementers established FPCs in treated areas to enable the bulk sale of outputs. Membership for these FPCs drew heavily from farmer group members who wished to continue with commercial pulse cultivation. In this secondary experiment, villages were assigned to either control where farmers could sell their output at the market rate secured by the FPC, or to treatment where this rate was augmented by a price support for black gram in the Kharif season and green lentils in the Rabi season. Treatment status was announced to each farmer group ahead of the planting season to allow participants to adjust inputs according to their expected returns.

Farmers in half of treated villages in this experiment were offered support in the form of a price floor. The floor was set to match the MSP offered by the Government of India, which was Rs. 56 ($0.80) per kilogram for black gram and Rs. 44.75 ($0.64) per kilogram for green lentils in the experiment year.[5] This intervention effectively eliminates the possibility of very low sale price realizations. As a result, it both raises the expected returns to pulse sales at the time of harvest as well as lowers the ex ante variance of possible returns.

In the other half of treated villages, farmers were offered a per-unit subsidy to isolate the effect of raising the expected return without altering variance. We calibrated the subsidy level using historical data on local harvest prices and MSP rates in the eleven years prior to the experiment. On average, the MSP would have delivered a premium of Rs. 6/kg for black gram ad Rs. 2/kg for lentils were it enforced locally. The per-unit subsidy was set at this level to match the effect of the MSP on expected returns without altering variance.

3.3 Randomization and Sample Selection

Randomization for both experiments took place at the village level. The primary input experiment comprised 174 villages, out of which 99 were assigned to receive input support over two years. Among treated villages, treatment intensity was experimentally varied over the first year with 33 villages receiving the full extension package, 34 receiving limited extension services, and 32 being offered subsidized seeds alone in the first Kharif and Rabi planting seasons. In the second year, all treated villages received the full support package with demonstration plots and individualized feedback for both seasons. Input subsidies and extension concluded after the second year. The randomization design for the input experiment is outlined in the top half of Figure 3. Village-level randomization for this experiment is stratified by block, with two participating blocks in each district.

[4]After the second year, implementers remained involved with project villages and may have provided further informal guidance, but no funding was allocated to these activities.

[5]While the MSP is technically a national policy, it was never implemented in Bihar. Therefore, it was not binding at the time of the experiment, and local wholesale prices had fallen below the official MSP multiple times in years prior.

[Figure 3 about here.]

Primary outcome data comes from surveys of a random sample of farmers in each study village. To ensure experimental comparability across treatment and control arms, we selected the survey sample before treatment status was assigned. At the start of the study, ahead of the initial Kharif planting period, we held a kickoff meeting in each village to identify those potentially interested in growing pulses. We then randomly selected around seven households per village from the kickoff meeting that make up the survey sample for the life of the experiment. This strategy ensures that sampling is not influenced by project participation in treatment villages.

Table 1 provides summary statistics for households participating in the input support experiment. The first panel presents details about the primary survey respondents. The primary farm respondents, predominantly male, are typically near fifty years old, and over half have completed primary education. Male respondents are slightly more educated on average in the treatment arm than in control. The primary food respondent, almost exclusively female, are typically in their mid thirties, and equally as well-educated as the farm respondents. The second panel of the table presents household characteristics for the study sample. Control households tend to be slightly larger on average, and nearly two thirds of study households have planted pulses in some form in the past. We control for respondent age, education, caste, and household size in all household-level regressions below.

[Table 1 about here.]

The final two of Table 1 present measures of household consumption and wealth. Consistent with the small gap in education of the farm respondent, treatment households report being slightly wealthier on average, though the scale of farming is consistent between treatment arms. Treatment households also report consuming slightly more pules and more protein on average than control households. However, it should be noted that questions on wealth and consumption were asked shortly after the first experimental Kharif planting season. Therefore, balance along these measures may be influenced by program activities or anticipation of future pulse harvests.

The secondary output support experiment takes place in the third project year after input interventions concluded. Farmers from 82 of the 99 treated villages in the primary experiment were incorporated into FPCs[6] along with producers from 70 non-study villages that had also received the input support package. FPCs serve as vehicles to agglomerate members' production and sell in bulk to the local market. Farmers in the 152 FPC villages that had previously received input support were randomly assigned to either receive the standard FPC price, the FPC price plus a fixed subsidy, or the FPC price with a price floor reflecting the Government of India's MSP, with assignment lasting through the Kharif and Rabi seasons. Figure 3 outlines the full randomization design with the transition across years.

Village-level randomization in the output support experiment is stratified by prior treatment assignment and by FPC board representative. FPCs are managed by a board of directors with each director representing a group of member villages. These groups serve as a dimension of stratification to minimize possible noise introduced by heterogeneity in directors' level of engagement. Evaluation data for this experiment comes from the internal operational records of the FPCs.

Table 2 provides summary statistics for input experiment participants in villages that participated in the output support experiment. The top two panels again present respondent and household characteristics, and the third panel presents outcomes from the second year of the input experiment immediately before randomization in the output experiment. Households from control villages in the output experiment are slightly more likely to be lower caste and less likely to have grown pulses prior to our intervention. However, we cannot control for any household-level or village-level characteristics in evaluation because all evaluation data for this experiment come from administrative records without detailed hosehold characteristics.

[Table 2 about here.]

[6] One block out of the ten involved in the input experiment was dropped for logistical reasons.

3.4 Data Collection and Analysis

Data for the primary (input support) evaluation comes from a series of household surveys asking about agricultural input, production, and consumption. In the third study year, we also conduct an incentive-compatible elicitation of demand for pulse seeds. Data for the secondary (output price) evaluation comes from FPC administrative records. Because all interventions are implemented experimentally, analysis follows a straightforward regression design with dummies for treatment status.

3.4.1 Household Survey Data

Data for the primary evaluation comes from six rounds of household surveys that took place over the three intervention years. Surveys are typically conducted in either May/June shortly after the Kharif planting or in November/December shortly after the Rabi planting. This timing allows us to ask about both the output from the previous harvest as well as planting and input decisions for the coming season. We preserve the same survey households over time to generate a panel spanning the life of the experiment.

In each survey round, we separately interview both the female and male heads of household, typically a husband and wife pair. Male respondents are asked questions about agricultural inputs, production, and profits. Female respondents are asked about food consumption, other uses of household production, and health. This breakdown corresponds to typical domains of responsibility in our area of study and affords some insight into the intrahousehold impacts of our interventions.

The final survey round was scheduled for June 2020 after the conclusion of all experimental activities. Due to the COVID-19 pandemic, this survey was eventually pushed back to August and conducted by phone rather than in person. As a result, only a limited subset of outcomes are available from this round and magnitudes are not directly comparable with prior data. Regression analysis on this round of data is generally presented separately from outcomes in other rounds.

3.4.2 FPC Administrative Records

Data for the secondary evaluation comes from FPC administrative records on seed purchases, area planted, production, and sales. At the time of planting, FPCs took over the implementers' role of sourcing and delivering certified pulse seeds, which they sold to member farmers at market price. They monitored members' area planted and anticipated output through the growing season to forecast their volume of sales, and then measured the actual quantity delivered by each member farmer at harvest time. These outcomes were recorded identically cross output payment arms and are therefore experimentally comparable.

