What Are the Barriers to Pulse Cultivation in India? Evidence from a Randomized Controlled Trial

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Abstract

India is the largest producer and consumer of pulses, but in recent years has needed to import pulses to meet domestic demand. In order to keep prices stable and control the balance of trade, increasing domestic pulse production has become a national policy priority. However, farmers face multiple constraints to pulse cultivation. We design an experiment to measure the relative importance of these constraints to design an optimal short-term policy for pulse promotion. We conduct an RCT testing three different implementation models designed to ease different constraints: the "high intensity" provides seed distribution, extension services, and demonstration plots, the "medium intensity" provides seed distribution and extension services, and the "low intensity" only provides seed distribution via a voucher system. Overall, we find that all three models are effective in promoting pulse cultivation, with no statistically significant differences between the models. Treatment increased farmers' propensity to grow pulses over two seasons by 12 and 15 percentage points, respectively. These results suggest that, at least for the initial phase of pulse adoption, access to quality seeds is the key constraint, as opposed to information. Therefore, seed distribution is likely a cost effective way to quickly increase the adoption and production of pulse crops.

1 Introduction

Pulses such as pigeon peas, chickpeas, and lentils are an important part of Indian diets, providing both macro- and micro-nutrients and a source of vegetarian protein. Despite their nutritional significance and soil health benefits, pulse crops have been relegated to rain-fed lands over the last fifty years and domestic pulse markets have been characterized by production and price volatility. Pulse availability in India decreased from 69 to 52.9 grams per capita per day between 1960 and 2017 and India relies on imports to fill the supply-demand gap (Tiwari and Shivhare 2017). Additionally, pulse prices are subject to sudden spikes in drought conditions such as those in 2014/2015 (Roy et al. 2022). Starting in 2017, the Government of India made concerted efforts to decrease reliance on pulse imports and to spur domestic production. On the trade front, India uses import duties and quantitative restrictions to limit imports. Although the exact tariff rates and quantities have fluctuated since 2017, trade policies remain consistently restrictive (Roy et al. 2022). With decreased reliance on imports, spurring domestic production is a policy priority. Increasing domestic production involves addressing the barriers farmers face when cultivating pulses such as the lack of an assured market, limited access to quality inputs, and lack of knowledge of best farming practices. This study takes place in five districts of Bihar, a state where pulse cultivation was once quite prevalent, but total production decreased by roughly a third between 2001 and 2015 with the rise of mono-cropped cereals (Singh, Shahi, and Singh 2016a).

In this study, we conduct a randomized controlled trial to test which constraints farmers face with regard to pulse adoption, and the most cost-effective way to overcome them. We identified three interventions that could help overcome barriers to pulse cultivation: access to high-quality seeds suitable to the specific geography; support for the establishment of demonstration plots for knowledge dissemination on best practices for pulses farming, and in-person extension services. However, it was uncertain whether all three interventions were necessary to address the most relevant constraints to initial pulse adoption, and whether governments looking to scale up similar programs would have the capacity to deliver all three interventions. Together, these three interventions constitute what we refer to as the "high-intensity" program model. We test two alternative treatments to the "high intensity" model. The "medium intensity" model drops the demonstration plots but includes seed access and extension services. The "low intensity" simply provides farmers access to high-quality seeds.

The study was conducted over two cropping seasons: the summer "Kharif" season in 2017 and the winter "Rabi" season of 2017/2018. As the motivation of the study was to test potential time-bound policies to overcome initial barriers to pulse cultivation, this paper focuses on short-term results of the interventions. We find that all treatment arms cause farmers to significantly increase pulse cultivation in the same season as the intervention, with an increased propensity to grow pulses by 12 percentage points in Kharif and 15 percentage points in Rabi. Comparing our pooled treatment arms to control we find that the production value of pulses cultivated increases by around 22% in the Rabi season, but we do not find significant increases in the Kharif season. We do not find any significant differences in adoption or production between the three treatment arms. In suggestive analyses, we do not find that treatment farmers adopted improved cultivation practices promoted by the project during the duration of the study, and also find that the treatment groups had lower yield compared to control. However, the results on both practices and yield must be interpreted with caution since they are only measured for farmers who cultivated pulses rather than the whole evaluation sample and may incorporate selection effects. We do see some indication that the treatment induced less-experienced farmers to grow pulses.[1]

Although pulses are not a "new" crop, technological and price supports for rice and wheat established during the Green Revolution prompted a shift away from growing pulses toward cereals over the past fifty years. Therefore, many farmers today have little experience with cultivating pulses and using modern inputs/practices for pulse farming. Therefore, the barriers Indian farmers face to pulse cultivation have parallels to those explored in the general agricultural technology adoption literature (Jack 2013). Specifically, farmers are unsure about the potential profitability of pulses, lack experience on how to cultivate them productively, and face a lack of access to quality inputs (which is exacerbated by limited access to credit). This paper focuses on which barriers are most important to address in prompting farmers to experiment with modern pulse cultivation. The motivation to focus on the initial barriers is that addressing them could facilitate learning and sustained adoption even past the period of initial support (Carter, Laajaj, and Yang 2014). A number of papers look specifically at the effect of easing the constraints on input access, which may result from a lack of liquidity or

[1] The focus of this paper is on interventions that address the initial barriers to adopting pulse cultivation. Using the same population and intervention, Lybbert et al. (2023) study longer-term outcomes such as profits and household nutrition.

lack of local availability. These studies have shown that increased access to improved seed increases adoption (Axmann et al. 2019; Carter, Laajaj, and Yang 2013). A Campbell Systematic Review of studies primarily in Sub-Saharan Africa finds that fertilizer and seed subsidies generally raise yields (Hemming et al. 2018).

Nevertheless, providing seeds (or other inputs) may not be enough when the benefits of new seeds are not well known among farmers and the new seeds require changing cultivation practices. These information barriers may be addressed through extension services. One particularly common form of extension (especially for government programs) is demonstration plots, which aim to convince the farmers of the benefit of a new technology and teach proper production packages. It is well-accepted that farmers can learn about new technologies from others (Foster and Rosenzweig 1995; Conley and Udry 2010; Jones et al. 2018), but there is limited evidence on whether demonstration plots in particular are a useful tool to spur adoption. Maertens, Michelson, and Nourani (2021) do find positive effects of demonstration plots managed by village farmer's clubs on technology adoption in Malawi, but the overall evidence base is relatively thin. Several recent papers have experimented with different extension modalities such as peer farmer extension (Beaman et al. 2018; Kondylis, Mueller, and Zhu 2017) and farmer field days (Emerick and Dar 2021; Fabregas et al. 2017; Maertens, Michelson, and Nourani 2021). In general, the returns to extension vary and appear to be context-specific, making the return on investment for providing extension services unclear. Our results suggest that the primary barrier to pulse cultivation in this context was access to quality seed and that informational constraints played a less important role. Demonstration plots and extension services were less effective in improving pulse cultivation and production within the timeframe of this study. Additionally, although seed distribution induced adoption, it did not improve yields, at least in the short term.

This paper proceeds by first describing the context of pulse cultivation in Bihar. Next, we summarize the program interventions, study design, and timelines. We then present summary statistics and the empirical strategy for our research questions, followed by presentation of results and discussion of threats to identification. Lastly, we discuss implications from our findings.

2 Context

With increased focus on cereals following the Green Revolution, pulses have been downgraded to lower-quality, rainfed lands in much of Northern India over the last fifty years. As a result, private companies have not found pulse seed production profitable, and much of the seed production is left to public sector institutions (Singh, Shahi, and Singh 2016b). The seed replacement rate is very low, ranging from 10-20% in 2011 for the most common pulses in Bihar (Ministry of Agriculture and Farmers' Welfare 2011). Pulses crops are also sensitive to production risks such as drought, extreme temperatures, and pest attacks, and there are large yield gaps between agricultural research stations and farmers (Singh, Shahi, and Singh 2016b) as well as between India and the rest of the world (Roy et al. 2022). Total pulse production in Bihar decreased from 987.4 thousand tons in 1970 to 522 thousand tons in 2014, mainly due to large decreases in area cultivated (Singh, Shahi, and Singh 2016a).

Despite these challenges, pulses remain an important part of Indian diets and there are opportunities for Indian pulses to catch up to the technological frontier. Intercropping with rice and wheat can potentially improve yields and improve sustainability in the face of climate change, as compared to mono-crop agriculture. There is also potential to grow pulses in the summer "Zaid" season, on land which lays fallow between rice and wheat planting. Bihar has large amounts of fallow land suitable for pulses. Additionally, advances in short-duration pigeon pea and new pulse varieties tolerant to abiotic stresses, such as heat-tolerant chickpea, can reduce the production risk faced by farmers (Singh, Shahi, and Singh 2016b). With these possibilities in mind, the program was created to reintroduce pulses in areas where it had once been prevalent and where productivity could be improved. The program targeted smallholders, with the purpose of making pulses attractive for both commercial and home production, as pulses fulfill important dietary requirements for these households.

Bihar has two main agriculture seasons: the dry "Rabi" season from November to March when wheat is cultivated and the monsoon "Kahrif" season from June to October when rice is cultivated. There is also a short "Zaid" season from March to May which occurs between Rabi and Kharif, but most land is left fallow during Zaid. In terms of pulse crops, green peas, lentils, fava beans, chickpeas, and kidney beans can be grown in the Rabi season. Pigeon pea is planted in the Kharif season but is a long-duration crop and stands in the field for both the Kharif and Rabi seasons. Black gram, cowpeas, and grasspeas can be grown in both the dry and wet seasons. Green gram is most suitable for the Zaid season on plots with residual moisture.

3 Intervention and Timeline

The program attempted to remove farmers' barriers related to quality seed availability and knowledge by providing support to smallholder farmers in the form of seed distribution, extension services, and demonstration plots to display pulse cultivation. We first describe the "high intensity" program, and then explain how it was modified for our two additional treatment arms.

The "high intensity" program distributed certified pulse seeds in the Kharif and Rabi seasons (the timeframe of our study).[2] Pigeon pea seed was distributed in all districts and treatment arms in the Kharif season. Lentil, pea, fava bean, chickpea, and kidney bean seeds were distributed in the Rabi season, although the exact mix of seeds distributed differs by district (see Appendix Table 1 for more details). Pigeon pea and lentil were the main crops promoted by the program but an important objective for program implementers was to encourage the cultivation of all suitable pulse crops and provide both general and crop-specific information to farmers. Implementers communicated upfront that seed subsidies would be temporary. This was done to incentivize take-up while holding the long-term costs of cultivation constant. The idea was that providing free seed would initially motivate farmers to take up pulse cultivation and to continue in subsequent seasons even without subsidies once they gained experience. Following this study, the subsidy on seed was gradually reduced and Farmer Producer Companies (FPCs) were formed, through which pulse seed was distributed at full cost to farmers. Results for marketing interventions can be found in (Lybbert et al. 2023).

