Value of Customized Advice: Experimental Evidence from India[1]

PRELIMINARY DRAFT
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Abstract

Optimal agricultural practices are highly dependent on local conditions, such as weather and soil fertility; yet, farmers in developing countries often lack accurate information on relevant local conditions and precise recommendations. We examine the effect of customized advice on farming decisions in the context of fertilizer recommendations for cotton farmers in Gujarat, India. We experimentally varied access to plot-level soil fertility information and corresponding fertilizer recommendations, delivered via Soil Health Cards (SHCs) and appropriately timed voice calls. Customized advice significantly increased adoption of recommended fertilizers by 3 - 12 percentage points during the sowing period, leading to a 0.121 standard deviation reduction in the fertilizer gap. These results highlight the potential importance of precise information in improving soil fertility management and agricultural productivity.

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1. Introduction

Precision farming - farm management informed by increasingly data-driven, dynamic, and accurate instructions - is gaining popularity among donors, governments and practitioners alike. Advanced remote sensing and digital technologies are improving efficiencies of agricultural production through site-specific input application in the US (Balafoutis et al., 2017). While agricultural recommendations available for smallholder farmers have remained general and static in much of the developing world, many governments are undertaking efforts to lay the groundwork for improving the quality and precision of agricultural information. India is no exception. For example, since the launch of the Soil Health Card (SHC) scheme in 2015, the Indian government reports having conducted at least 100 million plot-level soil tests and delivered SHCs.

Soil fertility management and fertilizer usage, in particular, may benefit from customized and precise advice. Returns to fertilizers have been shown to be highly sensitive to dosage and heterogeneous by local conditions (Duflo et al. 2008, Suri 2011). Focus on 'rate, timing, source and placement' could enhance effectiveness of fertilizer application on plant absorption (Pagani, Sawyer, & Mallarino, 2013). These four principles form basis of Site-Specific Nutrient Management (SSNM) and evidence suggests that SSNM under controlled environment can lead to enhanced yields and improved soil quality (Khurana et al. 2008, Pampolino et al. 2007, Cassman et al. 2002, and Matson et al. 1998). However, few studies have examined whether locally-specific advice on fertilizer dosage and usage would lead to similar results in real farm settings.

We designed an experiment to test the effect of customized fertilizer recommendations on fertilizer adoption and usage among cotton farmers in Gujarat, India. The sample for this experiment consists of 1,585 farmers who had recently signed up for a mobile phone-based agricultural advisory service, called Krishi Tarang (KT)[2]. The KT service provides comprehensive farming advice (on sowing, weeding, pesticides, harvesting, etc.) through automated voice messages over a cropping cycle. We randomly selected half of them to receive plot-level soil fertility information and customized recommendations on three of the most common macronutrient fertilizers (UREA, DAP, and MOP) and one micronutrient fertilizer (Zinc). These recommendations were delivered in a scalable manner: through the distribution of written information (Soil Health Cards and supplemental materials) prior to sowing, and a series of

[2] KT service is provided by Precision Agriculture for Development (PAD).

appropriately timed automated push calls throughout the growing season. PAD's administrative data indicate a high rate of service usage among farmers in our sample. The average pick-up rate of KT calls among farmers in the study reached over 91%, while an average farmer listened to 61% of message content. Among the treated farmers, the likelihood of listening to customized fertilizer recommendations ranged from 65 to 87.4% across four distinct messages.

This paper reports early-stage results, focusing on the effects on fertilizer usage during the sowing period. Customized fertilizer advice, on average, increased adoption of recommended fertilizers by 3.2 - 11 percentage points within the first month of sowing, reducing the fertilizer gap - distance between the optimal and actual fertilizer usage - by 0.121 standard deviations. These point estimates imply widely varying increases in adoption across four fertilizer types, but all are qualitatively substantial: increases of 200% for UREA (over a control mean of 7%), 7% for DAP (over a control mean of 68%), 400% for MOP (over a control mean of 6.5%), and 500% for zinc fertilizers (over a control mean of 0.6%). One caveat of this analysis, however, is that our adoption data relies of self-reports. It is plausible that treated farmers who receive fertilizer recommendations are more likely to overreport adoption.

The findings of this study advance our understanding of the role of information in farm management decisions. A small yet growing body of evidence suggests that customized advice delivered via mobile phones could increase technology adoption (Fabregas et al. 2018, Cole and Fernando 2016, etc.) and agricultural outcomes (Cole and Fernando 2016, Casaburi et al. 2014). Building on previous studies that demonstrated productivity gains from fertilizer adoption and heterogeneity in those gains (Beaman et al. 2013, Duflo et al. 2008 and Suri 2011), we examine how precise advice on optimal soil fertility management affects fertilizer usage at both the extensive and the intensive margins. Second, our results also add to the findings of recent studies that highlight the importance of the design of agricultural information interventions. Specifically in the context of soil fertility information, Fishman et al. (2016) find that soil nutrient management advice via government SHCs did not change farmer behavior in Bihar, India, and hypothesize that this failure was due to lack of understanding, trust in information, and cost of inputs. Similarly, Cole and Sharma (2018) find that majority of cotton farmers in their survey sample in Gujarat had difficulty understanding recommendations in a government SHC but that digital and non-digital aid materials significantly improved comprehension levels. Third, our paper contributes to a literature on whether individuals trust and follow electronic advice. To our knowledge this literature has mostly focused on developed markets (e.g., Sillence et al., 2006, or Bonhard and Sasse, 2006). Our findings that new users of mobile phone-based advisory service follow recommendations and adopt agricultural practices suggest that farmers in our sample do trust electronic advice. Finally, our study contributes to the policy discussion on precision farming. Many governments increasingly invest resources to build databases on local conditions and farmer characteristics with the goal of providing increasingly customized advice. Our findings could provide insights into their potential value in encouraging optimal farming practices and eventually agricultural productivity.

The rest of the paper is organized as follows. The next section provides context of the study and the description of the intervention. Section 3 discusses the experimental design and empirical method. We then discuss results and conclude in the final section.

2. Background

Soil fertility management in India

Soil fertility management - management of soil nutrients - in many parts of the world focuses on application of inorganic fertilizers. (GoI, 2012). Inorganic fertilizers are widely used in India, where more than seventy-five percent of the total cultivated land was treated with inorganic fertilizers in 2011-2012 (Input Survey, 2011). Expenditure on fertilizers in 2012-13 represented roughly twenty-five percent of the total expenditures on crop production (NSSO, 2013).