3.4.3 Input Demand Elicitation

Additional evaluation data comes from two incentive-compatible seed demand elicitations. These elicitations were conducted prior to the third-year Kharif and Rabi planting periods. This is after the primary input intervention had concluded, so comparing seed demand in treated villages relative to control provides additional evidence on the sustained effects of temporary input support. Elicitations took place after output price supports had been announced, so we can also compare seed demand across treatment arms in the secondary experiment.

Seed demand was elicited using an incentive-compatible Becker-DeGroot-Marschak mechanism. Participants were given a list of possible prices for insecticide-treated seeds for high-yielding varieties of pigeon pea and black gram in Kharif, and of green lentil in Rabi. They report their quantity demanded at each possible price, and then one price was selected at random for participants to purchase the quantity reported at that price.[7] This mechanism provides an incentive-compatible elicitation of each participant's demand curve over a range of prices. Details of the elicitation mechanism are discussed in Appendix **??**.

[7] To ensure incentive-compatibility, participants could not adjust their quantity demanded after the price was announced. However, they always had the option to purchase nothing at the experimental price or purchase extra at the market price. In practice, this was rare and nearly all participants purchased the quantity they committed to during the elicitation.

3.5 Methodology

We estimate the intention-to-treat (ITT) effect of the primary extension intervention on the panel of in-person survey outcomes using the regression specification

$$Y_{it} = \sum_t \beta_t T_i + \alpha_t + \gamma_{b(i)} + X_i'\delta + \epsilon_{it} \tag{1}$$

where Y_{it} is an outcome of interest for household i in block $b(i)$ in year t, and T_i is a dummy indicating the treatment status of household i. The coefficients of interest β_t represent the year-specific effects of treatment, and δ_t are year fixed effects that reflect the mean among the control group. The vector X_i controls for time-invariant household characteristics[8], and $\{\gamma\}$ control for block-specific fixed effects. All results are presented with heteroskedasticity-robust standard errors clustered at the village level.

Endline results include seed demand elicitations and responses from a phone survey shortly after the onset of COVID-19. These data do not have a panel structure, so we evaluate treatment effects for these outcomes using a simple cross-sectional comparison across treatment arms. Formally, this regression takes the form

$$Q_{icp} = \beta T_i + \sigma_c + \phi_p + \gamma_{b(i)} + \epsilon_{icp} \tag{2}$$

where Q_icp denotes the quantity demanded by individual i for seeds of crop c at price p. The coefficient of interest, β indicates how this demand differs on average for individuals originally in treatment villages, and γ again represent block fixed effects.

We further break down treatment status in the primary intervention by first-year treatment intensity. This specification replaces the treatment dummy T_i in (1) with a set of three separate dummy variables H_i, M_i, and L_i corresponding to high-, medium-, and low-intensity extension services, respectively. For first-year outcomes, this heterogeneity identifies the additional impact of agricultural extension in the presence of an input subsidy.In the second year, all three intensity arms receive the full extension package so heterogeneity in first-year intensity measures the importance of sustained extension services over time.

We evaluate the ITT effect of the secondary output price intervention using administrative data from FPCs. This allows for within-household comparisons across crops for agricultural inputs. Formally, we estimate

$$Y_{ic} = \beta^S Subsidy_{ic} + \beta^F Floor_{ic} + \phi_c + \gamma_i + \epsilon_{ic} \tag{3}$$

where $Subsidy_{ic}$ and $Floor_{ic}$ are indicators for whether household i was offered an output price subsidy or price floor, respectively. This was offered for only one crop per season, so we are able to make within-household comparisons to measure whether households with price supports devoted relatively more resources to the supported crop. Unfortunately we only observe output data on the subsidized crop sold to the FPC, so for production outcomes we run the regression

$$Y_v = \beta^S Subsidy_v + \beta^F Floor_v + \gamma_{b(v)} + \epsilon_v \tag{4}$$

For this regression we aggregate to village-level production, indexed by v, to account for selection into the decision to sell to the FPC. Heteroskedasticity-robust standard errors are again clustered at the village level.

To address the issue of multiple hypothesis testing, we first group outcomes into separate families of outcomes:

1. Production outcomes, Kharif
   a. Adoption of pulses in Kharif
   b. Total area under pulses in Kharif

[8]For analysis of pulse production, control variables include the farmers' gender, age, and education level, household caste, total land area owned at the start of the program, total land area cultivated in either Kharif or Rabi, quintiles of baseline wealth index (based on ownership of a set of durable assets and agricultural machinery), and a binary variable indicating whether the household had cultivated any type of pulses at least once in the two years preceding program implementation. For analysis of consumption in the food and nutrition survey, we control for the respondent's age and education level.

   c. Total pulse production in Kharif

2. Production outcomes, Rabi
   a. Adoption of pulses in Rabi
   b. Total area under pulses in Rabi
   c. Total pulse production in Rabi

3. Consumption outcomes
   a. Weekly pulse consumption
   b. Protein consumption per adult male equivalent
   c. Protein consumption of female respondent

Within each family of outcomes, we control the false discovery rate, that is, the proportion of rejections that are "false discoveries" or type I errors (Anderson, 2008), following the two-stage procedure proposed by Benjamini et al. (2006).

Throughout the paper, we preserve a balanced sample by excluding household that dropped out between survey rounds. The definition of attrition varies across specifications, depending on which rounds of data were used to construct the outcome variables in a given specification. Figure **??** describes how we define attrition for each outcome of interest.

3.6 Timeline

This study takes place from 2017 to 2020. The input intervention began with in the May 2017 Kharif planting season and ran for two years through the April 2019 Rabi harvest. Output subsidies were offered in the third year during the November 2019 Kharif and April 2020 Rabi harvests, with seed demand elicitations during the corresponding planting periods. Endline data collection concluded in August 2020. We provide a full timeline of study activities in Figure 4.

[Figure 4 about here.]

Note that the initial survey round took place during the first Kharif season of the input intervention. In this survey we ask about the prior year's production as well as household demographic characteristics. Although the survey was conducted after the input intervention had begun, it is well before the harvest when households would realize any profits or other agricultural outcomes from decisions made in response to treatment assignment. Therefore, we treat recall and demographic data from this survey round as baseline data in regression analysis.

4 Results

In this section we present results over three years on the impact of input subsidies, agricultural extension, and output price supports.

4.1 Impact of Input Support on Pulse Cultivation

Farmers expanded pulse production activities over the period when input subsidies and extension were ongoing, but subsequently scaled back to normal after program activities endd. This fact is most clearly demonstrated in Figure 5. The top panels show the fraction of farmers planting pulses in each season in each year of study. The input support program initially increased the fraction of farmers growing pulses by nearly double in the Kharif season, 50% in the Rabi season, and more than triple in the Zaid season. However, these differences dwindled in the second year, when subsidies were lowered. By the third year, when subsidies and extension had ended, the rate of pulse adoption among treated households was statistically indistinguishable from control. Estimates are provided in the odd-numbered columns of Table 3.