While the seed distribution eased access to quality seeds, the other program interventions focused on increasing farmer knowledge. Extension services were implemented through farmer

[2] The process of seed certification requires that a registered grower use foundation seed for production and that the production process is supervised and certified for quality by a state agency. Certified seeds generally have higher yield potential than indigenous seed varieties. Foundation seed is developed by public and private institutions under the supervision of seed certification agencies.
A pilot in the 2017 Zaid cropping season also distributed high-quality certified seeds to farmers who were not in the evaluation sample.

groups. Following the announcement of the program, implementers went to program villages and formed groups with farmers interested in pulse cultivation. Through these farmer groups, implementers conducted monthly meetings, trainings centered on important steps in the cultivation process such as germination, flowering, pruning, etc., and visits to individual member's farms by Agriculture Extension Officers, who were part of the implementing organization staff. The extension services also had an awareness generation component that was implemented at the village level. Interventions included wall paintings, billboards, video screenings, mic announcements, public plays and songs, puppet shows, literature distribution, and exposure visits to local agricultural universities. These media were used to communicate information about best cultivation practices, as well as information on the potential benefits of pulse cultivation such as increased income, increased protein intake, and improved soil quality.

The pulse promotion program also set up demonstration plots, in which selected farmers received additional support to demonstrate the recommended pulse varieties. The farmer groups identified demonstration farmers, which required 0.5 acres of available land, a suitable field location, and a willingness to adhere to the package of best practices for pulses farming. The program provided demonstration farmers with necessary inputs such as fertilizer, pesticide, and herbicide. Additionally, Agriculture Extension Officers from the implementing organization also provided weekly on-farm training which was more intensive than the on-farm visits provided through regular extension.

While the "high intensity" program provided farmers with a comprehensive support package, it would be costly to implement at scale. Therefore, the "high intensity" would have to show substantial returns to be scaled up as part of a government policy. The implementing partners and research team created two additional program models to identify the level of support necessary to assist farmers in initial pulse cultivation. Each model takes away one layer of intervention from "high" to "low intensity."

The "medium intensity" model removes the demonstration plots (keeps seed distribution and extension), and the "low intensity" model additionally removes the extension services (keeps seed distribution). In addition, seed distribution in the "low intensity" model varied slightly from the other models. In the "medium" and "high intensity" models, seed orders were taken in a village meeting and then seed was directly distributed to farmers at distribution points in their respective villages. In the "low intensity" model, seed vouchers were distributed to interested farmers in a village meeting, and farmers then had to bring the voucher to a central location on specific dates to avail free seed. Seed distribution points for "low intensity" villages were 1-5 km away from the village. A valid government ID was required to avail seed in all three program models. Although the seed distribution in "low intensity" is not identical to "medium" and "high", the "low intensity" model was designed to look similar to a government seed distribution program in which farmers need to come to block offices (sub district unit) to obtain seed. Compared to the "medium" and "high" distribution, this decreases implementation costs as implementing staff do not need to go directly to every village but it increases the opportunity cost for farmers as they now need to travel to obtain seed. With the opportunity cost in mind, we expect that treatment effects for the "low intensity" arm are a lower bound for what they would be if the seed distribution had been identical to "medium" and "high." Further description of the treatment arms can be found in Table 1.

Staff of implementing partner organizations began the Kharif season activities following initial meetings in June 2017. Meetings were held in all evaluation villages (both treatment and control) before random assignment was done. Implementing partners facilitated a general discussion about agriculture and pulse cultivation in these meetings. Attendance lists were collected at these meetings and served as the sampling frame for the evaluation. Implementers were informed of villages' treatment status after the initial meetings and seed distribution for treatment villages happened from June 15 to July 7th, 2017. The Kharif seed distribution missed the window for early sowing but was on time for regular and late sowing. Extension activities spanned the entire Kharif season from June to November 2017.

In October 2017, prior to the Rabi season, implementers visited "high", "medium", and "low intensity" villages to announce the program for Rabi. Solicitation of seed orders, establishment of demonstration plots, and seed distribution occurred in October 2017. Farmers sowed Rabi pulses following the rice paddy harvest in late-October to mid-November 2017. Extension activities spanned the duration of the season from November 2017 to April 2018. The main pulses crop in Kharif, pigeon pea, was not harvested until March/April 2018 (along with Rabi pulses) because of its longer duration.

Appendix Table 2 presents the proportion of households reached by specific demonstration and extension activities in each study arm. Around 25% of households in “high intensity” villages in our sample said they were aware of a demonstration plot for pulse cultivation in their village. A small percentage of households in “low”, “medium”, and control also said they were aware of demonstration plots. This is possible as villages were fairly close together and demonstration plots were visibly marked with signs. Additionally, some control farmers reported participating in other extension activities. However, the survey questions asked about general activities in the village, without regard to a specific NGO. There were other extension programs in the area supported by the government/NGOs that could be captured in these questions. Farmer group membership and meeting attendance was relatively high in the “medium” and “high” intensity groups, but awareness generation activities had a lower reach. For instance, 43% of farmers in our “high intensity” sample attended a farmer group meeting but only 17% of “high intensity” farmers attended a public video screening. Overall, the data on extension suggests reasonable extension penetration in the “medium” and “high” treatment arms.

4 Evaluation Design

The study design is a four-arm cluster randomized controlled trial (RCT) with randomization at the village level. We developed the randomization strategy and sampling design in collaboration with the research team conducting the long-term evaluation studied in Lybbert et al. (2023). One treatment arm was dedicated to each of the three program models, along with a control group. After conducting a pilot of the program in the 2017 Zaid (spring) season, implementing partner NGOs identified potential villages for roll-out in the 2017 Kharif season. Villages from the pilot were not eligible for the evaluation as implementers had already promised support for subsequent seasons, meaning these villages could not be randomized. Implementers identified 158 villages across all five program districts through this process which comprised our sample for randomization.

Randomization was stratified by block as villages in the same block are likely to share similar characteristics, helping to ensure balance across groups. There were ten blocks total, two contiguous blocks in each district. For all blocks except those in the East Champaran district, roughly 30% of villages were assigned to control and the remaining 70% were split between the three treatment arms. A larger proportion of the villages in East Champaran (52%) were assigned to the control group due to implementation constraints and the overall large number of villages in that district identified as eligible for the study.

The sample consists of a random selection of farmers who attended a pre-intervention meeting discussing pulse farming in their area. As mentioned earlier, meetings were held in both treatment and control villages before the random assignment was done. In these meetings, the implementing NGOs explained they might be working in the area and facilitated a general discussion about agriculture in the village. No inputs or other support were promised to farmers in these meetings. Farmers were asked to provide information in a sign-in sheet at the meeting and the households listed on the sign-sheets make up our sampling frame. The meeting was advertised to all farmers in the village as relevant for households interested in pulse cultivation. Therefore our study population (in both treatment and control), are farmers interested in pulse cultivation. As not all of the farmers in the treatment groups ended up attending future meetings or activities, our results can be thought of as an "intention to treat" estimator among this population.

5 Data and Descriptive Statistics

We conducted two rounds of surveys: one midline survey in-person during the Rabi season (before pigeon pea harvest but just after Rabi sowing), and an endline survey over the phone after the Rabi harvest. We did not conduct a baseline survey prior to randomization and therefore household characteristics reported for balance in Table 2 are those that are fixed and should not change as a result of treatment. The midline household survey, conducted from November 2017 - January 2018, focused on the outcomes of pulses adoption, area, and best practices.[3] For our survey sample, we randomly sampled fifteen households in each village from the list of "kick-off" meeting attendees. Sample households look identical on average across study arms as kick-off meetings were held in all treatment and control arms. A total of 2,346 households were surveyed.

A second round of surveys was conducted May-June 2018 to assess pulse production and yield outcomes. Although we followed up with the same farmers, the second round asked different

[3] This survey was conducted in coordination with researchers involved in the long-term impact evaluation. A subset of our sample received a longer questionnaire with extra sections related to their research questions.

questions and focused on different outcomes than the first round so the two surveys do not constitute a panel. We surveyed households that reported growing pulses in the pre-harvest survey to follow up about production outcomes for each type of pulse grown. Of the 2,346 households surveyed pre-harvest, 1,533 said they planted pulses in either the Kharif or Rabi season. The post-harvest survey was conducted over the phone, using the household phone numbers collected during the pre-harvest survey. We were able to reach and survey 1,266 of the 1,533 pulse-growing households from the first round, resulting in a response rate of 82.6%.[4] Slightly after our phone survey, researchers from the long-term impact evaluation team conducted a separate in-person survey on production outcomes on a subset of our sample with identical questions. A comparison of responses by survey mode can be found in (Anderson et al. 2024). Although production responses are larger over the phone, this holds for both treatment and control groups, and evaluation results are not affected by survey mode. We additionally use data from the in-person survey to obtain crop prices for our production value analysis.

Table 2 presents summary statistics and balance tests of baseline characteristics for our survey sample. The average respondent was a 48-year-old male whose household cultivated around 1 hectare of land across 6 plots. Household characteristics are mostly balanced across study arms, except for small differences in gender between the "low" and "medium intensities" and in the rate of sharecropping between the "high intensity" and control. Of all sample households, 64% had cultivated pulses in at least one season prior to Kharif 2017. There are no significant differences in prior cultivation between the treatment and control groups. As stated above, there was no baseline survey so we only included fixed characteristics in the balance table and, as the goal of the survey was to be relatively short, we did not conduct an in-depth socio-demographic module for the entire sample.[5]

6 Empirical Strategy

Our primary research question explores the effect of each treatment arm on adoption of pulse cultivation using a binary variable for whether the household planted pulses and total area un-

[4] Response rates were balanced across study arms; control: 82.1%, low: 82.3%, medium: 82.8%, high: 83.3%

[5] A random sample chosen for the extended questionnaire was asked additional questions such as housing type, participation in welfare programs, and household assets.

der pulse cultivation (ha). The empirical strategy closely follows that laid out in a registered pre-analysis plan with 3ie's Registry for International Development Impact Evaluations, and any deviations from the plan are explained in this section (Anderson and Stein 2018). We estimate the probability that household i in village j and block k cultivates any pulse variety in the 2017 Kharif or 2017-2018 Rabi season (Y_{ijk}) using Ordinary Least Squares (OLS) regression. Although the primary pulse cultivated in the Kharif season (pigeon pea) is a long-duration crop that was still in the field during Rabi, it is only counted as part of adoption in the Kharif season. The specification is represented by the following equation:

$$Y_{ijk} = \beta_0 + \beta_1 L_{jk} + \beta_2 M_{jk} + \beta_3 H_{jk} + \boldsymbol{\beta_4 \delta_{ijk}} + \gamma_k + \varepsilon_{ijk} \quad (1)$$

where L_{jk}, M_{jk}, and H_{jk} are binary variables indicating whether village j in block k was assigned to the "low", "medium", or "high intensity" treatment group respectively, with control as the reference group. $\boldsymbol{\delta_{ijk}}$ is a vector of additional household-level covariates which include: a binary variable for having cultivated pulses at least once in the 2 years prior to the 2017 Kharif season; binary variables for caste categories; respondent age; and respondent gender. γ_k is a block fixed effect as randomization was stratified at the block level and ε_{ijk} is the error term for household i in village j and block k. Standard errors are clustered at the village level. The same specification is used for binary adoption of pulse cultivation as well as area under cultivation. Given that we found no statistically significant differences between treatment groups, we also present results with all treatment groups pooled, providing higher precision.[6]