Through the practices promoted during the Green Revolution (FAO, 1994) and government subsidies, usage of inorganic fertilizers has grown disproportionately to the productivity increase over the last few decades (GoI, 2016). Between 1950-1955 and 2007-2008 fertilizer usage in India increased by three hundred and twenty-two times while cereal production increased only five times (Prasad, 2009). For example, globally, India ranks third in terms of its nitrogen and phosphate usage but fourteenth and sixteenth in terms of yields for rice and wheat respectively (Ayala & Rao, 2002).

Soil fertility is a key determinant of optimal fertilizer usage. While a simple soil test can provide information on relevant soil nutrients and corresponding fertilizer recommendations, Cole & Fernando (2016) suggest that the willingness to pay for soil tests among smallholder farmers is low. Available nutrients in the soil can be assessed by soil tests, but individual farmers have traditionally been unwilling to pay for it. Farmers may not be fully aware of the benefits of understanding soil fertility. A government report from 2012 points to the lack of knowledge about fertilizer products, dosage, and timing as one important barrier to efficient usage of fertilizers (GoI, 2012). In our study sample, over 90% of farmers who reported using fertilizers in the previous season at baseline believed that their practices were optimal, suggesting a large knowledge gap.

Access to agricultural information

Farmers in India lack access to reliable agricultural information. A nationally representative survey suggests that less than 41% of farmers have access to any source of agricultural information, and less than 10% have access to government sponsored sources of agricultural information, such as extension agents, farmer information centres and agricultural universities (NSSO, 2013). Low access to agricultural information has been attributed to difficulty in reaching farmers in remote places, especially through the traditional agricultural extension agent-based system (Cole & Fernando, 2016).

In an effort to improve access to local agricultural information, the National Mission for Sustainable Agriculture (NMSA) launched a Soil Health Card scheme[3] in 2015. Under this scheme, government extension workers collect soil samples from a determined land size (2 x 2 hectare-grids for irrigated lands), and all farmers with plots within the grid receive the same fertilizer recommendations (GoI, 2018). However, the SHC contains a large volume of technical information (i.e., values and levels of various macro and micro-nutrients and fertilizer recommendations), making it difficult for farmers to understand the results and the recommendations. In fact, Cole and Sharma (2017) demonstrate that fewer than 8% of cotton farmers in their study sample in Gujarat understood the basic recommendations on the SHC.

Mobile phone-based extension (SMS based and voice-based services) has emerged as an alternative, potentially more cost-effective and scalable method of providing information to a large number of farmers. Mobile phone ownership among farmers in rural India is steadily increasing, creating a new opportunity to improve the efficiency of agricultural information delivery.

Krish Tarang: Mobile phone-based agricultural extension

This study is being implemented in partnership with Precision Agriculture for Development (PAD), an NGO specialized in providing mobile phone-based agricultural extension service. PAD operates Krishi Tarang (KT), a, two-way mobile phone-based agricultural advisory service. Farmers subscribed to the KT service receive weekly push calls with information on seeds, pesticides, planting, harvesting, and other

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agricultural decisions.[4] Farmers can also call back into the system to access their personal inbox, re-listen to the messages sent through push calls, and record any questions, which would be answered by a PAD agronomist within 2 days. The service is available for free and currently has more than sixty-thousand active users, who are registered as cotton growers across thirty-six districts of Gujarat, state in western India.

3. Intervention

To examine the impact of customized fertilizer advice, we designed a new set of messages that explain the importance of soil fertility management and provide information on plot-level soil nutrient levels, benefits and recommended dosages of three macronutrient (UREA, DAP, MOP) one micronutrient fertilizer (Zinc)[5]. PAD's process to generate customized fertilizer recommendations was the following: trained field staff visited each farmer in the study and collected a soil sample from the primary cotton plot; soil tests were performed by a local agricultural university, and lastly, PAD followed the university's fertilizer calculator and used nutrient levels stated in soil test results to generate fertilizer recommendations[6] customized to reflect quantity of fertilizer needed per-unit of land.

Customized recommendations were delivered through multiple channels. At the start of the agricultural season, we hand-delivered a Soil Health Cards (SHC) and two supplementary materials to each farmer in our sample. To ensure that recommendations we provide are easily understandable and actionable, we simplified the design of SHC using an iterative process of testing the comprehension level and tweaking the design based on feedback from farmers in the study area while maintaining the amount of information provided in the SHC (Figure A1).

In addition, supplemental materials were designed to help farmers understand the fertilizer recommendations: a card (Figure A2) that lays out the timing and the quantities of different fertilizers recommended without detailed information on nutrient values and a booklet (Figure A3) that provides pictorial illustration of the potential effects of each fertilizer type on plant health and yields.

[4] Cole and Fernando (2016) studied the impact of the KT system and found that when provided with information on managerial practices through the platform, farmers increased investment on agricultural inputs and achieved substantial increase in crop yields.

[5] Only UREA was recommended for unirrigated cotton

[6] Technical details of the process of generating fertilizer recommendations are summarized in Appendix III.

Finally, appropriately timed recommendations on fertilizer application were delivered through push calls over four weeks during the sowing period.[7] Push calls were timed to coincide with crucial stages in the crop growth cycle. In each call, PAD announced the topic of the call (macronutrient fertilizers, MOP, or zinc fertilizers), specified whether the call was for irrigated or unirrigated cotton, explained the potential benefits of the fertilizer(s), and provided the recommended application quantities[8]. If farmers did not pick up the call in a scheduled day[9], calls were sent again the day after. On both days PAD made three attempts to reach farmers if they did not pick up the call. Average pick-up rate across all topics was more than ninety-percent.

4. Experimental Design

Sample frame

The sample of this study consists of cotton farmers who newly registered into KT service in the first quarter of 2018 across three districts (Surendranagar, Rajkot and Morbi) in the southern western region of Gujarat. PAD administered a screening survey and identified farmers who owned a mobile phone, were planning to grow cotton in the upcoming Kharif season and were interested in receiving agricultural information through the KT service but had not subscribed to the service before.

Out of the farmers PAD recruited between January and March 2018, we removed those who did not own any agricultural land, had not sown cotton in kharif 2017, or did not have a plot suitable for soil sample collection[10]. This process resulted in the base sample of 1,585 farmers.

Randomization and Sample Characteristics

Farmers in the base sample were stratified by block (district subdivision) and randomly assigned to a treatment or control group (793 and 792 respectively). Table 1 presents summary statistics of the key variables at baseline by experimental groups. Columns (1) and (2) report means and standard deviations for control and treatment group respectively. The average age of farmers in the study is 42 years, over

[7] These calls were delivered as part of PAD's mobile phone-based agriculture advisory service.

[8] PAD provided recommendations per area unit of optimal fertilizers and micronutrient usage to make the information more farmer friendly.