[Figure 5 about here.]

Greater rates of adoption were, for the most part, not accompanied by increases in area planted. Other than the initial Kharif season, point estimates of the change in area planted among treated farmers are far smaller in magnitude than the rates of adoption. Results are displayed in the bottom panels of Figure 5 with point estimates in the even-numbered columns of Table 3. The patterns of adoption and area combined are consistent with treated farmers testing pulses on a small portion of land while subsidies and extension are available, but ultimately rejecting their viability as a major crop.

[Table 3 about here.]

Elicitation of seed demand verifies lower desire for pulse inputs among treated farmers following two years of intervention. Table 4 reports results from our incentive-compatible elicitation. All survey farmers were invited to the elicitation exercise, but only half elected to participate. As shown in Column 1, the difference in participation between treatment groups is negligible. In each village, survey teams recruited additional volunteers on the day of the elicitation to fill available spots in each session.

[Table 4 about here.]

Upon attendance, participants were asked their seed demand over a range of prices, and one price was selected randomly for actual sale. At the elicitation, participants purchased a coupon for seeds from the implementing NGO so that expectations about seed quality or source did not vary by treatment status beyond any learning-by-doing in the treatment arm. In practice, over 90% of coupons were redeemed for seeds.

Columns 2 and 3 of Table 4 report differences in seed demand by treatment arm. Column 2 measures stated demand at the elicitation. Demand is lower for all seed types among treated farmers. To verify that demand is not depressed due to saved seeds from prior experiment years, in Column 3 we report the sum of stated demand and self-reported seed storage. This measure again reveals that post-intervention, there is lower desire to continue growing pulses among treated farmers. We show in Figure 6 that seed demand is consistently lower at every price. This result would suggest that, to the extent that farmers updated their beliefs about pulses during the intervention period, they inferred that pulses were not as profitable relative to their priors.

[Figure 6 about here.]

4.2 Role of Agricultural Extension

An explicit aim of the pulses project was to upgrade production technology among pulse farmers. As a proxy for upgrading, we measure whether a plot is dedicated to pulses as a mono-crop, or whether pulses are intermixed with other crops or grown on marginal border land. Cropping patterns among treated farmer suggest that agricultural extension spurs experimentation with modern cropping practices.

To isolate the role of extension, we leverage the fact that in the first year, some treated villages were offered only seed subsidies with minimal extension and others were offered intensive extension, with extension intensity being randomly assigned. In the second year, intensive extension activities were conducted in all treated villages.

In Figure 7 we relate cropping patterns to extension activities. The figure reveals that pulse adoption in the first year is highest among farmers receiving extension, although it is nearly as high among farmers receiving subsidies only. In the second year, when subsidized farmers receive extension for the first time, this relationship flips. In both the Kharif and Rabi seasons, there is a greater rate of pulse takeup among farmers receiving extension for the first time than among those who had already received agricultural extension for a year. This evolution is especially stark in the Kharif season, where nearly all new takeup is in monocropping with little excess mixed or border cropping in treatment villages relative to control. While these patterns are statistically noisy, they are consistent with extension services driving farmers to experiment with modern pulse practices.

[Figure 7 about here.]

Despite the use of modern cropping practices, we observe little evidence of increased pulse yields among treatment villages. Table 5 reports yields by year and by treatment status, with outcomes disaggeagted by the intensity of extension in the first year. Regression reveals no statistically significant difference in yield between treatment and control farmers, regardless of the presence of extension.

[Table 5 about here.]

Results on yield should be interpret with two caveats. First, yield is only measured conditional on adoption. Therefore, there may be selection bias in comparisons of yields between treatment and control. If input supports drew less skilled or more marginal farmers into pulse production, then this may lower realized average yields. Second, self-reported yield measurement is inherently noisy. We construct yield by dividing production by area. Both outcomes are self-reported with noise, and therefore their quotient is likely to include a substantial amount of measurement error. This fact is reflected in the large standard errors on Table 5.

4.3 Profitability and Household Consumption

The results above indicate by revealed preference that farmers in Bihar do not find pulse cultivation to be more profitable than the alternative. Survey evidence on household profits and consumption is consistent with this interpretation. In Table 6 we show that there is no statistically significant difference in household agricultural profits among treated households. Table 7 shows a comparable result for household consumption. While estimates in both tables are noisy, the magnitudes are small relative to the mean and statistically indistinguishable from zero.

[Table 6 about here.]

[Table 7 about here.]

4.4 Impact of Output Price Supports

Pulse cultivation generated by input supports does not persist after supports are removed. In an extension to this paper's main evaluation, we investigate whether output price subsidies can complement agricultural extension to sustain pulse cultivation. Table 8 reports the impact of a per-unit output subsidy and a guaranteed price floor on pulse cultivation and sales. Columns 1 and 2 estimate changes in area sown and seed quantity, respectively, for the Kharif season. Columns 4 and 5 show the same estimates for the Rabi season. In both seasons, we make within-household comparisons of the subsidized crop (black gram in Kharif and lentil in Rabi) against unsubsidized crops. In both cases, we find little evidence that an additional output subsidy increases cultivation.

[Table 8 about here.]

Nevertheless, it appears farmers respond to price signals in the sale of outputs. Farmers facing a per-unit price subsidy increased their sale of lentils in the Rabi season, as reported in Column 6 of Table 8. The price floor arm did not see a comparable increase in sales, likely because the output price was sufficiently high that the floor did no bind. This result suggests that, while a one-time experimental subsidy was not enough to affect farmers' input choices, pulse sales respond to price signals. Therefore, long-term price policy may have more success in shifting the market equilibrium.

5 Conclusion

In this paper, we show that intensive agricultural extension to promote pulse production in India increases cultivation, but gains do not persist over the long run.

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Figure 1: Map of Project Area

