AID-OAA-F-13-00016

President and Fellows of Harvard College

Reducing Imbalanced Fertilizer Use in Bangladesh

Milestone 1

Milestone 1

Updated Project Implementation Plan

With our local research partner, Center for Development Innovation and Practices (CDIP) the baseline survey and "leaf color charts" interventions (referred to as LCC from now on) have been completed. This intervention has been designed around the current *boro season* of 2013. A baseline survey was completed with 1547 farmers, another short survey (which included information on fertilizers and yields at the plot level, but not a full set of indicators) was completed for an additional 500 farmers due to concerns about statistical power. The surveys were conducted by CDIP staff.

Out of the sample, 50% of the farmers were randomized into the LCC treatment group. Leaf color charts imported from the International Rice Research Institute (IRRI) at the Philippines were distributed to the treatment group farmers. Short training sessions, led by extension workers from the Department of Agricultural Extension (DAE) were organized at the village level jointly with CDIP. Leaf color charts were given to the farmers during these sessions followed by training on how to use the charts. Due to an unusually cold winter, shortage of seedlings, and water shortages in some villages planting was delayed in many villages in our sample. Refresher training courses were also held by CDIP staff to refresh farmer's memory on the key points on using the charts and to answer any questions. *We have not separated the treatment farmers into two groups where the refresher trainings would be split between CDIP staff and DAE workers as suggested earlier* because of (1) feasibility concerns – in many cases DAE workers and CDIP staff both live in close proximity to the farmers and farmers go to both for advice without us arranging for help, so it would be difficult to interpret and separate the results; (2) concerns about statistical power in splitting the treatment group and (3) importance of the refresher training in ensuring that the instructions farmers received were standardized.

We are currently conducting pre-endline short surveys on time-use by farmers during the period of fertilizer application, which is also being conducted by CDIP staff. In addition photographs of paddy leaves are also being documented. We expect both indicators to serve independent measures of whether farmers use leaf color charts instead of just relying on self-reports, that will serve to complement the endline survey. The endline survey will be conducted after harvest starting end of May 2013. We will have an independent team conduct the endline surveys to prevent any bias as CDIP staff were part of the implementation.

We plan to conduct the baseline survey for the "soil testing" group (referred to as ST from now on), right after completing the LCC endline survey in July 2013. We will start collecting soil samples from farmers around the same time as the survey if whenever conditions permit (i.e. plot is not under water, urea was not applied in the last two weeks). Therefore soil samples will be collected by CDIP staff later if conditions do not permit samples to be collected by enumerators on the day of the survey. Enumerators and CDIP staff will be provided training beforehand on how to collect soil samples. The laboratories where soil tests are conducted are at full capacity now, so it may take a few months to get the soil test results back. We will aim to provide results back by September 2013 to target the post-monsoon season,

however, in case we do not get all results back in time, we will meet the target for the *boro season* of January 2014. Even if results are returned in time for the growing season starting in September 2013, since the *boro season* is the most productive and most resource intensive season in the year, we would like to conduct the follow-up survey to capture any changes in behavior in that season. Soil test results will be returned by CDIP staff to individual farmers where they will help them understand the results. CDIP staff will again follow-up and explain results before the 2014 *boro season.* The endline survey will be completed after harvest of the *boro season* crops in 2014.

Updated Evaluation Strategy

Evaluation Strategy:

The evaluation will be carried out through a randomized control trial, centered around two winter season (*Boro*) of January-April 2013 the main growing season in Bangladesh.

The LCC and ST treatment arms will be carried out separately. While both samples will be drawn from the networks of our partner CDIP, the LCC study is being conducted first, immediately followed by the PST study with a different sample. Therefore, we will also address design separately:

Treatment I: Leaf Color Charts

The LCC intervention is currently underway with baselines already completed and pre-endlines (to complement the endline) being conducted. A detailed baseline survey with all indicators listed in the next section was conducted for 1547 farmers. A shorter baseline with key indicator on yield and fertilizers (but not other inputs) was conducted on an additional 500 farmers to increase the sample size mainly due to concerns about statistical power. Treatment was randomized at the individual level. The sample includes 2,000 farmers, of which half received the treatment. The treatment consisted of the distribution of and training on how to use LCCs by CDIP (in collaboration with a government extension worker). CDIP staff also provided a refresher training a few weeks after the main training to address any questions farmers had once they started using the LCCs.

A pre-endline survey was conducted on 70% of the total sample (due to resource constraints) targeting 1500 farmers. The purpose of the first pre-endline is to collect information on actual adoption, constraints to adoption as well as usage of other inputs. By collecting leaf samples several times during the fertilizer application period of the growing season and documenting the color, we can independently assess whether farmers are utilizing the LCC in their decisions to apply nitrogen. Also, by conducting time-use surveys, we can determine behavioral responses to treatment. Due to problems of recall bias, we collect these data in real time. Although we are unable to conduct the pre-endline on the whole sample, these data will still be useful in complementing the final analysis with the endline data.

In June/July 2013, we will conduct the endline survey, collecting data on all inputs, prices and yields (for all indicators) on the whole sample.

Treatment II: Plot-specific Soil Testing

The PST intervention will have a sample size of 1,000 farmers drawn from CDIP's network. Five-hundred farmers will be randomly assigned to the treatment group. Soil testing and sample collection will be conducted together with the baseline survey around July 2013. By December 2013, recommendations based on the soil samples for different types of fertilizers will be distributed to farmers through individual counseling sessions conducted by CDIP. At the end of May/June 2014, the endline will be conducted. Besides collecting detailed data at baseline and endline on the use of all types of fertilizers,

other inputs, prices paid, and yield, we will collect data on family structure, other sources of income, risk preferences and patience.

Power Calculations:

Power calculations are shown in Appendix A. We will be able to detect an impact of 4.25% change in yields for the LCC intervention and of 6.01% change in yields for the PST intervention, which we think are sufficient based on the literature and pilot data for LCCs. Soil testing targets multiple fertilizers instead of just one, and may recommend fertilizers or micronutrients the farmers currently do not use so we expect returns to be higher.

Cost Effectiveness Methodology:

We will use estimates on benefits per farmers from adoption of LCC and ST separately, as calculated through the randomized evaluation detailed above. We will compute benefit per farmer with measures of gains in yield, cost savings in fertilizers if any, and gains in estimated profits. We will also compute cost per farmer for both LCC and ST. Some cost estimations are included below:

- LCCs are cheap as they cost less than $1. The estimated cost for the project to provide an LCC and training to a farmer is $2.25 (Details in Appendix B). An LCC is an asset that can be used for many years, and can be used for two rice crops in a year. If farmers can use it for at least 5 seasons (LCCs should last much longer), then it is a cost of $0.45 per season.
- At its subsidized price of Tk 50 ($0.60) for farmers, soil testing is currently is also quite cheap in Bangladesh. While the price without a subsidy is Tk 500 ($6.06). We present estimates of costs per farmer at both the subsidized ($2.81 per farmer) and non-subsidized rates ($13.71 per farmer) in Appendix B. Soil quality changes slowly over time, so the soil test results will be applicable for at least a few years. Also, recommendations are provided for all crops farmers are interested in growing for all three growing seasons of the year. On average if farmers cultivate crops for 2 seasons a year and use the recommendation for 5 years, then the subsidized cost is $0.281/crop/farmer and the non-subsidized cost is $1.37/crop/ farmer.