[9] Complete call schedule is shown in Table A5 nd intervention timeline is shown in Figure A5.

[10] A soil sample could not be collected if there were standing crops from the previous season or if fertilizer had been applied after harvesting of previous year's crop.

99% are men, and more than eighty-percent of respondents are literate (could read newspaper in local language). The average farmer has a total cultivated land size of 21 bigha (3.37 hectares), slightly above the national average of 2.35 hectares among all cotton farmers in India. Even though the Indian government launched a nationwide Soil Health Card scheme in 2015 with the plan of conducting a soil test for every farmer, fewer than 15% of farmers in our sample reported ever having their soil tested. Column (3) reports the difference in means between the control and treatment groups. Table 1 shows that the proportion of baseline variables imbalanced between the two experimental groups are below the corresponding significance levels, confirming that the two groups are well-balanced.

Data

We use two sources of data for analysis. First, we obtained administrative data on KT service usage from PAD. We calculate the pick-up and listening rates for customized fertilizer calls, which were only delivered to farmers in the treatment group, and for regular cotton advisory calls on other topics delivered to all farmers in the study. Second, we conducted a phone survey shortly after the end of sowing period ("basal survey") and collected data on cotton cultivation and fertilizer usage. Out of the base sample of 1,585, 1,436 completed the survey, 1,317 of whom reported planting cotton and completed the section on fertilizer usage. Table A1 in appendix reports the differential likelihood of completing the basal survey between the experimental groups (Columns 1-2) and that of completing the basal survey *and* cultivating cotton (Columns 3-4). Even though we observe that the likelihood of completing the basal survey is significantly higher among treated farmers, differences in the characteristics of those who completed the survey are insignificant between the experimental groups. In fact, p-values from the joint significance test across all interaction terms between the treatment indicator and baseline characteristics are greater than 0.6.

Empirical strategy

We estimate the treatment effects using the following OLS model:

$$Y_i = \alpha_b + \beta T_i + \epsilon_i$$

where Y_i denotes the post-intervention outcome for individual i, $T_i$the treatment indicator, and α_b the block fixed effects. Random assignment of the intervention ensures that the error term ei is uncorrelated with the treatment indicator. Thus, β in Equation 1, the coefficient of our interest, captures the unbiased Intent-to-treat (ITT) effect.

5. Results

Exposure to intervention: Listening Rates of Customized Fertilizer calls

We first report the level of exposure to intervention among treated farmers using PAD's administrative data. Table 3 reports the proportion of farmers in the treatment group who listened to relevant fertilizer recommendations sent via push calls. Panel A shows that 70% of farmers growing unirrigated cotton picked up and listened to the content on basal fertilizer recommendations for unirrigated cotton at least once. Farmer with irrigated cotton had even higher listening rates: 87% listened to the recommendations on basal fertilizers, 78% listened to recommendations of potash fertilizers, and 68% listened to recommendations on zinc fertilizers. In addition, 50% of treated farmers who received the recommendations via push calls listened to the same recommendations more than once[11].

Interestingly, treated farmers are less likely to listen to the subsequent calls on cotton farming advice - four calls with regular farming related information were sent to all farmers in the study sample. Table 4 indicates that farmers in the treatment group are 3.4 percentage point less likely to pick up these calls and listened to the 4.6 percentage points less content compared to farmers in the control group. These differences are significant at the 1% level.

Impact on cotton cultivation

We next examine whether providing soil fertility information and fertilizer recommendations via SHCs and supplementary materials affect farmer's decision on sowing. Table 2 shows that the intervention had no influence on farmer's decision on whether to cultivate cotton (Column 1) or how much cotton to cultivate (Column 3). Similarly, there is no treatment effect on the likelihood of growing irrigated cotton (Column 2). We note that our sample consists of farmers who had planned to cultivate cotton three months before sowing in the predominantly cotton-growing area of India. The decision not to grow cotton was likely driven by weather and other uncontrollable factors. Almost 8% of farmers did not sow cotton in the current cropping season and another 1.5% of farmers reported that their crops had already failed. Delay of monsoon and unavailability of water were the two most cited reasons for not sowing cotton and for causes of plant loss. In fact, ninety-one percent of all farmers who had sown cotton had access to irrigation.

[11] As shown in Table A5, each call for irrigated cotton was sent out multiple times over the course of four weeks.

Impact on Fertilizer Usage

We now turn to the treatment effects on self-reported fertilizer usage during the sowing period. First, Table 5 Panel A indicates a large variation in adoption levels of four recommended fertilizers among farmers in the control group. While use of DAP (the main fertilizer for supplying Phosphorus) was quite high at nearly 70%, only 13.74% applied UREA[12], and even fewer farmers applied MOP and Zinc (2.4% and 0.6% respectively).

In Tables 5, we report ITT estimates on the likelihood of using recommended fertilizers. Panel A shows large increases in adoption of all fertilizer types at the time of or before sowing. Point estimates imply more than two-fold, four-fold, and five-fold increases in the likelihoods of using UREA, MOP, and Zinc, respectively. Treated farmers on average also applied fertilizers in larger areas of their plots compared to farmers in the control group. Table 5, Panel B shows increases in the area on which fertilizer was applied by 1.3 bigha (0.22 hectare) for UREA and MOP, and 0.55 bigha (0.09 hectare) for Zinc. These increases are, however, at the extensive margin (i.e., more farmers using recommended fertilizers) rather than at the intensive margin (i.e., each farmer who adopt fertilizers applying them to a larger area). Our analysis on the volume of fertilizer usage suggests that customized recommendations, on average, help fertilizer usage move closer to the optimal. In Table 6, we estimate the treatment effect on the distance between recommended and reported volumes of fertilizer applied during the sowing period. In Panel A, we calculate ITT effects across the full sample. Even though the treatment effect is only statistically significant in Column (1) and Column (5), all coefficients on the treatment indicator are negative. Column (5) shows that the intervention resulted in a 0.121 standard deviation shift toward the optimal fertilizer usage across the four fertilizers, and we can reject the null hypothesis at a 99% confidence level that there was no shift.

