WORKING PAPER NO: 639

Hybrid Agricultural Information Delivery System as a Means to Improve Sustainability of Agriculture: Experimental Evidence from India

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Year of Publication – April 2021

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Abstract

Extant research and policy on agriculture tend to treat financial sustainability and ecological sustainability of agricultural operations as mutually exclusive goals. We show that sharing the current stock of agricultural research with farmers through an innovative information delivery method can help in pursuing these two goals simultaneously.

We used a mix of Information and Communication Technology (ICT) and agent-based information delivery methods to provide information about all aspects of crop production with a focus on nutrient management and plant protection to paddy (rice) and cotton farmers in a field experiment setup. The method of information delivery enabled us to provide customized and detailed information. Our study finds that two years of intervention led to an increase in paddy yields by 18 percent and cotton yields by 85 percent. The enhanced yields were achieved along with reduction in the use of inorganic fertilizers and crop protection chemicals. At end of two years, intervention led to optimal, balanced usage of inorganic fertilizers by farmers and an overall reduction in the quantity of fertilizers used. Intervention also led to reduction in expenses related to crop protection chemicals owing to their proper usage. Yield enhancement and cost reduction contributed to an increase in net returns by 78 percent and 221 percent for paddy and cotton crops, respectively. Along with improving the financial viability of farming, proper use of chemicals adds to the ecological sustainability of agriculture.

The results of this study are important because they show that improved delivery of agricultural information can be used to attain goals beyond yield enhancement and that significant results can be achieved in a relatively short span of time. The results also have important implications for the management of agricultural information delivery initiatives and the continuity of such initiatives.

Keywords: Agricultural information delivery, Agricultural sustainability, Information and communication technology, Randomized control trial

1. Introduction

A set of practices developed around irrigation, seeds with higher yield potential, fertilizers, and crop protection chemicals heralded the green revolution in India. However, due to their inefficient use of the inputs and farm management practices, the productivity achieved by farmers has not reached full potential, in addition to degrading land and water resources. On average, actual productivity realized by farmers in India is 68 percent and 53 percent for paddy (rice) and cotton crops, respectively (Aggarwal, et al., 2008). Moreover, 20 percent of the cultivable land in India is degraded due to incorrect use of fertilizers or irrigation (GoI, 2016). Water use efficiency in agriculture in India is one of the lowest in the world (Shah, 2016) and 66 percent of states (the second rung of the Indian federal structure) have contaminated groundwater due to leaching of harmful compounds from agricultural operations (Mali, Sanyal, & Bhatt, 2015).

Increasing productivity and protecting and enhancing natural resources are two of the five principles for balancing the social, economic, and environmental sustainability of agriculture (FAO, 2018). In this study, we explore whether providing information to farmers about efficient practices related to the use of agricultural inputs could help the country move closer to these goals.

While the importance of delivering research-based information to farmers for improving the use of agricultural inputs is well recognized, providing this information in the context of developing countries has been a difficult task. Farmers might fall anywhere in the spectrum between subsistence agriculture and commercial agriculture, and they might possess different capacities for information absorption (Babu, Glendenning, Asenso-Okyere, & Govindarajan, 2012). In addition, inadequate regulatory mechanisms and the proliferation of brands in the agricultural inputs market have made the choice of agricultural inputs a complex decision for farmers. Any attempt to address these issues needs to meet two criteria, namely customization of messages according to the farmers' needs and communication of messages in a manner that is easy for farmers to understand and adopt.

The two prevalent methods of communicating recommended practices to farmers fall short of one of the two criteria. The traditional method of using extension agents—agents trained by state agricultural departments, who contact farmers and provide them information—is suitable for customizing information according to the farmers' needs. However, this method has generally been useful only in cases where a specific set of messages had to be delivered to farmers (Davis, 2008). Modern methods of information delivery using information and communications technology (ICT) can be useful for disseminating vast amounts of information in an easy-to-understand multimedia format to a large number of farmers, but these methods are not suitable for providing farmer-specific advice (Umadikar, Sangeetha, Kalpana, Soundarapandian, & Prashant, 2014).

This study addresses the question of whether a mix of these two methods can help farmers to use key agricultural inputs more effectively and measures the magnitude of the benefits in terms of financial and ecological impact. Despite a growing understanding that neither of the methods is sufficient on its own, recent studies have been limited to the evaluation of either of the traditional services, i.e., extension agents visiting farmers and sharing information with them (Cerdan-Infantes, Maffioli, & Ubfal, 2008; Owens, Hoddinott, & Kinsley, 2003; Sheng, Gray, & Mullen, 2010; Romani, 2003) or ICT-based methods (Aker, 2011; Fafchamps & Minten, 2012; Cole & Fernando, 2016). An exception to this trend is a study by Gandhi et al., (2009) where the researchers studied the impact of digital videos along with mediation by agents. However, the study limited its impact evaluation to the impact of intervention on changes in agricultural practices and did not present quantifiable results on impact of information delivery methods on agricultural outcomes such as yield, cost reduction, and returns.

In this study, we provided information to farmers about the effective use of agricultural inputs through project-appointed extension agents whose agricultural knowledge was augmented through modules of information on best practices and a special pest-diagnosis mobile application (app) that were loaded on to an electronic tablet. The extension agent part of the intervention helped in customizing the information while the tablet part helped in communicating accurate information in an understandable way. In the area that we selected for intervention, we observed that agriculture was practiced on a commercial scale. Inorganic fertilizers and crop protection chemicals were used excessively on average in this area, and there were significant gaps between potential crop output and the output being achieved by farmers. We used a randomized control trial design to establish the effects of the intervention on agricultural outcomes.

The intervention led to highly significant increases in yields, namely, 18 and 85 percent for paddy and cotton crops, respectively, within a period of two years. The significant increases in crop yield were achieved along with a statistically significant reduction in the expenses incurred by farmers for inorganic fertilizers and crop protection chemicals and a reduction in the quantity of fertilizers used by farmers. Within two years, the farmers moved closer to the recommended balanced combination of fertilizer use.

This study makes multiple contributions to the extant literature. Firstly, the magnitude of the results achieved through our intervention is quite unprecedented and shows that agricultural information delivery systems can help states to quickly achieve multiple goals linked to agriculture, especially those linked to financial and ecological sustainability. Secondly, the present study is one of the few studies on the evaluation of agricultural information delivery methods that uses a widely accepted methodology to establish causal impact of intervention on crop outcomes. Randomization at both the village level and farmer level helped us in controlling the influence of farmer characteristics and agricultural endowments of the area on the results of the study. Further, an emphasis on minimizing the potential sharing of information between treatment farmers and control farmers helped us in accurately measuring the extent of the impact of information delivery on agricultural outcomes. Thirdly, our study shows that a mix of traditional and modern methods of agricultural information delivery can be effective, which opens doors for the use of more innovative methods in the information delivery space.

The rest of the paper is structured as follows. In the following section, we briefly discuss the context of poorly balanced agricultural practices and insufficient agricultural information provisioning in India within which this study is nested, followed by details of the information delivery project from which we draw our data. Subsequently, we discuss the identification strategy and the specifications of the econometric and data envelopment analysis methods that we used for data analysis. Then, we discuss the results obtained from the data analysis, and conclude the paper with the policy implications of our findings.

2. Contextual Background

2.1. Imbalance in agricultural practices in India

There are several dimensions of sub-optimal agricultural practices in India. The seed replacement rate, i.e., percentage of crop area that is sown with certified or quality seeds is much below the prescribed norms (Shreedhar, Gupta, Pullabhotla, Ganesh-Kumar, & Gulati, 2012). Another problem is the inefficient use of crop protection chemicals that are unable to arrest crop losses. Nearly 25 percent of the potential crop production in India is reported to be lost to pests, weeds, and diseases (FICCI, 2016).

The most significant sub-optimal practices are related to the use of inorganic fertilizers. While more than three-fourths of the total cultivated area is treated with inorganic fertilizers (MoAFD, 2016), the three major nutrients namely nitrogen, phosphorus, and potassium are not applied in sync with crop and land requirements (Pavithra & Chand, 2015), and micro-nutrients are underused, on average (Shukla, 2010). The problem of sub-optimal use of major nutrients is amplified by other factors such as a decline in the use of manure (DoF, 2014) and the abandonment of traditional methods of land regeneration such as leaving land fallow and returning crop residues to the land (Croppenstedt, Demeke, & Meschi, 2003).

Poorly balanced use of fertilizers has significant financial and ecological consequences. The expenditure incurred toward inorganic fertilizers forms an average of 24 percent of the total expenses incurred in crop production (NSSO, 2013). Excessive, poorly balanced, or insufficient use of fertilizers prevents farmers from reaping returns from their investment on fertilizers. The yield obtained by farmers per kilogram of fertilizer used has steadily declined (Planning Commission, 2010) over time, and between 1950–55 and 2007–08, while fertilizer usage increased by 322 times, cereal production increased by only 5 times (Prasad, 2009). Generally, when crop response to fertilizers declines, in the absence of any diagnosis of the problem by experts, farmers tend to apply even more fertilizers. This leads to additional costs without a commensurate increase in returns from crops (Mishra, 2007). Excess and poorly balanced use of fertilizers might also result in more instances of pest or disease attacks and an increase in the problem of weeds (Patil, Huggar, & Reddy, 2013).

Poorly balanced use of fertilizers has environmental consequences as well. Reduced use of organic sources of plant nutrition and poorly balanced use of inorganic nutrients result in land degradation, i.e., deterioration of the physical, chemical, and biological characteristics of soil (Yedla & Peddi, 2009), which in turn leads to the lower ability of the soil to utilize nutrients. About 20 percent of the cultivable area in India has degraded due to soil alkalinity, sodicity, soil acidity, or soil salinity, all of which are result of indiscriminate use of inorganic fertilizers (GoI, 2016). When land degrades, additional nutrients are not taken up by crops, and these nutrients seep into the soil, leading to adverse environmental impacts such as pollution of groundwater (Tilman, Cassman, Matson, Naylor, & Polasky, 2002), release of harmful gases into the atmosphere (Prasad, 2009), and reduction in biodiversity (Horrigan, Lawrence, & Walker, 2002).

Imbalances in agricultural practices, especially those related to the use of fertilizers and crop protection chemicals, also lead to yield gaps due to which the yield obtained by farmers is lower than the potential yield that could be obtained if an ideal set of agricultural practices were followed. In India, the yield gap for several crops is 50 percent or more, indicating that farmers obtain less than half of the possible yield from the crop that they grow (Singh, 2012).

2.2. Role of agricultural information delivery methods

Yield gaps and problems in the use of agricultural inputs have been attributed to poor knowledge of crop management techniques, among other factors (Alene & Manyong, 2006). The knowledge passed down generations might not be sufficient in an agricultural setting where technology is rapidly evolving (Welch, 2001). While there is a need for continuous sharing of research-based information with farmers, the current levels of access to agricultural information are quite low in India. Only 41 percent of Indian farmers have access to any source of information (NSSO, 2013), and only 6 percent have access to the public agricultural extension system. In India, information is supposed to be delivered through state-appointed extension agents, state-sponsored television and radio telecasts on agriculture, and articles in newspapers, and also through centers from where farmers can access information (Gupta & Shinde, 2013).

Agricultural extension in India is probably best known for its contribution in bringing about the green revolution. During the period starting in the 1960s and leading up to the late 1980s, agricultural extension was aggressively used to enhance agricultural productivity and to expand food stocks of cereal crops (Swanson, 2006). The Training and Visit (T&V) model of extension, which was launched in the late 1970s, was the most significant agricultural extension-related initiative of this period. Under the T&V model, farmers were told about best practices for various crops by extension workers (Feder & Slade, 1993), who were in turn trained by subject matter specialists and were regularly monitored by supervisors (Anderson & Feder, 2004). The T&V initiative lead to a higher level of contact between extension agents and farmers, increased the farmers' awareness of newer agricultural techniques, and increased agricultural productivity (Feder & Slade, 1993).

The T&V systems were dismantled in the 1990s. Since then, there has been low provisioning of agricultural information by public agencies, while the agricultural inputs market has become complex with the proliferations of brands. Low provisioning of agricultural information by the public sector is mainly linked to the structural adjustment and liberalization of the economy, which greatly reduced the funds at the disposal of the government for various developmental initiatives (Rivera W. M., 2001). Low provisioning of agricultural information is also related to a greater assurance of food security due to which agricultural research and extension now receive less attention from the state (Balasubramanian, 2014). Moreover, agricultural extension, like agriculture in general, is influenced by several factors and infrastructural variables, which makes it difficult to isolate the impact of extension from other environmental factors within the context of which extension operates (Birkhaeuser, Evenson, & Feder, 1991). That is, the impact of extension by itself is very difficult to trace (Anderson & Feder, 2004), which pushes it behind other factors such as irrigation, whose benefits are easier to establish, for purposes of budget allocation.

The agent-based system for information delivery has petered out in India, and only 6 percent of Indian farmers have access to state-appointed extension agents (NSSO 70th round), mostly due to budgetary cuts. Moreover, there are other problems with the model, such as the system's top-down approach and the limited skills and knowledge of the agents.

Several forms of information and communications technology (ICT) have emerged as alternatives to agent-based agricultural information delivery. Some of the common ICT formats used to deliver information are SMS-based and/or voice-based services available through mobile phones for communicating agriculture-related information to farmers, and web-based question and answer (Q&A) forums and web portals that act as information repositories (Umadikar, Sangeetha, Kalpana, Soundarapandian, & Prashant, 2014). Web-based services can be accessed through tele-centers, information kiosks, village knowledge centers, and multipurpose community centers (Mittal & Mehar, 2014). The main application of ICT in agriculture, at least in India, has been to provide farmers with information about prices and other market-related information (Mittal & Mehar, 2014), although other initiatives such as *Kisan* (farmer) call centers are meant to cater to all the information needs of farmers (Ferroni & Zhou, 2012).

Mixed results have been reported about the performance of the various agriculture-related ICT initiatives in India. Most applications are unable to provide farmer-specific advice, are not interactive, are mostly query-based, and might not be suitable for farmers with limited literacy and limited understanding of the use of internet or ICT applications (Umadikar, Sangeetha, Kalpana, Soundarapandian, & Prashant, 2014). Access to the facilities required for such applications might also be limited. Farmers with larger land holdings benefitted from these initiatives more than farmers with smaller landholdings (Ferroni & Zhou, 2012), and areas with better infrastructure have witnessed more progress in the use of ICT in agricultural information delivery (Mittal & Mehar, 2014). Similar to the older systems, information is provided in a top-down manner, with few options for farmers to seek further clarifications or to give feedback (Chapman & Slaymaker, 2002). Some studies found that the content provided through ICT initiatives is of poor quality (Heeks, 2002) and/or is not relevant (Roman & Colle, 2006).

The deficiencies in the various information delivery mechanisms are in large part due to the platform designs, which do not consider the different needs of farmers based on where the farmer is located on the spectrum that ranges from subsistence agriculture to commercial agriculture; the designs also do not account for the differences in the information absorption ability of the farmers (Babu, Glendenning, Asenso-Okyere, & Govindarajan, 2012).

There is little understanding of how groups with different levels of resources and skills or individuals of different genders, age, and occupation absorb and use information (Richardson, 2005) and (Roman & Colle, 2006), or what attributes of information—in terms of relevance, accuracy, affordability, trustworthiness of the source, etc.—are considered necessary by farmers (Roman & Colle, 2006). This argument is supported by data from the NSSO 70th round, which shows that access to information does not always translate into the adoption of the information. The three main reasons for not adopting information are the lack of financial resources to put the information into practice, non-availability of the suggested inputs and physical resources, and lack of technical follow-up related to the advice received from the source of information (NSSO, 2013).

We hypothesize that through a mix of agent-based agricultural information delivery and ICT tools, it is possible to design a system of agricultural information delivery that provides timely, reliable, accurate, and relevant information in a way that can be easily understood and used by farmers.

3. Intervention

3.1. Details on the Intervention

To examine the impact of agricultural information delivery method on the sustainability of agricultural operations, we designed a field intervention named Dynamic Agricultural Tablet-based Extension Services (DATES).[1] The intervention involved delivering agricultural information to farmers by project-appointed extension agents who were equipped with electronic tablets. We used modules of agricultural best practices, which had been developed and tested by a local agricultural university,[2] to provide information to the farmers.[3] Some of the information modules used for paddy crop are given in appendix 3. The intervention started in 2013 and concluded in 2015.