Our secondary research questions examine each program model's impact on pulse production. We estimate treatment effects for our secondary research questions using the same empirical model, however, we add weights to account for phone-based attrition. Production outcomes were collected over the phone in an endline survey for pulse growers. Households that did not report growing pulses at midline are assumed to have zero production. To account for attrition in the phone survey, we assign a weight of 1 to pulse-growing respondents and a weight of 0.83 (the phone survey response rate) to non-pulse growers. This assumes that attrition patterns for non-pulse growers would have been the same as for pulse growers. We measure

[6]The plan to pool treatments if they have similar outcomes was described in the pre-analysis plan. Additionally, the specification in the pre-analysis plan includes a control variable for households with pulses crops affected by flooding in the Kharif season. Unfortunately, this variable was misspecified in the programming of the survey, as it was only asked of households that planted pulses, and is therefore endogenous.

the production outcome through total production of pulses crops, total production value, and production of individual pulses crops. The total production variable was constructed by adding the weight harvested (kg) across all pulse crops cultivated in the relevant season. Kharif pulses production includes pigeon pea, black gram, and cowpea. Seed was only distributed for pigeon pea as pigeon pea is the most commonly grown pulse in that season. Rabi season production is aggregated across peas, lentils, fava beans, chickpeas, kidney beans, black gram, cowpeas, and grass peas. Although production value (weighting the amount harvested by each crop's farm gate price, i.e., the price (INR) received directly by the farmer) is not captured in our pre-analysis plan, we decided to include it as a production outcome considering that total production includes multiple crops which sell for different prices. We multiplied production for each pulse crop and household by the median farm gate price in each district to construct production value. We also analyzed the amount harvested (kg) for individual pulse crops; however, it should be noted that the evaluation sample size was not calculated with differences among individual crops in mind.

The regression coefficients of our model estimate the effect of each treatment group compared to the control, but they do not test differences between each of the three program models. We therefore conduct pairwise comparisons of the three program models for each outcome using Wald tests, which test the equality of combinations of regression coefficients.

In addition, we conduct exploratory analyses of the program models' effects on best pulse farming practices and yield. These outcomes are specified in our pre-analysis plan, however, we will refer to them as exploratory because they are not causally identified. Pulse farming practices and yield can only be measured for those households that planted pulses and the decision to plant is endogenous, whereas adoption and production can be measured for all households. The results presented for best practices and yield are a combination of treatment and selection effects. Best pulse practices adoption was measured using an index for each season. Farmers who identified growing pulses were asked about their practices in the pre-harvest survey. Binary variables, indicating whether a practice was adopted by the farmer, were created for each practice recommended by the program. Best practices included in the index are rounds of plowing, use of planking or harrowing, use of cultivator as part of land preparation, use of recommended seed treatments, use of line sowing, seed rate, line-to-line and plant-to-plant distance if line sowing, use of recommended fertilizers, use of weedicides and/or weeding, disease and insect attack mitigation strategies if relevant, and knowledge of soil moisture. The binary variables were then combined into a single index using the inverse-covariance weighting approach described in Anderson (2008).

Similar to production, we measure the yield outcome through total pulses yield, yield value, and individual crop yields. To calculate total pulse yield, production was added across crops and divided by total land cultivated (kg/ha). The yield value represents the monetary value of pulses produced per hectare (INR/ha). Lastly, we explore yields for individual crops (kg/ha). For the best practices and yield outcomes, we run the same specification as for the main outcomes.

7 Results

This section provides estimates of treatment effects for each of the three treatment arms on our outcomes of interest. For most outcomes, we estimate the effect of each treatment separately as well as pooled. We report results for 2017 Kharif and 2017-2018 Rabi agricultural seasons and perform a cost-effectiveness analysis to place these treatment effects in the context of implementation costs.

7.1 Adoption

Table 3 presents treatment effects on the binary adoption outcome for the Kharif (columns 1-2) and Rabi seasons (columns 5-6), as well as a continuous outcome for area under pulse cultivation in Kharif (columns 3-4) and Rabi (columns 7-8). The pooled treatment increased the share of households cultivating any pulses in the Kharif season by 12 percentage points, compared to 20% of households that cultivated pulses in the control group. In the Rabi season, the pooled treatment increased the share of households cultivating pulses by 15 percentage points compared to 48% of households cultivating in the control group. Treatment also increased the total area under pulse cultivation, increasing by .011 hectares in Kharif and .016 hectares in Rabi (compared to control means of .015 and .053 hectares respectively). It is possible that pigeon pea growers are less likely to grow Rabi pulses because the duration for pigeon pea spans both seasons, taking up land that might have been available were shorter duration crops planted. When looking at both seasons combined (Appendix Table 6), treatment increased combined adoption by 16 percentage points, compared to 57% of control households cultivating in either season. Treatment increased the total area cultivated across both seasons by 0.027 ha compared to a control mean of 0.069 ha. While the treatment increased pulse cultivation, we cannot speak to the crops displaced by pulses or the opportunity cost of pulses in relation to other crops. However, displacement was likely low as the program encouraged farmers to grow pulses on the border of plots or inter-cropped with other crops such as mustard, coriander, and turmeric. In the long-term study, Lybbert et al. (2023) found that increased area for Kharif pulses mostly displaced rice paddy.

While treatment certainly increased pulse cultivation, we do not find any significant differences among our treatment arms. This is true for both the dummy of cultivating as well as the measure of area under cultivation and holds for both Kharif and Rabi seasons. This lack of a result is less surprising for Kharif season given that many of the differences between the treatment arms (extension, demonstration plots) take place after the planting decisions have been made. However, the non-results in Rabi are a bit more unexpected given that farmers would have learned about the services provided during the Kharif season (either first-hand or through their neighbors), which could have affected their planting decisions during Rabi. Although there were no differences in adoption between the treatment arms in either season, we do find that a higher proportion of "medium" and "high intensity" households received seed from an implementing partner NGO in Rabi compared to "low intensity" (Appendix Table 3). Farmers in the "low intensity" group were more likely to reuse older pulses seeds. There were no significant differences in seed take-up between treatment arms in Kharif.

7.2 Production

Even though we did not find differences in the adoption of pulses between the treatment arms, it could still be possible that there were differences in production due to the greater amount of extension services received by farmers in the "medium" and "high" treatment arms. Table 4 shows treatment effects on household production (kg) across all pulse crops cultivated in a season and monetary value of production (INR). Panel A presents estimates for the Kharif season and Panel B for the Rabi season. The estimates on production include all study households, weighted to account for attrition patterns in the phone survey.[7]

Overall findings are mixed by season. We do not find any significant effects on production in Kharif but do find that treatment increased production in Rabi. Although Kharif is not the main pulse cropping season in Bihar, we would have expected to see modest production increases given the increase in area cultivated. In the Rabi season, we find a significant increase in production of 18.61 kg per household from the pooled treatment, compared to the control mean of 53.09 kg per household. We do not find significant differences in production among the three treatment arms (for both Rabi and Kharif seasons). When adding total pulse production across the two seasons, we found that treatment increased total production by 19.23 kg compared to an average of 57.07 kg per household in control (Appendix Table 6).

7.3 Exploratory Outcomes

Table 5 presents estimates of the program models' effect on adoption of best farming practices (PoP). As described in Section 6, the dependent variable is an index of binary variables, indicating whether the household adopted a set of recommended farming practices. Adoption of best practices could only be assessed for households that planted pulses, and since we know that treatment induced some farmers to grow pulses, these estimates cannot be interpreted as strictly causal. Instead, they potentially represent a combination of causal and selection effects. We do not find differences between the pooled treatment and control in terms of best practices adoption in either season. This is somewhat unexpected given the differences in extension services between the arms. However, this could be a result of less-experienced farmers choosing to grow pulses in the treatment villages.

With changes in production and areas, one might expect effects on yield. Table 6 shows the effects on total yield of pulse crops (kg/ha) and monetary value of yield (INR/ha). Panel A presents estimates for the Kharif season and Panel B for the Rabi season. As with farming practices, the estimates of yield are only calculated for households that cultivate pulses, representing a combination of treatment and selection effects. We find that yields were significantly

[7] Additionally, 13 households in the midline survey reported growing pigeon peas on their plots for Rabi but not Kharif, and they were missed in the endline programming of pigeon pea questions. These households have missing values for Kharif production and are the reason for the difference in sample size between Kharif and Rabi.

lower in the treatment arms compared to the control group in both Kharif and Rabi seasons. In Kharif, yield in treatment was lower by 166.1 kg/ha compared to a control mean of 482.1 kg/ha. In Rabi, yield was lower by 153.8 kg/ha in treatment villages, compared to a control mean of 965.0 kg/ha. Once again, there were no statistically different estimates among the three treatment arms.

While the negative point estimates for yields are certainly surprising, it should be interpreted with caution. As mentioned earlier, yield estimates are only calculated for households that grow pulses, and therefore the coefficient on treatment will reflect both treatment and selection effects. As the treatment induced more farmers to grow pulses, this could mean that the sample of pulse-growers in treatment consists of less experienced farmers, therefore driving down yields. In fact, we do find that pulse-growers in treatment are 7 percentage points less likely to report having grown pulses in the previous two years (8 percentage points among Kharif pulse-growers and 6 percentage points among Rabi pulse-growers).

Table 7 presents production and yield effects of the most common individual pulses crops. Again, the production estimates are causally identified but the yield effects are potentially endogenous. We include pigeon pea in Kharif and lentil, pea, fava bean, chickpea, and kidney bean in Rabi. Consistent with overall Kharif results, we find no significant difference between treatment and control for pigeon pea production, and find a significant decrease of 186.7 kg/ha for pigeon pea yield. We find that the overall increase in Rabi production was driven by a large increase in pea production, an increase 22.81 kg per household in treatment compared to a control mean of 10.55 kg. We also found significant decreases in yield for the pooled treatment for lentil, 177.2 kg/ha, and kidney bean, 415.7 kg/ha, compared to control. There are no statistically significant differences for production and yield in chickpea or fava bean.

7.4 Cost-Effectiveness

To fully understand the results of the pulses program and its potential for scale, we conduct a cost-effectiveness analysis. For our analysis, we use the associated project implementers' 2017 budget utilization documentation to estimate the total cost of implementation per village in each treatment arm. The data includes line-item costs for all program activities and inputs.