We will determine cost-effectiveness of the intervention by calculating the magnitude of impact (as determined by the RCT) from a certain dollar amount spent on each intervention. These can then be analyzed for comparative cost-effectiveness of the various interventions. We can estimate the benefits for the season we evaluate as well as benefits over time. Given how low the cost for these interventions are and given that soil testing recommendation and LCC can be used for multiple years, we expect that the interventions will be cost effective if farmers do have detectable positive returns.

<u>Updated List of Indicators</u>

The following indicators mentioned in the milestones have been or will be collected. For Indicators 1 to 3, questions are included in the baseline survey (specific indicators within each category are also listed). Household profits gained (indicator 4), will be computed based on the other indicators (1 to 3) as farmers. The intervention took place after the baseline survey so data on take-up and use rates will be collected at the endline survey. *Note: All indicators collected at baseline for 1547 farmers as stated in*

the Milestones, but fertilizers used and yields also collected for an additional 500 farmers. The endline survey will collect data on all indicators for the whole sample.

1. Fertilizers Used
    a. Urea
    b. Tri-Superphosphate (TSP)
    c. Muriate of Potash
    d. Others including zinc, manure.
2. Prices
    a. Prices of each fertilizer used by the individual farmers
    b. Market price of rice at time of harvest
3. Other Agricultural Inputs and Yields
    a. Total yield by plots
    b. Insecticides
    c. Other costs including rent of tractors, transportation of inputs
    d. Costs of hiring temporary agricultural labor
4. Household Profits Gained
    a. To be computed using the variables above
5. Take-up and Use Rates of Intervention
    a. Will be determined during pre-endline and endline surveys

Baseline Survey

The English and Bangla versions of the Baseline Survey for Leaf Color Charts are enclosed.

Appendix A: Power Calculations

Assumptions:
$t_{(1-k)} = 0.253$
$t_{\alpha} = 1.96$
N (LCC) = 2000
N (PST) = 1000
The mean and standard deviations of yield and urea (in kilograms per decimal) are from the LCC baseline survey data for the project.

	Yield		**Urea**	
Mean	25.788		1.037	
Standard Deviation	15.587		0.813	
	R2=0.2	R2=0	R2=0.2	R2=0
LCC (N=2000)				
MDE	1.096	1.226	0.0572	0.0639
MDE (%)	4.25%	4.75%	5.51%	6.16%
PST (N=1000)				

MDE	1.551	1.734	0.081	0.090
MDE (%)	6.01%	6.72%	7.80%	8.72%

Appendix B: Costs per Farmer

Leaf Color Charts: Estimated Costs	
Cost of 1000 LCCs ($1/lcc including shipping from the Philippines)	$1000
Fees for importing (bank fees, agent)	$300
Payments to DAE extension workers for training at village level ($5 per session, 90 villages)	$450
Refreshments during training ($0.50 per farmer)	$500
Total budgeted costs by project	$2250
Cost per farmer (1000 farmers)	**$2.25**
Soil Testing: Estimated Costs (Commercial Rate)	
Cost of 1000 soil tests for 500 farmers at commercial rate (2 plots on average)	$6060
Transporting soil samples to the lab	$300
Providing training to CDIP staff	$500
Total budgeted costs by project	$6860
Cost per farmer at non-subsidized rate (500 farmers)	**$13.72**
Soil Testing: Estimated Costs (Subsidized Rate)	
Cost of 1000 soil tests for 500 farmers at subsidized rate (2 plots on average)	$606
Transporting soil samples to the lab	$300
Providing training to CDIP staff	$500
Cost per farmer at subsidized rate (500 farmers)	$1406
Cost per farmer at subsidized rate	**$2.81**

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Milestone 2

Milestone 2

Randomization

Randomization had been completed.

Treatment Group: 1024 farmers

Control Group: 1023 farmers

Updated Project Implementation

No updates in implementation plan compared to what is stated in Milestone 1.

Implementation team includes Center for Development Innovation and Practices (CDIP) staff and Department of Agricultural Extension (DAE) workers. The baseline survey was conducted by CDIP staff as is the ongoing pre-endline survey. However, the endline survey will be conducted by an external and independent team of enumerators who were not involved with the implementation.

A challenge in implementation included very staggered and delayed planting dates of farmers compared to the norm due to (1) cold winter (2) seed shortages and (3) water shortages in some areas. This may lead to a higher than expected rate of attrition (we had less than 5% attrition for the pilots). We will know the full extent of attrition once the pre-endline surveys are completed as leaf color charts were mostly distributed before planting, and farmers may have been unable to grow rice despite intending to do so at the time of receiving the leaf color charts.

Update on Baseline Survey

Baseline survey has been completed. A detailed survey with 1547 farmers, with all indicators mentioned in Milestone 1, have been completed. The sample has been extended by an additional 500 farmers, for whom a shorter version of the baseline survey with indicators on fertilizer use and yields have also be collected. The same endline survey will be conducted for all farmers. Some summary statistics from the baseline survey are included below:

Summary Statistics from Baseline Survey:

(Using Detailed Baseline Data for 1547 Farmers)

	Means (Standard Deviation in Parentheses)
Farmer Characteristics:	
Average Age (years)	45.6
	(12.7)
% of Farmers with no schooling	24.8
	(43.1)
% of Farmers with some primary schooling	10.8
	(31.1)
% of Farmers who completed upto primary schooling	13.1
	(33.7)
% of Farmers with schooling above primary	27.7
	(44.7)
Average number of Plots Cultivated by Farmers	2.4
	(1.2)
Total Plot Area cultivated by Farmer (decimals*):	69.0
	(45.9)
Fertilizer Use and Yields at Baseline:	
% of Farmers Using Urea	99.1
	(9.2)
Average Quantity of Urea Used per Farmer (kg)	46.3
	(52.8)
% of Farmers Using TSP	95.0
	(21.8)
Average Quantity of TSP Used per Farmer (kg)	26.1
	(32.4)
% of Farmers using MoP	87.1
	(33.5)
Average Quantity of MoP Used per Farmer (kg)	15.5
	(19.1)

*Local unit for land area

Questionnaire:

CDIP Agricultural Practices Survey 2012-2013

Baseline Survey

For Surveyor :

P1	Enumerator's name:	
P2.	Enumerator mobile:	
P3.	Survey complete?	1. Yes 2. No
P4	FO Initials:	
P5	MO Initials:	
P6.	Comments:	

Surveyor: Complete ID and farmer's name from checklist before going to the farmer's household.