Further analysis provides some qualitative indication that customized fertilizer calls may have also improved fertilizer usage at the intensive margin. First, Table 6, Panel B reports ITT effects using the identical specification to that of Panel A but with a restricted sample of farmers that applied each fertilizer. Even though small sample sizes mean insufficient power, the direction of the coefficients remain consistently negative. Figures 1 provide further qualitative evidence that the intervention affected the pattern of fertilizer usage among those who adopted each fertilizer. Each figure presents kernel density estimates of the difference between the applied and recommended fertilizer doses for a given fertilizer type. Figures 1(a) and 1(b) in particular visually demonstrate the distributions among treated

[12] At baseline, over 95% of farmers in the sample reported having applied UREA during the cropping season in 2017. However, the common practice in this region is to apply UREA a few weeks to a month after sowing.

farmers are skewed more toward zero relative to the distributions among farmers in the control group. Figure 1(b) also demonstrates that fewer treated farmers are overusing DAP (i.e., a small hump *over* 40kg/bigha threshold for the control group, as opposed to a small hump *under* the same threshold for the treatment group). These patterns indicate that treated farmers adopting fertilizers, on average, apply doses closer to the recommended amounts, even though this indication is only suggestive at best. The analysis over the full cropping season, likely with a larger proportion of farmers adopting fertilizers, may provide more insights on this point.

6. Conclusion

Increasing availability of new technologies creates opportunities to expand access to high-quality agricultural information to smallholder farmers at a low cost. Governments, practitioners, and private-sector players in the agricultural sector offer innovative solutions to generate and deliver more precise agricultural advice to farmers. Relatively little is known, however, about how such information affects farmer behavior and agricultural practices. As more resources become directed towards improving and scaling precision farming technologies for farmers in developing countries, it is critical to understand how to best deliver agricultural information to facilitate improvement in farming practices and agricultural outcomes. This study explores this question in the context of fertilizer usage in a field experiment among cotton farmers in India. We provide initial evidence that customized agricultural advice, generated based on the results of plot-level soil tests, could increase adoption of appropriate fertilizers and improve soil fertility management practices. After the sowing period, farmers receiving customized fertilizer recommendations report a significantly higher likelihood of adopting recommended fertilizers, leading to a 0.121 standard deviation reduction in the fertilizer gap. Future analysis will assess whether these effects remain robust throughout the cropping season and result in improved agricultural productivity.

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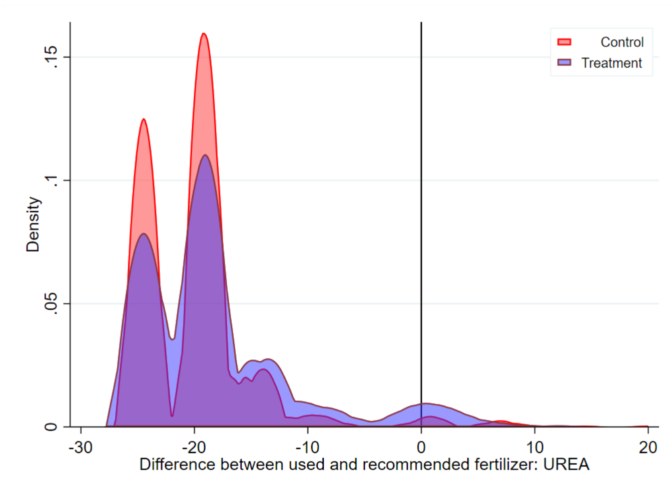
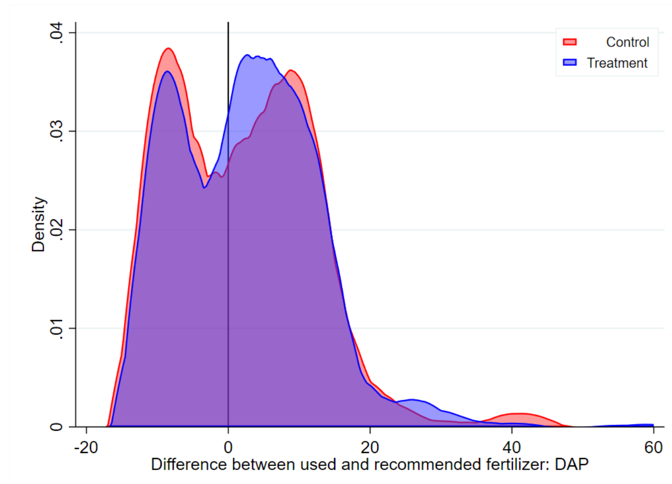
Figures

Figure 1: Applied minus recommended fertilizer (kg/bigha)

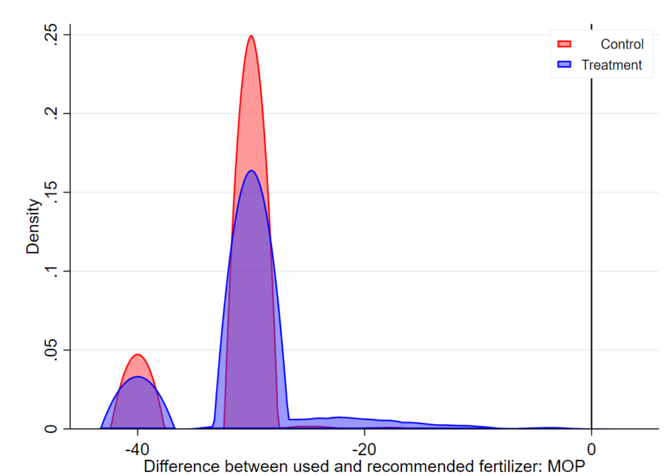
(a) UREA



(b) DAP



(c) MOP



(d) Zinc

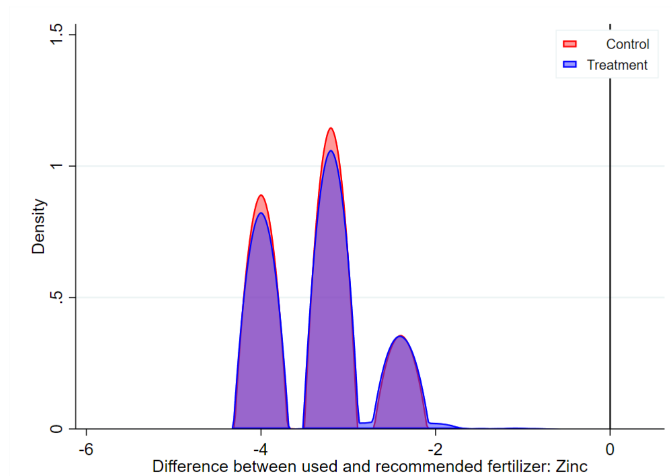


Figure 1 displays kernel density estimates for the difference between the applied and recommended Basal fertilizer dose in kg/bigha. Differences were calculated by subtracting the lab recommended fertilizer dose from the farmer's self-reported use. The density plots use a Epanechnikov kernel function. Estimates were calculated separately for treatment (red) and control (blue). Values below 0 indicate that the farmer applied less than the recommended dose, and values above 0 indicate that the farmer applied more than the recommended dose. The sample size used to derive each figure is 1317 which consists of all farmers that answered the fertilizer section of the phone survey.