We frame cost-effectiveness as the change in adoption and production resulting from a 1 lakh (100,000 INR or 1,566 USD at the time of the program) investment in each program model. To calculate program costs, line-item expenses from partner budget utilization data were split between the program models based on the number of villages in each arm and apportioning percentages provided by implementers. For example, project managers spent 10% of their time working on the low-intensity model, 40% on medium, and 50% on high intensity, and we attribute their salaries to the three program models in those proportions. We then add up all costs attributed to each arm and divide by the number of villages in that arm. This produced the benchmark cost estimate, which includes all costs experienced during the implementation of this study. However, it is reasonable to think that marginal costs could be much lower if scaled by the government. We therefore analyze three costing scenarios: including capital costs, excluding capital costs, and seed only. The first scenario is the benchmark which includes all program costs. In the second scenario, we categorize costs into capital and non-capital and exclude capital costs from total program costs. Capital costs include expenses incurred to run an organization that are not directly part of program delivery such as laptops, cameras, motorcycles, office equipment, and office rent. An organization looking to scale up the pulses promotion program would likely already incur these costs to run their offices. Non-capital costs include those incurred to directly run the program such as the salaries of agricultural extension officers, seeds, inputs for demonstration plots, and costs for media used in extension. In our third scenario, we focus on the low-intensity model and only include the costs of seeds, leaving out any staff salaries associated with seed distribution. This provides a lower bound for the cost-effectiveness of the "low-intensity" model. While a scaled program from the government would certainly have some logistical and management costs, in theory, they could be minimal if seed distribution were tightly integrated into existing procedures.

To calculate cost-effectiveness, we multiply the treatment effect by the number of farmers targeted by the program per village and divide by the cost per village in lakhs of INR. Cost-effectiveness for each outcome and program model are shown in Table 8. The "low intensity" model was considerably more cost-effective than the "medium" and "high intensity" across all outcomes and seasons. This result is not very surprising considering the three program models had similar treatment effects and the "low intensity" was the least expensive. The production return from the "low intensity" model was 2.5 times higher than "medium intensity" and 3.2 times higher than "high intensity." Focusing on the Rabi season (where we found significant results on pulse production), we find that an investment of 1 lakh (100,000 INR or 1,566 USD) in the "low intensity" treatment arm would result in an additional production of 7,369 kg of pulses produced. As a benchmark, 7,369 kg of peas procured in the open market in 2018 would have cost around 1.62 lakh INR or 2,300 USD.[8]

Taking into consideration our alternative costing scenarios, cost-effectiveness increases only moderately when excluding capital costs, as capital costs were only a small fraction of overall costs. However, the return on investment increases by 250%, to 25,818 kg produced per 1 lakh (1,566 USD), when only considering seed costs. Production per lakh of "low intensity" for each cost scenario is displayed in Table 9.

7.5 Threats to Identification and Robustness Checks

There were some instances where members of one household attended the initial meetings, where we collected our sampling frame, in more than one village and were sampled twice, or where a household was listed in the wrong village. To try and account for this, we conducted a robustness check in which we dropped villages where three or more respondents reported living in a village other than the one listed in our sampling frame. Dropping this condition, our results remain consistent and point estimates are similar to those of the full sample. Regression results can be found in Appendix Table 7.

In our overall sample, average adoption and area showed a sizeable increase from control to treatment arms. When splitting the sample by districts, we observed this same trend in all districts except East Champaran, where we observed the lowest adoption and area in the "high intensity", even lower than control. Based on feedback from the implementer, we had reasons to believe there may have been a higher number of spillovers in East Champaran due to proximity of treatment and control villages. We then looked at the average adoption and area, dropping treatment and control villages which were close together or had overlapping households from our sample. When doing this, the trend in East Champaran matches that of the other districts. We also ran our analysis dropping East Champaran (Appendix Table 8), and our overall results did not change.

[8] Based on 312 USD/metric ton. This corresponds to the Cost, Insurance, and Freight (CIF) price of green pea from August 2018, from http://www.agriwatch.com/newsdetails.php?Green-Pea-Import-Update&st=NEWS&commodity_id=5&sid=467075

Additionally, there are a large number of outliers at the right end of the distribution for the area, production, and yield variables. To account for this, we winsorized the area and production variables at the 95th percentile, and both trimmed yield at 3000 kg/ha and winsorized the yield at the 99th percentile. To ensure our strategy for outliers was not driving the overall results, we conducted robustness checks using different methods of handling outliers: using the same winsorization (95th percentile for production, 99th percentile for yield) without covariates, winsorization at the 99th percentile for production and 95th percentile for yield, and performing an inverse hyperbolic sine transformation instead of winsorization. We found that our overall results, presented in Appendix Tables 9, 10, and 11, are robust to the different strategies.

7.6 Limitations

The scope of this study only covers two agricultural seasons and one round of harvest. Additionally, different crops with different significance in the area are cultivated in these seasons. Our results show that seed distribution is a catalyst for increasing cultivation, but it is not clear whether the increases in adoption will be sustained, and whether adoption of best farming practices will increase in the long run. In addition, flooding and unusually cold temperatures during the study period may have brought down average production in some areas. While this effect would be similar across treatment and control, treatment effects may be different in seasons with better weather. Indeed, Rosenzweig and Udry (2020) show that causal effects vary substantially in a fixed population over time due to aggregate shocks. Additionally, the majority of pigeon pea seeds distributed by the program were of the LRG 41 variety. There is anecdotal evidence that this variety is more sensitive to cold temperatures than other certified varieties, which could have also hampered Kharif production and yield.

Our study also focuses specifically on barriers related to production inputs and information. Prices and market linkages are also important factors in farmers' cultivation decisions. Although the latter phase of the program addressed these factors, they are outside the scope of our study. Lybbert et al. (2023) find that price supports and market linkages do not increase profits compared to control farmers. Lastly, we measure post-harvest outcomes using phone surveys with self-reported production. Self-reported production can be prone to measurement error (Gourlay, Kilic, and Lobell 2019), which may be exacerbated by the phone survey format. However, in a separate study using the same data, we find that the measurement error is independent of treatment status and that treatment effects are consistent across phone and in-person survey modes (Anderson et al. 2024).

8 Conclusion and Policy Recommendations

This study examines the impact of seed distribution, extension services, and demonstration plots in overcoming initial barriers to adoption of pulses farming, and incentivizing farmers to increase their cultivation and production. We measure the impact of three program implementation models, varying the amount of support provided to farmers. Overall, we observe positive effects of all three program models on pulses adoption and production, but do not find differences between the three arms. This confirms that access to quality seed is the most important barrier to pulse cultivation. Although exploratory, we do not find evidence of increases in best practices adoption and see lowered yield in the treatment groups compared to control.

Despite mixed findings on production and yield, our results highlight that seed distribution was effective in increasing cultivation and production of pulses in a short timeframe and provided the largest return per unit of money invested. This suggests that access to quality seed is the key barrier to overcome in convincing farmers to experiment with growing pulses. Seed distribution is a promising policy option for an immediate increase in cultivation as long as suitable seeds are being distributed and the varieties being distributed do not require different practices from those traditionally used by farmers in the area. Our results suggest that the addition of demonstration plots and extension services had a limited effect on pulses adoption or productivity over this limited time horizon.

Although the success of the "low intensity" model is promising, it still leaves some unanswered questions. The program made seed available locally, had a trusted source vouch for its quality, and provided the seed for free. Therefore, it is natural to ask whether simply making trusted seed available at market price would be even more effective. Or what if the price was only partially subsidized? Lybbert et al. (2023) show that pulse adoption decreased in subsequent years of the program as seed subsidies were reduced and then removed. This suggests that price is an important factor in addition to availability. Additionally, Lybbert et al. (2023) do not find that experience with pulses throughout the program leads to sustained adoption and improved productivity in the longer term. Although seed distribution can provide a short-run increase in adoption and production, it will not sustain adoption without improvements in profitability relative to other crops.

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Table 1: Intervention Descriptions

	Activities	**Treatment Groups**
Seed distribution	Distribution of free certified pulses seeds in village	High, Medium
	Distribution of vouchers for free certified pulses seeds to be pciked up at distriution points	Low
Extension	Farmer group meetings and trainings on pulses farming best practices	High, Medium
	Farm visits from extension workers	
	Information, education, and communication activities including: Wall paintings, Street plays, Puppet shows, Literature distribution, Sign boards, Video screenings, Mic announcements, Public songs, Night meetings, Exposure visits to Agricultural Universities	
Demonstration	Establishing demonstration plots in villages to show best practices in pulses farming	High
	Free inputs such as fertilizer for demonstration farmers	
	Demonstration farmer training on best practices	
	Visits to demonstration plots by extension workers	

This table outlines the specific activities that made up the three program interventions: seed distribution, extension, and demonstration plots. We also map activities to relevant treatment arms.

Table 2: Summary Statistics

	(1) Control Mean (sd)	(2) Low - Control	(3) Medium - Control	(4) High - Control	(5) Medium - Low	(6) High - Low	(7) High - Medium	(8) N
Male	0.84	0.05	-0.02	-0.01	-0.07**	-0.06	0.01	2,346
	(0.37)	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.03)	
Age	47.57	-0.38	-1.36	-0.41	-0.98	-0.03	0.95	2,342
	(15.94)	(1.11)	(1.14)	(1.13)	(1.42)	(1.40)	(1.45)	
Respondent Household Head	0.76	0.03	-0.01	0.01	-0.04	-0.02	0.03	2,346
	(0.43)	(0.03)	(0.03)	(0.02)	(0.04)	(0.03)	(0.03)	
Caste: SC	0.16	-0.01	0.01	0.04	0.02	0.05	0.03	2,335
	(0.37)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	
Caste: ST	0.05	0.03	0.01	0.01	-0.02	-0.02	-0.00	2,335
	(0.22)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)	
Caste: OBC	0.54	0.00	0.07	0.09	0.06	0.09	0.02	2,335
	(0.50)	(0.06)	(0.06)	(0.06)	(0.07)	(0.07)	(0.07)	
Total hectares owned	0.67	-0.18	-0.17	-0.15	0.00	0.03	0.03	2,346
	(1.30)	(0.13)	(0.11)	(0.09)	(0.18)	(0.16)	(0.13)	
Total hectares cultivated	0.76	-0.14	-0.16	-0.10	-0.02	0.04	0.06	2,346
	(1.26)	(0.12)	(0.11)	(0.09)	(0.16)	(0.14)	(0.12)	
Sharecropping	0.33	0.02	0.01	0.08*	-0.01	0.05	0.06	2,346
	(0.47)	(0.05)	(0.05)	(0.04)	(0.06)	(0.05)	(0.05)	
Grew Pulses Previously	0.64	0.03	-0.01	-0.01	-0.04	-0.04	0.00	2,344
	(0.48)	(0.05)	(0.04)	(0.04)	(0.05)	(0.05)	(0.05)	
Joint F-stat		1.62	0.51	1.01	0.89	1.44	0.70	
Joint P-value		0.093	0.887	0.436	0.546	0.157	0.721	

This table summarizes OLS estimates of balance between study arms. Variables are listed on the left. Column (1) reports the mean and standard deviation of the control group. Columns (2)-(7) report the difference between group means for pairs of study arms. Standard errors are reported under the difference in means. Column (8) reports the sample size for each variable. The unit of observation is the household for all variables. All sample households are included; however, age, caste, and previous experience with pulses information is missing for some households. The pulses experience variable indicates whether the household had grown any pulses in the 2 years prior to the 2017 Kharif season. * significant at 10%; ** significant at 5%; *** significant at 1%. F-statistics and p-values for joint test of significance between arms are reported at the bottom of the table.