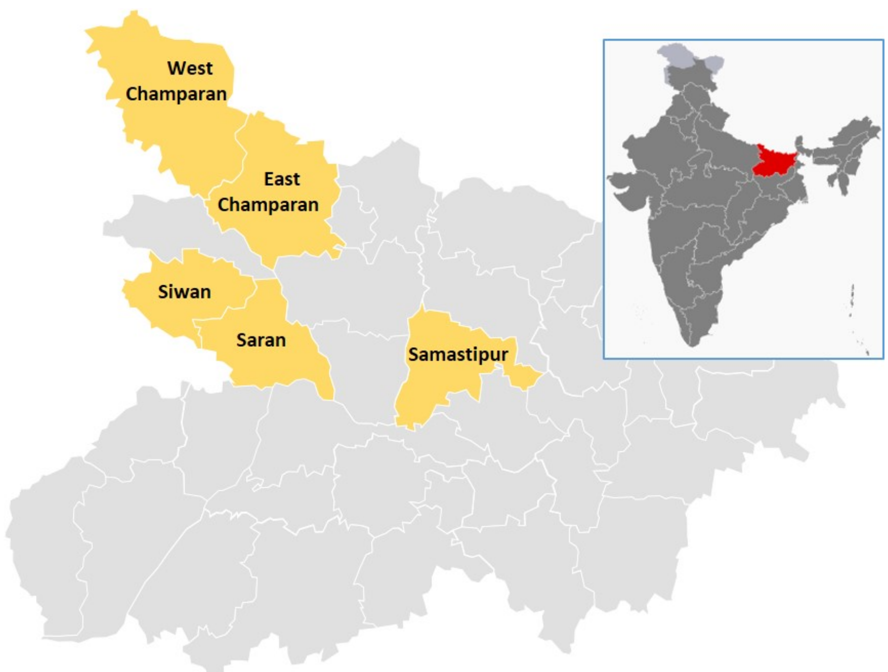
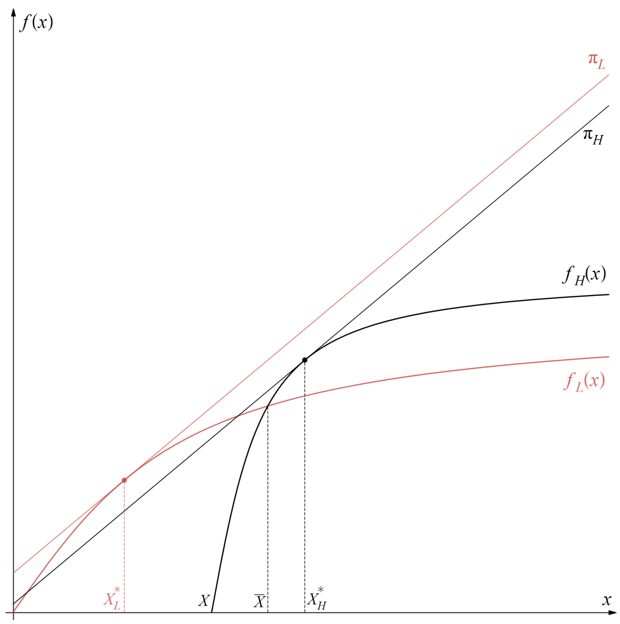
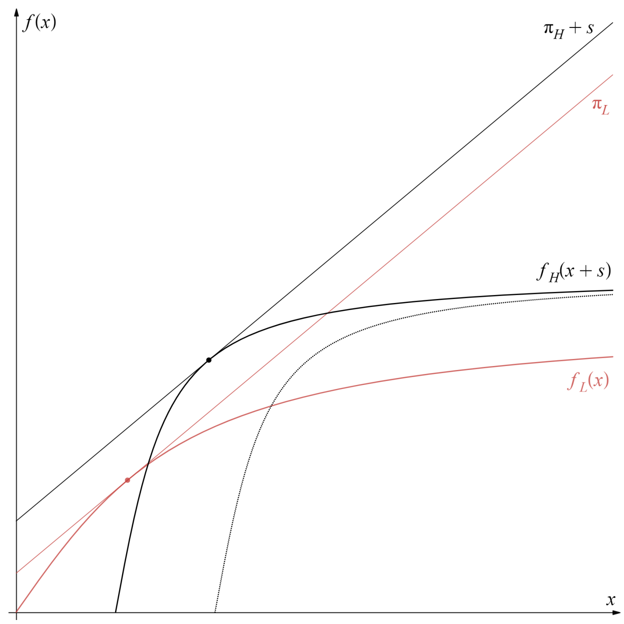