I1.	CDIP member?	1.Yes>>I2 2. No>>I3
I2.	Member's name:	
I3.	ID Number	
I4.	Farmer's name:	
I5.	Farmer's father's name:	
I6.	Gender:	1.পুরুষ 2. মহিলা
I7.	Village:	
I8.	Neighborhood:	
I9.	Union:	
I10.	Upazila:	
I11.	District:	
I12.	Mobile number:	
I13.	Neighbor's mobile number:	

সবাইকে জিগ্গেস করুন (Ask All Respondents)

A1	Are you currently a farmer?	1. Yes >>A2		2. No >>থামুন	
A2	In the upcoming boro season, do you plan to plant rice in this village?	1. Yes >>A4		2. No >> থামুন	
A3	In the previous boro season, did you grow rice in this village?	1. Yes >>A4		2. No >>থামুন	
A4	What is your age?	_____ বৎসর			
A5	Which grade did you complete in school?	1. Did not go to school		2.Class 1	3.Class 2
		4.Class 3	5.Class 4	6. Class 5	7. Class 6
		8. Class 7	9. Class 8	10. Class 9	11.Class10
		12.SSC/Dakhil		13. Class 11	14.Class12
		15.HSC/Alim		16.University(ongoing/dropout)	
		17.BA/BSc/Hons/Fazil		18.Masters/MBA/Kamil	
		19.Vocational		20.Other- - - - - - - - - - - - -	
A6	Literacy level?	1.Can write a letter 2. Can read, but cannot write a letter 3. Can read sentences 4. Can read but can write name 5. Cannot write name			
A7	In the previous year (last 12 months), on how many plots did you farm? (own plots, sharecropped plots, mortgaged plots, leased plots, etc)				

A6. Household Roster

a. Line number	b. Name	c. Relationship to head of household	d. Gender	e. Age (years)	f Which grade did you complete? (school code)	g. Literacy level code	h. Parti-cipates in farming?	i.Name of occupation, other than farming, if any.	j. Monthly income from other occupation (Taka)
1		Household head	1.Male 2.Female				1.Yes 2. No		
2			1.Male 2.Female				1.Yes 2. No		
3			1.Male 2.Female				1.Yes 2. No		
4			1.Male 2.Female				1.Yes 2. No		
5			1.Male 2.Female				1.Yes 2. No		
6			1.Male 2.Female				1.Yes 2. No		
7			1.Male 2.Female				1.Yes 2. No		
8			1.Male 2.Female				1.Yes 2. No		
9			1.Male 2.Female				1.Yes 2. No		
10			1.Male 2.Female				1.Yes 2. No		
11			1.Male 2.Female				1.Yes 2. No		
A7	Income (average montly) sent from members living outside the household, i.e. remittance etc (Taka)								
A8	Household total monthly income								

Schooling code: 1.Did not go to school; 2.Class 1; 3.Class 2; 4.Class 3; 5.Class 4; 6.Class 5; 7.Class 6; 8.Class 7; 9.Class 8; 10.Class9; 11.Class10; 12.SSC/Dakhil; 13.Class11; 14. Class12; 15.HSC/Alim; 16.University(ongoing/dropout); 17.BA/BSc/Hons/Fazil; 18.Masters/MBA/Kamil; 19.Vocational; 20.Other- - - - - - - -

Literacy level code: 1.Can write a letter; 2. Can read, but cannot write a letter; 3. Can read sentences; 4. Can read but can write name; 5. Cannot write name

Information about all plots on which you farmed last year (own plots, share-cropped, mortgaged, leased plots)							
	A9.Plot name	A10. Plot code	A11. Plot area (decimal)	A12.Ownership status 1. Owned by farmer 2. Mortgaged 3. Rented by year 4. Rented by season 5. Sharecropped 6. Other (specify)	A13.Quality 1. Below average in village 2. Average Above average	A14.Plot type (water level during normal monsoon) 1.High/no water 2.Medium high <3' 3.Medium low 3'-6' 4.Low 6'-9' 5.Very Low 9'+	A15. Comments
1		A					
2		B					
3		C					
4		D					
5		E					

A16. For all plots that are mortgaged (If none, skip to A17)

Sl	1. Plot Code	2. Year in which you started the mortgage (year)	3. Total amout paid (Taka)	4. Was the total amount paid all at once?
1				1. Yes 2. No
2				1. Yes 2. No
3				1. Yes 2. No
4				1. Yes 2. No
5				1. Yes 2. No

A17 For all plots that are rented annually (If none, skip to A18)

sl	1. Plot Code	2. Year in which you started renting (year)	3. When did you pay for current use (dd/mm/yy)	4. Total amout paid this year (Taka)	5. Was the total amount paid all at once?
1					1. Yes 2. No
2					1. Yes 2. No
3					1. Yes 2. No
4					1. Yes 2. No
5					1. Yes 2. No

A18. For all plots that are rented seasonally (If none, skip to A19)

Sl	1. Plot Code	2. Year in which you started renting (year)	3.Season (state month) – dd/mm/yy to dd/mm/yy	4. Total amout paid the season (Taka)	5. Was the total amount paid all at once?
1					1. Yes 2. No
2					1. Yes 2. No
3					1. Yes 2. No
4					1. Yes 2. No

A19. For all plots that are sharecropped (If none, skip to A21)

Are the terms of contract the following: 50% of crop to be paid to landlord, expenses borne by tenant except irrigation (paid by landlord).

1. Yes
2. No

A20. If No, state terms of contract:

Surveyor: First, explain to the farmer what a leaf color chart is, and then complete the question-

The following is a hypothetical situation and I will ask you a series of questions on what you would prefer between two choices. Please answer truthfully about which option you prefer for each choice. There are no right or wrong answers, we want to understand the general valuation of leaf color charts in your area.