While information was provided about multiple aspects of crop production, namely, crop rotation, plant variety, irrigation and drainage, weather forecasts, and weed control, the focus was on nutrient management and plant protection. For pest management, the farmers were given information about the types of pesticides to use for various pest infestations, the ideal time and procedure for applying the chemicals, and organic alternatives to the chemicals. Similarly, for nutrient management, information included organic alternatives to inorganic fertilizers[4] and effective use of inorganic fertilizers. The farmers

[1] DATES was a joint effort of Indian Institute of Management Bangalore and the University of Glasgow. The initiative was funded by the Economic and Social Research Council and Indian Institute of Management Bangalore.

[2] The name of the local agricultural university: University of Agricultural Sciences, Raichur.

[3] Information related to inorganic fertilizers and crop protection chemicals was found to be insufficient and a little dated; therefore, we updated this information.

[4] Organic alternatives are farmyard manure and green manure. Green manure is obtained by growing certain crops (mostly field plants from the leguminous family) in the field and then incorporating the crops into the soil by ploughing after sufficient growth.

were encouraged to match the application of inorganic fertilizers to crop requirements, which mostly involved applying fertilizers that were dense in certain nutrients at specific crop stages.[5]

The information was delivered to farmers by agricultural graduates from the area designated for the study, who were appointed under the project as extension agents. The extension agents were equipped with electronic tablets on which we loaded the best practices modules and a special mobile application (app) for pest diagnosis and pesticide recommendation, named Electronic Solutions against Agricultural Pests (e-SAP). The main screen of the app contains photographs of crops infested with common pests. When a user clicks on a photograph, the photograph gives way to details about the pest and suggested pesticide details. The information contained in the e-SAP app was in the local language (Kannada) and was in written, audio, and visual form. Printed copies of the suggested fertilizers and pesticides were provided to enable farmers to purchase and apply the recommended chemicals accurately.

Armed with tablets, the extension agents paid regular visits to the treatment farmers, mostly in their agricultural fields but occasionally at the farmers' homes. Each agent provided information to 50 farmers. In situations where the farmers faced pest-related problems, the agents would first try to diagnose the problem with the help of the information available in the tablet and through the e-SAP app[6], and then suggest remedial actions to the farmers[7].

If an agent was unable to diagnose the problem, he would take three photographs of the affected crop parts and field conditions, and then submit the photographs to the online server. A scientist at the back-end would diagnose the problem and upload suggested actions to the server, which the agent would then communicate to the farmers. The names of crop protection chemicals were given as printouts to the farmers by the extension agents. For other types of information, the agents relied on their own knowledge and on the information modules in their tablets. For certain suggestions, such as those related to spacing between crops or seed treatments, the agents demonstrated the process to the farmers and farm laborers.

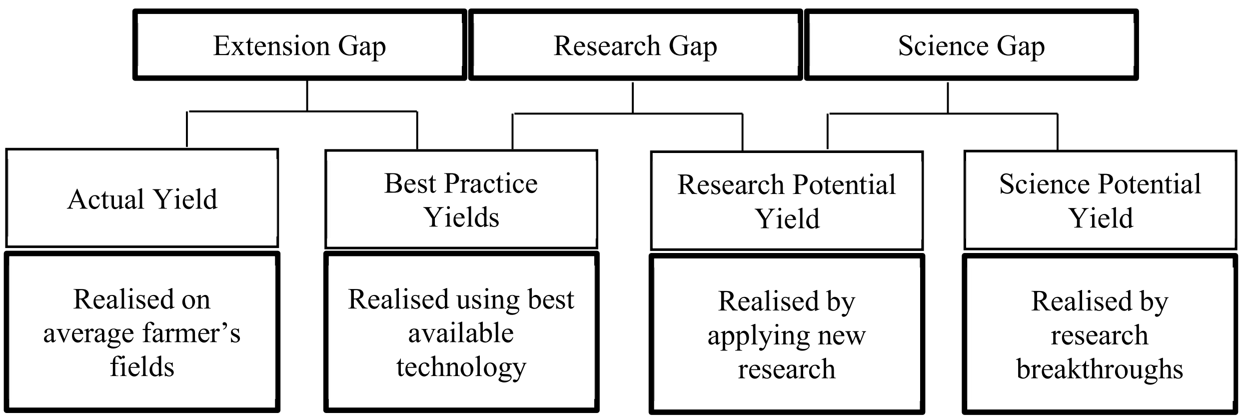
The agents visited the farmers on a bi-monthly basis; over a period of two years, each treatment farmer was visited 10 to 12 times by the extension agents based on the crop requirements[8]. The visits were planned to coincide with key stages in crop production, namely, sowing, flowering, and harvesting. The

[5] Crop stages relevant for fertilizer application are sowing, crop establishment, flowering, and grain setting.
[6] Appendix 3 contains representational photographs from e-SAP mobile application
[7] Appendix 4 contains some photographs of interaction of extension agents with farmers
[8] Appendix 5 contains a proforma of weekwise roster that was drawn for every extension agent throughout the intervention

farmers were also encouraged to call up the extension agents if they required any advice or additional information.[9]

3.2. Mechanism for Impact of DATES intervention

Under DATES initiative, farmers were provided information on best practices for their crops, given their unique economic and agricultural conditions. The aim was to bridge the gap between actual yield, i.e. the yield realized by the farmers at start of the intervention and best practice yield, i.e. the maximum potential yield of a given crop variety. This gap is known as extension gap. A typology of various possible crop yields and corresponding gaps is given in figure 1.



Source: Evenson (2000)

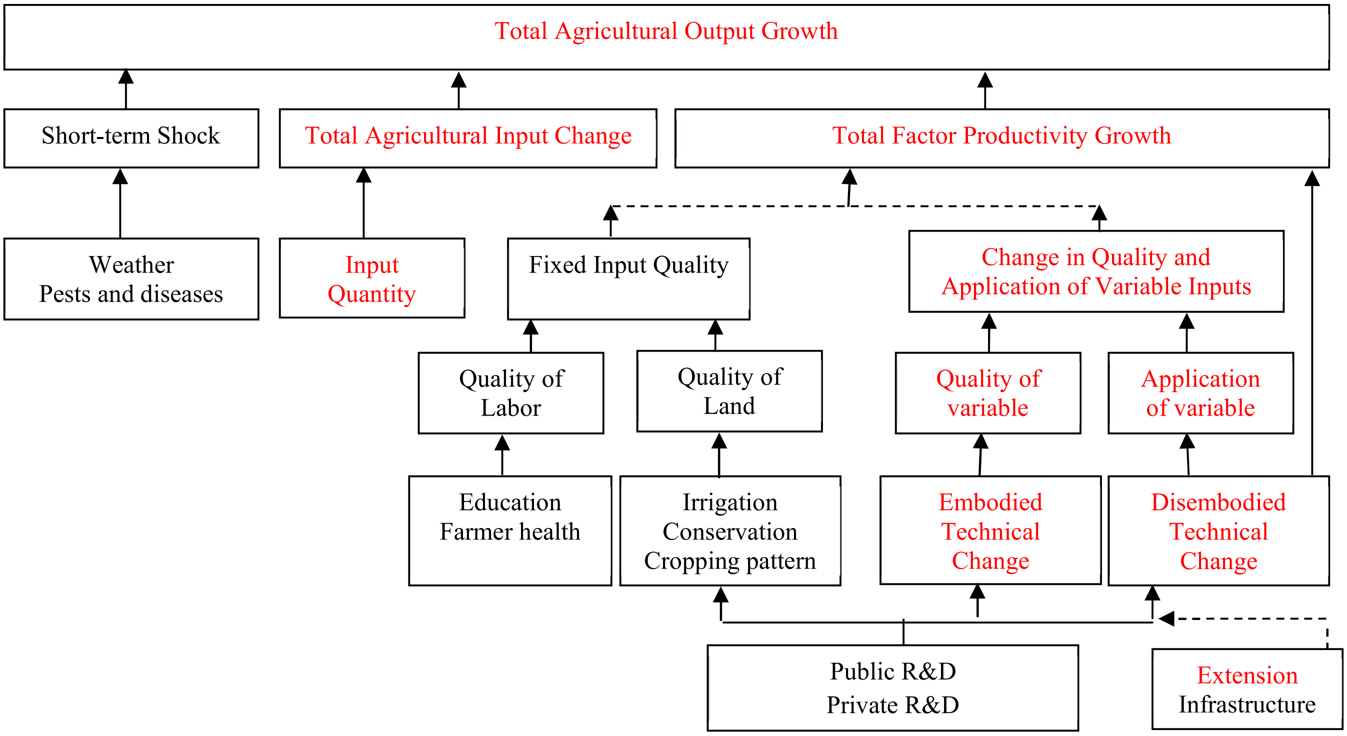
Figure 1: Role of Agricultural Extension in Increasing Yields

Information provided under DATES fell in categories of quantity of variable inputs, embodied technical change and disembodied technical change. These categories are situated under framework of total agricultural output growth, given in figure 2.

Embodied technical change refers to use of products that have been modified and enhanced, such as seeds with higher yield potential or better resistance to diseases. Disembodied technical change refers to change in application of variable inputs and farm management practices. DATES encouraged farmers to use better products, especially better seeds, fertilizers (organic and inorganic) and plant protection chemicals. Farmers were also provided information on right product, right quantity, right method and right timing of

[9] Several farmers reached out to the extension agents via mobile phones. However, an exact record of how many farmers called and the number of times each farmer called an extension agent was not maintained.

use of variable inputs. The suggestions together led to increase in total factor productivity, defined as output realized per unit of input.



Source: (Wang, Heisey, Schimmelpfenning, & Ball, 2015)

Figure 2: DATES Intervention in terms of Total Agricultural Output Growth Model

Other components of total agricultural productivity growth, namely quality of fixed inputs and random fluctuations like weather were not influenced by DATES intervention but were balanced between treatment and control groups due to randomised control trial design.

4. Experimental Design

4.1. Randomization and sample characteristics

Since we were interested in preventing information sharing between treatment farmers and control farmers as far as possible, we decided to stratify the farmers according to their *gram panchayats* (GP).[10] We assigned an entire GP as either treatment or control. The GPs were divided into two groups through a

[10] For the purpose of this study, a *gram panchayat* (GP) is a cluster of villages. Across India, a gram panchayat is formed by clustering three to five villages, on average. However, the number of villages under a GP can go up to 15 in certain geographies. Formally, GPs are the base level of the rural local self-governance system in India, and representatives elected at the GP level represent members at higher levels of local self-governance.

lottery system. To further increase the geographical distance between the groups of treatment and control farmers, randomization was done to ensure that none of the control and treatment GPs were neighbors. When a treatment GP was picked through lottery, all the GPs neighboring the selected treatment GP would be removed from the lottery. The map of Siruguppa taluk given in Appendix 1 shows that the treatment and control GPs were non-neighboring. Of the total 27 GPs in Siruguppa, six GPs were selected for the treatment group, and six were selected for the control group. From each of the 12 GPs, we randomly selected 50 farmers[11] who met all the criteria in the screening survey.

The sample for this study consists of paddy (rice) and cotton[12] farmers whose land records existed in an online portal for land records[13]. The farmers were selected from the Siruguppa taluk of Bellary district in the state of Karnataka. We created a list of all the farmers in the selected treatment and control GPs, and then conducted a screening survey and identified farmers from the shortlist who maintained residence in the village, had grown at least one of the major crops in the previous year, and were planning to grow at least one of the major crops in the upcoming agricultural season.

Based on power calculation (details in Appendix 2), we decided to conduct the study with 300 treatment farmers and 300 control farmers.

5. Data and Empirical Strategy

5.1. Data

We used data collected at three different points during the intervention for our analysis. The first set of data (the baseline) was collected at the start of the intervention for the year before the intervention. The second set of data (the midline) was collected at end of the first year of intervention, and the third set of data (the endline) was collected at end of two years of intervention[14]. At all three points, we collected detailed crop production-related information and used that to construct variables for analysis. We analyzed the impact of the intervention on yield (quantity of crop harvested per unit of cultivated area), revenue

[11] Fifty farmers are about one-sixth of the total number of farmer-cultivators in a GP in the area of our study. Source: https://data.gov.in/catalog/villagetown-wise-primary-census-abstract-2011-karnataka

[12] Both rice and cotton are prominent crops in India and are grown on 31 percent and 8 percent respectively of country's net sown area (DACFW, 2017). Rice is an important food crop and staple food of almost 60 percent of the population of the country (NFSM, 2016), and likewise cotton is an important fibre and cash crop (NFSM, 2018). Both crops play important role in country's agricultural economy but lag in terms of productivity when compared with rest of the world. Average productivity of paddy and cotton realized by Indian farmers is 36 percent and 54 percent respectively of productivity realized by the most productive nation (NFSM, 2018) , (NFSM, 2016).

[13] Link to the portal: http://landrecords.karnataka.gov.in/service0/RTCHome.aspx

[14] All three surveys, namely baseline, midline and endline had taken place after harvest of crops grown last agricultural season of the year

(money from crop sales and imputed value of produce consumed at home), cost of production (actual and imputed[15] value of human labor, bullock and machine power, and agricultural inputs), net returns (difference between revenue and cost), and the use of major nutrients (nitrogen, phosphorous, and potassium).

5.2. Matching of observables

We wanted to understand the impact of the intervention on the major crops of the area. Hence, we restricted the analysis to only those farmers who had grown either one of both of the two main crops (paddy and cotton) at baseline and in either one or both of the other time periods (midline and endline). 50 out of 600 households (32 from the treatment group and 18 from the control group) did not meet this criterion, and hence were not considered for analysis. For the remaining 550 households, we matched the baseline observables of the treatment and control groups on 13 parameters. Table 1 presents the summary statistics of the key variables categorized by the experimental groups.

Table 1: Comparison of Observables at Baseline

Panel A: General Observables	(1) Control	(2) Treatment	(1) Vs (2)
Age of family (Years)	29.35 (0.49)	28.86 (0.46)	0.49 (0.68)
Education of family (Years)	4.10 (0.18)	4.96 (0.21)	-0.86*** (0.27)
Experience in crop production (Years)	22.38 (0.69)	21.56 (0.73)	0.81 (1.01)
Land owned at Baseline (Acre)	8.74 (0.60)	10.17 (0.68)	-1.42 (0.91)
Age of farmer (Years)	44.46 (0.82)	42.28 (0.75)	2.18* (1.11)
Education of farmer (Years)	4.64 (0.28)	5.82 (0.30)	-1.18*** (0.41)
Visits by extension agent at baseline	0.99 (0.01)	.92 (0.02)	0.06*** (0.02)
Visits to agricultural service centre at baseline	0.10 (0.02)	0.24 (0.03)	-0.15*** (0.03)
Faced income shortage	0.73 (0.03)	0.74 (0.03)	0.00 (0.04)
Female farmers	0.01 (0.01)	0.01 (0.01)	0.00 (0.01)

[15] The imputed values were calculated by obtaining the number of home-owned units used for a certain process and multiplying that with the per-unit rental rate. Example, if two units of machinery were used for a task and one of them was owned by the family, then the imputed cost of machinery for that process was one machinery multiplied by the number of hours for which it was used multiplied by the hourly rental rate.

Panel B: Caste Categories			
	(1) Control	(2) Treatment	(1) Vs (2)
General Caste	0.30 (.03)	0.44 (0.03)	-015*** (0.04)
Scheduled Caste	0.08 (0.02)	0.09 (0.02)	0.00 (0.02)
Scheduled Tribe	0.24 (0.03)	0.10 (0.02)	0.14*** (0.03)
Other Backward Caste	0.38 (0.03)	0.37 (0.03)	0.01 (0.04)
Panel C: Land Ownership Categories			
	(1) Control	(2) Treatment	(1) Vs (2)
Marginal	0.19 (0.02)	0.16 (0.02)	0.03 (0.03)
Small	0.24 (0.03)	0.21 (0.02)	0.04 (0.04)
Semi-Medium	0.27 (.03)	0.27 (0.03)	0 (0.04)
Medium	0.22 (0.02)	0.27 (0.03)	-0.05 (0.04)
Large	0.07 (0.02)	0.09 (0.02)	-0.02 (0.02)
Panel D: Asset Index Categories			
	(1) Control	(2) Treatment	(1) Vs (2)
Asset Index 1	0.23 (0.03)	0.18 (0.02)	0.05 (0.03)
Asset Index 2	0.20 (0.02)	0.17 (0.02)	0.03 (0.03)
Asset Index 3	0.18 (0.02)	0.22 (0.03)	-0.04 (0.03)
Asset index 4	0.17 (0.02)	0.22 (0.03)	-0.05 (0.03)
Asset index 5	0.21 (0.02)	0.20 (0.02)	0.01 (0.03)
N	282	268	

Columns (1) and (2) report sample means with standard errors in paraentheses. Column (3) reports difference between the two experimental groups. **Panel B** reports the proportion of farmers from both groups in various caste categories. Caste is a hereditary social stratification in India which is based on historic occupation of a group of people. Belonging to certain caste has implications on status on social hierarchy. **Panel C** reports proportion of farmers from both groups in various land ownership categories. Farmers are classified as marginal if they own less that one hectare land, as small if they own between one to two hectares, as semi-medium if they own between two to four hectares, as medium if they own between four to ten hectares and as large if they own more than ten hectares of land. Cut-off limits for categorization by land ownership have been taken from http://raitamitra.kar.nic.in/landholdings.html. **Panel D** reports categorization of farmers by asset index categories. To calculate asset index categories, we ran principal component analysis on ownership of eleven types of agricultural equipment and eleven types of household consumer durables. We then predicted scores based on PCA results and using the scores divided farmers into five categories. Farmers with least predicted score were included in asset index 1 and those with the highest score were included in asset index 5. The analysis has been done only farmers who grew either or both of the main crops analysed in the study, namely cotton and paddy, at baseline.