Table 3: Adoption and Area Results for Kharif and Rabi

	(1) Kharif Adoption	(2) Kharif Adoption	(3) Kharif Area Planted (ha)	(4) Kharif Area Planted (ha)	(5) Rabi Adoption	(6) Rabi Adoption	(7) Rabi Area Planted (ha)	(8) Rabi Area Planted (ha)
Treatment	0.118***		0.011***		0.148***		0.016**	
	(0.025)		(0.003)		(0.032)		(0.007)	
Low Intensity		0.103***		0.010**		0.119***		0.017
		(0.037)		(0.004)		(0.044)		(0.011)
Medium Intensity		0.112***		0.010***		0.165***		0.019**
		(0.032)		(0.003)		(0.040)		(0.008)
High Intensity		0.138***		0.012***		0.159***		0.013
		(0.030)		(0.004)		(0.040)		(0.008)
Observations	2346	2346	2346	2346	2346	2346	2346	2346
R-squared	0.219	0.220	0.199	0.199	0.142	0.143	0.146	0.146
Control Mean	0.199	0.199	0.015	0.015	0.477	0.477	0.053	0.053
Low vs. Medium (P-value)		0.815		0.983		0.330		0.859
Low vs. High (P-value)		0.355		0.648		0.393		0.725
Medium vs. High (P-value)		0.443		0.581		0.888		0.504

Note: This table presents OLS estimates of treatment effects for adoption and area. Outcome variables are listed in column headings. Columns (1)-(2) report treatment effects for pulse adoption in the 2017 Kharif season and (3)-(4) for area under pulse cultivation (hectares) in the Kharif season. Columns (5)-(8) report the same for the 2017-2018 Rabi season. For each dependent variable, the first column reports the pooled effect of all treatment groups and the second column reports treatment effects of the low, medium, and high treatment groups respectively compared to control. All regressions include covariates and fixed effects at the block (sub-district) level. P-values of Wald post-estimation tests for each pair of coefficients are reported under regression results. Standard errors are clustered at the village level, and displayed in parentheses under the coefficient. The unit of observation is the household for all variables. Crop areas for individual agricultural plots were aggregated at the household level. All sample households are included. Crop areas were approximated for plots with mixed or intercropped cropping patterns. Area is winsorized at the 95th percentile. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 4: Production Results for Kharif and Rabi

Panel A: Kharif Results

	(1) Kharif Production (kg)	(2) Kharif Production (kg)	(3) Kharif Production Value (INR)	(4) Kharif Production Value(INR)
Treatment	0.72		25.22	
	(0.87)		(30.68)	
Low Intensity		0.63		21.65
		(1.22)		(42.33)
Medium Intensity		0.83		26.45
		(1.39)		(48.50)
High Intensity		0.68		27.31
		(0.99)		(35.70)
Observations	2066	2066	2066	2066
R-squared	0.11	0.11	0.11	0.11
Control Mean	4.72	4.72	165.31	165.31
Low vs. Medium (P-value)		0.90		0.93
Low vs. High (P-value)		0.97		0.90
Medium vs. High (P-value)		0.92		0.99

Panel B: Rabi Results

	(1) Rabi Production (kg)	(2) Rabi Production (kg)	(3) Rabi Production Value (INR)	(4) Rabi Production Value (INR)
Treatment	18.61**		296.53*	
	(7.63)		(168.40)	
Low Intensity		18.69		290.20
		(13.34)		(289.15)
Medium Intensity		19.06*		307.25
		(9.80)		(201.11)
High Intensity		18.07**		291.24
		(8.01)		(182.15)
Observations	2079	2079	2079	2079
R-squared	0.17	0.17	0.17	0.17
Control Mean	53.09	53.09	1346.37	1346.37
Low vs. Medium (P-value)		0.98		0.95
Low vs. High (P-value)		0.96		1.00
Medium vs. High (P-value)		0.92		0.94

Note: This table summarizes OLS estimates of treatment effects for production. Outcome variables are listed in column headings. Panel A includes estimates for the 2017 Kharif season and Panel B for the 2017-2018 Rabi season. Columns (1)-(2) report treatment effects for pulses production (kg), (3)-(4) for pulses production weighted by each crop's average farm gate price per kg (INR). For each dependent variable, the first column reports coefficients for the pooled treatment effect and the second column reports treatment effects of the low, medium, and high treatment groups respectively compared to control. All regressions include covariates and fixed effects at the block (sub-district) level. P-values of Wald post-estimation tests for each pair of coefficients are reported under regression results. Standard errors are clustered at the village level, and displayed in parentheses under the coefficient. The unit of observation is the household for all variables. All sample households are included in production regressions. Households that did not grow pulses were assigned zero production. As households that did not plant pulses were not surveyed at harvest and did not have the opportunity to attrit from the survey, we assigned pulse-growing households a weight of 1 and non-pulse growing households a weight of 0.83 (the response rate to the survey). There were 13 households that reported growing pigeon pea in Rabi and not Kharif (when pigeon pea is planted) and they were mistakenly skipped in the programming of the survey for the pigeon pea production question. Therefore, they have missing values for pigeon pea production, which is the reason for the difference in sample size between Kharif and Rabi. Production is Winsorized at the 95th percentile. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 5: Best Practices Adoption Results for Kharif and Rabi

	(1) Kharif PoP	(2) Kharif PoP	(3) Rabi PoP	(4) Rabi PoP
Treatment	0.13		-0.06	
	(0.10)		(0.06)	
Low Intensity		0.21*		-0.11
		(0.12)		(0.07)
Medium Intensity		0.08		-0.05
		(0.10)		(0.08)
High Intensity		0.13		-0.02
		(0.14)		(0.09)
Observations	687	687	1274	1274
R-squared	0.05	0.05	0.03	0.03
Control Mean	-0.00	-0.00	0.00	0.00
Low vs. Medium (P-value)		0.23		0.46
Low vs. High (P-value)		0.52		0.32
Medium vs. High (P-value)		0.68		0.77

Note: This table summarizes OLS estimates of treatment effects for adoption of the package of best farming practices (PoP) recommended by program implementers. Outcome variables are listed in column headings. Column (1)-(2) reports treatment effects for PoP adoption in the 2017 Kharif season and (3)-(4) for the 2017-2018 Rabi season. The first column for each outcome estimates pooled treatment effects and the second reports effects for each treatment group separately. PoP adoption is measured through an index of binary variables for individual farming practices constructed using the method in Anderson (2008). All regressions include covariates and fixed effects at the block (sub-district) level. P-values of Wald post-estimation tests for each pair of coefficients are reported under regression results. Standard errors are clustered at the village level, and displayed in parentheses under the coefficient. The unit of observation is the household for all variables. The sample is restricted to households growing pulses in the relevant season. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 6: Yield Results for Kharif and Rabi

Panel A: Kharif Results				
	(1) Kharif Yield (kg/ha)	(2) Kharif Yield (kg/ha)	(3) Kharif Yield Value (INR/ha)	(4) Kharif Yield Value (INR/ha)
Treatment	-166.1***		-5975.3***	
	(60.3)		(2113.2)	
Low Intensity		-233.7***		-8269.1***
		(60.9)		(2141.5)
Medium Intensity		-122.8		-4518.2
		(82.6)		(2949.2)
High Intensity		-158.6**		-5707.8***
		(61.7)		(2157.8)
Observations	535	535	535	535
R-squared	0.05	0.06	0.05	0.05
Control Mean	482.1	482.1	17483.7	17483.7
Low vs. Medium (P-value)		0.12		0.15
Low vs. High (P-value)		0.12		0.15
Medium vs. High (P-value)		0.61		0.64
Panel B: Rabi Results				
	(1) Rabi Yield (kg/ha)	(2) Rabi Yield (kg/ha)	(3) Rabi Yield Value(INR/ha)	(4) Rabi Yield Value (INR/ha)
Treatment	-153.8**		-4274.0**	
	(62.8)		(1822.8)	
Low Intensity		-126.0		-3944.2*
		(83.5)		(2290.8)
Medium Intensity		-179.2**		-5058.7**
		(72.2)		(2013.5)
High Intensity		-151.4*		-3732.6*
		(77.4)		(2200.8)
Observations	852	852	852	852
R-squared	0.09	0.09	0.08	0.08
Control Mean	965.0	965.0	25893.8	25893.8
Low vs. Medium (P-value)		0.51		0.58
Low vs. High (P-value)		0.77		0.92
Medium vs. High (P-value)		0.70		0.48

Note: This table summarizes OLS estimates of treatment effects for yield. Outcome variables are listed in column headings. Panel A includes estimates for the 2017 Kharif season and Panel B for the 2017-2018 Rabi season. Columns (1)-(2) report treatment effect for pulses yield (kg/Ha) and (3)-(4) for monetary yield (INR/Ha). For each dependent variable, the first column reports coefficients for the pooled treatment effect and the second column reports treatment effects of the low, medium, and high treatment groups respectively compared to control. All regressions include covariates and fixed effects at the block (sub district) level. P-values of Wald postestimation tests for each pair of coefficients are reported under regression results. Standard errors are clustered at the village level, and displayed in parentheses under the coefficient. The unit of observation is the household for all variables. Yield variables are limited to households growing pulses in the relevant season. The production variables and areas used for the yield calculation were aggregated across all pulses crops relevant for the season. Yield is trimmed at 3,000 kg/ha and Winsorized at the 99th percentile. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 7: Pooled Treatment Crop-Wise Production and Yield Results for Kharif and Rabi

Panel A: Pigeon Pea, Lentil, Pea

	(1) Kharif Pigeon Pea Production (kg)	(2) Kharif Pigeon Pea Area Planted (ha)	(3) Kharif Pigeon Pea Yield (kg/ha)	(4) Rabi Lentil Production (kg)	(5) Rabi Lentil Area Planted (ha)	(6) Rabi Lentil Yield (kg/ha)	(7) Rabi Pea Production (kg)	(8) Rabi Pea Area Planted (ha)	(9) Rabi Pea Yield (kg/ha)
Treatment	0.59	0.012***	-186.7***	-1.65	0.008**	-177.2***	22.81***	0.006***	-73.7
	(1.82)	(0.003)	(63.9)	(6.59)	(0.004)	(64.9)	(7.97)	(0.001)	(142.1)
Observations	2066	2066	529	2079	2079	611	2079	2079	224
R-squared	0.08	0.21	0.06	0.15	0.20	0.07	0.14	0.11	0.22
Control Mean	8.38	0.014	495.6	40.08	0.030	929.0	10.55	0.003	997.1