A21. Suppose I provide you a choice between getting a leaf color chart or getting a specific amount of money. For each amount of money, please state which option you prefer.

a.	1. 500 Taka	2. 'Leaf color chart'
b.	1. 200 Taka	2. 'Leaf color chart'
c.	1. 100 Taka	2. 'Leaf color chart'
d.	1. 50 Taka	2. 'Leaf color chart'
e.	1. 10 Taka	2. 'Leaf color chart'

SECTION B: Summary of Crops planted by Season

For each plot, specify what crops were planted last year (May 2011 to June 2012) by season

B1. Boro Season: Harvest in March/April 2012

a.Plot Code	b.Crop Name	c.Crop Variety/ Number	d.Date planted/ Transplanted (dd/mm/yy)	e.Date harvested (dd/mm/yy)	f. Date for first time urea was applied (dd/mm/yy)	g. How many times was urea applied?	h. If no crop was grown, state why 1.Under water 2. Everyone leaves it empty 3. Not profitable 4. Other

B2. Kharif II Season: Harvest in December 2011/January 2012

a.Plot Code	b.Crop Name	c.Crop Variety/ Number	d.Date planted/ Transplanted (dd/mm/yy)	e.Date harvested (dd/mm/yy)	f. Yield obtained (Mon)?	g. How much urea was used in total? (kg)	h. How much TSP was used in total? (kg)	i. How much MoP was used in total? (kg)	j. If no crop was grown, state why 1.Under water 2. Everyone leaves it empty 3. Not profitable 4. Other

B3. Kharif II Season: Harvest in August/September 2011

a.Plot Code	b.Crop Name	c.Crop Variety/ Number	d.Date planted/ Transplanted (dd/mm/yy)	e.Date harvested (dd/mm/yy)	f. Yield obtained (Mon)?	g. How much urea was used in total? (kg)	h. How much TSP was used in total? (kg)	i. How much MoP was used in total? (kg)	j. If no crop was grown, state why 1.Under water 2. Everyone leaves it empty 3. Not profitable 4. Other

SECTION C: Inputs & Outputs by Season/Plot/Crop

For enumerator: For each crop in the boro season by each plot ask about inputs and yields.

C. BORO SEASON

	Plot 1 Code: _____	Plot 2 Code: _____	Plot 3 Code: _____	Plot 4 Code: _____	Plot 5 Code: _____
1. Name of Crop					
2. Variety/Number of crop					
3. Area cultivated (decimals)					
4. Irrigated?	1. Yes 2. No	1. Yes 2. No	1. Yes 2. No	1. Yes 2. No	1. Yes 2. No
5. How much seeds did you (kg)					
6. Cost of seeds per kg(Taka)					
FERTILIZERS					
7. Did you use urea?	1. Yes 2. No >> 11 3. DK>> 11	1. Yes 2. No >> 11 3. DK>> 11	1. Yes 2. No >> 11 3. DK>> 11	1. Yes 2. No >> 11 3. DK>> 11	1. Yes 2. No >> 11 3. DK>> 11
8. How much urea did you use? (kg)					
9. Was it deep placement (guti urea) ?	1. Yes, 2. No, 3. DK	1. Yes, 2. No, 3. DK	1. Yes, 2. No, 3. DK	1. Yes, 2. No, 3. DK	1. Yes, 2. No, 3. DK
10. What was the price paid per kg of urea? (Taka)					
11. Did you use TSP?	1. Yes 2. No >> 14 3. DK>> 14	1. Yes 2. No >> 14 3. DK>> 14	1. Yes 2. No >> 14 3. DK>> 14	1. Yes 2. No >> 14 3. DK>> 14	1. Yes 2. No >> 14 3. DK>> 14
12. How much TSP did you use? (kg)					
13. What was the price paid per kg of TSP? (Taka)					
14. Did you use MOP/Potash?	1. Yes 2. No >> 17 3. DK>> 17	1. Yes 2. No >> 17 3. DK>> 17	1. Yes 2. No >> 17 3. DK>> 17	1. Yes 2. No >> 17 3. DK>> 17	1. Yes 2. No >> 20 3. DK>> 20

	Plot 1 Code: _____	Plot 2 Code: _____	Plot 3 Code: _____	Plot 4 Code: _____	Plot 5 Code: _____
15. How much MOP/potash did you use (kg)					
16. What was the price paid per kg of Potash? (Taka)					
17. Did you use zinc sulphate /Dosta?	1. Yes 2. No >> 20 3. DK>> 20	1. Yes 2. No >> 20 3. DK>> 20	1. Yes 2. No >> 20 3. DK>> 20	1. Yes 2. No >> 20 3. DK>> 20	1. Yes 2. No >> 20 3. DK>> 20
18. How much zinc sulphate/Dosta did you use (kg)					
19. What was the price per kg of dosta/zinc sulphate?					
20. Did you use manure/compost?	1. Yes 2. No >> 24 3. DK>> 24	1. Yes 2. No >> 24 3. DK>> 24	1. Yes 2. No >> 24 3. DK>> 24	1. Yes 2. No >> 24 3. DK>> 24	1. Yes 2. No >> 24 3. DK>> 24
21. If 1 (Yes), how much manure/compost did you use (baskets)					
22. How many kilograms of manure was in each basket? (kg)					
23. What was the price paid per basket of manure? (Tk)					
24. Did you use anything else?	1. Yes 2. No >> 27 3. DK>> 27	1. Yes 2. No >> 27 3. DK>> 27	1. Yes 2. No >> 27 3. DK>> 27	1. Yes 2. No >> 27 3. DK>> 27	1. Yes 2. No >> 27 3. DK>> 27
25. How much _____ did you use (kg)					
26. Price per kg of _____. (Taka)					
OUTPUT					
27. How much crop did you produce/what was the yield (Mon)?					
28. Unit price (per mon) of crop in Taka					
29. How much did your household sell? Write total quantity in Mon					
30. How much did your household consume? Write total quantity in Mon					

	Code: _____	Code: _____	Code: _____	Code: _____	Code: _____
EXPENSES					
31. Tractor/tiller/power tiller rental (Taka)					
32. Irrigation expenses (Tk)					
33. Insecticides (ml)					
34. Insecticides (Tk)					
35. Transport of agri. goods (Tk)					
36. Power & Fuel (Tk)					
37. **Agricultural workers:** a. Labor costs for field preparation and planting (Tk)					
b. Labor costs for weeding (Tk)					
c. Labor costs for harvesting (Tk)					
d. Labor costs for other activities (Tk)					
Time Use					
38. Field preparation & planting a. How many hours did you spend for field preparation and planting?					
b. How many other household members worked?					
c. How many did they spend in total?					
39. Weeding a. How many hours did you spend for weeding?					
b. How many other household members worked?					
c. How many did they spend in total?					
40. Harvesting a. How many hours did you spend during harvest?					
b. How many other household members worked?					
c. How many did they spend in total?					
41. Other activities a. How many hours did you spend for other activities?					
b. How many other household members worked?					
c. How many did they spend in total?					