The average age of the farmers was 43 years. In this group, the average number of years of schooling was less than 6 years, and the average number of years of crop production experience was around 22 years. Of the thirteen variables, difference between treatment and control groups was significant at the 1 percent level for five variables. These five variables are average education of members of farmer's family, years of education of farmer, proportion of farmers visited by extension agents in previous year, proportion of farmers who visited agricultural service centre in previous year and caste composition of farmers.
Similar summary statistics were compiled for cotton and paddy farmers and are given in appendix 7 and 8 respectively. We control for variables on which treatment and control farmers differ at baseline in regression analysis of respective crops.

5.3. Empirical strategy

For our econometric analysis, we used a three-period difference-in-differences (DID) technique. The DID specification is given in equation 1. Equation 1 is based on specification for decomposing partial factor productivity provided by Evenson (2000), which allows us to consider agricultural extension as the main independent variable. The DID specification controls for differences between the control group and treatment group at baseline (Kusuma, et al., 2017) and assumes changes in values of the dependent variable for the control group as a time effect (Athey & Imbens, 2006). Thus, this technique separates out the effect of the intervention on the treated group from the effect of time and group-specific characteristics (Puhani, 2008). Thus, β_1 and β_2, which are the coefficients of the interaction terms, capture the effect of the treatment on the treated group for the midline and endline, respectively, relative to the baseline. We cluster standard errors at the first level of randomization, i.e., at the GP level.

(1) $Y_{it} = a + \beta_1 Treatment_i * Midline + \beta_2 Treatment_i * Endline + \beta_3 Midline + \beta_4 Endline + \beta_5 Treatment + \sum_i X_i + \varepsilon_i$

where,

Y_{it}: Value of the outcome variable for farmer i at the baseline, midline, or endline

$Treatment_i * Midline$: Interaction between *Midline* and the treatment dummy, which takes the value 1 if the farmer from the treatment group grew the crop in the midline

*Treatment_i*Endline*: Interaction between *Endline* and the treatment dummy, which takes the value 1 if the farmer from the treatment group grew the crop in the endline

Midline: Time dummy that takes the value 1 if the farmer grew the crop in the midline

Endline: Time dummy that takes the value 1 if the farmer grew the crop in the endline

$Treatment_i$: Dummy for the treatment status of the farmer, which takes the value 1 if the farmer is a treatment farmer

X_i: Variables on which treatment and control farmers differ at baseline

As a robustness check, we also estimate p-value of wild bootstrapping of standard errors, with 100 repetitions.

To determine whether the farmers became more efficient in their agricultural operations due to the intervention, we computed and compared technical efficiency scores for the farmers growing the two crops. The technical efficiency scores were computed using the data envelopment analysis (DEA) method. We analyzed the data using the DEA method to understand whether the intervention had an impact on the efficiency of the farming enterprise. The measure of change in efficiency in the DEA method is better than that used in the DID of returns for three reasons: (a) we can include the element of land, which could not be included in the regression analysis due to lack of data about land rent; (b) we could remove price from the equation to obtain the direct impact of the intervention on the output obtained from various inputs; and (c) unlike the regression equation for crop returns, where every input received equal weight, in this case, the inputs received weight proportionate to their importance to crop cultivation.

The DEA method uses linear programming techniques to construct a production frontier of various combinations of inputs and outputs (Coelli, Rahman, & Thirtle, 2005). The most efficient farms lie on the frontier and are given a technical efficiency score of 1. Farmers that are not efficient lie below this frontier, and their efficiency scores are computed in terms of their distance from the frontier (Ji & Lee, 2010). Because the DEA method is non-parametric, we did not have to assume or specify the functional form of the frontier or the distributional form of the error term (Coelli, 1995), or provide weights for the various inputs and outputs (Cooper, Seiford, & Tone, 2000).

We used variable returns to scale and output oriented DEA model for analysis the data. Model specification is given in equation 2.

(2) $Max\ \Phi$ s.t.

$\Phi y_{j,m} \leq \sum_j z_j y_{j,m} \quad \forall\ m$

$\sum_j z_j x_{j,n} \leq x_{j,n}\phi \quad \forall\ n$

$\sum_j z_j = 1$

where, ϕ is a scalar outcome showing how much the production of each crop can increase by using the inputs (both fixed and variable) in a technically efficient configuration. $y_{j,m}$ is the amount of output m by firm j, $x_{j,n}$ is the amount of input n used by firm j, and z_j are weighting factors. The restriction $\sum_i z_i = 1$ allows for variable returns to scale.

For DEA analysis we used crop yields as output and consumables, labor, machine and animal power, and size of land in which the crop was cultivated as input.

6. Results

6.1 Impact of intervention on yields, revenues, costs and returns

The crop-wise details of the number of farmers who had grown the crops, the average area cultivated by them, and the percentage of farmers who had access to irrigation are given in Table 2.

Table 2: Descriptive Statistics

	Comtrol Farmers			Treatment Farmers		
Panel A: Number of farmers						
	Baseline	Midline	Endline	Baseline	Midline	Endline
Paddy	178	173	147	199	197	146
Cotton	146	140	128	119	112	111
Panel B: Average area under cultivation (acre)						
	Baseline	Midline	Endline	Baseline	Midline	Endline
Paddy	7	8	9	8	9	10
Cotton	6	8	10	6	8	9
Panel C: Access to Irrigation (% of farmers)						
	Baseline	Midline	Endline	Baseline	Midline	Endline
Paddy	100	100	98	99	99	100
Cotton	28	37	31	19	38	22

Panel A reports the number of farmers who had grown the respective crop at the respective survey points. **Panel B** reports the average area in acre cultivated of respective crop at the respective survey points and **panel C** reports the percentage of farmers who had access to the irrigation for the respective crops. Farmers who did not grew the respective crops at baseline have been excluded from analysis.

Given that paddy is the dominant crop of the region, at all the three time periods, the number of farmers growing paddy was higher than the number growing cotton. Further, the farmers devoted more land to paddy crop, on average. Most paddy farmers had assured access to irrigation in all the three time periods, while less than 40 percent of the cotton farmers had access to irrigation.

The average values and standard deviations of yields, revenues, costs, and net returns for paddy and cotton crop at the three time periods are reported in Table 3.

Table 3: Average Values of Yields, Revenues, Costs and Returns

	Control Farmers			Treatment Farmers		
Panel A: Yields (Quintal/Acre)						
	Baseline	Midline	Endline	Baseline	Midline	Endline
Paddy	25	26	27	24	26	31
	(7)	(6)	(4)	(7)	(5)	(3)
Cotton	7	9	9	6	11	14
	(4)	(4.)	(1)	(4)	(4)	(2)
Panel B: Revenues (Rs./Acre)						
	Baseline	Midline	Endline	Baseline	Midline	Endline
Paddy	35830	39515	40268	35695	41566	50752
	(13301)	(10397)	(7042)	(12819)	(9264)	(5714)
Cotton	28610	42172	34941	22861	50820	58471
	(16508)	(19235)	(5681)	(15765)	(20183)	(11397)
Panel C: Costs (Rs./Acre)						
	Baseline	Midline	Endline	Baseline	Midline	Endline
Paddy	19396	20538	23960	20931	23011	19753
	(4854)	(4221)	(3566)	(5364)	(5559)	(2697)
Cotton	23589	25192	24704	23539	28803	23147
	(6944)	(7207)	(4267)	(7132)	(8143)	(4556)
Panel D: Returns (Rs./Acre)						
	Baseline	Midline	Endline	Baseline	Midline	Endline
Paddy	16434	18976	16308	16016	18555	30999
	(14012)	(11612)	(7197)	(13907)	(11393)	(6457)
Cotton	6021	16979	10237	-678	22017	35324
	(15992)	(17292)	(6579)	(15680)	(20515)	(10774)

The table reports average values of yields, revenue, cost and returns at the three survey points as reported by farmers in the study. Standard deviations are given in parentheses. Farmers who did not grew the respective crops at baseline have been excluded from analysis.

In terms of average yields, at the baseline, the paddy farmers from both the treatment group and control group had similar average yields. However, the control farmers growing cotton had higher yields on average compared to the treatment farmers at the baseline. At the midline, the average yields were similar for the treatment and control farmers for paddy but were higher for the treatment farmers for cotton. At the endline, the treatment farmers were getting higher yields than the control farmers for both crops.

Comparison of values of yields, revenues, costs and net returns obtained by treatment and control farmers at baseline is given in Table 4.

Table 4: Comparing values at baseline: Yields, Revenues, Costs and Returns

Panel A: Yields (Quintal/Acre)			
	(1) Control	(2) Treatment	(1) Vs (2)
Paddy	25	24	1
	(1)	(0)	(1)
Cotton	7	6	2***
	(0)	(0)	(0)
Panel B: Revenues (Rupees/Acre)			
	(1) Control	(2) Treatment	(1) Vs (2)
Paddy	35830	36947	-1117
	(997)	(891)	(1333)
Cotton	28610	22861	5749***
	(1366)	(1445)	(1998)
Panel C: Cost (Rupees/Acre)			
	(1) Control	(2) Treatment	(1) Vs (2)
Paddy	19396	20931	1535***
	(364)	(380)	(529)
Cotton	22589	23539	-950
	(575)	(654)	(868)
Panel D: Returns (Rupees/Acre)			
	(1) Control	(2) Treatment	(1) Vs (2)
Paddy	16434	16016	418
	(1050)	(986)	(1440)
Cotton	6021	-678	6699***
	(1324)	(1437)	(1958)

The table reports comparison of yields, revenues, cost and returns observed at baseline for the two crops between treatment and control group. Columns (1) and (2) report sample means with standard errors in paraentheses. Column (3) reports difference between the two experimental groups. Farmers who did not grew the respective crops at baseline have been excluded from analysis.

Between the two groups, there were statistically significant differences at baseline in yields, revenues and returns for cotton crop and cost for paddy crop. At baseline, cotton farmers in control group realized higher yields, which also resulted in higher revenues and returns as compared to the treatment group. On the other hand, control farmers growing paddy incurred significantly lesser cost per acre for their crops at baseline as compared to treatment farmers.

Table 5: Treatment effect on crop yields, revenue, cost and returns

	(1) Yield	(2) Revenue	(3) Cost	(4) Returns
Panel A: Paddy Crop				
Treatment*Midline	0.950	1273.7	864.5	249.5
	(0.857)	(1997.8)	(1380.8)	(2338.6)
	[.31]	[.57]	[.56]	[.92]
Treatment*Endline	5.036***	9263.3***	-5715.8***	14901.8***
	(0.908)	(1828.2)	(870.3)	(2103.0)
	[.01]	[0]	[0]	[0]
Mean of dep. Var	26.22	40367.5	21251.9	19122.4
Observations	1040	1040	1040	1040
R-Square	0.178	0.210	0.134	0.199
Adjusted R-square	0.165	0.197	0.121	0.187
Panel B: Cotton Crop				
	(1) Yield	(2) Revenue	(3) Cost	(4) Returns
Treatment*Midline	3.503**	14400.2**	2700.4	11550.1
	(1.204)	(5385.6)	(2648.9)	(6733.6)
	[.01]	[.01]	[.44]	[.14]
Treatment*Endline	7.174***	29289.4***	-2451.4	31761.4***
	(1.450)	(6254.6)	(1519.9)	(5569.4)
	[.01]	[0]	[.08]	[.03]
Mean of dep. var	9.161	38913.6	24568.4	14365.2
Observations	756	756	756	756
R-Square	0.400	0.399	0.103	0.391
Adjusted R-square	0.387	0.387	0.0852	0.378

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

Clustered standard errors in parenthesis. Wild bootstrap p-value in square brackets.

Panel A reports results of regressions of per acre yield, revenue, cost and returns for paddy crop on treatment and time interaction terms in a difference-in-difference setup. Panel B reports the same results for cotton crop. Yield is measured in terms of quintals per acre and revenue, cost and returns are measured in terms of rupees per acre. Values of all variables were winsorized at the 99th percentile. The standard errors were clustered at level of Gram Panchayat (first level of randomization).

The interaction coefficients from the difference-in-differences (DiD) regression for the four dependent variables are reported in Table 5.

In the DiD analysis[16], no significant change in the yields of paddy crop was observed at the midline. By the time DATES was operational, several farming-related decisions relating to paddy crop had been taken

[16] Full results from DiD analysis are given in appendix

by the farmers, due to which the intervention did not have a significant impact on the crop at the midline. However, a statistically significant increase in yields was observed for the treatment farmers for paddy crop at the endline compared to the baseline. The intervention led to increase in yields of paddy crop by 19.2 percent.

For cotton crop, significant changes in crop yields were observed at both midline and endline for treatment farmers. Cotton yields for the treatment farmers increased by 38 percent at the midline and 78 percent at the endline, as compared to baseline.

There was greater scope for improvement of the yields for cotton compared to paddy, which also explains the difference in the magnitude of impact of the intervention. The potential yields for the prominent varieties of the two crops are given in Table 6. At the baseline paddy farmers in treatment group were realizing 85 percent of the potential yield. In contrast, the cotton farmers in the treatment group were realizing only 41 percent of the potential yields at baseline.

Table 6. Potential Yields of Prominent Varieties of Crops grown by Farmers

Crop	Variety	Potential Yield	Average Yield Recorded at Baseline	
			Treatment farmers	Control farmers
Paddy	Sona Masuri	28	23.8	25.9
Cotton	Ajith Jadoo	13.9	5.7	7.2

Note: Potential yields were compiled by project staff using information from various sources. Unit for yield is quintals per acre

Cotton is a more difficult crop to manage compared to paddy due to the longer crop cycle and susceptibility to various pests. The DATES intervention led to farmers achieving substantial part of the yield potential of their crops. Since the yield gap was higher for cotton, we see a higher impact of the intervention on the cotton crop compared to that of paddy.

The DiD coefficients for revenue were similar to those obtained for yields in terms of magnitude and significance. Statistically significant results for revenue were obtained for paddy at the endline (23 percent) and for cotton at the midline and the endline (37 percent and 75 percent, respectively).

In terms of average costs, at the baseline, the per-acre costs incurred by the treatment farmers for paddy and cotton were marginally higher than those incurred by the farmers in the control group. A similar difference between the groups continued at the midline for both crops. However, at the endline, the average costs incurred by the treatment farmers were lower than the costs incurred by their control counterparts.

The DiD coefficient for costs was positive but not statistically significant at the midline for the treatment farmers for paddy crop. However, the coefficients were negative and statistically significant for paddy at the endline. The DATES intervention led to a reduction in the cost of cultivation by almost 26 percent for paddy and 10 percent for cotton for the treatment farmers at the end of two years of intervention. Results for paddy are significant at one percent and those for cotton are significant at eight percent level[17].