Panel B: Fava Bean, Chickpea, Kidney Bean

	(10) Rabi Fava Bean Production (kg)	(11) Rabi Fava Bean Area Planted (ha)	(12) Rabi Fava Bean Yield (kg/ha)	(13) Rabi Chickpea Production (kg)	(14) Rabi Chickpea Area Planted (ha)	(15) Rabi Chickpea Yield (kg/ha)	(16) Rabi Kidney Bean Production (kg)	(17) Rabi Kidney Bean Area Planted (ha)	(18) Rabi Kidney Bean Yield (kg/ha)
Treatment	2.49	0.000	-85.2	-0.43	0.001	-111.1	0.71	0.000	-415.7*
	(1.69)	(0.001)	(146.8)	(1.57)	(0.001)	(179.0)	(1.05)	(0.001)	(225.3)
Observations	2079	2079	253	2079	2079	61	2079	2079	50
R-squared	0.07	0.10	0.08	0.03	0.03	0.36	0.05	0.06	0.18
Control Mean	8.19	0.005	956.4	1.66	0.002	661.1	0.92	0.001	831.6

Note: This table summarizes OLS estimates of treatment effects for individual crops. Outcome variables are listed in column headings. Columns (1)-(3) report treatment effects for Kharif pigeon pea production, area and yield, (4)-(6) for Rabi lentil production, area and yield, (7)-(9) for Rabi pea production, area, and yield, (10)-(12) for Rabi fava bean production, area, and yield, (13)-(15) for Rabi chickpea production, area, and yield, and (16)-(18) for Rabi kidney bean production, area, and yield. Coefficients are reported for pooled treatment compared to control. All regressions include covariates and fixed effects at the block (sub district) level. P-values of Wald postestimation tests for each pair of coefficients are reported under regression results. Standard errors are clustered at the village level, and displayed in parentheses under the coefficient. The unit of observation is the household for all variables. All sample households are included for production and area with production regressions including weighting for attrition. Yield variable is limited to households growing pulses in relevant season. There were 13 households that reported growing pigeon pea in Rabi and not Kharif (when pigeon pea is planted) and they were mistakenly skipped in the programming of the survey for the pigeon pea production question. Therefore, they have missing values for pigeon pea production, which is the reason for the difference in sample size between Kharif and Rabi. For all crops except chickpea and kidney bean, production is Winsorized at the 99th percentile; area is Winsorized at the 95th percentile; and yield is trimmed at 3,000 kg/ha and then Winsorized at the 99th percentile. Yield was trimmed at 3000 kg/hecate for chickpea and fava bean, however, no values were Winsorized as these crops had fewer than 100 observations. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 8: Cost Effectiveness Including Capital Costs

	Low	Medium	High
Costs per Village	55976	140782	172661
Households per 1lakh (Kharif)	41	18	18
Households per 1lakh (Rabi)	47	26	20
Hectares per 1lakh (Kharif)	4	2	2
Hectares per 1lakh (Rabi)	7	3	2
Production (kg) per 1lakh (Kharif)	248	130	87
Production (kg) per 1lakh (Rabi)	7369	2988	2310

Note: This table presents implementation costs per village for each treatment arm (INR) and the change in outcomes per 1 lakh (100,000) INR invested in each treatment. Implementation costs include capital costs such as vehicles, office supplies, etc. Costs were split by treatment arms based on percentages given by implementers for each budget line item. Changes in outcomes were determined by treatment effects in Tables 3 and 4 and the number of farmers targeted by the program per village.

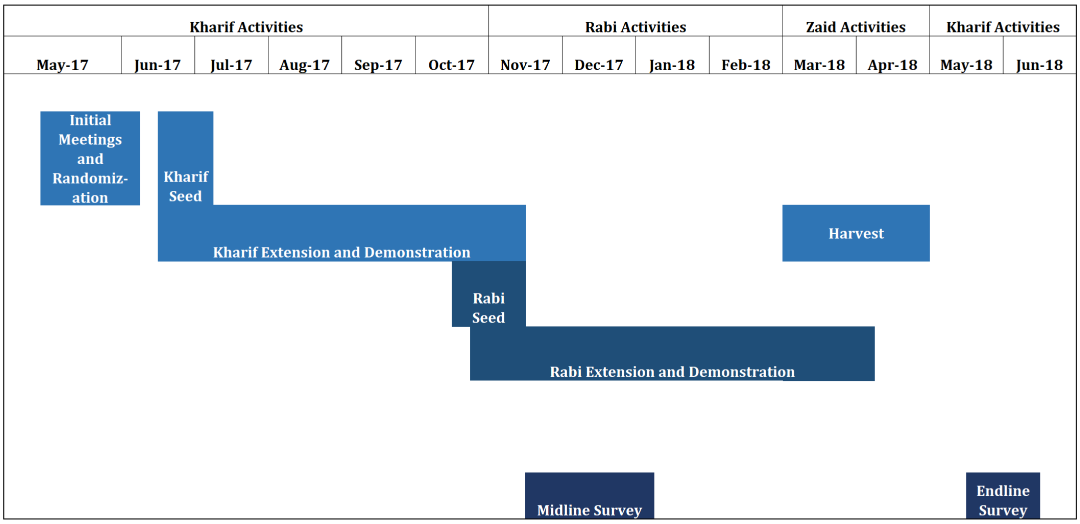
Table 9: Cost Effectiveness Low Intensity Production

	Cost per village	Production per 1lakh	
		Kharif	Rabi
Including Capital Costs	55,976	248	7,369
Excluding Capital Costs	49,355	282	8,357
Seed Only	15,976	870	25,818

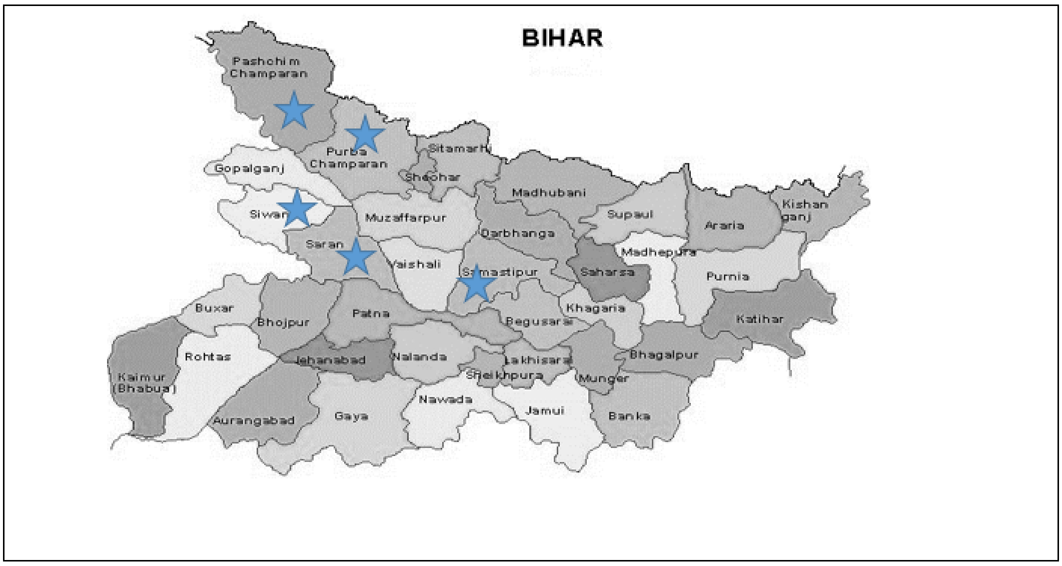
Note: This table presents implementation costs per village and the change in outcomes per 1 lakh (100,000) INR invested in the "low-intenisty" model under different costing scenarios. The first row includes all costs. The second row excludes capital costs that are necessary for running an organization but not for directly implementing the program such as such as vehicles, office supplies, etc. The third row presents the return on investment for the "low-intensity" model only taking seed costs into account. Costs were split by treatment arms based on percentages given by implementers for each budget line item. Changes in outcomes were determined by treatment effects in Tables 3 and 4 and the number of farmers targeted by the program per village.

Supplementary Appendix for "What Are the Barriers to Pulse Cultivation in India? Evidence from a Randomized Controlled Trial"

Appendix Figure 1: Timeline of Interventions and Data Collection



Appendix Figure 2: Map of Study Districts



Appendix Table 1: Seed Types Distributed

	Districts	**Treatment Arms**
Pigeon pea	All	High, Medium, Low
Lentil	All	High, Medium, Low
Pea	Samastipur, Saran, Siwan	High, Medium, Low
	West Champaran	High demonstration farmers only
Fava bean	Samastipur	High, Medium, Low
Chickpea	Samastipur	High, Medium, Low
	East Champaran	High, Medium
	West Champaran	High demonstration farmers only
Kidney Bean	Samastipur	High, Medium, Low
	West Champaran	High demonstration farmers only

Note: This table indicates the type of pulse seeds distributed by the program in each district and treatment arm. The study included 5 districts: East Champaran, West Champaran, Saran, Siwan, and Samastipur. Although a mix of seeds was distributed, the main crops promoted by the program were pigeon pea and lentil.

Table 2: Extension Exposure

	Control	Low	Medium	High
Aware of demonstration plot	0.05	0.09	0.14	0.25
Memeber of farmers group	0.34	0.54	0.61	0.58
Attended farmer group meeting	0.23	0.32	0.45	0.43
Attended training	0.07	0.17	0.26	0.31
Attended street play	0.02	0.04	0.09	0.07
Attended night meeting	0.01	0.02	0.06	0.04
Attended video screening	0.02	0.04	0.16	0.17
Attended puppet show	0.01	0.00	0.01	0.02
Observed wall painting	0.05	0.15	0.34	0.38
Observed billboard	0.03	0.14	0.27	0.26
Heard mic announcement	0.07	0.09	0.17	0.18
Heard public song	0.01	0.02	0.05	0.08
Aware of literature distribution	0.05	0.07	0.18	0.20
N	876	464	513	493

This table presents percentages of farmers aware of demonstration and extension activities happening in their village in each study arm. The survey questions on farmer group membership and meeting attendance did not specifically mention implementing NGOs and may refer to any program working in the area.

Appendix Table 3: Seed Take-up for Kharif and Rabi

	(1) Kharif Take-up	(2) Kharif Take-up	(3) Rabi Take-up	(4) Rabi Take-up
Treatment	0.18***		0.21***	
	(0.02)		(0.02)	
Low Intensity		0.15***		0.12***
		(0.02)		(0.02)
Medium Intensity		0.19***		0.26***
		(0.02)		(0.03)
High Intensity		0.21***		0.24***
		(0.03)		(0.03)
Observations	2346	2346	2346	2346
R-squared	0.16	0.16	0.12	0.14
Control Mean	0.00	0.00	0.02	0.02
Low vs. Medium (P-value)		0.18		0.00
Low vs. High (P-value)		0.09		0.00
Medium vs. High (P-value)		0.64		0.72

This table reports estimates of the effect of treatment on take-up of seed distributed by the implementing NGOs. Seed take-up is indicated by a binary variable equal to 1 if the household reported that the source of their seeds was one of the implementing NGOs. All households are included. Standard errors are clustered at the village level, and displayed in parentheses under the coefficient. * significant at 10%; ** significant at 5%; *** significant at 1%.