Figure 2: Theory of Change

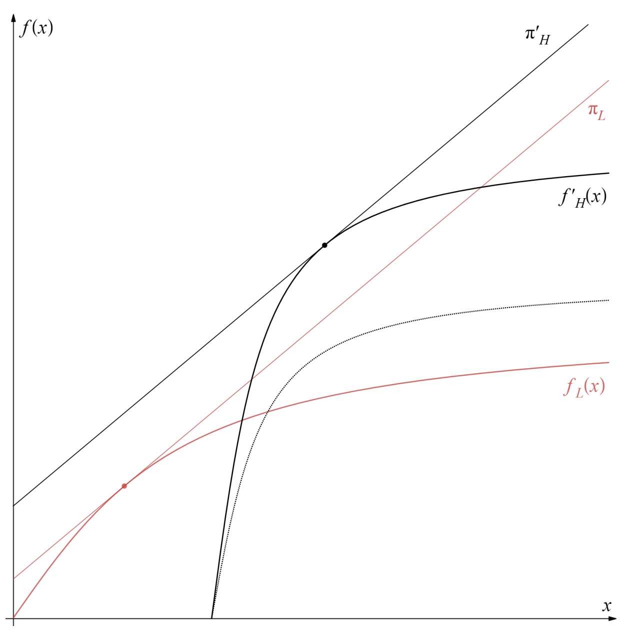
(a) Low Investment Equilibrium



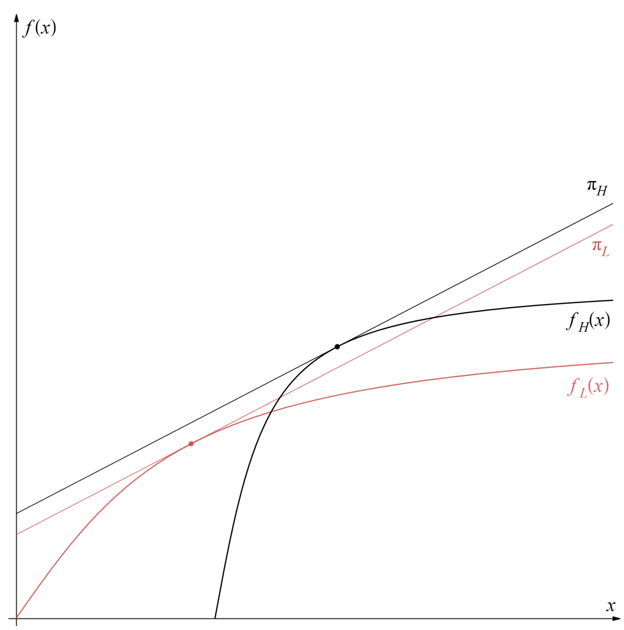
(b) Equilibrium with Input Subsidy



(c) Equilibrium with Returns to Experience

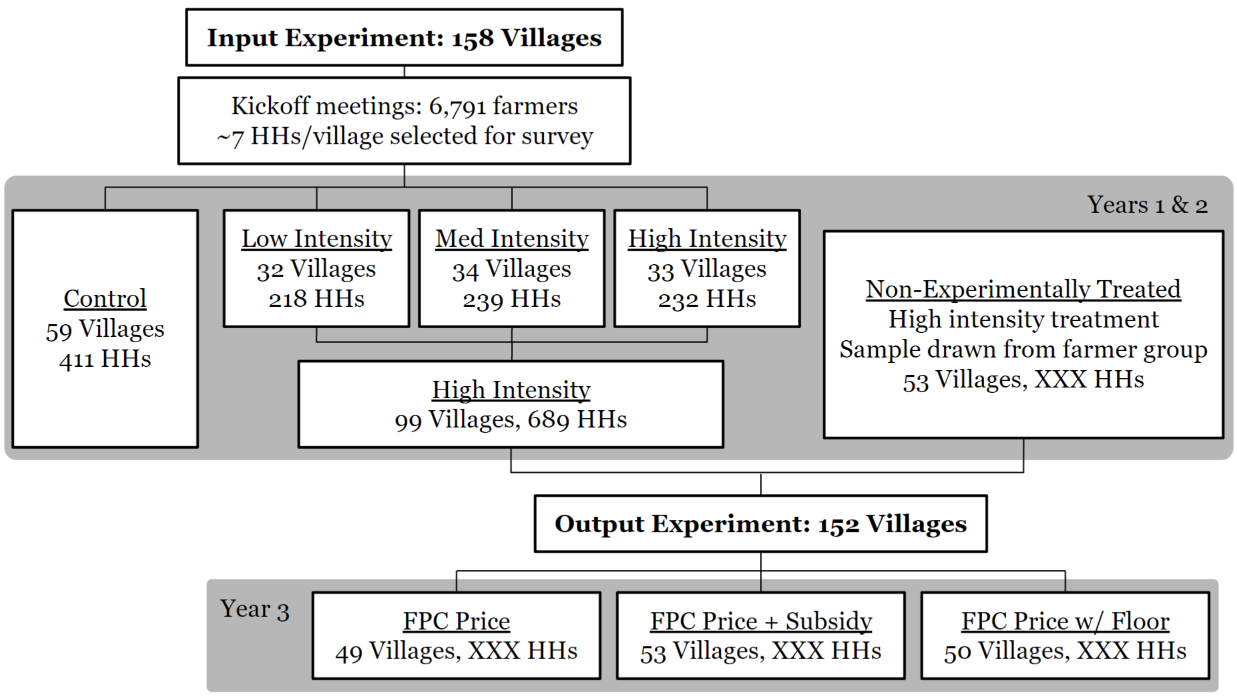


(d) Equilibrium with Output Price Support



Notes: Production functions and isoprofit curves at the optimal level of production. $f_L(x)$ represents traditional production technology, and $f_H(x)$ represents modern technology. (a) Pre-study equilibrium with low investment and output. Profit from low investment (X_L^*) with traditional technology exceeds profit from high investment (X_H^*) with modern technology. (b) Equilibrium during input intervention with subsidy s for modern variety seeds and inputs. Subsidized profit from modern technology now exceeds profit from traditional technology. (c) Post-intervention equilibrium when there are returns to experience. Production function with modern technology grows from $f_H(x)$ to $f'_H(x)$, and is now more profitable than traditional technology. (d) Equilibrium with output price support. An increase in the output price flattens isoprofit curves, creating the possibility that modern technology dominates traditional technology even under the existing production functions without returns to experience.

Figure 3: Randomization Design for Primary and Secondary Experiments



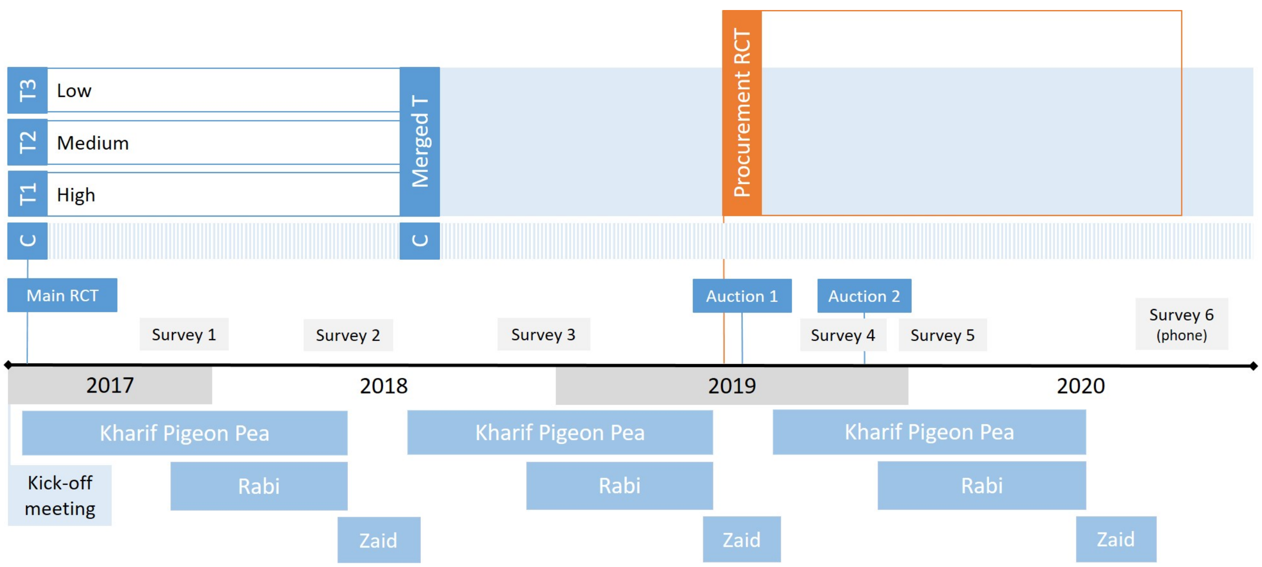


Figure 4: Timeline of research activities and experiments relative to cropping seasons