Table 7: Treatment effect on major components of cost

Panel A: Paddy Crop						
	(1) Plowing	(2) Seeds	(3) Transplanting	(4) Irrigation	(5) Weeding	(6) Harvesting
Treatment*Midline	48.40	725.9**	-115.7	-1041.0***	99.65	429.4
	(123.1)	(308.0)	(90.32)	(193.8)	(266.6)	(285.0)
	[.57]	[.01]	[.33]	[.01]	[.73]	[.2]
Treatment*Endline	-349***	6.075	-280.5***	-114.5	-1195***	65.31
	(104.3)	(338.4)	(77.04)	(217.9)	(139.1)	(283.5)
	[.02]	[.97]	[0]	[.66]	[0]	[.8]
Mean of dep. var	1127.7	1648.7	2064.6	1767.8	1863.2	2605.1
Observations	1040	1040	1040	1040	1040	1040
R-Square	0.262	0.0788	0.485	0.171	0.112	0.129
Adjusted R-square	0.250	0.0644	0.477	0.158	0.0978	0.115
Panel B: Cotton Crop						
	(1) Plowing	(2) Seeds	(3) Sowing	(4) Intercultivation	(5) Weeding	(6) Harvesting
Treatment*Midline	298.3**	33.55	107.7	63.27	553.0	-842.9
	(99.08)	(211.3)	(222.8)	(279.9)	(927.0)	(502.4)
	[.09]	[.88]	[.62]	[.86]	[.56]	[.17]
Treatment*Endline	208.6	-246.3	95.80	-681.2**	-54.94	201.7
	(125.1)	(142.7)	(141.3)	(227.0)	(431.4)	(767.6)
	[.26]	[.19]	[.58]	[.06]	[.88]	[.85]
Mean of dep. var	1036.5	2415.3	697.0	1957.9	2433.9	3927.2
Observations	756	756	756	756	756	756
R-Square	0.157	0.0645	0.0284	0.0621	0.0589	0.0967
Adjusted R-square	0.140	0.0456	0.00866	0.0431	0.0398	0.0784

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Clustered standard errors in parenthesis. Wild bootstrap p-value in square brackets.
Panel A reports results of regressions of major components of cost of production on treatment and time interaction terms in a difference-in-difference setup. Panel B reports the same results for cotton crop. Values for all dependent variables are in terms of rupees per acre. Values of all variables were winsorized at the 99th percentile. The standard errors were clustered at level of Gram Panchayat (first level of randomization).

[17] Costs reduction for cotton crop are significant according to p-values compiled through wild bootstrapping of standard errors

To understand the components of cost on which the project had an impact, we ran DiD regressions for the main components of cost. The results are presented in Table 7.

For the paddy farmers, at the midline, the project led to a significant increase in the cost of seeds and a significant reduction in the cost of irrigation. The farmers were advised to use 'younger' paddy saplings, which were more expensive. This accounts for the increase in seed related expenses. Also, the farmers adopted the advice on better water management, which might have led to them using lesser water for irrigation at midline as compared to baseline, thus reducing the cost of labour needed for irrigation. At the endline, the treatment farmers spent significantly lesser on plowing and weeding for paddy crop than they did at baseline. For cotton crop, the regression coefficients are statistically significant and negative for interculture. We explain reduced cost of weeding and interculture in later part of the section.

In terms of average net returns, at the baseline, the treatment farmers growing cotton received negative returns on average, implying that when the imputed value of family labor was included in the calculation of costs, the costs exceeded the revenue. In the case of both paddy and cotton, while the average returns were higher for the treatment farmers at the midline compared to those for the control farmers, the results of the DiD analysis showed that there was no statistically significant increase in the returns obtained by the treatment farmers at the midline because of the intervention.

At the endline, for both the crops, the treatment farmers obtained higher returns than the control farmers did. This finding is supported by the DiD coefficients. The project led to an increase in returns for the paddy farmers by 78 percent and for the cotton farmers by 221 percent at the end of two years of intervention. The substantial increase in returns is a result of the combined effect of the increase in revenues and the decrease in costs for the treatment farmers at the endline.

6.2 Impact of intervention on efficiency of agricultural operations

The results of the analysis of the changes in yields, costs, and returns were validated through a comparison of the technical efficiency scores obtained by the treatment farmers and control farmers in the three time periods. As mentioned in section 5.3, the technical efficiency scores reflect the relative positioning of the farmers with regard to the frontier of efficient transformation of inputs to outputs. The higher the technical efficiency score, the closer a farmer is to the frontier, and the more efficient the farmer is in transforming inputs to outputs.

Table 8 presents the percentage of the treatment and control farmers in various categories according to their technical efficiency scores for the two crops in the three time periods.

Table 8: Technical efficiency score

	Treatment Farmers			Control Farmers		
Panel A: Paddy Crop						
TE Score Range	Baseline	Midline	Endline	Baseline	Midline	Endline
<.7	62.94	67.00	4.11	62.29	63.00	35.37
.7 - .8	16.24	13.71	20.55	18.28	14.45	35.37
.8 -.9	8.62	6.10	39.00	5.14	6.93	19.05
.9 – 1	12.18	13.20	36.30	14.28	15.61	10.20
Panel B: Cotton Crop						
TE Score Range	Baseline	Midline	Endline	Baseline	Midline	Endline
<.7	77.97	73.21	32.43	75.86	72.14	91.41
.7 - .8	5.93	7.14	37.83	6.89	7.14	0
.8 -.9	5.08	6.25	11.71	2.76	5.00	2.34
.9 – 1	11.02	13.39	18.02	14.48	15.71	6.25

Panel A reports percentage of farmers in respective categories of technical efficiency scores for paddy crop. While calculating technical efficiency scores, crop yields were used as output and cultivated area (in acre) and expense on consumables (seeds, fertilizers etc.), human labour (actual and imputed) and bullock and machine power (actual and imputed) as inputs. Panel B reports the results for cotton crop.

Between the baseline and the endline, there is a clear movement of the treatment farmers from the lower technical efficiency score ranges (lower than 0.7) to the higher ranges (0.8 to 1). For instance, 63 percent of the treatment farmers growing paddy had technical efficiency scores lower than 0.7, and 12 percent had technical efficiency scores between 0.9 and 1 at the baseline. At the endline, only 4 percent of the treatment farmers had technical efficiency scores lower than 0.7, and 36 percent had technical efficiency scores between 0.9 and 1.

In case of cotton, percentage of treatment farmers in 0.9 – 1 score category increased from 11 percent at baseline to 18 percent at endline and percentage of treatment farmers in the lower score category (lower than 0.7) reduced to 32 percent in the endline, compared to close to 78 percent in the baseline and the midline. It is important to remember that the technical efficiency scores are relative in nature. Hence, any worsening in the scores obtained by the control farmers, while supported by the earlier data about declining revenues and increasing costs, is partly due to the treatment farmers becoming more efficient in their operations as compared to control farmers and moving toward the efficiency frontier.

6.3 Impact of intervention on use of inorganic fertilizers and plant protection chemicals

Average value and standard deviation of expense incurred by treatment and control farmers on fertilizers and insecticides are presented in table 9 and comparison of expenses incurred at baseline by the two groups of farmers is presented in table 10. For both paddy and cotton, expense incurred by control farmers at baseline on fertilizers and insecticides was significantly lower than expense incurred by treatment farmers.

Table 9: Average Values of Expenses on Fertilizers and Insecticides

	Control Farmers			Treatment Farmers		
Panel A: Expense on Fertilizers (Rupees/Acre)						
	Baseline	Midline	Endne	Baseline	Midline	Endline
Paddy	4817 (2260)	4536 (1680)	7138 (1704)	5768 (2582)	5990 (2801)	4587 (1336)
Cotton	3641 (2197)	6702 (3031)	7363 (1867)	4210 (2103)	8645 (3528)	6356 (1783)
Panel B: Expense on Insecticides (Rupees/Acre)						
	Baseline	Midline	Endline	Baseline	Midline	Endline
Paddy	1023 (768)	1065 (513)	2433 (1154)	1234 (817)	1364 (1027)	2114 (974)
Cotton	1167 (864)	1666 (949)	2854 (943)	1637 (1289)	2190 (1126)	1991 (607)

The table reports average quantities and standard deviation (in brackets) of expense incurred on fertilizers and insecticides at the three time periods by treatment and control farmers. Farmers who did not grew the respective crops at baseline have been excluded from analysis.

Table 10: Comparing values at baseline: Expense on fertilizers and insecticides

Panel A: Expense on Fertilizers (Rupees/Acre)			
	(1) Control	(2) Treatment	(1) Vs (2)
Paddy	4817 (169)	5768 (183)	950*** (251)
Cotton	3641 (182)	4210 (193)	-568** (266)
Panel B: Expense on Insecticides (Rupees/Acre)			
	(1) Control	(2) Treatment	(1) Vs (2)
Paddy	1023 (58)	1234 (58)	-212** (82)
Cotton	1167 (72)	1637 (118)	-470*** (133)

The table reports comparison of expense incurred on fertilizers and insecticides at baseline for the two crops by treatment and control group. Columns (1) and (2) report sample means with standard errors in paraentheses. Column (3) reports difference between the two experimental groups. Farmers who did not grew the respective crops at baseline have been excluded from analysis.

On average, control farmers incurred higher expense on fertilizers and insecticides for both paddy and cotton crop at midline and endline, as compared to baseline. On the other hand, expense incurred by treatment farmers on the two products increased in midline as compared to baseline but reduced again in midline for both paddy and cotton crop.

Table 11: Treatment effect on expense on fertilizers and insecticides

Panel A: Paddy Crop		
	(1) Fertilizers	(2) Insecticides
Treatment*Midline	464.7	63.38
	(562.2)	(181.1)
	[.44]	[.69]
Treatment*Endline	-3464.4***	-531.9*
	(390.2)	(244.3)
	[0]	[.04]
Mean of dep. Var	5458.5	1476.7
Observations	1040	1040
R-Square	0.157	0.295
Adjusted R-square	0.144	0.284
Panel B: Cotton Crop		
	(1) Fertilizers	(2) Insecticides
Treatment*Midline	1381.6	44.27
	(901.3)	(308.9)
	[.19]	[.92]
Treatment*Endline	-1600.7**	-1310.1***
	(649.6)	(198.8)
	[.03]	[.01]
Mean of dep. Var	6066.2	1885.2
Observations	756	756
R-Square	0.343	0.258
Adjusted R-square	0.330	0.243

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

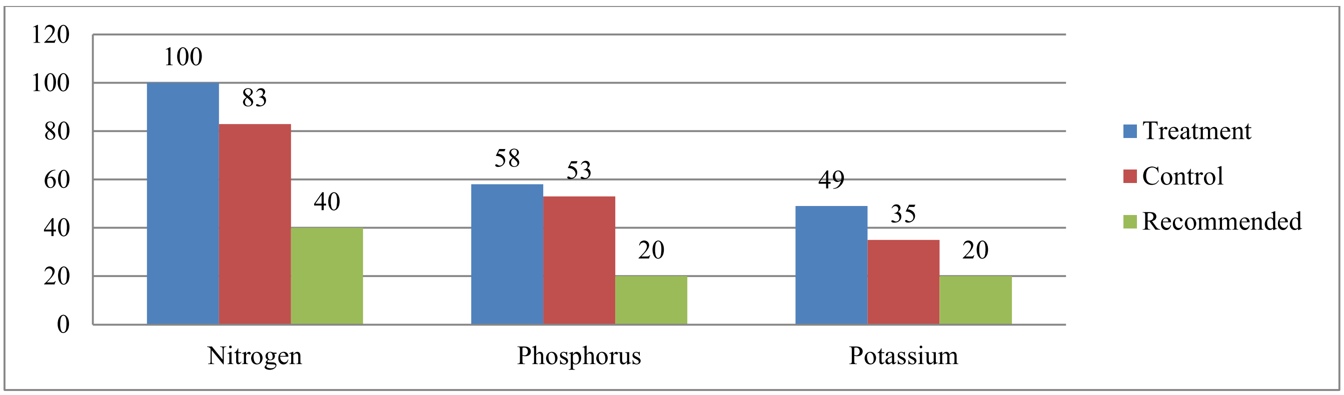
Clustered standard errors in parenthesis. Wild bootstrap p-value in square brackets.

Panel A reports results of regressions of expenses incurred on fertilizers and insecticides on treatment and time interaction terms in a difference-in-difference setup. Panel B reports the same results for cotton crop. Values for all dependent variables are in terms of rupees per acre. Values of all variables were winsorized at the 99th percentile. The standard errors were clustered at level of Gram Panchayat (first level of randomization).

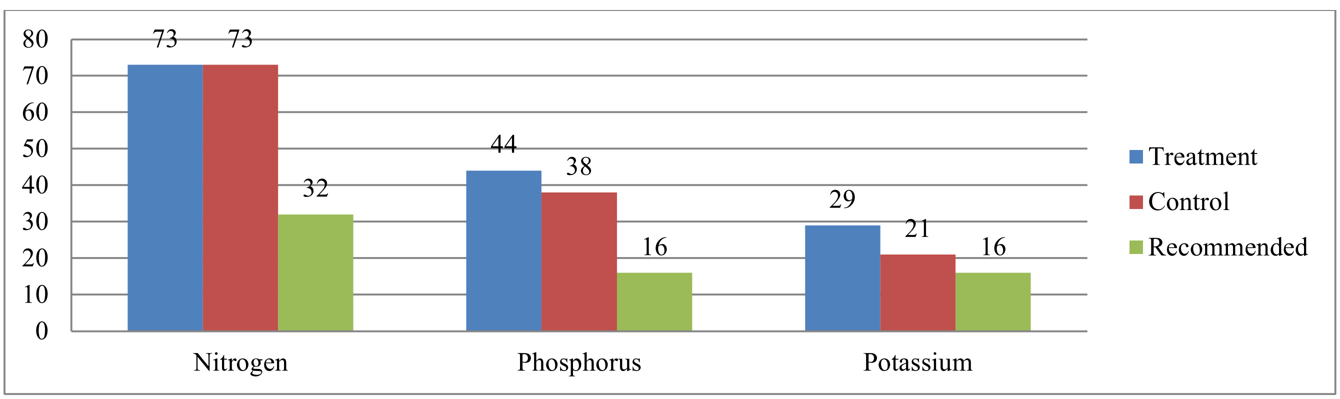
The DiD analysis (the coefficients for the interaction terms are presented in Table 11) of the expenses incurred for plant protection chemicals shows that due to the intervention, at the endline, the treatment farmers incurred 69 percent and 36 percent less expense for plant protection chemicals for cotton and paddy crops, respectively.

Similar results are observed for fertilizers. The intervention led to a reduction in expenses incurred for fertilizers by 63 percent for paddy and by 26 percent for cotton. Both results are statistically significant. Rationalizing fertilizer usage was a big part of the intervention. Data collected at the baseline showed that the farmers used fertilizers excessively. Figure 3 shows that, on average, the treatment farmers applied 100 kg of nitrogen per acre of cultivated area, while as per recommendation by local agricultural university the crop required only 40 kg per acre.

Paddy



Cotton



Note: Graphs show average figures for kilograms of nutrients applied by treatment and control farmers per acre of cultivated area. Data on recommended fertilizer quantity was obtained from a local agricultural university

Figure 3: Quantity of nutrients applied by farmers at baseline

Comparison between quantity of macro-nutrients used by treatment and control farmers at baseline is presented in table 12. In almost all instances, nutrients applied by treatment farmers for paddy and cotton crop were more than the nutrients applied by control farmers.

Table 12: Comparing values at baseline: Macro-nutrient use

Panel A: Nitrogen (Kilogram/Acre)			
	(1) Control	(2) Treatment	(1) Vs (2)
Paddy	83	100	-17***
	(3)	(3)	(5)
Cotton	73	73	0
	(4)	(4)	(5)
Panel B: Phosphorous (Kilogram/Acre)			
	(1) Control	(2) Treatment	(1) Vs (2)
Paddy	48	58	-9***
	(2)	(2)	(3)
Cotton	38	44	-7**
	(2)	(2)	(3)
Panel C: Potash (Kilogram/Acre)			
	(1) Control	(2) Treatment	(1) Vs (2)
Paddy	35	49	-13***
	(2)	(2)	(3)
Cotton	21	29	-7***
	(2)	(2)	(3)

The table reports comparison of macro-nutrient quantities used at baseline for the two crops by treatment and control group. Columns (1) and (2) report sample means with standard errors in paraentheses. Column (3) reports difference between the two experimental groups. Farmers who did not grew the respective crops at baseline have been excluded from analysis.

The DiD analysis of the impact of the intervention on nutrient use (reported in Table 13) showed that the intervention led to a significant reduction in the quantity of nitrogen and phosphorous used by the farmers for both the crops. The treatment farmers reduced nitrogen use by 75 percent and 27 percent for paddy and cotton crops, respectively. They also reduced phosphorous use by 73 percent and 40 percent for paddy and cotton, respectively. The significant reduction in nutrient use was observed only at endline.

The reduction in the quantity of nutrient application and expenses related to fertilizers did not come at the cost of the net returns from farming, as the regression results show that the treatment farmers gained significantly in terms of additional net returns. One reason for this could be that though there was a reduction in the quantity of nutrients applied, the nutrient absorption increased due to the application of the right products in the right quantities and at the right time.