Tables

Table 1: Summary statistics, baseline

Panel A: Full sample

	(1) Control	(2) Treatment	(3) (1) vs. (2)
Age	42.56	42.35	0.20
	(0.41)	(0.43)	(0.59)
Literacy	0.84	0.83	0.01
	(0.01)	(0.01)	(0.02)
Total land (bigha)	24.34	24.00	0.33
	(0.87)	(0.85)	(1.21)
Pucca house (English)	0.61	0.63	-0.02
	(0.02)	(0.02)	(0.02)
Received a prior soil test	0.14	0.12	0.02
	(0.01)	(0.01)	(0.02)
Sampled plot size in bigha	12.62	12.26	0.36
	(0.36)	(0.33)	(0.49)
Primary occupation is self-employed farming	0.98	0.98	-0.00
	(0.01)	(0.00)	(0.01)
UREA usage last season (kg/bigha)	44.71	43.60	1.12
	(0.95)	(0.92)	(1.32)
DAP usage last season (kg/bigha)	24.36	23.07	1.29
	(0.59)	(0.56)	(0.81)
MOP usage last season (kg/bigha)	0.79	0.83	-0.04
	(0.12)	(0.12)	(0.17)
Zinc usage last season (kg/bigha)	0.19	0.25	-0.06
	(0.03)	(0.04)	(0.05)
N	792	793	1585

Panel B: Basal survey respondents

	(1) Control	(2) Treatment	(3) (1) vs. (2)
Age	42.85	42.41	0.43
	(0.43)	(0.45)	(0.62)
Literacy	0.85	0.84	0.01
	(0.01)	(0.01)	(0.02)
Total land (bigha)	24.26	24.50	-0.24
	(0.93)	(0.91)	(1.30)
Pucca house (English)	0.61	0.63	-0.03
	(0.02)	(0.02)	(0.03)
Received a prior soil test	0.14	0.13	0.01
	(0.01)	(0.01)	(0.02)
Sampled plot size in bigha	12.52	12.38	0.14
	(0.38)	(0.35)	(0.52)
Primary occupation is self-employed farming	0.98	0.98	0.00
	(0.01)	(0.01)	(0.01)
UREA usage last season (kg/bigha)	44.39	43.10	1.29
	(0.99)	(0.93)	(1.36)
DAP usage last season (kg/bigha)	24.27	22.83	1.43
	(0.62)	(0.58)	(0.85)
MOP usage last season (kg/bigha)	0.82	0.86	-0.04
	(0.12)	(0.13)	(0.18)
Zinc usage last season (kg/bigha)	0.20	0.26	-0.06
	(0.04)	(0.04)	(0.05)
N	707	729	1436

Columns (1) and (2) report sample means with standard errors in parentheses. Column (3) reports the mean difference between the two experimental groups. All measures of fertilizer usage are winsorized at the 99th percentile.

Table 2: Treatment effect on cotton cultivation
Phone survey data

	(1) Sowed cotton	(2) Growing irrigated cotton	(3) Cotton sowing area (bigha)
Treatment	0.00550	0.0145	-0.0677
	(0.0160)	(0.0196)	(0.482)
Constant	0.965***	0.822***	10.65***
	(0.0145)	(0.0251)	(0.642)
Block FE	Yes	Yes	Yes
Observations	1436	1436	1436
R^2	0.009	0.004	0.070
Control mean of dep var	0.930	0.830	10.20

Robust standard errors in parenthesis. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Column (1) reports the results of a regression of treatment status on an indicator variable that is assigned a value of 1 if the farmer sowed cotton this season. Treatment adopts a value of 1 if the farmer was in the treatment group. Column (2) is the same as column (1) except the dependent variable is only assigned a value of 1 if the farmer is growing irrigated cotton. Column (3) records the results of a regression of treatment status on the area in bigha on which the farmer is sowing cotton. The cotton sowing area is assigned a value of 0 if the farmer did not sow cotton. All regressions control for the block in which the farmer is located.

Table 3: Listening rates of fertilizer calls
Administrative data

	Number	Percent
Basal call - unirrigated (UREA)		
Did not hear any recommendations	62	34.6
Heard at least 1 recommendation	117	65.4
Total	179	100.0
Basal call - irrigated (UREA, MOP, and DAP)		
Did not hear any recommendations	84	12.4
Heard at least 1 recommendation	594	87.6
Total	678	100.0
Potash call - irrigated		
Did not hear any recommendations	147	21.7
Heard at least 1 recommendation	531	78.3
Total	678	100.0
Zinc call - irrigated		
Did not hear any recommendations	207	30.5
Heard at least 1 recommendation	471	69.5
Total	678	100.0

Table 3 reports the number and percent of relevant farmers that heard at least 1 customized fertilizer recommendation of the indicated type. A relevant farmer means that they have an irrigated plot if the advice is for irrigated plots or an unirrigated plot if the recommendation is for unirrigated plots. Customized calls were only sent to farmers in the treatment group. All treatment farmers received the same call. If the call duration exceeded the point where a recommendation was given, then heard recommendation was assigned a value of 1. The first panel has a smaller sample size because most farmers have irrigated plots.

Table 4: Attention Crowd-Out: Treatment effect on listening rates of non-fertilize KT Calls
Administrative data

	(1) Share of KT calls picked up	(2) Average proportion of KT calls listened to
Treatment	-0.0344***	-0.0457***
	(0.0107)	(0.0155)
Constant	0.939***	0.643***
	(0.0130)	(0.0195)
Block FE	Yes	Yes
Observations	1317	1317
R^2	0.024	0.016
Control mean of dep var	0.917	0.619

Robust standard errors in parenthesis. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Both treatment and control farmers are able to receive Krishi Tarang (KT) agricultural advisory calls. Column (1) reports the results of a regression of the average pickup rate across KT calls on treatment status. Column (2) contains the results of a regression on the average proportion of each call that was listened to on treatment status. Listen proportion was coded to 0 if the farmer did not answer the call. Both regressions control for the block in which the farmer is located. The sample size of 1317 consists of all farmers that completed the Basal survey and sowed cotton.