Section D: Hypothetical Lottery Question 1

D1. Suppose you have won a lottery. Which would you prefer between 1(FO: read option) and 2(FO: read option) for each of these options?

a.	1. 1000 Taka today >> b.	2. 1000 Taka one month later >>f
b.	1. 1000 Taka today >> c	2. 1100 Taka one month later >>f
c.	1. 1000 Taka today >> d	2. 1200 Taka one month later >> f
d.	1. 1000 Taka today >> e	2. 1500 Taka one month later >> f
e.	1. 1000 Taka today >> f	2. 2000 Taka one month later >> f
f Why? Explain your decision		
g. Which would you prefer between 1 and 2?	1. 1200 Taka today	2. 1000 Taka one month later

D2. Suppose you have won a lottery. Which would you prefer between 1(FO: read option) and 2(FO: read option) for each of these options?

a.	1. 100,000 Taka today >> b.	2. 100,000 Taka one year later >>f
b.	1. 100,000 Taka today >> c	2. 110,000 Taka one year later >>f
c.	1. 100,000 Taka today >> d	2. 120,000 Taka one year later >> f
d.	1. 100,000 Taka today >> e	2. 150,000 Taka one year later >> f
e.	1. 100,000 Taka today >> f	2. 200,000 Taka one year later >> f
f Why? Explain your decision		
g. Which would you prefer between 1 and 2?	1. 120,000 Taka today	2. 100,000 Taka one year later

Section E: Hypothetical Lottery Question 2

E1. Consider the hypothetical set of lotteries below. For enumerator: Please explain the rules of the game. In the game a coin in flipped. If it's heads, then for option A you receive 50 takas, and in option B you also receive 50 takas. For option B, heads receives 45 takas and tails received 95 takas and so on. The lottery option (A,B,C,D,E or F) must be chosen before the coin is flipped and the choice cannot be changed afterwards. [Please explain this is hypothetical, but they should answer the same way in which they would were the game real]. Please select which lottery (one option) the respondent prefers.

Lottery	Shapla (Heads)	Other side (Tails)
A	50	50
B	45	95
C	40	120
D	30	150
E	10	190
F	0	200

E2. **Same game, with different payoffs. Please select one lottery.**

Lottery	Shapla (Heads)	Other side (Tails)
A	50,000	50,000
B	45,000	95,000
C	40,000	120,000
D	30,000	150,000
E	10,000	190,000
F	0	200,000

Section F: Household Characteristics

F1	What is the main source of drinking water for the members of this household?	1. Piped Water/Supply water 2. Shallow tubewell (<500 ft) 3. Deep tubewell(>500 ft) 4. Pond/River 5. Well 6. Other: _____
F2	Was the tube well tested for arsenic?	1. Yes>>F3 2. No>>F4
F3	Was arsenic found?	1. Yes 2.No
F4	Does the household have electricity connection (non-solar)?	1. Yes 2.No
F5	Does the household have solar electricity connection?	1. Yes 2.No
F6	Does the household have a radio?	1. Yes 2.No
F7	Does the household have a television?	1. Yes 2.No
F8	Does the household have a refrigerator?	1. Yes 2.No
F9	Does the household have a bicycle?	1. Yes 2.No
F10	Does the household have a motocycle?	1. Yes 2.No
F11	Does the household have a mobile?	1. Yes>>F12 2.No>>F13
F12	How many mobile sets?	
F13	What is the main floor material for household dwelling?	1. Earth/sand 2.Wood planks 3.Palm/bamboo 4.Polished wood 5.Ceramic tiles 6.Cement/Concrete 7.Other:_____
F14	What is the main wall material?	1.No walls 2.Cane/palm/trunks 3.Dirt 4.Bamboo with mud 5.Tin 6. Bricks (with plaster) 7. Wood planks 8. Bricks (w/o plaster) 9.Other:_____
F15	What is the main roof material?	1.No roof 2.Thatch/palm leaf 3.Bamboo 4.Tin 5.Ceramic tiles 6.Cement 7.Other:_____
F16	How many rooms does the dwelling have?	
F17	How many rooms are used for sleeping?	
F18	Does the household own this dwelling?	1. Yes 2. No
F19	Total land owned by household (agriculture, dwelling, etc)? (decimal)	
F20	What is the main type of toilet facility for this household?	1.Sanitary (flush) 2. Pit latrine (with slab) 3.Pit latrine (without slab) 4.No facility/bush/field 5.Hanging toilet/latrine 6.Other:_____
F21	Do you share a toilet with other households?	1. Yes 2.No

F22	Does the household own a wardrobe/almirah?	1. Yes 2.No
F23	Does the household own a table?	1. Yes 2.No
F24	Does the household own a rickshaw or van?	1. Yes 2.No
F25	What type of stove is used? (circle all that apply)	1. Kerosene stove 2.Gas stove 3.Open fire 4.Open fire or stove with chimney 5.Closed stove with chimney 6.Other:_____
F26	Where is cooking usually done?	1.Room used for sleeping or living 2.Seprate room in same building 3.Separate building used as kitchen 4.Outdoors 5.Other:_____
F27	What is the main type of cooking fuel that is used?	1.Natural gas 2.Kerosene 3.Wood 4.Straw/shrubs/grass 5.Agricultural crop 6.Animal dung 7.Other:_____
F28	Do you use a mosquito net for sleeping?	1. Yes>>F29 2.No>>F30
F29	How many mosquito nets do you have?	
F30	Do you do anything to water to make it safe?	1. Yes>>F31 2.No>>F32
F31	What do you do to make it safe? (circle all that apply)	1. Boil 2.Bleach/chlorine 3. Fitkari 4.Strain through a cloth 5.Use water filter 6.Other:_____
F32	Do you have poultry (chickens or ducks)?	1. Yes>>F35 2.No>>F34
F33	How many chickens ad ducks?	
F34	Do you have cows?	1. Yes>> F37 2.No>> F38
F35	How many cows?	
F36	Do you have goats or sheep?	1. Yes>> F39 2.No>> F40
F37	How many goats and sheep?	
F38	Do have a fish farm?	1. Yes>> F39 2.No>> F40
F39	How many decimals do you have for the fish farm?	
F40	Do you wash your hands with soap before eating?	1. Yes 2.No
F41	Do you wash your hands with soap after using the toilet?	1. Yes 2.No
F42	Do you clean your hands with ash or soil after using the toilet?	1. Yes 2.No
F43	Does anyone in household have a bank account?	1. Yes 2.No

AID-OAA-F-13-00016

President and Fellows of Harvard College

Reducing Imbalanced Fertilizer Use in Bangladesh

Milestone 3

Milestone 3

Leaf Color Chart (LCC) Intervention

The LCC intervention has been completed. Treatment was randomized at the individual level. 1077 farmers were assigned to receive treatment. Each treatment farmer was invited to attend a training session in their village where they received an LCC. The training sessions were organized and overseen by local CDIP staff, and the training sessions were led by an extension worker or officer from the Department of Agriculture Extension. If a treatment farmer was unable to attend the training session, or send someone else from the household who is also involved in the family farm[1], the CDIP staff member visited the household afterwards to give them the LCC and to provide instructions on how to use it. CDIP staff also provided a refresher training to all treatment farmers, a few weeks after the main training, to address any questions farmers had once they started using the LCCs. These conducted more informally in small groups or with farmers individually. One implementation challenge faced was that the government extension workers provided training that was not standardized, despite standardized written instructions provided. For example, the trainers provided different instructions on the way leaf samples should be collected to be checked with the chart. One additional purpose of the refresher training was to provide simple and standardized instructions to reinforce the key instructions of using a leaf color chart.