Figure 5: Pulse Adoption and Area Sown

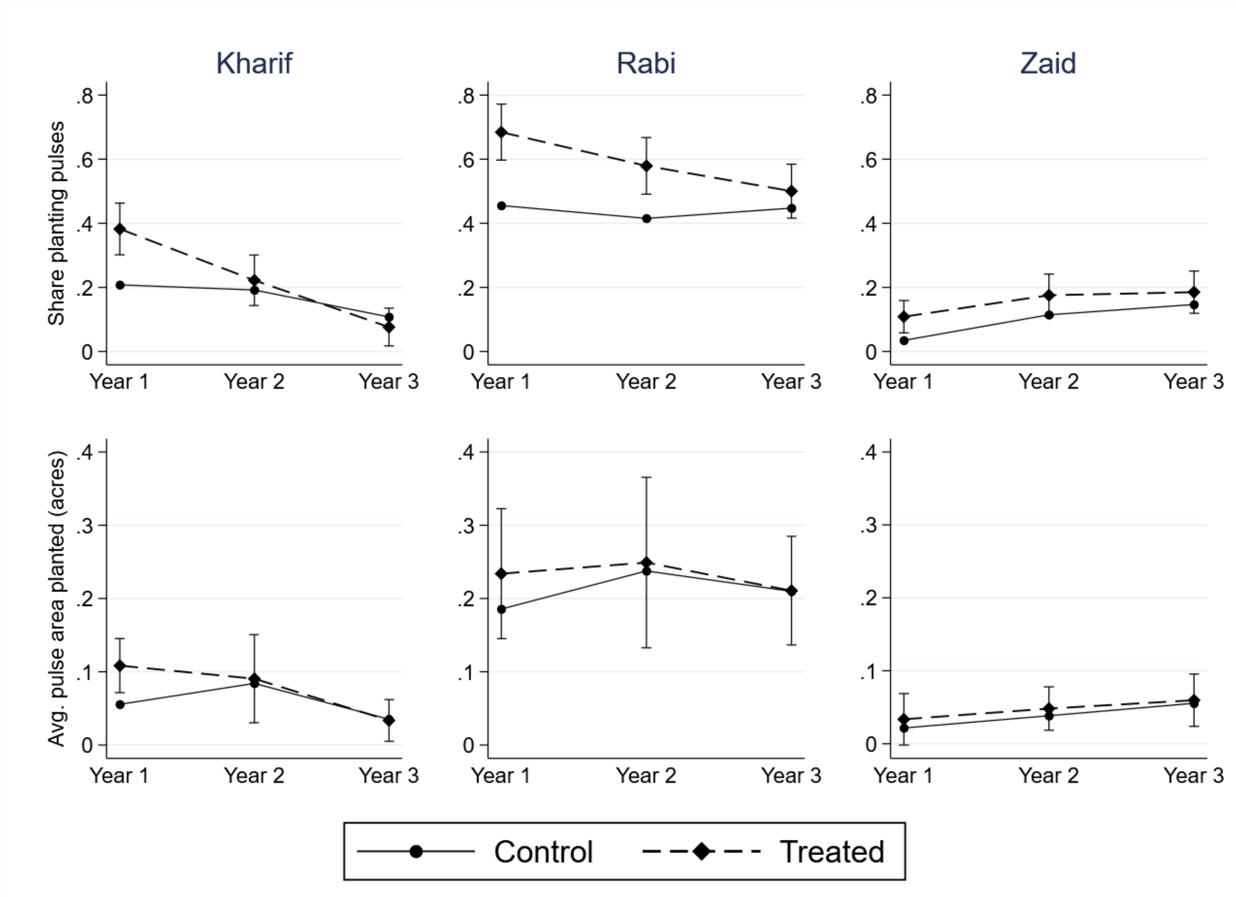


Figure 6: Seed Demand Curves

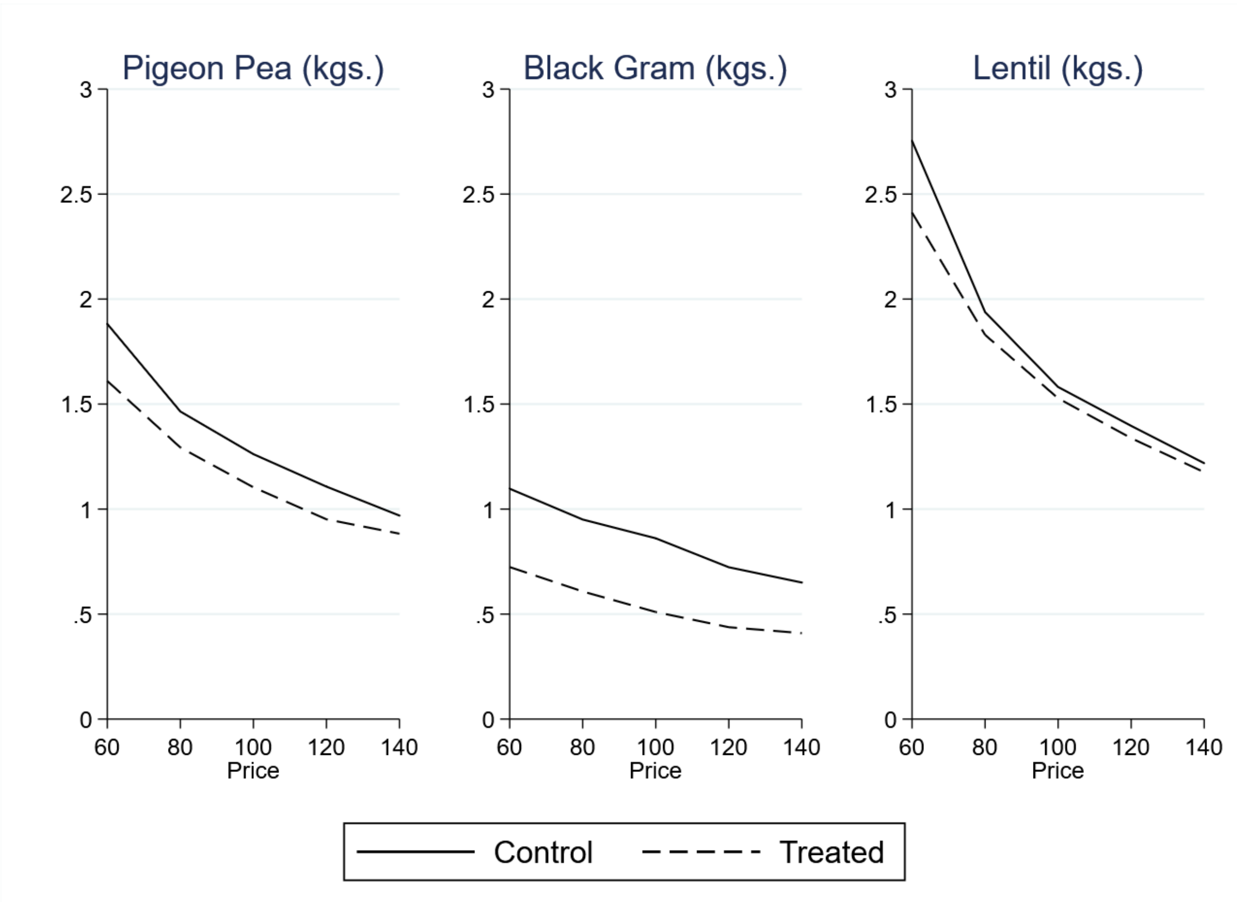
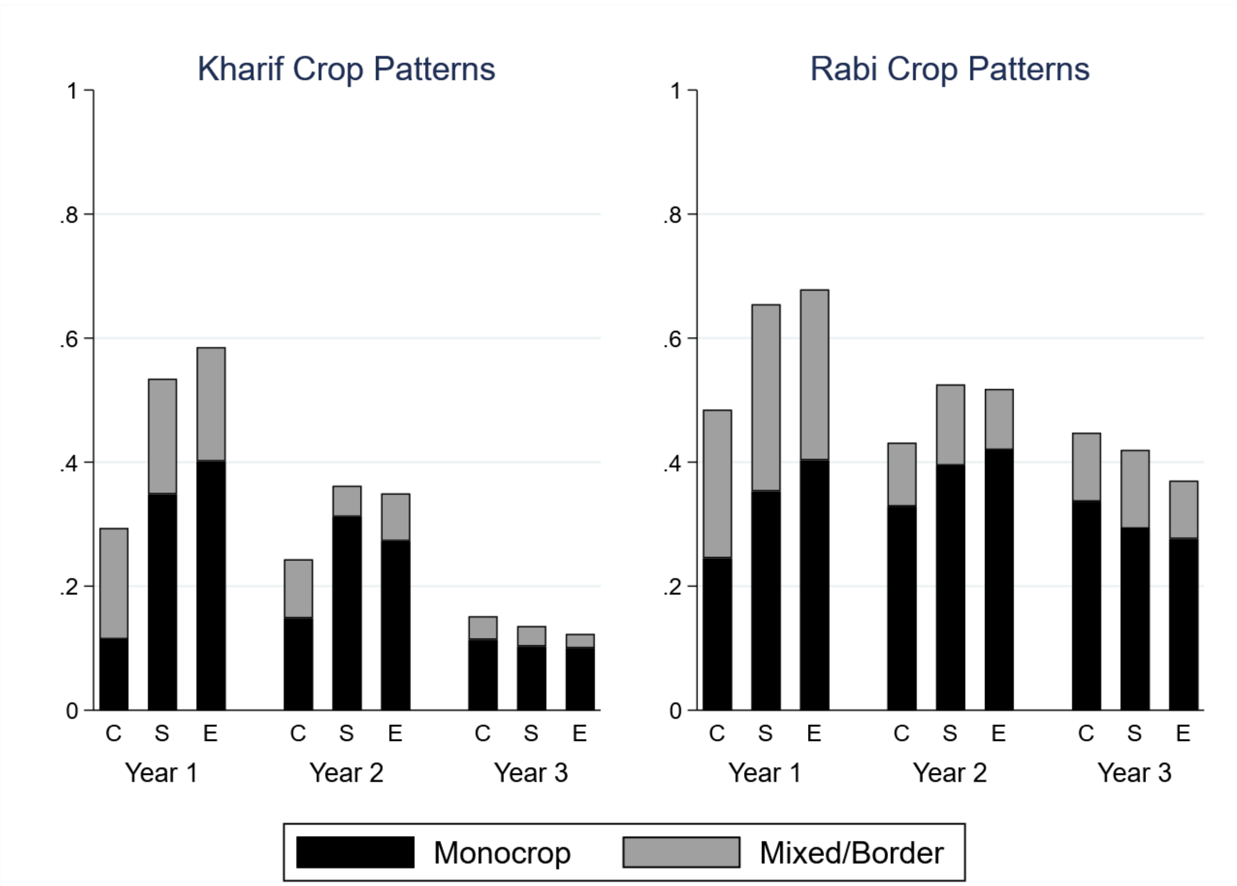