Appendix Table 4: Phone Connectivity by Treatment Arm

	(1)	(2)	(3)	(4)
	Study Arm Response Rate	Response Rate Omitting Selected Study Arm	Difference in Response Rate	Observations
Control	0.821	0.83	-0.01 (0.03)	1533
Low Intensity	0.823	0.83	-0.00 (0.04)	1533
Medium Intensity	0.828	0.83	0.00 (0.03)	1533
High Intensity	0.833	0.82	0.01 (0.03)	1533

Note: This table presents phone survey response rates. Column (1) presents the response rate of each treatment arm, (2) presents the response rate of the entire sample omitting the selected treatment arm, and (3) presents the difference in response rates of the selected treatment and remaining arms. Standard errors are clustered at the village level, and displayed in parentheses under the coefficient. * significant at 10%; ** significant at 5%; *** significant at 1%.

Appendix Table 5: Differences Between Contacted and Uncontacted HHs in Phone Survey

	(1) Respondent Mean (S.D.)	(2) Non-respondent Mean (S.D.)	(3) Difference between Respondents and Non-respondents (Std. Err.)
Gender	0.89	0.77	0.11***
	(0.32)	(0.42)	(0.03)
Age	45.99	48.9	-2.91***
	(15.87)	(16.26)	(1.04)
No. plots	7.26	6.63	0.63
	(4.58)	(4.79)	(0.42)
Total landholding (ha)	1.16	1.15	0.01
	(1.60)	(2.13)	(0.15)
Kharif pulses adoption	0.46	0.39	0.07*
	(0.50)	(0.49)	(0.04)
Rabi pulses adoption	0.84	0.81	0.03
	(0.37)	(0.40)	(0.03)
Kharif pulse area (ha.)	0.05	0.04	0.01
	(0.12)	(0.12)	(0.01)
Rabi pulse area (ha.)	0.11	0.16	-0.04
	(0.28)	(0.36)	(0.04)
Kharif PoP index	0.15	0.15	0.00
	(0.98)	(0.14)	(0.11)
Rabi PoP index	0	-0.07	0.07
	(1.03)	(0.06)	(0.07)
Observations	1266	267	1533

Note: This table presents differences in characteristics between end-line phone survey respondents and non-respondents based on mid-line survey variables (collected for all households). Column (1) presents means of mid-line characteristics for households contacted in the phone survey, (2) presents means for mid-line characteristics of households we were unable to reach through the phone survey, and (3) presents the difference between contacted and uncontacted households. Data on household characteristics was collected for all households in the mid-line in-person survey. Standard errors are clustered at the village level, and displayed in parentheses under the coefficient. * significant at 10%; ** significant at 5%; *** significant at 1%.

Appendix Table 6: Adoption and Production Results Combined Seasons

	(1) Combined Adoption	(2) Combined Adoption	(3) Combined Area Planted (ha)	(4) Combined Area Planted (ha)	(5) Combined Production (kg)	(6) Combined Production (kg)
Treatment	0.16***		0.027***		19.23**	
	(0.03)		(0.008)		(7.83)	
Low Intensity	(0.830)	0.15***	(30.786)	0.027**	(60.353)	19.77
		(0.04)		(0.011)		(13.81)
Medium Intensity		0.16***		0.029***		18.96*
		(0.04)		(0.008)		(9.71)
High Intensity		0.16***		0.025***		19.02**
		(0.04)		(0.009)		(8.37)
Observations	2346	2346	2346	2346	2066	2066
R-squared	0.20	0.20	0.19	0.19	0.16	0.16
Control Mean	0.57	0.57	0.069	0.069	57.07	57.07
Low vs. Medium (P-value)	4.78	0.74	176.54	0.88	482.1	0.96
Low vs. High (P-value)		0.62		0.90		0.96
Medium vs. High (P-value)		0.88		0.73		1.00

Note: This table summarizes OLS estimates of treatment effects for adoption, area, and production of the Kharif and Rabi seasons combined. Households were considered adopters if they grew pulses in at least one season. Area and production were calculated by adding across the two seasons. Outcome variables are listed in column headings. Columns (1)-(2) report treatment effects for pulse adoption, (3)-(4) for area under pulse cultivation (hectares), and (5)-(6) for pulse production. For each dependent variable, the first column reports coefficients for the pooled treatment effect of all treatment groups and the second column reports treatment effects of the low, medium, and high treatment groups compared to control. All regressions include covariates and fixed effects at the block (sub district) level. P-values of Wald post-estimation tests for each pair of coefficients are reported under regression results. Standard errors are clustered at the village level, and displayed in parentheses under the coefficient. The unit of observation is the household for all variables. Crop areas for individual agricultural plots were aggregated at the household level. All sample households are included. The production regressions are weighted to account for phone-based attrition. Crop areas were approximated for plots with mixed or intercropped cropping patterns. Area and production are winsorized at the 95th percentile. * significant at 10%; ** significant at 5%; *** significant at 1%.

Appendix Table 7: Robustness Check Dropping Overlapping Vilages

	(1) Kharif Adoption	(2) Kharif Adoption	(3) Kharif Area Planted (ha)	(4) Kharif Area Planted (ha)	(5) Rabi Adoption	(6) Rabi Adoption	(7) Rabi Area Planted (ha)	(8) Rabi Area Planted (ha)
Treatment	0.118***		0.011***		0.142***		0.016**	
	(0.027)		(0.003)		(0.033)		(0.008)	
Low Intensity		0.090**		0.008**		0.106**		0.017
		(0.040)		(0.004)		(0.047)		(0.012)
Medium Intensity		0.115***		0.010***		0.155***		0.017*
		(0.033)		(0.003)		(0.041)		(0.009)
High Intensity		0.147***		0.013***		0.161***		0.013
		(0.032)		(0.004)		(0.041)		(0.009)
Observations	2142	2142	2142	2142	2142	2142	2142	2142
R-squared	0.212	0.213	0.192	0.193	0.150	0.152	0.160	0.160
Control Mean	0.204	0.204	0.015	0.015	0.477	0.477	0.054	0.054
Low vs. Medium (P-value)		0.544		0.644		0.323		0.982
Low vs. High (P-value)		0.160		0.313		0.265		0.732
Medium vs. High (P-value)		0.355		0.494		0.897		0.643

Note: This table summarizes OLS estimates of treatment effects for adoption and area, dropping overlapping villages. Villages in which three or more respondents reported living in a different village, other than the one listed in the sampling frame, were dropped from the analysis. Outcome variables are listed in column headings. Columns (1)-(2) report treatment effects for pulses adoption in the 2017 Kharif, (3)-(4) for area under pulses cultivation (hectares) in the Kharif season. Columns (5)-(8) report the same for the 2017-2018 Rabi season. For each dependent variable, the first column reports coefficients for the pooled treatment effect and the second column reports treatment effects of the low, medium, and high treatment groups respectively, compared to control. All regressions include covariates and fixed effects at the block (sub-district) level. P-values of Wald post-estimation tests for each pair of coefficients are reported under regression results. Standard errors are clustered at the village level, and displayed in parentheses under the coefficient. The unit of observation is the household for all variables. Crop areas for individual agricultural plots were aggregated at the household level. Crop areas were approximated for plots with mixed or intercropped cropping patterns. Area is winsorized at the 95th percentile. * significant at 10%; ** significant at 5%; *** significant at 1%.

Appendix Table 8: Adoption and Area Results for Rabi and Kharif Without East Champaran

	(1) Kharif Adoption	(2) Kharif Adoption	(3) Kharif Area Planted (ha)	(4) Kharif Area Planted (ha)	(5) Rabi Adoption	(6) Rabi Adoption	(7) Rabi Area Planted (ha)	(8) Rabi Area Planted (ha)
Treatment	0.142***		0.013***		0.206***		0.017**	
	(0.029)		(0.003)		(0.040)		(0.007)	
Low Intensity		0.112***		0.009**		0.150***		0.010
		(0.042)		(0.004)		(0.054)		(0.009)
Medium Intensity		0.132***		0.012***		0.234***		0.020**
		(0.036)		(0.004)		(0.048)		(0.008)
High Intensity		0.182***		0.017***		0.231***		0.020**
		(0.032)		(0.004)		(0.046)		(0.008)
Observations	1697	1697	1697	1697	1697	1697	1697	1697
R-squared	0.247	0.250	0.232	0.234	0.108	0.112	0.084	0.087
Control Mean	0.226	0.226	0.017	0.017	0.342	0.342	0.028	0.028
Low vs. Medium (P-value)		0.644		0.627		0.121		0.239
Low vs. High (P-value)		0.096		0.176		0.126		0.217
Medium vs. High (P-value)		0.177		0.303		0.945		0.927

Note: This table summarizes OLS estimates of treatment effects for adoption and area dropping the East Champaran district. Outcome variables are listed in column headings. Columns (1)-(2) report treatment effects for pulses adoption in the 2017 Kharif and (3)-(4) for area under pulses cultivation (hectares) in the Kharif season. Columns (5)-(8) report the same for n the 2017-2018 Rabi season. For each dependent variable, the first column reports coefficients for the pooled treatment effect and the second column reports treatment effects of the low, medium, and high treatment groups respectively compared to control. All regressions include covariates and fixed effects at the block (sub-district) level. P-values of Wald post-estimation tests for each pair of coefficients are reported under regression results. Standard errors are clustered at the village level, and displayed in parentheses under the coefficient. The unit of observation is the household for all variables. Crop areas for individual agricultural plots were aggregated at the household level. All sample households included. Crop areas were approximated for plots with mixed or intercropped cropping patterns. Area is winsorized at the 95th percentile. * significant at 10%; ** significant at 5%; *** significant at 1%.