Table 13: Treatment effect on macro-nutrient application

Panel A: Paddy Crop			
	(1) Nitrogen	(2) Phosphorous	(3) Potash
Treatment*Midline	-3.218	-2.616	-0.631
	(11.87)	(4.939)	(5.268)
	[.87]	[.67]	[.95]
Treatment*Endline	-71.66***	-37.31***	-16.53**
	(8.158)	(3.331)	(6.427)
	[0]	[0]	[.01]
Mean of dep. Var	93.11	51.25	44.45
Observations	1040	1040	1040
R-Square	0.189	0.109	0.0900
Adjusted R-square	0.176	0.0953	0.0758
Panel B: Cotton Crop			
	(1) Nitrogen	(2) Phosphorous	(3) Potash
Treatment*Midline	17.49**	10.06	6.875
	(7.037)	(11.76)	(10.62)
	[.07]	[.42]	[.64]
Treatment*Endline	-29.74***	-22.80**	5.062
	(7.342)	(7.455)	(6.253)
	[0]	[0]	[.49]
Mean of dep. Var	109.2	56.59	45.15
Observations	756	756	756
R-Square	0.309	0.211	0.316
Adjusted R-square	0.295	0.195	0.302

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Clustered standard errors in parenthesis. Wild bootstrap p-value in square brackets.
Panel A reports results of regressions of quantity of macro-nutrients on treatment and time interaction terms in a difference-in-difference setup. Panel B reports the same results for cotton crop. Values of all dependent variables are in terms of kilograms per acre. Values of all variables were winsorized at the 99th percentile. The standard errors were clustered at level of Gram Panchayat (first level of randomization).

The changes in nutrient management also explain the increase in labor outlay for fertilizer application and reduced expenses for interculture operations and weeding. It was suggested to the farmers that fertilizers should be applied in multiple doses during the crop lifecycle, which led to an increase in the cost of applying fertilizers. The reduced use of fertilizers led to reduced growth of weeds, which in turn reduced the labor required for weeding.

6.4 Cost of the intervention

Various components of cost of DATES intervention are given in table 14. In the DATES project, providing customized information for two years cost Rs. 12,000 per farmer. This does not include the expenses incurred for conducting research and for collecting data from the treatment and control farmers.

Table 14: Cost of running DATES project

	Particulars	Qty./No.	Cost/unit (Rs.)	Total Periods	Total budget (Rs.)
I	*Salaries (Monthly Expenses)*				
a	Extension Agents	3	15,000	24	1080000
b	Field level supervisor	1	50,000	24	1200000
c	Research Assistant (office level)	1	18,000	24	432000
II	*Travel and Other Allowances (Monthly Expenses)*				
a	Extension Agents	3	5000	24	360000
b	Field level supervisor	1	6000	24	144000
III	*Yearly Expenses*				
a	Operational cost	1	20,000	2	40000
b	Training and HRD	1	25,000	2	50000
c	eSAP licenses	3	25,000	2	150000
IV	*Non-Recurring Expenses**				
a	Hand-held devices	3	9,000	1	27000
B	Thermal Printer	3	9,500	1	28500
	Total Expense for 300 Treatment Farmers				3511500
	Expense per Treatment Farmer				11705

* the hand-held devices and thermal printer would have life expectancy of three years
The table reports total and per farmer cost of running the DATES intervention in the area of intervention. This does not include cost of research and data collection. Costs and budget have been reported in rupees.

Returns to the farmers due to the intervention outweigh the the costs by a large amount and make information delivery an effective initiative that the public sector can easily undertake.[18]

[18] Further research is required to explore whether the farmers would be willing to pay part of the cost of the intervention. The farmers in the area of our study continued to call the graduates who served as extension agents even after the intervention was completed to seek advice, which is a good indicator that they found the service extremely useful.

7. Conclusion and Policy Implications

While agricultural information delivery is not an actively used tool for the enhancement of agricultural productivity in India, we show that it holds immense potential for enhancing agricultural productivity in an ecologically and financially sustainable way. In this study, we presented results from an agricultural information delivery project named DATES that used a mix of traditional extension methods and modern information and communications technology to provide information about agricultural best practices to 300 farmers who were growing paddy and cotton.

The results achieved through the DATES intervention show that given the high gaps in yield of the various crops grown in India, it is possible to achieve significant increases in yield via the proper delivery of information related to agricultural practices. The intervention also shows that by providing information about better farm management practices, it is possible to improve the technical efficiency of farming enterprises. Additionally, the increase in productivity does not come with higher costs to farmers nor is it at the cost of the environment. Information about the process of applying agricultural inputs can simultaneously increase the effectiveness of the products and rationalize the quantity of inputs required, thereby reducing the costs of production and reducing the various adverse environmental impacts that these products may have. The findings of this study support the work of Pagani, Sawyer, & Mallarino (2013) on the optimal nutrient rates for crops and show that a reduction in fertilizer quantity need not lead to a drop in yields in areas where intensive agriculture is practiced. The results are also significant considering that studies like Fishman et al., (2017) did not find any impact of providing agricultural information on fertilizer use.

The DATES intervention showed that a substantial increase in productivity and profitability is possible by providing information about best practices to farmers. However, our findings are limited to irrigated areas, to crops for which large investments are made by farmers in terms of inputs, and to crops that are highly susceptible to pest attacks. Similar interventions should be tried out for other agro-ecological zones, other crops and on a larger scale to understand the robustness of the project outcome.

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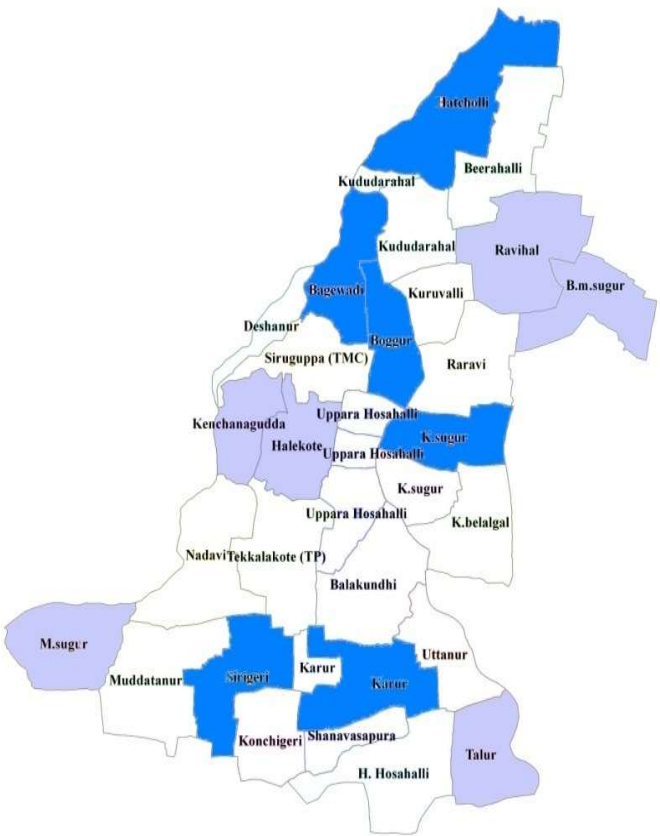
Appendix 1

Map of treatment and control Gram Panchayats in DATES



Source: Map obtained from Karnataka Remote Sensing Applications Centre, Bangalore

Treatment GPs have been filled in dark blue and control gram panchayats have been filled in light blue.

Appendix 2

Power Calculation to Determine Number of Farmers to be Studied

Decision on number of farmers to be studied was made on basis of power size calculation. A RCT should have sufficient statistical power to detect differences between treatment and control groups. For sample size calculation a standard formula is used. The assumption behind this formula are: (i) one control & one treatment group of same size; and (ii) standard deviation of the variable of interest is constant across the groups. Sample size in each group is given by

$$n = 2s^2 \left[\frac{z_C + z_P}{\Delta} \right]^2$$

where, s denotes pulled standard deviation of both comparison groups, z is standard normal variate, Z_C and Z_P are the values for desired significance level and statistical power respectively, and Δ is the minimum expected difference between means in two groups (or, effect size). We chose 80% power and 95% significance level for our analysis. For sample size calculation we used the crop cutting experiment data maintained by Agriculture Insurance Company of India (AIC) available at hobli level[19].

Sample size calculation using pilot AIC data

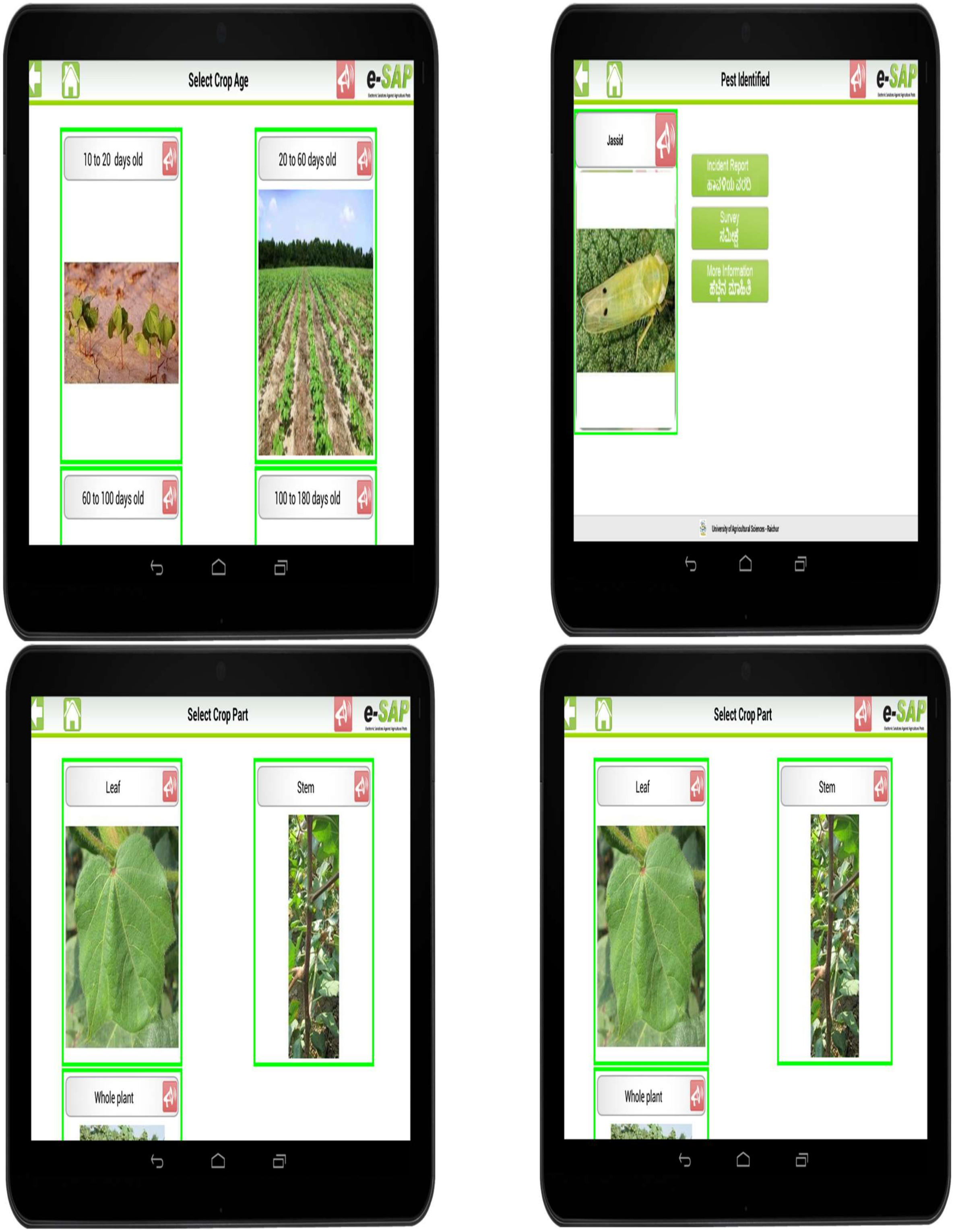
	No. of obs.	Avg. yield (q/ac)	Std. dev. (q/ac)	Sample size (n)
Paddy (irrigated)	33	16.22	3.57	77
Sunflower (irrigated)	28	4.14	0.99	90
Sunflower (rainfed)	31	1.39	0.66	353

Source: AIC data and own calculations

Based on the above sample size computations, the team decided to have 300 farmers each in control and treatment group in both project sites. Thus, for each GP, 50 farmers were surveyed.

[19] Hobli refers to cluster of gram panchayats (generally 3-4 gram panchayats)

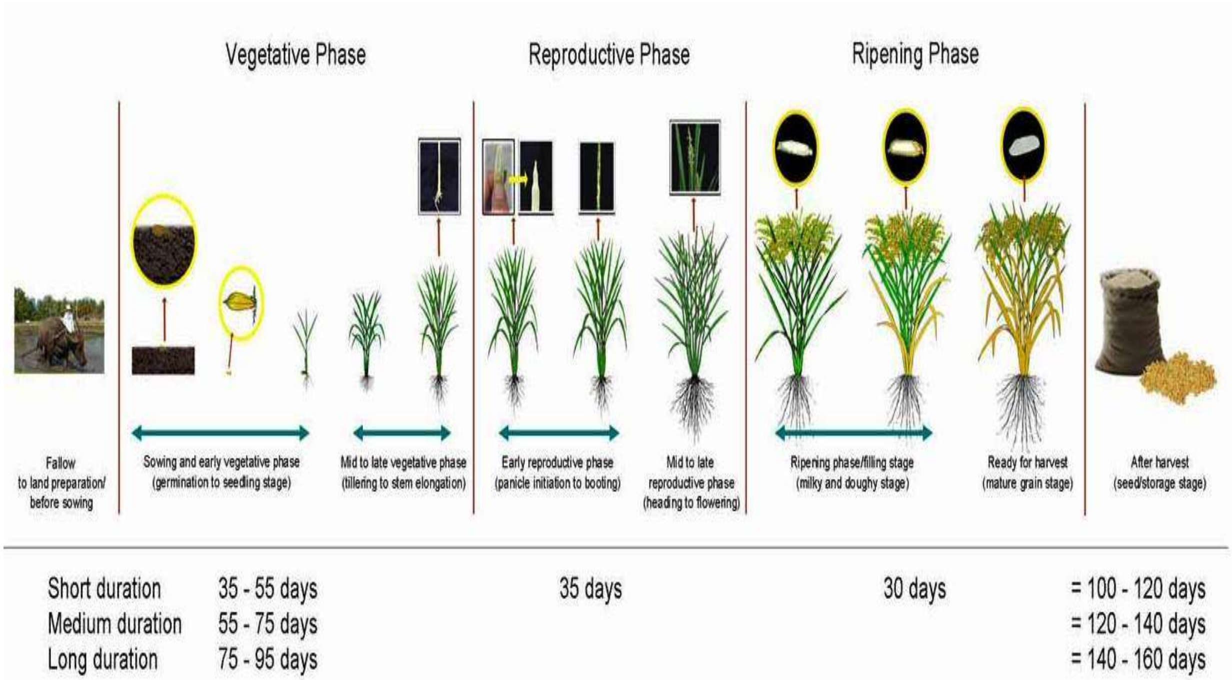
Appendix 3: e-SAP Mobile Application



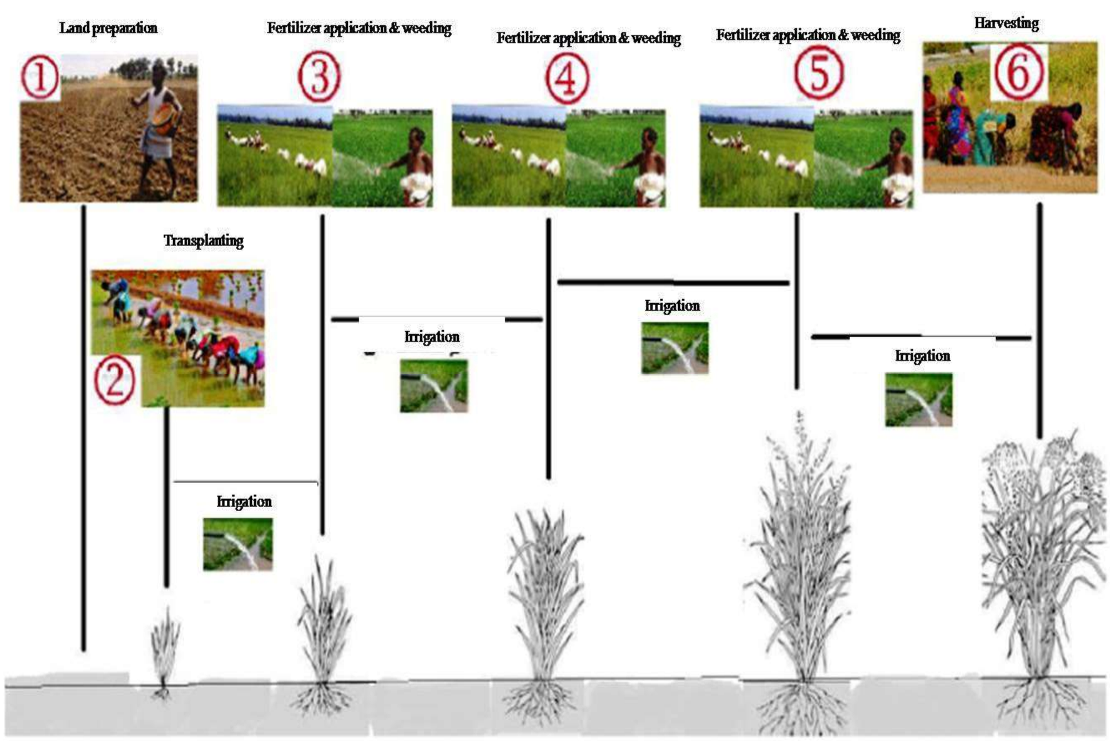
Appendix 4: Using e-SAP to provide suggestion to farmers