LCC Endline Survey

The endline survey has been written, finalized and the survey has been completed. It included all the indicators mentioned including fertilizers used, prices, other inputs used, yields, stated use of the LCC. Household profits will be computed from these indicators. Additional questions included questions on household assets, cognition of the respondent, risk preferences, knowledge of LCCs by treatment farmers. The survey was completed around the end of August 2013 and the data are currently being cleaned for analysis.

[1] The farmer surveyed in the baseline was encouraged to attend the training, although in the event that they could not come (usually due to a secondary occupation or because they would be away from the village) then they could send a family member instead.

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Milestone 4

Draft of Scaling and Dissemination Strategy

There are several ways in which in the project can potentially be scaled up, once viability is established through our project. Leaf color charts are cheap (costs about $1), can be imported easily from the International Rice Research Institute (IRRI) in the Philippines and so there is scope for distribution to be scaled up through the public and/or private sectors. Preliminary results show high returns to leaf color charts on average. Therefore it indicates that the strategy to distribute the leaf color charts through CDIP, a local microfinance organization was effective. Therefore, we propose to follow a similar strategy for scaling up and distribute through microfinance organizations and non-government organizations similar to the Centre for Development Innovation and Practices CDIP. In Bangladesh, due to the popularity of micro-credit, microfinance organizations have access to extended networks of farmers and agricultural households. Therefore it is likely to be an effective way of scaling up this project to reach large numbers of farmers. To encourage dissemination, we will first provide our results to CDIP to encourage them to scale up the program. CDIP works with over 10,000 households, the majority of which are engaged in agriculture and we will propose recommendations on how to scale up to include all their clients.

To share and discuss the findings of this study we will share the final report and policy brief with Mr. Muhammad Yahiya, Executive Director of CDIP. We will also schedule a dissemination workshop at CDIP to be led by one of this project's lead researchers, Mahnaz Islam, during a next visit to Bangladesh. We will present the findings of the study in that workshop and discuss strategies for scaling up with CDIP and partner organizations working in rural areas in Bangladesh. CDIP staff who were directly involved with the project will be requested to attend so they can share their experiences with the training and distribution of the leaf color charts and provide feedback on any concerns about scaling up using the similar guidelines.

CDIP has already acquired and disseminated 1000 leaf color charts (LCCs) outside our project, and thus have some familiarity with the procurement process. However, we will provide any additional support, if requested, to connect organizations interested in scaling up the innovation with contacts at the International Rice Research Institute (IRRI) at the Philippines, where the LCCs are produced.

In this workshop, we will disseminate the findings to similar organizations to encourage them to adopt similar programs. We will invite NGOs such as Integrated Development Foundation (IDF), Uddipana, Rangpur Dinajpur Rural Services (RDRS), Proshika Foundation and Bangladesh Rural Advancement Committee (BRAC). CDIP has suggested these names as they are organizations with whom they have

good relationships and who are likely to be interested in our project. The majority of households in rural areas are involved in agriculture, so leaf color charts can be made available to micro-credit clients by NGOs or to participants of other programs run by the NGOs, then to other agricultural households in the village through the NGO members' social networks. However, as demand increases, the next step would be for the private sector and not just NGOs to bring in or even produce leaf color charts, as the technology involved is simple, and sell it through local shops or fertilizer dealers.

Endline Survey

The endline survey was completed in August 2013. 1,994 farmers were surveyed. This represents a tracking rate of 97.5% of the households included in the baseline survey. Households that could not be tracked had moved away from the village either permanently or temporarily. Overall, 75.7% of household from the baseline survey were still involved in rice cultivation at the endline survey. Therefore, there was some attrition from rice cultivation, however, the decision to cultivate rice is unlikely to be related to the treatment status of the farmer and farmers would have made decision on whether to cultivate rice before they were invited to the training to receive the leaf color charts. Moreover, randomization checks shows balance across the two samples. Data for all the main variables have been cleaned and analyzed. Tables showing randomization checks and the main results are attached.

Table 1 shows summary statistics and checks for balance across the treatment and control groups at baseline. Columns (1) and (2) show summary statistics for the control and treatment groups. On average, farmers in the control group are 45 years old, have 5.9 years of schooling, cultivate rice on 2.37 plots in the *Boro* season, and have a monthly non-agricultural household income of Tk 10,330 (USD 132). The average plot area is 29 decimals, and 1.01 kilograms of urea are applied per decimal and yield of 26.22 kilograms per decimal are obtained. Column (3) shows estimates from regressions of each baseline variable on a treatment dummy and strata fixed effects. There are no significant differences between the two groups for average age, years of schooling, number of plots farmed, non-agricultural income of the household, total plot area cultivated, urea use, yield, revenue or costs. A joint test reveals that the coefficients are not jointly significant.

Since some of the midline surveys were conducted on a sub-sample and there was also some attrition at endline, we also conduct randomization checks for the midline and endline samples as shown in Table 2.[1] There are no differences at baseline for the midline sample. For the endline sample (farmers remaining in rice cultivation), revenue and costs are marginally lower (significant at 10% level) but the estimates have similar magnitudes as estimates for the baseline sample. The coefficients are not jointly significant. Treatment farmers were invited to the training in January around the time of planting and did not know about their treatment status before then. Farmers make decisions on rice cultivation before planting, as seedlings are grown separately prior to that date so they can be transplanted to the plots at planting. Therefore, decisions on whether to cultivate rice or what varieties to cultivate will not be related to treatment.

[1]Locations for the midline surveys were selected randomly after excluding some areas with expected CDIP staff shortages in that time period.

Table 3 shows the ITT effects of gaining an LCC through the intervention on urea used and yields attained by farmers. Columns (1) and (4), shows the treatment effects without any controls. Controls for age and years of education of the farmer, non-agricultural family income, total area cultivated by the farmer and the variety of rice cultivated on the plot, are included in the rest of the regressions. Household fixed effects are also included in columns (3) and (6). The unit of observation is a plot and all regressions are clustered at the household level and include strata fixed effects.

On average, urea use declines while yield increases for the treatment group relative to the control due to the intervention, and that these results are robust across the three specifications discussed above. Column (2), shows that having access to leaf color charts result in a decrease in urea use of 0.079 kilograms per decimal (significant at the 5% level). The coefficient is not significantly different without other control variables (Column (1)) or when household fixed effects are included (Column (3)). This is equivalent to an 8% decrease in urea use on average. Average area cultivated by farmers is about 66 decimals, so farmers in the treatment group save about 5.2 kilograms of urea on average, which is a savings of Taka 104 (USD 1.33). Column (5), shows that getting access to LCCs lead to an increase in yields of 1.757 kilograms per decimal (statistically significant at the 5% level), which is an increase of 6.8% from the mean baseline yield. The mean price of rice is Tk 15 per kilogram, so for average plot holding of 66 decimals, there is a gain of Tk 1739 in revenue (USD 22.3). The effect is not precise with household fixed effects.