Table 5: Treatment effect on fertilizer usage
Phone survey data

Panel A: Fertilizers applied (yes/no)

	(1)	(2)	(3)	(4)	(5)
	UREA	DAP	MOP	Zinc	Standardized joint effects
Treatment	0.119***	0.0484**	0.108***	0.0322***	0.413***
	(0.0184)	(0.0236)	(0.0143)	(0.00794)	(0.0462)
Constant	0.0343*	0.791***	0.0289*	0.00162	
	(0.0189)	(0.0271)	(0.0162)	(0.00764)	
Block FE	Yes	Yes	Yes	Yes	No
Observations	1317	1317	1317	1317	1317
R^2	0.054	0.111	0.065	0.035	
Control mean of dep var	0.0762	0.687	0.0249	0.00622	

Panel B: Area on which fertilizer was applied (bigha)

	(1)	(2)	(3)	(4)	(5)
	UREA	DAP	MOP	Zinc	Standardizd joint effects
Treatment	1.352***	0.287	1.200***	0.353***	0.289***
	(0.261)	(0.486)	(0.217)	(0.0956)	(0.0448)
Constant	0.339	8.834***	0.268	-0.0304	
	(0.258)	(0.572)	(0.228)	(0.0813)	
Block FE	Yes	Yes	Yes	Yes	No
Observations	1317	1317	1317	1317	1317
R^2	0.052	0.084	0.064	0.033	
Control mean of dep var	0.939	8.830	0.406	0.0747	

Robust standard errors in parenthesis. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Panel A reports the results of regressions of a binary variable indicating whether or not the farmer used any of the given fertilizer type on treatment status. Panel B presents the results of a regression of the area (in bigha) of the farmer's plot on which they applied the given type of fertilizer on treatment status. All fertilizer values in Panel B were winsorized at the 99th percentile. Column (5) reports the average standardized effect across Columns (1) - (4), which is an equally-weighted sum across the standardized treatment effects on the outcome for four fertilizer types. The sample size of 1317 consists of all farmers that completed the Basal survey and sowed cotton.

Table 6: Treatment effect on the distance between suggested and applied fertilizer amounts (absolute differences in kg/bigha)
Phone survey data

	(1)	(2)	(3)	(4)	(5)
Panel A: Full sample					
	UREA	DAP	MOP	Zinc	Standardized joint effects
Treatment	-1.546***	-0.313	-0.912	-0.00856	-0.121***
	(0.293)	(0.333)	(0.563)	(0.0611)	(0.0353)
Constant	20.22***	10.91***	25.67***	2.847***	
	(0.307)	(0.450)	(0.719)	(0.0833)	
Block FE	Yes	Yes	Yes	Yes	No
Observations	1315	1315	1315	1315	1315
R^2	0.040	0.063	0.043	0.023	
Control mean of dep var	20.01	8.612	28.63	3.049	

	(1)	(2)	(3)	(4)
Panel B: Restricted sample of farmers who reported using the indicated fertilizer type				
	UREA	DAP	MOP	Zinc
Treatment	-0.695	-0.523	-0.981	-0.107
	(1.092)	(0.448)	(2.167)	(0.280)
Constant	10.27***	11.74***	19.34***	2.317***
	(1.284)	(0.535)	(2.949)	(0.464)
Block FE	Yes	Yes	Yes	Yes
Observations	181	936	106	30
R^2	0.004	0.092	0.037	0.174
Control mean of dep var	9.953	8.826	22.43	2.764

Robust standard errors in parenthesis. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 6 reports regressions of the absolute value of the difference between the recommended basal fertilizer dose and farmer-reported application of fertilizer on treatment status. All differences are winsorized at the 99th percentile. Column (5) reports the average standardized effect across Columns (1) - (4), which is an equally-weighted sum across the standardized treatment effects on the outcome for four fertilizer types. Panel A includes all farmers that completed the Basal survey. The sample size of 1315 differs from the sample size of 1317 in Table 5 because the soil testing lab did not return recommendations for 2 farmers. Panel B only includes farmers that that reported applying any of the indicated fertilizer type.

Appendix I: Tables

Table A1: Basal survey results

	Control		Treatment		Total	
	Number	Percent	Number	Percent	Number	Percent
Survey status						
Incomplete	148	18.7	118	14.9	266	16.8
Farmer gave land on rent	1	0.1	0	0.0	1	0.1
Partially complete	0	0.0	1	0.1	1	0.1
Complete	643	81.2	674	85.0	1317	83.1
Total	792	100.0	793	100.0	1585	100.0
Growing cotton						
No sowing	60	8.5	54	7.4	114	7.9
Sowing	634	89.7	665	91.2	1299	90.5
Crop failure	13	1.8	10	1.4	23	1.6
Total	707	100.0	729	100.0	1436	100.0

Panel A provides a breakdown of the completion rate of the Basal survey. A survey status of ”incomplete” indicates that surveyors were unable to reach the farmer by phone or that the farmer did not consent to be interviewed. A status of ”farmer gave land on rent” indicates that the farmer rented the sampled plot to someone else. One survey is partially complete because it was disrupted midway through and surveyors were unable to complete it at a later date. Panel B tabulates cotton sowing among farmers that completed the Basal survey.

Table A2: Attrition

	(1) Survey completed	(2) Survey completed	(3) Complete & sowed cotton	(4) Complete & sowed cotton
Treatment	0.0381**	0.136	0.0343*	0.0989
	(0.0188)	(0.0929)	(0.0187)	(0.0919)
Age		0.00282**		0.00225*
		(0.00127)		(0.00125)
Literate		0.0710*		0.0542
		(0.0406)		(0.0398)
Pucca house (English)		-0.0266		-0.0214
		(0.0295)		(0.0293)
Received a prior soil test		0.0407		0.0360
		(0.0374)		(0.0371)
Sampled plot size (bigha)		0.00127		0.00142
		(0.00138)		(0.00138)
Treatment x Age		-0.00262		-0.00211
		(0.00167)		(0.00166)
Treatment x Literate		-0.0238		-0.00639
		(0.0551)		(0.0545)
Treatment x Pucca house (English)		0.0442		0.0402
		(0.0400)		(0.0398)
Treatment x Received a prior soil test		-0.0222		-0.0202
		(0.0515)		(0.0512)
Treatment x Sampled plot size (bigha)		0.000937		0.000815
		(0.00180)		(0.00180)
Constant	0.812***	0.693***	0.817***	0.728***
	(0.0139)	(0.0730)	(0.0138)	(0.0719)
Block FE	No	Yes	No	Yes
Observations	1585	1585	1585	1585
R^2	0.003	0.026	0.002	0.022
Control mean of dependent variable	0.810	0.810	0.820	0.820
p-val. of joint orthogonality of interactions		0.603		0.756

Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Survey completed indicates that the respondent finished the basal survey. Complete & sowed cotton indicates that the respondent finished the basal survey and attempted to grow cotton (even if the crop failed). Harvest data was missing for five observations and interpolated by replacing the missing values with the median value. The p-value of the joint orthogonality of interactions gives the p-value for the F-test that all interaction terms (Treatment x Age ... Treatment x Sampled plot size) are jointly equal to 0.