Appendix 5: Information Module on Paddy

PADDY GROWTH STAGES



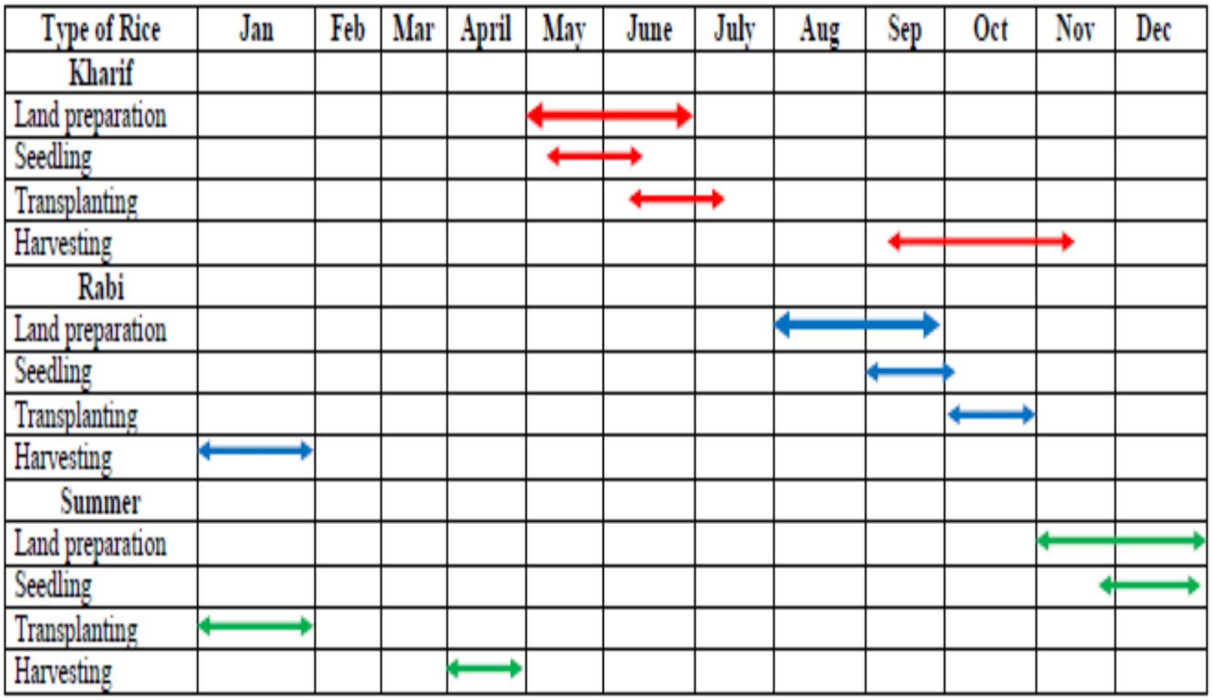
Transplanted Rice



Direct Seeded Rice

a) Vegetative (germination to panicle initiation) b) Reproductive (panicle initiation to flowering) c) Ripening (flowering to mature gran)

CROP CALENDAR



CROP VARIETIES


BP 520


CSR 22


Gangavathi Sona


Jaya

Varieties	Situation		Sowing time	Duration (Days)	Characteristics
	Rainfed	Irrigated			
Jaya	*	*	June October	140-150 120-145	1. Long and bold seed 2. Resistant to blast disease
BPT-5204	-	*	June	140-150	Long slender seed
CSR-22	-	*	June	130-135	Long slender seed
Gangavathi	-	*	June	130-135	Medium slender seed
Siri-1253	-	*	June	135-140	Medium Small seed
IR-64	-	*	January	125-130	Long small seed
ES-18	-	*	January	120-125	Medium slender seed
Telhumsa	-	*	January	120-125	Long small seed
Sujata	-	*	January	130-135	Long small seed

SEED QUALITY TEST

Salt Water Treatment

Steps: a) Pour water into container b) Add salt or urea to increase specific density of water c) Keep on adding salt or urea until egg can float on the surface d) Soak paddy seeds in salt water for fifteen minutes and remove the chaffy seeds that float on water e) Collect the treated seeds of paddy from the bottom of the bucket f) Wash it with clean water two times and dry it in shade

Rag Doll Test

a) Soak the cloth in clean water and spread them out on a flat surface b) From the seed sample, count out exactly 100 grains for each rag and distribute the grains evenly around the cloth (ten rows of ten grains facilitates counting c) Carefully roll each rag around a separate stick, leaving the seeds undisturbed inside d) Fasten the rags to the sticks with string and store the finished Rag Dolls in a warm moist place for five (5) days. e) Moisten the cloth several times every day (this is very important; if the Rag Dolls are allowed to dry out, the seeds will die.) f) After five (5) days, unroll the rags and count the number of seeds with roots. If each Rag Doll contains exactly 100 seeds, the number of sprouted seeds will equal the germination rate of the sample (e.g. if 85 seeds out of 100 sprouted, the germination rate equals 85%) g) Average out the germination rates indicated by the 3-5 separate Rag Dolls to derive a more reliable overall germination rate.

SEED TREATMENT

Bio-agents seed treatment for paddy

Bio-agent	Rate	Purpose
Trichoderma harzianum/ T. viride/ T. virens	5 - 10 g/kg of seed	Control *Pythium* seed rot and damping-off and Bacterial shealth blight
Pseudomonas fluorescens	5 - 10 g/kg of seed	Control *Pythium* seed rot and damping-off and Bacterial shealth blight
Azospirillum	1g/kg of seed	N fixation by rice seedlings (mix with primed wet seed just before sowing)

Chemical Seed Treatment			
Method	Chemical	Rate	Purpose

Wet seed treatment	Carbendazim or Tricyclozole	2 gram per litre of water for 1 kg of seeds (Soak the mixture for 10 hrs and drain excess water)	Protection to the seedlings up to 40 days from blast disease
Dry seed treatment	Captan or Thiram	4 gram per 1 kg of seed (Mix the chemical with the seed 24 hours before sowing)	

Seedling Treatment

Steps: a) Prepare slurry by mixing *Azospirillum* @ 1 kg in 40 litres of water and dip the root portion of rice seedlings in this bacterial suspension for 15-30 minutes and then transplant the seedlings in the field b) Dip seedling root in chlorpyrifos @2 ml/litre of water (Control Yellow stem borer)

Seed treatment to break seed dormancy
Method: Soak the seeds in hot water(4 5°C) for 72 hours Or Soak seeds in KNo3 1.5 per cent or 50 mg Gibberellic acid in one litre of water for 10 hours
Purpose: Breaks the seed dormancy in IR-64 and Gangavathi Sona varieties
Next steps: After the treatment dry the seeds in shade and continue with other seed treatment methods(Care should be taken while using KNo3)

NURSERY

Wet bed nursery

Steps: a) Plough and harrow the soil twice to obtain a fine till b) Puddling and levelling of nursery area c) Construct drainage canals for proper water removal d) Nursery area: 300 m^2 (e) Seed bed size: 7 – 7.5 m x 1.2 – 1.5 m x 10 cm (f) Number of seed beds/ha: 75 (g) FYM or Compost: 250 kg (h) Urea: 2.17 kg (i) DAP: 0.868 kg (j) MOP: 0.835 kg (k) Top dressing 0.65 – 1.30 kg Urea six days before transplanting (l) Seed rate: 62 kg/ha. Broadcast the pre-germinated seed. The application rate: 50-70 gm/m^2 (m) Irrigation: when seedlins are 1inch height allow to stand a thin layer of water (n) Transplanting: 20-25 days onwards

LAND PREPARATION

Wet land preparation

Steps: a) Plough immediately after the previous harvest b) Plough the field using disc or mouldboard plough preferably 6-8 weeks before planting with maximum depth of 10 cm and secondary ploughing 2-3 weeks before planting c) Later, puddle the field with 5-10 cm of standing water 2-3 times d) Incorporate 5-7 tonne of FYM or compost or 1 tonne of poultry manure per hectare or incorporate 10 tonne of green leaf manure three weeks before transplanting. e) The fertilizers recommended for basal application have to be applied before the last puddling and incorporated f) After fertilization avoid moving of water from one field to another g) Later, proper levelling has to be made before transplanting the seedlings h) Apply mud paste to the side and top of the bund to a thickness of 2.5 cm with a spade and plaster it using the flat surface of the spade.

Dry land Preparation (for Direct Sowing Rice)

Steps: a) Whenever possible give one or two summer ploughings to minimize weed growth b) Dry plough to get fine tilth taking advantage of rains and soil moisture availability c) Perfect land leveling for efficient weed and water management d) Ensure deep tillage and fine tilth at the time of final land preparation for sowing e) Provide shallow trenches (15 cm width) at an interval of 3m all along the field to facilitate draining excess water at the early growth stage.

PADDY PLANTING

Drill Sowing

Details: a) In irrigation command areas, before 30-35 days of receiving water from the canal after one rain or even before drill sowing can be done. In case where irrigation facility is availing watering can be done soon after sowing b) Tractor driven drill sowing can be done c) At the time of sowing after proper land preparation basal dosage of fertilizer can be applied along with sowing d) Row to row spacing to be maintained is 20 cm or 25 cm f) Time of Planting: May 3rd week to July 2nd week.

Machine Transplanting

There are two types of machines for transplanting paddy.

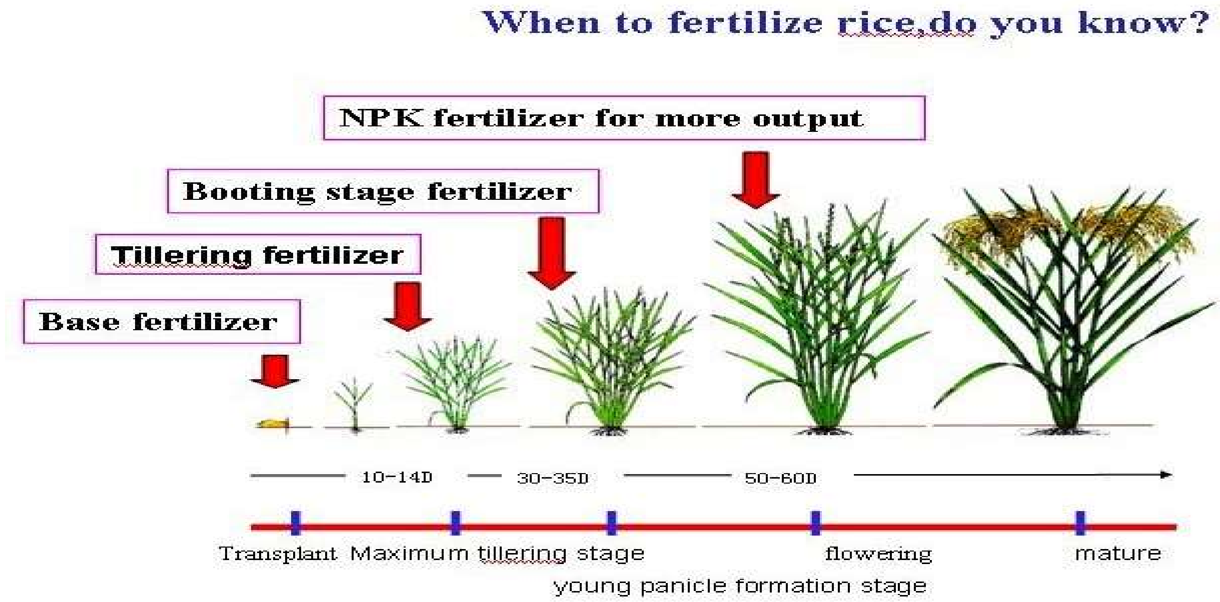
A) Paddy Transplanter – Walk behind and operate: i) Can transplant 4 rows of 30 cm apart at a time ii) Has petrol engine which consumers 0.9 to 1 litre of petrol per hour iii) Can transplant 2.5 to 3.1 acre for 8 hours.

B) Paddy Transplanter – Sit and operate: i) Can transplant 7.5 to 8.8 acres in 8 hours ii) 8 rows with 23 cm apart can be transplanted at a time iii) Has diesel engine which consumers 0.75 litre/hour.

Benefit of machine transplanting: 1. Cage wheel has been adopted for operating in puddled land 2. Can be used for weeding in plots where transplanting is done by machine 3. Can obtain more that 18% higher yield and reduce cost by 30%.

Manual Transplanting

MANURE AND FERTILIZERS



Stages of Paddy at which fertilizer needs to be applied

Incorporation of green manure into land

Steps for green manure (transplanted paddy): **Green manure crops :** *Sesbania aculeata*, *Crotalaria juncea* **Seed rate :** 25-30 kg/ha **Planting method :** Broadcast or line sowing with 45 cm row spacing **Irrigation :** One pre-sowing irrigation followed by 1-2 irrigation in between **Time of sowing :** Last week of April to first fortnight of May **Time of incorporation**: Crop to be turned down around 55-60 days after sowing. The*Trichoderma* (10 g/l) should be sprayed on turned *Sesbania/Crotalaria* crop in the field before one week of puddling and transplanting rice crop.

Advantage: The 60-day-old crop can contribute approximately 100 kg N/ha, 25-30 kg P/ha and 75 kg K/ha.

Steps for green manure (direct seeded rice): a) Sow sunhemp green manure seeds @10kg/ha mixed with paddy seeds b) Carry out hodta operation (Planking) in standing water after 40 DAS for in situ incorporation of sunhemp in the soil (OR) Ex situ incorporation of green leaf manuring of Eupatorium/parthenium/cassia and other weeds green material @ 5 t/ha in between the two paddy rows by carrying out hodta operation.

Advantage: Provides only 50% nutrients to maintain good yield

Chemical Fertilizers

Recommended nutrient quantity: 150:75:75 kg NPK / ha

Time of application		
At the time of sowing or transplanting	Basal dose	75:75:37.5 NPK/ha
After 25-30 days	1st Top dressing	37.5 :0:0 kg NPK/ha
After 50-55 days or panicle initiation	2nd Top dressing	37.5 :0:37.5 kg NPK/ha

Combination of fertilizers

Type of fertilizer	Total qty (kg / ha)	Basal dose (kg/ha)	Top Dressing I	Top Dressing II	Remarks
UreaRock	217	109	54	54	
Phosphate	175	175	-	-	
MOP	80	40	-	-	
Urea	174	66	54	54	
DAP	109	109	-	-	
MOP	80	40	-	40	
Urea	109	-	55	54	Addition of MOP at the rate of 40 kg/ha as 2nd top dressing is advisable
NPK 19-19-19	263	263	-	-	
Urea	109	-	55	54	
NPK 15-15-15	333	333	-	-	

Application suggestion: 24 hours before the top dressing drain out the field and 24 hours after top dressing irrigate the field

IRRIGATION

Irrigation in transplanted paddy:

Short Duration Variety			Medium Duration Variety			Long Duration Variety		
Days	No. of irrigation	Water level (cm)	Days	No. of irrigation	Water level (cm)	Days	No. of irrigation	Water level (cm)
125	5-7	2-3	1-30	5-7	2-3	1-35	6-8	2-3
25	-	Thin film of water	30	-	Thin film of water	35	-	Thin film of water
28	-	Lift irrigation	33	-	Lift irrigation	38	-	Lift irrigation
29-50	6	2-5	34-65	6-8	2-5	39-90	12-15	2-5
51-70	5-6	2-5	66-95	8-10	2-5	96-125	7-9	2-5
71-105	5-6	2-5	96-125	6-8	2-5	126-150	5-6	2-5

Irrigation in Dry Seeded Rice

a) For drill sown rice care should be taken to drain out excess rain water during first 10-15 DAS and the water level in the field should not be more than 2.5cm height during tillering stage. b)In drill sown rice carry out hodta operation (Planking) in standing water at 40 DAS, and impound sufficient rain water through the crop growth period.