Figure 7: Adoption Patterns by Year and Treatment Status



Notes: Fraction of farmers growing pulses by cropping practice. E denotes extensions in first year; S denotes subsidy only in first year; C denotes control. In second year, both E and S received high-intensity extension.

Table 1: Baseline Covariates by Input Experiment Treatment Status

Variable	(1) Control Mean/SE	(2) Treatment Mean/SE	(3) Total Mean/SE	T-test Difference (1)-(2)
Farm respondent:				
Male	0.868	0.840	0.850	0.028
	(0.018)	(0.016)	(0.012)	
Age	48.264	49.371	48.952	-1.107
	(0.884)	(0.664)	(0.531)	
Primary School	0.548	0.658	0.616	-0.109***
	(0.027)	(0.020)	(0.016)	
Secondary School	0.390	0.485	0.449	-0.095***
	(0.026)	(0.021)	(0.017)	
Food respondent:				
Male	0.008	0.004	0.006	0.003
	(0.004)	(0.003)	(0.002)	
Age	35.627	36.142	35.947	-0.515
	(0.646)	(0.505)	(0.397)	
Primary School	0.506	0.588	0.557	-0.082
	(0.050)	(0.036)	(0.029)	
Secondary School	0.391	0.461	0.434	-0.069
	(0.049)	(0.037)	(0.029)	
Household:				
HH Size	7.524	6.656	6.984	0.868***
	(0.217)	(0.143)	(0.122)	
SC/ST	0.179	0.150	0.161	0.029
	(0.021)	(0.015)	(0.012)	
Past Pulses	0.642	0.665	0.656	-0.023
	(0.026)	(0.020)	(0.016)	
Wealth Index	-0.253	-0.018	-0.107	-0.235**
	(0.078)	(0.067)	(0.051)	
Land Owned	1.383	1.684	1.570	-0.301**
	(0.090)	(0.080)	(0.060)	
Land Farmed	1.448	1.557	1.516	-0.109
	(0.070)	(0.057)	(0.044)	
Weekly Pulses (g/capita)	379.076	416.700	402.476	-37.625
	(21.155)	(21.103)	(15.374)	
Daily Protein (g/capita)	14.070	16.843	15.795	-2.773***
	(0.593)	(0.581)	(0.427)	
Pulse Stock Left (months)	1.290	1.670	1.527	-0.380*
	(0.148)	(0.134)	(0.101)	
N	341	561	902	

Notes: Mean values of baseline covariates. Wealth, land area, and consumption are censored at the 95th percentile. The value displayed for t-tests are the differences in the means across the groups. ***, **, and * indicate significance at the 1, 5, and 10 percent critical level.

Table 2: Baseline Covariates by Output Experiment Treatment Status

Variable	(1) Control Mean/SE	(2) Subsidy Mean/SE	(3) Floor Mean/SE	T-test Difference (1)-(2)	(1)-(3)
Farm respondent:					
Male	0.831	0.849	0.868	-0.019	-0.038
	(0.027)	(0.024)	(0.024)		
Age	48.969	50.324	48.493	-1.355	0.477
	(1.164)	(1.105)	(1.042)		
Primary School	0.634	0.628	0.709	0.006	-0.075
	(0.034)	(0.032)	(0.031)		
Secondary School	0.461	0.459	0.576	0.003	-0.114**
	(0.035)	(0.033)	(0.034)		
Male	0.006	0.005	0.000	0.000	0.005
	(0.005)	(0.005)	(0.000)		
Food respondent:					
Age	34.979	38.306	35.510	-3.326***	-0.531
	(0.841)	(0.879)	(0.760)		
Primary School	0.559	0.578	0.708	-0.019	-0.149*
	(0.052)	(0.068)	(0.071)		
Secondary School	0.415	0.463	0.600	-0.048	-0.185**
	(0.052)	(0.068)	(0.072)		
Household:					
HH Size	6.621	6.528	6.591	0.093	0.030
	(0.253)	(0.227)	(0.220)		
SC/ST	0.200	0.110	0.122	0.090**	0.078**
	(0.029)	(0.021)	(0.023)		
Past Pulses	0.564	0.689	0.678	-0.125***	-0.114**
	(0.036)	(0.031)	(0.033)		
Wealth Index	-0.116	0.008	-0.001	-0.124	-0.115
	(0.108)	(0.116)	(0.108)		
Land Owned	1.482	1.709	1.693	-0.228	-0.212
	(0.130)	(0.128)	(0.124)		
Land Farmed	1.376	1.647	1.514	-0.271**	-0.139
	(0.095)	(0.095)	(0.088)		
Weekly Pulses (g/capita)	255.921	268.198	257.128	-12.277	-1.207
	(16.894)	(15.792)	(17.800)		
Daily Protein (g/capita)	19.839	20.954	26.490	-1.116	-6.651
	(2.811)	(2.836)	(3.763)		
Pulse Stock Left (months)	1.344	1.496	1.676	-0.152	-0.332
	(0.168)	(0.163)	(0.185)		
N	195	219	205		

Notes: Mean values of baseline covariates. Wealth, land area, and consumption are censored at the 95th percentile. The value displayed for t-tests are the differences in the means across the groups. ***, **, and * indicate significance at the 1, 5, and 10 percent critical level.