Table A3: Treatment effect on the distance between suggested and applied nutrient applications (absolute differences in kg/bigha)

	(1) Nitrogen	(2) Phosphorus	(3) Potassium	(4) Zinc
Treatment	-0.620***	-0.218	-0.706***	-0.0351
	(0.146)	(0.161)	(0.185)	(0.0327)
Constant	7.054***	4.831***	17.80***	3.333***
	(0.173)	(0.220)	(0.171)	(0.0388)
Block FE	Yes	Yes	Yes	Yes
Observations	1315	1192	1192	1192
R^2	0.051	0.060	0.058	0.019
Control mean of dep var	7.800	3.875	18.84	3.375

Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A3 reports regressions of the absolute value of the difference between the recommended nutrient quantity and farmer-reported application of nutrients on treatment status. Nutrient quantities were arrived at summing quantities of Nitrogen, Phosphorous, Potassium and Zinc contained in each fertilizer. All regressions control for the block in which the farmer is located. All differences are winsorized at the 99th percentile. The sample size of 1315 differs from the sample size of 1317 in Table 5 because the soil testing lab did not return recommendations for 2 farmers.

Table A4: Randomization verification

Imbalance level	Number of variables with imbalance	Percent	Cumulative Percent
1%	7	0.9	0.9
5%	20	2.6	3.5
10%	35	4.5	8.0
None	717	92.0	100.0
Total	779	100.0	

Table A4 was constructed by removing numeric tracking variables, then regressing each numeric variable with at least 100 non-missing observations on treatment status. An imbalance level of 1% indicates that $p < .01$, 5% indicates that $.01 \leq p < .05$, and 10% indicates that $.05 \leq p < 0.1$. None indicates that $p \geq 0.1$. Variables were then tabulated by imbalance level. The column "Percent" indicates the percent of variables with the given imbalance level, and "Cumulative Percent" records the percent of variables with imbalance at the indicated level or lower.

Table A5: Call Calendar

Date	Call Topic
02 June 2018	Introduction Call
04 June 2018	Irrigated Basal Application
06 June 2018	Additional Potash Call
08 June 2018	Zinc Call
12 June 2018	General Call
13 June 2018	Irrigated Basal Application
15 June 2018	Additional Potash Call
17 June 2018	Zinc Call
19 June 2018	General Call
20 June 2018	Un-Irrigated Basal Application
22 June 2018	Irrigated Basal Application
24 June 2018	Additional Potash Call
26 June 2018	General Call
27 June 2018	Un-Irrigated Basal Application
30 June 2018	Irrigated Basal Application
03 July 2018	General Call

Appendix III: Generating recommendations from soil test results

A four-step process was followed to generate customized fertilizer recommendations for each farmer:

1. Before the start of the agricultural season, we collected soil samples from one of the plots owned by each farmer in the sample and tested the soil samples for pH and EC and various macronutrients (nitrogen, phosphorus, potassium) and micro nutrients (zinc, sulphur, iron). The soil test results contained the quantity of each nutrient in the soil and the level of each nutrient (low, medium or high).
2. We used nutrient levels to generate nutrient-specific recommendations. For doing so we used template developed by Junagarh Agricultural University, in which quantities of nutrients are recommended for each of three nutrient levels. The recommended nutrient quantities for every nutrient label are the following:

	Low	Medium	High
Nitrogen (N)	300	240	180
Phosphorus (P)	62.5	50	37.5
Potassium (K)	187.5	150	112.5
Zinc	25	20	15

3. Nutrient levels were then converted s to fertilizer recommendations. We focused on three macronutrients (nitrogen, phosphorus and potassium) and one micronutrient (zinc for irrigated cotton and sulphur for unirrigated cotton).
    - In irrigated plots HYV seeds are used. These seeds require adequate amounts of the three macronutrients selected, Nitrogen and phosphorus are important for crop development and potassium improves water use efficiency, builds resilience of crop against certain diseases and improves fibre quality. Application of zinc was also recommended because plants from HYV seeds respond better to macronutrients when micronutrients are available in adequate quantity and most plots in the study area were deficient in this micronutrient.
    - In non-irrigated or rainfed plots, non-HYV seeds are used. Nitrogen and sulphur were recommended because the nutrient requirements can be met with these two nutrients.

4. Our fertilizer recommendations were in terms of quantities of UREA, Di-ammonium Phosphate (DAP), Muriate of Potash (MOP), Zinc Sulphate (Zinc) and Gypsum. The table shows the nutrients contained in each fertilizer.

Fertilizer	Nutrient Content (%)				
	Nitrogen	Phosphorus	Potassium	Zinc	Sulphur
UREA	46	x	x	x	x
DAP	18	46	x	x	x
MOP	x	x	60	x	x
Zinc Sulphate (Zinc)	x	x	x	36	14
Sulphur	x	x	x	x	100

The nutrient levels in each fertilizer were used to calculate the exact quantity of fertilizer recommended for each plot. Our previous field surveys had shown that all the recommended fertilizers were easily available, reasonably priced and were effective for supplying nutrients to soil.

5. Given that fertilizers are more effective when applied in multiple small doses at various crop stages, total fertilizer recommendation were split into dose-wise recommendations. All doses contained equal quantities of fertilizer. Following are the number of doses in which application of various nutrients is suggested:

	Irrigated Crop		Un-irrigated Crop	
	Number of Doses	Timing of Doses	Number of Doses	Timing of Doses
Nitrogen	4	- At time of sowing (basal dose) - One month after sowing - Two months after sowing - Three months after sowing	2	- At time of sowing (basal dose) - One month after sowing
Phosphorus	2	- At time of sowing (basal dose) - One month after sowing	0	
Potassium	1	- At time of sowing (basal dose)	0	
Zinc	1	- At time of sowing (basal dose)	0	
Sulphur	1	- At time of sowing (basal dose)	1	- At time of sowing (basal dose)

Fertilizer and nutrient recommendations were generated for 'per unit of area' o make recommendations farmer friendly. This means that the recommendations were generated for the area unit in which farmer had reported crop area at baseline. For example, if farmer had reported land in acre, then customized fertilizer recommendations were made in per acre terms. Also, since irrigation status of crop is uncertain for farmers in India at start of agricultural season, recommendations for both irrigated and unirrigated cotton were generated for each farmer.