WEED MANAGEMENT

Take up hand weeding at 20 and 40 days after transplanting and at 20 and 40 days after sowing in transplanted and drill sown paddy respectively

Herbicide	Quantity (ha)	Time of application	Remarks
2,4-D Sodium salt 80%	2.5 kg	3-4 weeks after transplanting	Care should be taken to avoid herbicidal drift to nearby fields
Propanil 35 EC	7.5 lt	Weeds are at 1 or 2 leaf stage	Do not mix any chemical with these herbicides
Butachlor 5% G	30 kg	Broadcast the granules at 5 -7 days after transplanting	-
2,4 – Dethylester 5% G	15 kg	Spray 5-7 days after transplanting	-
Anilogard	1.5 lt	--do--	-
Thiobencarb (Benthiocarb) 50EC	40 lt	Within 5 days after transplanting	-
Pendimethalin 30 EC	3.25 lt	Within 3-5 days after transplanting	-
Oxadiazon 25 EC	1 lt	Within 3-5 days after transplanting	-

Appendix 4: Interaction of Extension Agents with Farmers

Collection of soil sample

Soil samples for testing bagged and labeled


Inspection of paddy after sowing


Helping farmer install yellow stick trap (used for attracting insects)

Interaction of farmers with scientists from local agricultural university

Interaction of farmers with scientists from local agricultural university

Appendix 6: Proforma of Soil Test Result

SOIL TEST BASED FERTILIZER RECOMMENDATION-SIRUGUPPA TALLUK

Name of the Farmer: raghavendra s/o chanal siddlingappa HHID: 20601 Village: sirigeri Gram Panchayat: sirigeri

SOIL TEST RESULTS:

pH: 6.5 NITROGEN: MEDIUMPHOSPHOROUS: MEDIUM POTASH: MEDIUM

FERTILIZER RECOMMENDATIONS

RICE: (BLANK RECOMMENDATION : 100:50:50; SOIL TEST BESED RECOMMENDATION: 100: 50: 50 kg/Ha)

OPTION1: UREA: 2200000000003 Kg +SUPER PHOSPHATE: 312.5 Kg + MURATE OF POTASH: 50 Kg APPLY ALL SUPERPHOSPHATE AS BASAL, AND UREA AND POTASH MAY BE APPLIED 25% BASAL, 25% AFTER 1ST WEEDING, 25 AFTER 2ND WEEDING AND 25% AFTER FLOWERING.

OPTION2: (17:17:17 COMPLEX BESED RECOMMENDATION)

17-17-17 COMPLEX: 295 Kg +UREA: 1100000000001 Kg + SUPER PHOSPHATE: 0 Kg + POTASH: 0 Kg APPLY ALL THE 17-17-17 COMPLEX AND SUPER PHOSPHATE AS BASAL. UREA AND POTASH MAY BE APPLIED 25% BASAL, 25% AFTER 1ST WEEDING, 25 AFTER 2ND WEEDING AND 25% AFTER FLOWERING.

OPTION3: (15:15:15 COMPLEX BASED RECOMMENDATION)

15:15:15 COMPLEX: 335 Kg +UREA: 1100000000001 Kg + SUPER PHOSPHATE: 0 Kg + POTASH:0 Kg APPLY ALL THE 15:15:15 COMPLEX AND SUPER PHOSPHATE AS BASAL. UREA AND POTASH MAY BE APPLIED 25% BASAL, 25% AFTER 1ST WEEDING, 25 AFTER 2ND WEEDING AND 25% AFTER FLOWERING.

COTTON: (BLANK RECOMMENDATION: 80:40:40; SOIL TEST BASED =80 : 40 : 40 Kg/Ha)

OPTION1: UREA: 176 + SUPER PHOSPHATE: 250 + 4068. APPLY ALL SUPERPHOSPHATE AS BASAL, AND UREA AND POTASH MAY BE APPLIED 25% BASAL, 25% AFTER 1ST WEEDING, 25 AFTER 2ND WEEDING AND 25% AFTER ONE MONTH.

OPTION2: 17-17-17 COMPLEX=236 Kg + UREA=88 Kg + SUPER PHOSPHATE=0 Kg + 0 Kg

OPTION3: 15-15-15 COMPLEX=268 Kg + UREA=88 Kg + SUPER PHOSPHATE=0 Kg + 0 Kg

APPLY ALL THE 17:17:17 OR 15:15:15 COMPLEX AND SUPER PHOSPHATE AS BASAL. UREA AND POTASH MAY BE APPLIED 25% BASAL, 25% AFTER 1ST WEEDING, 25 AFTER 2ND WEEDING AND 25% AFTER FLOWERING.

Appendix 7: Roster for Farmer Visit

Agent # 1: RAM					
Week: 1					
Day / GP	Sl. No.	Village	Farmer	Father	Mobile
MON	1	Ibrahimpura			
Bagewadi	2				
	3				
	4				
	5				
	6				
	7				
	8				
TUE	1	Ibrahimpura			
Bagewadi	2				
	3				
	4				

	5				
	6				
	7				
	8				
	9				
WED	1	Ibrahimpura			
Bagewadi	2				
	3				
	4	Bagewadi			
	5				
	6				
	7				
	8				
THU	1	Bagewadi			
Bagewadi	2				
	3				
	4				
	5				
	6				
	7				
	8				
FRI	1	Bagewadi			
Bagewadi	2				
	3				
	4				
	5				
	6				
	7				
	8				

Appendix 8: Comparison of Observables at Baseline (Paddy)

Panel A: General Observables			
	0 Control	1 Treatment	(1) vs. (2)
Avg age of all family members (in years)	28.67	28.96	-0.29
	(0.57)	(0.53)	(0.77)
Avg years of schooling of all family members (in yers)	4.25	5.20	-0.9***
	(0.22)	(0.25)	(0.34)
Experience of farmer in crop cultivation (in years)	21.24	21.37	-0.13
	(0.82)	(0.81)	(1.15)
Land owned by farmer (in acre)	9.09	10.39	-1.31
	(0.84)	(0.80)	(1.16)
Age of farmer (in years)	42.43	41.81	0.62
	(0.97)	(0.83)	(1.27)
Years of schooling of farmer (in years)	4.98	6.25	-1.27**
	(0.37)	(0.35)	(0.50)
Visits to agri extension centre in previous year	0.10	0.21	-0.1***

	(0.02)	(0.03)	(0.04)
Visits by agri extension agent in previous year	0.98	0.90	0.08***
	(0.01)	(0.02)	(0.02)
Whether farmer faced income shortage in previous year	0.68	0.71	-0.03
	(0.04)	(0.03)	(0.05)
Whether or not farmer is female	0.01	0.01	0.00
	(0.01)	(0.01)	(0.01)
Panel B: Land Ownership Categories			
	0 Control	1 Treatment	(1) vs. (2)
Marginal Farmers	0.21	0.15	0.07*
	(0.03)	(0.03)	(0.04)
Small Farmers	0.21	0.21	0.01
	(0.03)	(0.03)	(0.04)
Semi-Medium Farmers	0.27	0.28	-0.01
	(0.03)	(0.03)	(0.05)
Medium Farmers	0.22	0.27	-0.05
	(0.03)	(0.03)	(0.04)
Large Farmers	0.08	0.10	-0.02
	(0.02)	(0.02)	(0.03)
Panel C: Asset Index Categories			
	0 Control	1 Treatment	(1) vs. (2)
Asset Index 1	0.20	0.18	0.01
	(0.03)	(0.03)	(0.04)
Asset Index 2	0.18	0.15	0.03
	(0.03)	(0.03)	(0.04)
Asset Index 3	0.19	0.23	-0.04
	(0.03)	(0.03)	(0.04)
Asset Index 4	0.19	0.23	-0.04
	(0.03)	(0.03)	(0.04)
Asset Index 5	0.24	0.21	0.03
	(0.03)	(0.03)	(0.04)
Panel D: Caste Categories			
	0 Control	1 Treatment	(1) vs. (2)
General Caste	0.29	0.49	-0.2***
	(0.03)	(0.04)	(0.05)
Scheduled Caste	0.08	0.08	0.00
	(0.02)	(0.02)	(0.03)
Scheduled Tribe	0.23	0.09	0.14***
	(0.03)	(0.02)	(0.04)
Other Backward Caste	0.40	0.34	0.06
	(0.04)	(0.03)	(0.05)
N	178	198	376

"Columns (1) and (2) report sample means with standard errors in parentheses. Column (3) reports the mean difference between the two experimental groups."

Appendix 9: Comparison of Observables at Baseline (Cotton)

Panel A: General Observables			
	0	1	
	Control	Treatment	(1) vs. (2)
Avg age of all family members (in years)	30.10	27.97	2.13**
	(0.72)	(0.67)	(1.00)
Avg years of schooling of all family members (in yers)	4.22	4.61	-0.40
	(0.25)	(0.30)	(0.39)
Experience of farmer in crop cultivation (in years)	23.56	21.58	1.98
	(1.02)	(1.13)	(1.52)
Land owned by farmer (in acre)	10.17	11.30	-1.12
	(0.98)	(1.07)	(1.46)
Age of farmer (in years)	46.00	42.08	3.92**
	(1.19)	(1.15)	(1.68)
Years of schooling of farmer (in years)	4.62	5.10	-0.48
	(0.36)	(0.42)	(0.56)
Visits to agri extension centre in previous year	0.09	0.27	-0.18***
	(0.02)	(0.04)	(0.05)
Visits by agri extension agent in previous year	0.99	0.97	0.01
	(0.01)	(0.01)	(0.02)
Whether farmer faced income shortage in previous year	0.79	0.79	0.00
	(0.03)	(0.04)	(0.05)
Whether or not farmer is female	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)
Panel B: Land Ownership Categories			
	0	1	
	Control	Treatment	(1) vs. (2)
Marginal	0.12	0.13	-0.01
	(0.03)	(0.03)	(0.04)
Small	0.23	0.18	0.05
	(0.04)	(0.04)	(0.05)
Semi-Medium	0.32	0.26	0.06
	(0.04)	(0.04)	(0.06)
Medium	0.23	0.32	-0.09
	(0.04)	(0.04)	(0.05)
Large	0.10	0.11	-0.01
	(0.02)	(0.03)	(0.04)
Panel C: Asset Index Categories			
	0	1	
	Control	Treatment	(1) vs. (2)
Asset Index 1	0.25	0.16	0.09*
	(0.04)	(0.03)	(0.05)
Asset Index 2	0.21	0.21	0.00
	(0.03)	(0.04)	(0.05)
Asset Index 3	0.15	0.19	-0.04
	(0.03)	(0.04)	(0.05)
Asset Index 4	0.19	0.21	-0.02
	(0.03)	(0.04)	(0.05)
Asset Index 5	0.20	0.23	-0.03
	(0.03)	(0.04)	(0.05)

Panel D: Caste Categories			
	0 Control	1 Treatment	(1) vs. (2)
General Caste	0.33	0.37	-0.04
	(0.04)	(0.04)	(0.06)
Scheduled Caste	0.08	0.08	-0.01
	(0.02)	(0.03)	(0.03)
Scheduled Tribe	0.23	0.11	0.12***
	(0.04)	(0.03)	(0.05)
Other Backward Caste	0.36	0.44	-0.07
	(0.04)	(0.05)	(0.06)
N	146	119	265

"Columns (1) and (2) report sample means with standard errors in parentheses. Column (3) reports the mean difference between the two experimental groups."

Appendix 10: Treatment effect on crop yields, revenue, cost and returns (Paddy Crop)

	(1) Yield	(2) Revenue	(3) Cost	(4) Returns
Treatment*Midline	0.950	1273.7	864.5	249.5
	(0.857)	(1997.8)	(138.8)	(2338.6)
	[.31]	[.57]	[.56]	[.92]
Treatment*Endline	5.036***	9263.3***	-5715.8***	14901.8***
	(0.908)	(1828.2)	(870.3)	(2103.0)
	[.01]	[0]	[0]	[0]
Midline	1.267*	3559.1*	1153.4	2422.9
	(0.664)	(1853.8)	(648.4)	(1568.5)
Endline	2.635***	4663.2**	4540.2***	152.3
	(0.767)	(1580.2)	(517.1)	(1486.3)
Treatment	-0.786	639.2	1674.6	-986.3
	(1.405)	(2041.5)	(1132.8)	(2397.6)
Years of schooling (Family)	-0.0156	-21.62	6.142	-14.79
	(0.0962)	(168.5)	(82.88)	(206.2)
Years of schooling (Farmer)	0.177**	303.6**	-7.286	305.7**
	(0.0670)	(106.0)	(52.14)	(137.2)
Visit to extension centre	0.102	-160.2	490.9	-632.2
	(0.508)	(1089.8)	(480.7)	(1157.3)
Visit by extension agent	0.113	-2278.4	1150.9	-3512.8
	(0.881)	(1629.4)	(1042.6)	(2036.7)
Marginal farmer	0	0	0	0
	(.)	(.)	(.)	(.)

Small farmer	0.724	502.8	-827.5	1282.9
	(0.832)	(1269.0)	(535.8)	(1408.1)
Semi-medium farmer	-0.923	-1756.2	50.97	-1786.4
	(0.848)	(1305.3)	(368.3)	(1346.2)
Medium farmer	-0.224	79.31	-520.9	608.9
	(0.649)	(1021.0)	(380.4)	(1275.1)
Large farmer	-0.0196	81.57	-1972.6***	1963.7
	(0.723)	(1228.2)	(442.7)	(1474.3)
General Caste	-0.396	181.9	-567.2	655.6
	(0.880)	(1503.7)	(844.5)	(1911.4)
Scheduled Caste	0	0	0	0
	(.)	(.)	(.)	(.)
Scheduled Tribe	0.370	476.5	-402.3	801.7
	(0.539)	(801.1)	(766.7)	(1126.7)
Other Backward Caste	0.448	1069.5	-718.2	1786.5
	(0.886)	(1533.9)	(845.3)	(1902.2)
Constant	23.60***	36279.2***	19193.9***	17194.7***
	(2.089)	(3860.1)	(1434.7)	(3596.7)
Mean of dep. Var	26.22	40367.5	21251.9	19122.4
Observations	1040	1040	1040	1040
R-Square	0.178	0.210	0.134	0.199
Adjusted R-square	0.165	0.197	0.121	0.187

Standard errors in parentheses
All values were winsorized at the 99th percentile
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Appendix 11: Treatment effect on major components of cost (Paddy Crop)

	(1) Plowing	(2) Seeds	(3) Transplanting	(4) Irrigation (labour)	(5) Weeding	(6) Harvesting
Treatmen*Midline	48.40	725.9**	-115.7	-1041.0***	99.65	429.4
	(123.1)	(308.0)	(90.32)	(193.8)	(266.6)	(285.0)
	[.57]	[.01]	[.33]	[.01]	[.73]	[.2]
Treatment*Endline	-349***	6.075	-280.5***	-114.5	-1194***	65.31
	(104.3)	(338.4)	(77.04)	(217.9)	(139.1)	(283.5)
	[.02]	[.97]	[0]	[.66]	[0]	[.8]
Midline	-462***	-527.6**	335.7***	192.0*	59.37	282.8
	(109.3)	(210.6)	(72.93)	(101.5)	(175.1)	(215.6)