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Milestone 5

Project Implementation Update

Data from the baseline, midline and endline surveys have been cleaned and analyzed for the key indicators. We are working on completing the cleaning for the rest of the data (collected for seasons other than main season for the intervention that is not part of the main analysis), so that it can be made available. We have funding from the Agricultural Technological Initiative (ATAI) grant to conduct a follow up study to examine whether the treatment effects of gaining access to leaf color charts are sustained two years after the intervention. We have started developing survey instruments for the study. We are also working on developing the baseline questionnaire for the "soil testing" component of this study. We had faced several unavoidable delays in starting the "soil testing" component, largely due to political unrest, illness among the research team, and our need to strictly time the soil testing. However, we have asked for and received a no-cost extension to accommodate the delay. We expect to start the "soil testing" baseline survey in April 2015.

Summary of Key Findings from Leaf Color Chart Intervention

The key findings of the "leaf color charts" component of this project are summarized below. Overall, we find high returns to providing farmers access to a leaf color chart (LCC), which suggest considerable scope for productivity gains through better management of inputs. A leaf color chart helps farmers improve the timing of urea applications, which may be difficult to learn on their own. On average, treatment group farmers reduce urea use by 8% while their yields increase by 7%. Results show that farmers apply urea too early in the season, during a period when it is likely to be wasted, and that farmers at all levels of urea use can save urea without sacrificing yields. Farmers who performed better at baseline have the largest gains from treatment. Cost-effectiveness estimates suggest that each $1 spent on this intervention produces a return of $9 through a combination of savings of urea and higher revenue.

(1) Main Results: Treatment Effects on Urea Use and Yields

Table 1 shows the intent-to-treat effects of gaining an LCC through the intervention on urea used and yields attained by farmers. We estimate the treatment effects using a difference-in-difference estimator. Columns (1) and (4), show the treatment effects without any controls. Controls for age and years of education of the farmer, non-agricultural family income, total area cultivated by the farmer and the variety of rice cultivated on the plot, are included in the rest of the regressions. Household fixed effects are also included in columns (3) and (6). The unit of observation is a plot and all regressions are clustered at the household level and include strata fixed effects. On average, urea use declines while

yield increases for the treatment group relative to the control due to the intervention, and that these results are robust across the three specifications discussed above. Column (2) shows that having access to leaf color charts result in a decrease in urea use of 0.079 kilograms per decimal[1] (significant at the 5% level). The coefficient is not significantly different without other control variables (Column (1)) or when household fixed effects are included (Column (3)). This is equivalent to an 8% decrease in urea use on average. Column (5), shows that getting access to LCCs lead to an increase in yields of 1.757 kilograms per decimal (statistically significant at the 5% level), which is an increase of 6.8% from the mean baseline yield. The effect is not precise with household fixed effects.

(2) Changes in Timing of Urea Applications

In the last round of the midline survey, timed around the end of the urea application period, we collected data at the plot level for all farmers on urea application dates and quantities applied on each date. We use these data to examine differences in the timing of urea applications between the treatment and control groups.

Table 2 shows difference estimates for several outcomes with and without individual and household level controls. The dependent variable in column (1) is a dummy variable that takes on a value of 1 if the first urea application in a plot took place on or after 21 days after planting[2]. Panel B presents the results without controls and shows that farmers in the treatment group are much more likely to have waited until 21 days to start urea application compared to the control group. About 11.9% of farmers in the control group wait 21 days, and this increases by 4 percentage points in the treatment group (significant at the 1% level). The dependent variable in column (2) is a dummy variable that takes on a value of 1 if the last urea application took place after flowering, the time when farmers should stop applying urea. Farmers in the treatment group are much less likely to apply urea at this period (a decline of 0.9 percentage points), although these results come from a very small number of farmers who make this mistake. The mean interval between urea applications overall declines by 0.55 days (significant at 10% level), which is likely due to the delay in start time.

Columns (4), (5) and (6) show estimates for differences in frequency of urea applications between the treatment and control groups. The dependent variable in column (4) is the total number of times urea is applied while this variables is split up into the number of applications at the period of high-returns and low-returns respectively.[3] There is no significant difference in the frequency of urea applications overall, but the coefficient is positive and significant at the 10% level in the high-return period. The coefficient on treatment for the number of applications at the low-return period is negative but not significant. Columns (7), (8) and (9) show treatment effects on average quantity of urea in each application overall,

[1] 1 acre = 100 decimals

[2] The period of high-returns to urea fertilizers are between 21 days after planting until the start of the flowering stage that takes places a month before harvest. Returns to urea before or after that period are considered to be lower.

[3] High-return period is defined as the interval from day 21 after planting until the flowering date, and the low-return period is defined as any time before or after that period.

in the high-return and low-returns periods. The coefficients in columns for urea per application overall and urea per application in the high-return period are negative but not significant. There is a decline in urea per application of 0.03 kilograms per decimal in the low-return period, which is significant at the 1% level. This is a 6% decrease compared to the control group. The results are consistent with or without controls (Panel A).

Overall, these results show strong evidence that treatment farmers, on average, delay the starting date of urea applications to a more productive period and reduce urea use in the low-returns period. There is weaker evidence that suggests that the intervention increases the frequency of urea applications in the high-return period. Overall, the treatment effects are substantial, particularly in savings of urea. The results on changes in timing of urea applications above suggest that the reduction in urea use observed overall comes from a reduction in urea use during the low-returns period. The change in start date is not sufficient to explain an increase in yield, as applying urea before the third week will not harm the crop. However, an increase in yield can be explained if farmers improve timing of urea application within the period of high returns. There is some evidence that the treatment group farmers visit their fields more often (Table 4) and apply urea more frequently in the high-returns period, although the coefficients are small as discussed in the previous section. These results provide suggestive evidence that treatment farmers may learn to improve the timing of urea use and spend more time on fertilizer application to ensure that returns to urea are higher.

(3) Cost-Effectiveness

Table 4 shows a cost-benefit analysis of the intervention and an estimate of the cost-effectiveness. Each LCC costs US $1.3 including shipping from Philippines and indirect fees. The expenses for the intervention included honorariums for DAE trainers, refreshments during training sessions, transportation costs and direct expenses incurred by CDIP workers to arrange the local training sessions and printing expenses for training materials. After including these expenses, the total cost per LCC is approximately $2.60.