Table 3: Adoption and Area Cultivated by Input Treatment Status

	Kharif Season		Rabi Season		Zaid Season	
	Adoption (1)	Area (2)	Adoption (3)	Area (4)	Adoption (5)	Area (6)
Treat Yr. 1	0.174***	0.0528**	0.229***	0.0483	0.0739**	0.0119
	(0.0412)	(0.0188)	(0.0446)	(0.0453)	(0.0257)	(0.0180)
Treat Yr. 2	0.0302	0.00637	0.164***	0.0114	0.0609	0.00982
	(0.0402)	(0.0307)	(0.0451)	(0.0594)	(0.0337)	(0.0152)
Treat Yr. 3	-0.0317	-0.00152	0.0528	0.000919	0.0385	0.00416
	(0.0301)	(0.0145)	(0.0430)	(0.0378)	(0.0336)	(0.0183)
Year 2	-0.0160	0.0285	-0.0400	0.0520	0.0800**	0.0168
	(0.0369)	(0.0226)	(0.0374)	(0.0349)	(0.0264)	(0.0192)
Year 3	-0.1000*	-0.0205	-0.00800	0.0242	0.112***	0.0339
	(0.0407)	(0.0156)	(0.0352)	(0.0449)	(0.0318)	(0.0208)
ctrl_mean	0.317	0.0852	0.538	0.185	0.0638	0.0275
r2	0.225	0.0983	0.177	0.123	0.0917	0.0812
N	2004	2004	2004	2004	2004	2004

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Notes: Regressions according to (1). ***, **, and * indicate significance at the 1, 5, and 10 percent critical level.

Table 4: Seed Demand by Input Treatment Status

	Survey Farmer	Seed Quantity (kg.)	
	Participate	Purchased	Total
	(1)	(2)	(3)
Treat	0.0216	-0.174	-0.712*
	(0.0336)	(0.105)	(0.323)
price=60		0.824***	0.824***
		(0.0519)	(0.0519)
price=80		0.445***	0.445***
		(0.0350)	(0.0350)
price=100		0.245***	0.245***
		(0.0227)	(0.0227)
price=120		0.0998***	0.0998***
		(0.0151)	(0.0151)
ctrl_mean	0.456	0.936	3.036
r2	0.0277	0.143	0.135
N	3244	17865	17865

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Notes: Regressions according to (2). Control mean evaluated at prrice of Rs. 140. ***, **, and * indicate significance at the 1, 5, and 10 percent critical level.

Table 5: Productivity by Input Treatment Status

	Yield (Kg/Acre)		
	Kharif	Rabi	Zaid
	(1)	(2)	(3)
Ext. Yr. 1	3.703	-120.6	72.50
	(117.1)	(376.3)	(253.4)
Ext. Yr. 2	-190.3	-169.6	94.20
	(253.0)	(187.5)	(166.8)
Ext. Yr. 3	-8.781	-287.7	74.88
	(97.21)	(251.6)	(123.1)
Subs. Yr. 1	-20.66	-137.3	-1.061
	(117.4)	(397.4)	(177.4)
Subs. Yr. 2	38.67	310.3	45.03
	(348.9)	(333.8)	(123.3)
Subs. Yr. 3	135.5	458.1	139.2
	(108.0)	(619.6)	(194.5)
Year 2	269.5	-266.6	-5.366
	(318.7)	(289.7)	(151.9)
Year 3	-6.543	-283.3	109.8
	(157.4)	(289.4)	(231.1)
ctrl_mean	134.4	736.8	155.8
r2	0.0584	0.0422	0.125
N	469	917	252

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 6: Profits and Costs by Input Treatment Status

	Profits (1)	Revenue (2)	Sales (3)	Costs (4)	Farm Area (5)
Treat Yr. 1	2752.1	4663.4	2230.9	4042.8	0.0844
	(3743.8)	(3046.8)	(2489.4)	(3643.6)	(0.102)
Treat Yr. 2	-1698.4	8903.1	3179.4	6347.7	0.163
	(3571.4)	(4877.8)	(3530.0)	(3912.3)	(0.114)
Treat Yr. 3	261.5	-3549.8	782.1	-2939.0	-0.0314
	(1623.1)	(2008.7)	(3211.9)	(2039.0)	(0.117)
Year 2	12716.2**	15066.5***	11726.2***	-376.1	0.242**
	(4023.3)	(3425.7)	(2994.3)	(2745.8)	(0.0837)
Year 3	19005.7***	-26680.3***	6776.7**	-34323.8***	0.0814
	(3783.9)	(2700.3)	(2489.7)	(2906.0)	(0.0928)
ctrl_mean	-16983.2	35388.8	16061.2	55610.8	1.443
r2	0.0724	0.369	0.308	0.406	0.317
N	2004	2004	2004	2004	2004

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 7: Consumption and Stocks by Input Treatment Status

	Pulse Stock		Weekly Pulses	Daily Protein (g)	
	Kgs.	Months	Consumed (kg)	HH/capita	Female
	(1)	(2)	(3)	(4)	(5)
Treat Yr. 1	0.899	0.194	18.90	-0.610	
	(0.759)	(0.432)	(42.65)	(1.261)	
Treat Yr. 2	0.788	0.456	-20.78	-1.330	6.517
	(0.932)	(0.465)	(18.95)	(3.738)	(21.50)
Treat Yr. 3	0.290	-0.740	-9.338	-4.978	-9.425
	(0.459)	(0.907)	(21.27)	(4.704)	(21.67)
Year 2	0.998	0.0320	-139.6***	4.813	-18.99
	(0.765)	(0.322)	(29.57)	(3.177)	(25.25)
Year 3	-2.136**	-6.212***	-95.32**	9.203*	0
	(0.650)	(0.888)	(33.54)	(4.151)	(.)
ctrl_mean	4.857	2.117	420.9	16.15	105.0
r2	0.158	0.239	0.167	0.0893	0.0265
N	2004	2004	1971	1971	1301

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 8: Cultivation and Sales by Output Treatment Status

	Kharif Season			Rabi Season		
	Area	Sown	Sold	Area	Sown	Sold
	(1)	(2)	(3)	(4)	(5)	(6)
Subsidy	-0.000196	0.0941	5.053	0.0440	0.663	112.4*
	(0.205)	(1.305)	(18.67)	(0.152)	(1.757)	(54.83)
Floor	0.00812	0.0388	-2.632	0.0349	0.515	29.29
	(0.179)	(1.077)	(12.81)	(0.139)	(1.683)	(36.14)
ctrl_mean	0.0923	0.978	51.48	0.146	1.861	75.36
FE_HH	X	X		X	X	
r2	0.910	0.912	0.472	0.951	0.945	0.177
N	3356	3356	112	10725	10725	152

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$