Endline	-351***	-395.3**	828.2***	-1223.9***	465.0***	528.6*
	(60.44)	(178.3)	(56.02)	(163.9)	(109.0)	(255.4)
Treatment	29.06	-207.6	274.6**	135.2	44.38	17.12
	(75.03)	(454.5)	(94.96)	(246.9)	(145.4)	(216.9)
Years of schooling (Family)	0.620	-19.71	-2.550	-26.28	11.58	-6.458
	(6.488)	(21.78)	(2.682)	(22.78)	(18.62)	(13.96)
Years of schooling (Farmer)	-4.006	-6.757	2.971	-4.630	-7.298	16.21
	(3.572)	(20.53)	(2.052)	(16.60)	(10.69)	(10.03)
Visit to extension centre	-7.465	-118.5	68.05**	129.7	-169.7	25.09
	(59.84)	(79.55)	(25.44)	(77.32)	(122.0)	(112.8)
Visit by extension agent	126.9*	-320.7*	50.88	216.5	156.7	40.02
	(65.97)	(175.7)	(35.55)	(189.8)	(111.6)	(141.4)
Marginal farmer	0	0	0	0	0	0
	(.)	(.)	(.)	(.)	(.)	(.)
Small farmer	-27.06	-432.6**	-6.066	-265.2**	118.2	-88.05
	(43.02)	(173.3)	(49.79)	(112.4)	(144.7)	(94.29)
Semi-medium farmer	-128.0***	-118.8	59.88*	-83.01	182.2	-38.73
	(15.26)	(99.76)	(31.47)	(171.6)	(119.2)	(88.53)
Medium farmer	-215.***	-241.3*	59.33**	-232.7	371.2***	-188.8**
	(56.42)	(115.5)	(25.86)	(132.3)	(94.41)	(72.26)
Large farmer	-477***	-624.3***	52.80	-60.58	376.1**	-348.8***
	(62.87)	(119.5)	(34.12)	(228.7)	(133.5)	(95.23)
General Caste	-84.36	224.1	26.30	-5.619	-139.5	-60.13
	(96.7)	(230.1)	(35.11)	(153.4)	(106.5)	(82.17)
Scheduled Caste	0	0	0	0	0	0
	(.)	(.)	(.)	(.)	(.)	(.)
Scheduled Tribe	-98.56	-7.868	52.66	42.36	56.21	-100.6
	(71.99)	(196.2)	(38.57)	(165.8)	(90.82)	(97.26)
Other Backward Caste	-82.43	47.75	-24.37	-124.1	-91.59	-96.61
	(93.30)	(179.5)	(43.62)	(167.2)	(112.2)	(98.78)
Constant	1533***	2500.2***	1522.8***	2298.3***	1584.3***	2335.0***
	(120.2)	(349.8)	(89.59)	(332.0)	(174.6)	(292.7)
Mean of dep. var	1127.7	1648.7	2064.6	1767.8	1863.2	2605.1

Observations	1040	1040	1040	1040	1040	1040
R-Square	0.262	0.0788	0.485	0.171	0.112	0.129
Adjusted R-square	0.250	0.0644	0.477	0.158	0.0978	0.115

Standard errors in parentheses
All values were winsorized at the 99th percentile
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Appendix 12: Treatment effect on expense on fertilizers and insecticides (Paddy Crop)

	(1) Fertilizers	(2) Insecticides
Treatment*Midline	464.7	63.38
	(562.2)	(181.1)
	[.44]	[.69]
Treatment*Endline	-3464.4***	-531.9*
	(390.2)	(244.3)
	[0]	[.04]
Midline	-280.9	39.58
	(424.8)	(69.83)
Endline	2313.7***	1412.3***
	(249.0)	(219.2)
Treatment	971.0*	236.4*
	(445.8)	(116.7)
Years of schooling (Family)	19.47	-5.862
	(28.32)	(14.16)
Years of schooling (Farmer)	10.11	8.234
	(28.35)	(11.10)
Visit to extension centre	-47.30	43.19
	(157.4)	(95.50)
Visit by extension agent	899.3**	22.64
	(328.8)	(128.8)
Small farmer	33.32	-94.00
	(150.4)	(92.61)
Semi-medium farmer	-64.95	-151.8
	(124.3)	(100.2)

Medium farmer	-0.953	-188.9
	(229.2)	(112.3)
Large farmer	-72.15	-401.6**
	(223.1)	(138.3)
General Caste	-20.04	-144.2
	(467.3)	(90.28)
Scheduled Caste	0	0
	(.)	(.)
Scheduled Tribe	-160.1	-32.45
	(336.9)	(139.0)
Other Backward Caste	-31.86	-154.7*
	(447.5)	(83.61)
Constant	3877.4***	1220.4***
	(553.6)	(202.1)
Mean of dep. Var	5458.5	1476.7
Observations	1040	1040
R-Square	0.157	0.295
Adjusted R-square	0.144	0.284

Standard errors in parentheses
All values were winsorized at the 99th percentile
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Appendix 13: Treatment effect on macro-nutrient application (Paddy Crop)

	(1) Nitrogen	(2) Phosphorous	(3) Potash
Treatment*Midline	-3.218	-2.616	-0.631
	(11.87)	(4.939)	(5.268)
	[.87]	[.67]	[.95]
Treatment*Endline	-71.66***	-37.31***	-16.53**
	(8.158)	(3.331)	(6.427)
	[0]	[0]	[.01]
Midline	-4.290	-2.522	-0.200
	(10.15)	(3.585)	(2.489)
Endline	46.81***	17.68***	17.60***
	(4.801)	(1.663)	(5.596)

Treatment	17.30**	8.323	13.74**
	(6.185)	(5.184)	(5.761)
Years of schooling (Family)	0.516	0.0299	0.596
	(0.431)	(0.365)	(0.359)
Years of schooling (Farmer)	-0.132	0.0672	-0.100
	(0.364)	(0.319)	(0.253)
Visit to extension centre	-2.159	-0.890	1.464
	(2.019)	(1.332)	(2.376)
Visit by extension agent	6.582*	2.082	9.850**
	(3.095)	(2.804)	(4.280)
Marginal farmer	0	0	0
	(.)	(.)	(.)
Small farmer	-1.540	1.651	0.820
	(2.155)	(2.034)	(2.156)
Semi-medium farmer	-0.362	-1.273	0.446
	(2.684)	(1.495)	(1.737)
Medium farmer	-2.932	1.329	-0.238
	(3.819)	(2.473)	(2.669)
Large farmer	-1.913	3.281	-0.926
	(5.243)	(2.510)	(3.105)
General Caste	0.834	3.037	-2.993
	(5.905)	(4.899)	(4.765)
Scheduled Caste	0	0	0
	(.)	(.)	(.)
Scheduled Tribe	-4.296	-0.395	-1.811
	(4.250)	(3.195)	(4.559)
Other Backward Caste	2.712	0.984	-1.057
	(4.023)	(4.433)	(4.991)
Constant	76.20***	44.14***	24.81***
	(7.845)	(5.959)	(7.174)
Mean of dep. var	93.11	51.25	44.45
Observations	1040	1040	1040
R-Square	0.189	0.109	0.0900
Adjusted R-square	0.176	0.0953	0.0758

Standard errors in parentheses
All values were winsorized at the 99th percentile
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Appendix 14: Treatment effect on crop yields, revenue, cost and returns (Cotton Crop)

	(1) Yield	(2) Revenue	(3) Cost	(4) Returns
Treatment*Midline	3.503**	14400.2**	2700.4	11550.1
	(1.204)	(5385.6)	(2648.9)	(6733.6)
	[.01]	[.01]	[.44]	[.14]
Treatment*Endline	7.174***	29289.4***	-2451.4	31761.4***
	(1.450)	(6254.6)	(1519.9)	(5569.4)
	[.01]	[0]	[.08]	[.03]
Midline	1.958**	13332.5***	2588.2*	10871.6***
	(0.865)	(3322.4)	(1170.3)	(3003.0)
Endline	1.275	6269.5	2057.6***	4226.3
	(1.239)	(5292.2)	(424.5)	(5036.7)
Treatment	-1.678	-6260.8	1066.8	-7301.1
	(1.140)	(4781.1)	(1579.6)	(4145.5)
Age of family members(avg)	0.0324**	155.6**	15.11	143.5**
	(0.0133)	(66.51)	(17.31)	(56.17)
Age of farmer	-0.00741	-42.19	15.99	-61.12
	(0.00905)	(40.31)	(14.77)	(41.64)
Visit to extension centre	-0.351	-941.1	-393.1	-487.3
	(0.330)	(1385.2)	(901.8)	(1476.9)
Asset Index 1	0	0	0	0
	(.)	(.)	(.)	(.)
Asset Index 2	0.575*	2245.9	1733.8***	522.3
	(0.313)	(1546.5)	(448.5)	(1330.9)
Asset Index 3	1.076*	4682.2*	1131.0	3531.0**
	(0.522)	(2204.2)	(1165.9)	(1452.3)
Asset Index4	0.267	1219.9	1572.9	-256.3
	(0.441)	(2124.8)	(1095.0)	(1232.2)
Asset Index 5	1.279**	5620.3**	163.4	5539.7**
	(0.490)	(2191.7)	(1099.1)	(1854.6)
General Caste	0.287	1826.2	-1421.7	3128.6
	(0.549)	(2493.4)	(950.8)	(1782.5)
Scheduled Caste	0	0	0	0
	(.)	(.)	(.)	(.)
Scheduled Tribe	-0.721	-2315.4	-1042.9	-1333.3

	(0.433)	(2017.1)	(835.9)	(1937.2)
Other Backward Caste	0.212	1249.7	-1271.5	2501.3
	(0.655)	(2895.4)	(994.0)	(2456.2)
Constant	6.042***	22913.8***	21715.3***	1234.1
	(1.459)	(6250.1)	(1402.4)	(5986.7)
Mean of dep. var	9.161	38913.6	24568.4	14365.2
Observations	756	756	756	756
R-Square	0.400	0.399	0.103	0.391
Adjusted R-square	0.387	0.387	0.0852	0.378

Standard errors in parentheses
All values were winsorized at the 99th percentile
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Appendix 15: Treatment effect on major components of cost (Cotton Crop)

	(1) Plowing	(2) Seeds	(3) Sowing	(4) Intercultivation	(5) Weeding	(6) Harvesting
Treatment*Midline	298.3**	33.55	107.7	63.27	553.0	-842.9
	(99.08)	(211.3)	(222.8)	(279.9)	(927.0)	(502.4)
	[.09]	[.88]	[.62]	[.86]	[.56]	[.17]
Treatment*Endline	208.6	-246.3	95.80	-681.2**	-54.94	201.7
	(125.1)	(142.7)	(141.3)	(227.0)	(431.4)	(767.6)
	[.26]	[.19]	[.58]	[.06]	[.88]	[.85]
Midline	-618.8***	-169.7	-50.52	-4.381	-883.0	1563.3***
	(56.72)	(170.4)	(143.0)	(109.2)	(708.9)	(370.5)
Endline	-486.7***	-67.03	42.69	-105.4	-673.6**	-668.8*
	(108.8)	(89.94)	(85.14)	(129.0)	(270.4)	(333.5)
Treatment	-25.00	-149.4	-120.0	176.7	-76.58	150.4
	(85.11)	(126.6)	(96.75)	(192.2)	(405.1)	(629.9)
Age of family members(avg)	1.895	7.894**	0.0582	1.335	-1.686	-13.34
	(1.735)	(2.506)	(1.905)	(5.607)	(6.109)	(9.873)
Age of farmer	0.567	-1.461	1.317	0.483	3.849	9.690
	(2.053)	(1.595)	(0.955)	(1.936)	(4.064)	(7.261)
Visit to extension centre	61.74	40.27	57.18	-141.8*	-99.97	-500.6*
	(60.00)	(95.18)	(55.04)	(70.56)	(118.8)	(248.1)
Asset Index 1	0	0	0	0	0	0
	(.)	(.)	(.)	(.)	(.)	(.)
Asset Index 2	-30.43	91.25	7.063	84.77	46.36	547.0
	(71.76)	(100.6)	(43.38)	(148.7)	(198.2)	(312.4)

Asset Index 3	51.40	172.6*	-17.53	221.7	-184.5	257.6
	(81.68)	(81.84)	(51.77)	(151.6)	(236.6)	(289.6)
Asset Index4	-50.07	245.0*	8.599	124.0	24.66	333.5
	(78.02)	(112.5)	(51.54)	(144.8)	(188.8)	(331.6)
Asset Index 5	-205.0**	68.58	-72.83	-137.8	28.18	271.1
	(79.36)	(84.28)	(51.71)	(109.8)	(206.0)	(427.9)
General Caste	-43.44	-68.41	-68.27	-254.6	-118.8	260.3
	(76.79)	(74.94)	(69.95)	(192.5)	(241.6)	(426.1)
Scheduled Tribe	8.108	145.2	-28.67	183.9	-116.1	-212.6
	(57.64)	(113.3)	(35.18)	(154.5)	(261.9)	(456.7)
Other Backward Caste	-2.832	93.97	-17.27	-31.23	18.66	-217.7
	(67.31)	(84.10)	(43.81)	(221.2)	(254.6)	(322.3)
Constant	1308.1***	2266.4***	705.4***	1984.4***	2862.2***	3440.2***
	(86.85)	(177.7)	(70.57)	(203.7)	(623.0)	(646.5)
Mean of dep. var	1036.5	2415.3	697.0	1957.9	2433.9	3927.2
Observations	756	756	756	756	756	756
R-Square	0.157	0.0645	0.0284	0.0621	0.0589	0.0967
Adjusted R-square	0.140	0.0456	0.0086	0.0431	0.0398	0.0784

Standard errors in parentheses
All values were winsorized at the 99th percentile
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Appendix 16: Treatment effect on expense on fertilizers and insecticides (Cotton Crop)

	(1) Fertilizers	(2) Insecticides
Treatment*Midline	1381.6	44.27
	(901.3)	(308.9)
	[.19]	[.92]
Treatment*Endline	-1600.7**	-1310.1***
	(649.6)	(198.8)
	[.03]	[.01]
Midline	3058.0***	499.4**
	(400.0)	(157.0)
Endline	3711.0***	1678.1***
	(425.4)	(22.42)
Treatment	522.2	493.7**
	(487.3)	(192.6)

Age of family members(avg)	12.59	3.981
	(10.35)	(3.416)
Age of farmer	1.008	-1.591
	(7.375)	(1.849)
Visit to extension centre	142.5	-91.58
	(414.1)	(107.2)
Asset Index 1	0	0
	(.)	(.)
Asset Index 2	633.1**	62.20
	(258.7)	(119.9)
Asset Index 3	538.5	8.612
	(329.2)	(151.9)
Asset Index4	592.6*	-70.43
	(290.1)	(148.6)
Asset Index 5	286.4	-10.29
	(426.2)	(203.1)
General Caste	-229.2	-303.4***
	(295.6)	(74.57)
Scheduled Caste	0	0
	(.)	(.)
Scheduled Tribe	-256.3	-179.2**
	(221.9)	(66.57)
Other Backward Caste	-211.6	370.6***
	(286.2)	(103.9)
Constant	3030.6***	1407.3***
	(589.0)	(190.4)
Mean of dep. Var	6066.2	1885.2
Observations	756	756
R-Square	0.343	0.258
Adjusted R-square	0.330	0.243

Standard errors in parentheses
All values were winsorized at the 99th percentile
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Appendix 17: Treatment effect on macro-nutrient application (Cotton Crop)

	(1) Nitrogen	(2) Phosphorous	(3) Potash
Treatment*Midline	17.49**	10.06	6.875
	(7.037)	(11.76)	(10.62)
	[.07]	[.42]	[.64]
Treatment*Endline	-29.74***	-22.80**	5.062
	(7.342)	(7.455)	(6.253)
	[0]	[0]	[.49]
Midline	47.27***	28.97***	25.30***
	(5.880)	(3.261)	(7.175)
Endline	69.26***	25.74***	33.09***
	(1.877)	(6.534)	(3.448)
Treatment	0.159	6.016	6.849
	(8.153)	(4.755)	(4.831)
Age of family members(avg)	0.271	0.277***	-0.0234
	(0.191)	(0.0750)	(0.126)
Age of farmer	-0.119	-0.0240	-0.0606
	(0.160)	(0.0851)	(0.0638)
Visit to extension centre	-7.959	1.446	0.803
	(7.626)	(4.771)	(3.487)
Asset Index 1	0	0	0
	(.)	(.)	(.)
Asset Index 2	5.296	6.572	1.876
	(6.965)	(4.031)	(1.291)
Asset Index 3	15.78**	5.559	1.587
	(5.231)	(4.403)	(2.416)
Asset Index4	11.04*	7.288**	2.690
	(5.828)	(3.077)	(3.363)
Asset Index 5	7.758	0.538	1.457
	(7.918)	(5.075)	(2.145)
General Caste	-10.10	-3.488	1.583
	(7.936)	(4.386)	(2.085)
Scheduled Caste	0	0	0
	(.)	(.)	(.)

Scheduled Tribe	-9.011	-6.057*	3.161
	(7.141)	(3.289)	(3.047)
Other Backward Caste	-7.222	-4.812	2.648
	(6.389)	(3.812)	(2.051)
Constant	72.23***	30.88***	20.94**
	(12.29)	(6.517)	(6.486)
Mean of dep. var	109.2	56.59	45.15
Observations	756	756	756
R-Square	0.309	0.211	0.316
Adjusted R-square	0.295	0.195	0.302

Standard errors in parentheses
All values were winsorized at the 99th percentile
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$