Appendix Table 9: Robustness Checks of Adoption and Area Result

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Kharif Results								
	Kharif adoption without covariates	Kharif adoption without covariates	Kharif area unwinsorized (ha)	Kharif area unwinsorized (ha)	Kharif area winsorized upper 5% without covariates (ha)	Kharif area winsorized upper 5% without covariates (ha)	Kharif area winsorized upper 1% (ha)	Kharif area winsorized upper 1% (ha)
Treatment	0.13***		0.017***		0.012***		0.015*	
	(0.028)		(0.005)		(0.003)		(0.004)	
Low Intensity		0.10**		0.013**		0.010**		0.013**
		(0.041)		(0.006)		(0.005)		(0.006)
Medium Intensity		0.12***		0.018***		0.012***		0.013***
		(0.035)		(0.006)		(0.004)		(0.005)
High Intensity		0.16***		0.019***		0.015***		0.018***
		(0.035)		(0.007)		(0.004)		(0.006)
Observations	2346	2346	2346	2346	2346	2346	2346	2346
R-squared	0.144	0.146	0.129	0.129	0.130	0.131	0.159	0.159
Control Mean	0.20	0.20	0.020	0.020	0.015	0.015	0.02	0.02
Low vs. Medium (P-value)		0.598		0.531		0.707		0.918
Low vs. High (P-value)		0.215		0.459		0.344		0.495
Medium vs. High (P-value)		0.423		0.891		0.478		0.503
Panel B: Rabi Results								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Rabi adoption without covariates	Rabi adoption without covariates	Rabi area unwinsorized (ha)	Rabi area unwinsorized (ha)	Rabi area winsorized upper 5% without covariates (ha)	Rabi area winsorized upper 5% without covariates (ha)	Rabi area winsorized upper 1% (ha)	Rabi area winsorized upper 1% (ha)
Treatment	0.15***		0.008		0.018**		0.013	
	(0.035)		(0.028)		(0.008)		(0.015)	
Low Intensity		0.11**		0.015		0.015		0.017
		(0.048)		(0.036)		(0.011)		(0.022)
Medium Intensity		0.17***		0.017		0.021**		0.018
		(0.042)		(0.028)		(0.008)		(0.016)
High Intensity		0.17***		-0.009		0.017*		0.005
		(0.046)		(0.029)		(0.009)		(0.016)
Observations	2346	2346	2346	2346	2346	2346	2346	2346
R-squared	0.060	0.062	0.068	0.070	0.080	0.081	0.117	0.119
Control Mean	0.48	0.48	0.080	0.080	0.053	0.053	0.07	0.07
Low vs. Medium (P-value)		0.223		0.943		0.608		0.967
Low vs. High (P-value)		0.272		0.365		0.891		0.506
Medium vs. High (P-value)		0.943		0.143		0.631		0.292

Note: This table presents robustness checks for adoption and area treatment effects. OLS estimates of the treatment effects are presented for different regression specifications and strategies for outliers. The upper panel presents estimates for the 2017 Kharif season and the lower panel for the 2017-2018 Rabi season. Columns (1)-(2) show treatment effects for pulses adoption without added covariates; (3)-(4) show household total area (hectares) under pulses cultivation unwinsorized; (5)-(6) household total area (hectares) under pulses cultivation winsorized at the upper 5% tail without added covariates; (7)-(8) household total area (hectares) under pulses cultivation winsorized at the upper 1% tail; and (9)-(10) inverse hyperbolic sine transformation of household total area (hectares) under pulses cultivation. All regressions include fixed effects at the block (subdistrict) level and additional covariates, unless otherwise specified in the column heading. P-values of Wald post-estimation tests for each pair of coefficients are reported under regression results. Standard errors are clustered at the village level, and displayed in parentheses under the coefficient. * significant at 10%; ** significant at 5%; *** significant at 1%.

Appendix Table 10: Robustness Checks of Production and Yield Results for Kharif

Panel A: Production Results								
	(1) Kharif production unwinsorized (kg)	(2) Kharif production unwinsorized (kg)	(3) Kharif production winsorized upper 5% wihtout covariates (kg)	(4) Kharif production winsorized upper 5% wihtout covariates (kg)	(5) Kharif production winsorized upper 1% (kg)	(6) Kharif production winsorized upper 1% (kg)	(7) Kharif production inverse hyperbolic sine transformation	(8) Kharif production inverse hyperbolic sine transformation
Treatment	-4.24		1.09		0.31		0.13	
	(6.630)		(0.958)		(1.946)		(0.091)	
Low Intensity		1.74		0.65		0.07		0.12
		(9.030)		(1.292)		(2.643)		(0.127)
Medium Intensity		-5.47		1.26		1.55		0.13
		(7.128)		(1.452)		(3.222)		(0.145)
High Intensity		-8.61		1.32		-0.76		0.13
		(7.276)		(1.146)		(2.047)		(0.111)
Observations	2066	2066	2066	2066	2066	2066	2066	2066
R-squared	0.03	0.03	0.05	0.05	0.07	0.07	0.12	0.12
Control Mean	15.97	15.97	4.72	4.72	9.15	9.15	0.56	0.56
Low vs. Medium (P-value)		0.40		0.71		0.69		0.92
Low vs. High (P-value)		0.19		0.63		0.75		0.93
Medium vs. High (P-value)		0.52		0.97		0.48		0.98

Panel B: Yield Results								
	(1) Kharif yield unwinsorized (kg/ha)	(2) Kharif yield unwinsorized (kg/ha)	(3) Kharif yield winsorized upper 1% wihtout covariates (kg/ha)	(4) Kharif yield winsorized upper 1% wihtout covariates (kg/ha)	(5) Kharif yield winsorized upper 5% (kg/ha)	(6) Kharif yield winsorized upper 5% (kg/ha)	(7) Kharif yield inverse hyperbolic sine transformation	(8) Kharif yield inverse hyperbolic sine transformation
Treatment	-173.4***		-175.9***		-155.9***		-1.23***	
	(61.8)		(61.2)		(51.2)		(0.35)	
Low Intensity		-243.2***		-240.1***		-209.6***		-1.33***
		(63.1)		(61.2)		(53.3)		(0.37)
Medium Intensity		-128.6		-131.9		-125.6*		-1.01*
		(83.8)		(84.2)		(70.6)		(0.53)
High Intensity		-166.4***		-172.1***		-145.6***		-1.39***
		(62.9)		(62.8)		(52.9)		(0.38)
Observations	535	535	535	535	535	535	535	535
R-squared	0.05	0.06	0.04	0.04	0.06	0.06	0.07	0.07
Control Mean	486.5	486.5	482.1	482.1	445.9	445.9	4.71	4.71
Low vs. Medium (P-value)		0.11		0.13		0.18		0.53
Low vs. High (P-value)		0.11		0.16		0.16		0.88
Medium vs. High (P-value)		0.59		0.58		0.74		0.45

Note: This table presents robustness checks for production and yield treatment effects in the 2017 Kharif season. OLS estimates of the treatment effects are presented for different regression specifications and strategies for outliers. The upper panel presents estimates for the total production outcome and the lower panel for the yield outcome. Columns (1)-(2) show treatment effects without added covariates; (3)-(4) without winsorization; (5)-(6) winsorized at the upper 5% tail without added covariates for production and winsorized at the upper 1% tail without covariates for yield; (7)-(8) winsorized at the upper 1% tail for production and upper 5% tail for yield; and (9)-(10) inverse hyperbolic sine transformation. All regressions include fixed effects at the block (subdistrict) level and additional covariates, unless otherwise specified in the column heading. P-values of Wald post-estimation tests for each pair of coefficients are reported under regression results. Standard errors are clustered at the village level, and displayed in parentheses under the coefficient. * significant at 10%; ** significant at 5%; *** significant at 1%.

Appendix Table 11: Robustness Checks of Production and Yield Results for Rabi

Panel A: Production Results

	(1) Rabi production unwinsorized (kg)	(2) Rabi production unwinsorized (kg)	(3) Rabi production winsorized upper 5% wihtout covariates (kg)	(4) Rabi production winsorized upper 5% wihtout covariates (kg)	(5) Rabi production winsorized upper 1% (kg)	(6) Rabi production winsorized upper 1% (kg)	(7) Rabi production inverse hyperbolic sine transformation	(8) Rabi production inverse hyperbolic sine transformation
Treatment	33.49		18.88**		26.23*		0.75***	
	(22.860)		(8.654)		(14.799)		(0.172)	
Low Intensity		48.59		16.58		36.31		0.60**
		(44.015)		(14.628)		(30.765)		(0.255)
Medium Intensity		26.53		19.97*		20.84		0.83***
		(26.236)		(10.318)		(16.613)		(0.229)
High Intensity		26.58		19.86**		22.39		0.82***
		(23.351)		(9.421)		(14.446)		(0.193)
Observations	2079	2079	2079	2079	2079	2079	2079	2079
R-squared	0.07	0.07	0.09	0.09	0.11	0.11	0.19	0.19
Control Mean	74.77	74.77	53.09	53.09	67.80	67.80	2.08	2.08
Low vs. Medium (P-value)		0.62		0.82		0.62		0.42
Low vs. High (P-value)		0.62		0.82		0.65		0.37
Medium vs. High (P-value)		1.00		0.99		0.93		0.99

Panel B: Yield Results

	(1) Rabi yield unwinsorized (kg/ha)	(2) Rabi yield unwinsorized (kg/ha)	(3) Rabi yield winsorized upper 1% wihtout covariates (kg/ha)	(4) Rabi yield winsorized upper 1% wihtout covariates (kg/ha)	(5) Rabi yield winsorized upper 5% (kg/ha)	(6) Rabi yield winsorized upper 5% (kg/ha)	(7) Rabi yield inverse hyperbolic sine transformation	(8) Rabi yield inverse hyperbolic sine transformation
Treatment	-158.8**		-164.1***		-156.2**		-0.20	
	(63.4)		(62.7)		(61.2)		(0.16)	
Low Intensity		-131.0		-142.5*		-128.4		-0.33
		(83.7)		(82.9)		(80.9)		(0.23)
Medium Intensity		-181.1**		-183.1**		-175.9**		-0.12
		(72.7)		(71.8)		(70.7)		(0.19)
High Intensity		-159.8**		-163.0**		-160.0**		-0.18
		(80.3)		(79.4)		(77.5)		(0.20)
Observations	852	852	852	852	852	852	852	852
R-squared	0.09	0.09	0.07	0.07	0.09	0.09	0.07	0.07
Control Mean	965.5	965.5	965.0	965.0	951.1	951.1	6.91	6.91
Low vs. Medium (P-value)		0.54		0.62		0.55		0.37
Low vs. High (P-value)		0.74		0.81		0.71		0.55
Medium vs. High (P-value)		0.78		0.79		0.83		0.77

Note: This table presents robustness checks for production and yield treatment effects in the 2017-2018 Rabi season. OLS estimates of the treatment effects are presented for different regression specifications and strategies for outliers. The upper panel presents estimates for the total production outcome and the lower panel for the yield outcome. Columns (1)-(2) show treatment effects without added covariates; (3)-(4) without winsorization; (5)-(6) winsorized at the upper 5% tail without added covariates for production and winsorized at the upper 1% tail without covariates for yield; (7)-(8) winsorized at the upper 1% tail for production and upper 5% tail for yield; and (9)-(10) inverse hyperbolic sine transformation. All regressions include fixed effects at the block (subdistrict) level and additional covariates, unless otherwise specified in the column heading. P-values of Wald post-estimation tests for each pair of coefficients are reported under regression results. Standard errors are clustered at the village level, and displayed in parentheses under the coefficient. * significant at 10%; ** significant at 5%; *** significant at 1%.