Appendix II: Soil Health Cards and supplemental materials

Figure A1: Soil Health Card developed by PAD

ક્રિષી તરંગ
ખેતી માહિતી સેવા

Soil Health Card		Name of the Lab:				
Farmer's Details		**Soil Test Results**				
Name		**#**	**Parameter**	**Test Value**	**Unit**	**Level**
Village						
Block						
District		**1**	pH	8.26		Acidic
Mobile Number		**2**	EC	0.19	dS/m	Normal
UID		**3**	Nitrogen	50	Kg/Ha	Medium
Soil Sample Information		**4**	Phosphorous	30	Kg/Ha	Medium
MM-YYYY of Collection		**5**	Potash	30	Kg/Ha	Low
Plot Name		**6**	Sulphur	20	PPM	Low
Plot Size		**7**	Zinc	0.80	PPM	Low
Irrigated		**8**	Iron	1.79	PPM	Low

<table>
<tr><th colspan="13">Fertilizer Recommendation</th></tr>
<tr><th colspan="3">Secondary & Micro Nutrient Recommendations</th><th rowspan="2">#</th><th rowspan="2">Crop</th><th rowspan="2">FYM</th><th colspan="6">Fertilizer</th></tr>
<tr><th>#</th><th>Fertilizer</th><th>Quantity</th><th>#</th><th>Fertilizer</th><th>Basal Fertilizer</th><th>1 Month After Sowing</th><th>2 Month After Sowing</th><th>3 Month After Sowing</th></tr>
<tr><td rowspan="3">1</td><td rowspan="3">Zinc Sulphate</td><td rowspan="3">1 Kg/Vigha</td><td rowspan="3">1</td><td rowspan="3">Irrigated Cotton</td><td rowspan="3">10 Ton/ha</td><td>1</td><td>Urea</td><td>24 Kg/Vigha</td><td>24 Kg/Vigha</td><td>24 Kg/Vigha</td><td>24 Kg/Vigha</td></tr>
<tr><td>2</td><td>DAP</td><td>9 Kg/Vigha</td><td>9 Kg/Vigha</td><td></td><td></td></tr>
<tr><td>3</td><td>Muriate of Potash</td><td>29 Kg/Vigha</td><td></td><td></td><td></td></tr>
<tr><td>2</td><td>Gypsum</td><td>100 Kg/Vigha</td><td>2</td><td>Un-Irrigated Cotton</td><td>10 Ton/ha</td><td>1</td><td>Urea</td><td>10 Kg/Vigha</td><td>10 Kg/Vigha</td><td></td><td></td></tr>
</table>

Figure A2: Supplement to SHC

ક્રિષી તરંગ
ખેતી માહિતી સેવા

Name: Village: Block: UID:

Plot Name:

Summary of Nutrient Levels in Your Plot				
	Macronutrients			Micronutrients
Nutrient Name	**Nitrogen**	**Phosphorus**	**Potash**	**Zinc**
Nutrient Level	Low	High	Medium	Low

Recommendations of Chemical Fertilizers for Irrigated Cotton					
When to Apply?		**Urea**	**DAP**	**Muriate of Potash (MoP)**	**Zinc Sulphate**
Basal	At the time of sowing	**24 Kg/Bigha**	**9 Kg/Bigha**	**29 Kg/Bigha**	**1 Kg/Bigha**
Dose 1	1 month after sowing	**24 Kg/Bigha**	**9 Kg/Bigha**	×	×
Dose 2	2 months after sowing	**24 Kg/Bigha**	×	×	×
Dose 3	3 months after sowing	**24 Kg/Bigha**	×	×	×

Application of FYM: Before sowing of Cotton it is advised to apply 1.5 tonn Farm Yard Manure (FYM) per Bigha

Recommendations of Chemical Fertilizers for Un-Irrigated Cotton		
When to Apply?		**Urea**
Basal	At the time of sowing	**10 Kg/Bigha**
Dose 1	1 month after sowing	**10 Kg/Bigha**

Application of Gypsum: Before sowing of Un-Irrigated Cotton it is advised to apply 100 kg Gypsum per Bigha

Figure A3: Booklet

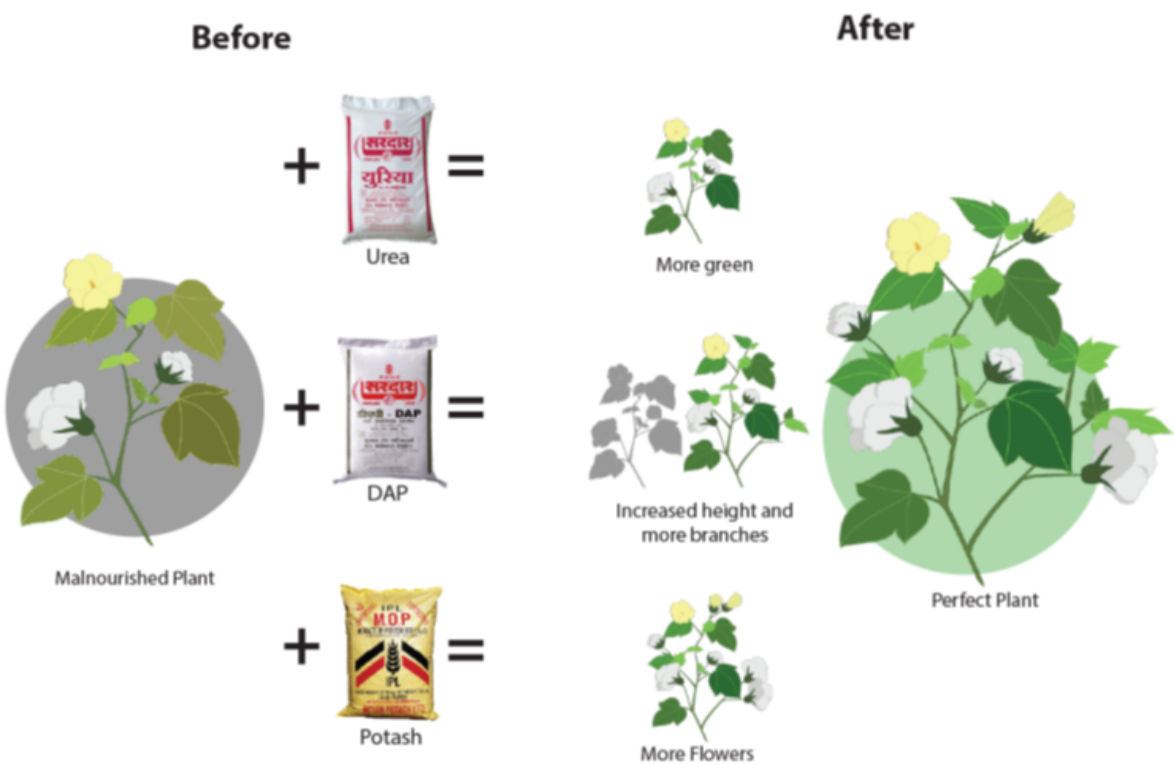


Figure A4: Project Intervention Timeline