To estimate benefits, I use treatment effects on urea and yield to compute back-of-the-envelope estimates of urea saved and yield gained for the mean farmer. On average farmers, cultivate rice on 66 decimals of land. Using the official price of urea and the average reported price of rice at the endline survey, I estimate that farmers save $1.34 on average from reducing urea use. This amount is larger than the cost of one LCC. I also estimate that the average farmer gains $22.34 additional returns from higher yields. Combining both, the total benefit is $23.68. Overall, the cost-effectiveness of the intervention is 9.10, i.e. every $1 spent on the intervention generated a return of $9.10. The cost-effectiveness is much higher when we consider the fact that the costs are a one-time expense, however, the LCC is durable and can be used by the farmer for many years. A range of cost-effectiveness estimates will be provided in reports based on different assumptions, however, if we assume that returns were zero and that the only treatment effect came from savings in urea of $1.34, even in that extreme scenario the program is cost-effective if the LCC is used in two seasons.

<u>Dissemination Plan</u>

Findings of the study have been presented at Harvard University Development Economics seminar on November 11, 2014 and at the North Eastern Universities Development Consortium (NEUDC) conference on November 2, 2014. We will present the paper to academic audiences in the US through additional seminars next year.

The findings of the study will be provided to our local partner, the Center for Development Innovation and Practices (CDIP) once we finish writing the non-technical report as well as a policy brief. We will also distribute the policy brief and report to organizations similar to CDIP in Bangladesh, starting with organizations that CDIP works with directly but also contact other organizations with similar scope at a workshop aimed at both disseminating the research findings and building the capacity to scale the intervention.

"Reducing Imbalanced Fertilizer Use in Bangladesh"

Award Number: AID-OAA-F-13-00016

Endline Report

February 6, 2015

Executive Summary

A development challenge faced in agriculture around the world is to increase food production in a sustainable manner, a manner that prevents decline in soil quality and reduces mismanagement of plant nutrients. Overuse of chemical fertilizers results in environmental pollution mainly through run-off of chemicals into water bodies. On the other hand, underuse of chemical fertilizers mines nutrients from the soil and contributes to soil fertility degradation, threatening the long-run sustainability of farms[1]. Evidence suggests that farmers fail to achieve balanced fertilization, probably due to a combination of market failures and externalities.

Leaf color charts (LCCs) are small plastic strips displaying an array of potential leaf colors for a particular crop[2]. If farmers compare their leaves against the LCC, they can assess the need for adding nitrogen-based fertilizer. While several studies by agricultural researchers have shown the benefits of LCCs, rational or behavioral constraints to correct usage and take-up may limit the effectiveness of LCCs. The primary objective of the project was to evaluate LCCs, currently available in a limited capacity in Bangladesh, to understand how successful they are in improving efficiency of fertilizer use when farmers are provided access. Secondly, as the intervention was conducted through an NGO, the study suggests that the social networks of NGOs can be utilized successfully in promoting adoption. LCCs are being made available to farmers in many other developing countries, so certain lessons learned may be broadly applicable to and useful in other places.

Funded by the US Agency for International Development's Development Innovation Ventures unit (USAID DIV), the Agricultural Technology Adoption Initiative (ATAI), and the South Asia Initiative at Harvard University, research was conducted in coordination with the Center for Development Innovation and Practices (CDIP) in Bangladesh and Evidence for Policy Design (EPoD) at the Center for International Development at the Harvard Kennedy School. The Department of Agricultural Extension (DAE) in Bangladesh provided training for CDIP field staff and farmers in the study.

The project implemented a randomized control trial with 2,043 farmers across eight districts in Bangladesh. Farmers in the treatment group received an LCC and basic training while farmers in the control group did not. We collected data on urea use and yields before and after the intervention and measure changes in both due to treatment.

We find that the treatment group farmers reduced urea use by 8% while yields increased by 7% on average compared to baseline levels, suggesting there is significant scope to use LCCs to improve urea management. Results show that farmers apply urea too early in the season, during a period when it is

[1] *Gruhn, P., Goletti, F., Yudelman, M.* (2000):Integrated nutrient management, soil fertility, and sustainable agriculture: current issues and future challenges. Food, Agriculture, and the Environment Discussion Paper 32, International Food Policy Research Institute, Washington, D.C.

[2] The leaf color charts used in this study were obtained from the International Rice Research Institute in the Philippines.

likely to be wasted, and that farmers at all levels of urea use can save urea without sacrificing yields. Farmers who performed better at baseline have the largest gains from treatment. Cost-effectiveness estimates suggest that each $1 spent on this intervention produces a return of $9 through a combination of savings of urea and higher revenue.

We encourage multilateral organizations to scale-up LCC usage through support to social entrepreneurs, governments, and non-governmental organizations, utilizing the networks of local organizations. As the study served as a pilot for LCC dissemination, we also share experiential learnings from implementation to encourage particular aspects of training and areas for future research.

On our part, we plan to disseminate our findings in Bangladesh through our partnership with CDIP and a workshop with four local organizations: Integrated Development Foundation (IDF), Uddipana, Rangpur Dinajpur Rural Services (RDRS), Proshika Foundation and Bangladesh Rural Advancement Committee (BRAC). We also plan to disseminate findings through the academic sphere through conferences and presentations, and through the web using EPoD and ATAI websites, and if possible, through international organizations. We are eager to obtain USAID DIV's assistance in reaching a larger network of organizations.

Introduction

As rice is a staple source of food and employment in Bangladesh, considerable efforts are underway to increase agricultural productivity to the benefit of households and domestic suppliers. In a randomized control trial of 2043 households in Bangladesh, we examined the effectiveness of leaf color charts, by providing farmers with plot-level data to identify outcomes in fertilizer usage and annual yields. The report below details the motivation behind the research, the details of the leaf color chart and why it may create changes in behavior, how the research was implemented, our findings, and relevant policy implications.

Background and Motivation

Rice cultivation remains vital for Bangladesh, both as the primary source of nutrition and also as an important source of livelihood. Rice is the staple food of Bangladesh, providing over 70% of direct caloric intake (Alam, et al 2011). The population of 157 million consumes 34.5 million tons of rice for food and seed annually (Hussain 2013). Agriculture accountedfor nearly 30% of Bangladesh's GDP in 2000-01, and rice was grown on 75% of the cultivable land (Biswajit et al 2013).Additionally, 13 million agricultural households are involved in rice cultivation. Agriculture made up 65% of female employment and 40% of male employment in 2010, and is the main source of income for 46.5% of households in Bangladesh. While male participation in agriculture declined by 0.5% in 2010, female participation increased by 7.8% (BBS Report on Labor Force Survey 2010). As social norms often constrain labor market opportunities available to women, rice cultivation and processing offers an important source of home-based work (Raman and Hassan 2011).

Bangladesh is a net importer of rice, experiencing a cultivation shortage of 0.5 to 1.5 million tons per year. According to an International Food Policy Research Institute (IFPRI) study, Bangladesh depended on imports for rice price stabilization from 1994 to 2007, particularly after massive floods in 1998. However, the 2007-2008 world food crisis caused skyrocketing rice prices when India cutoff exports to Bangladesh to protect its own domestic market. Thus, the report points to the importance of securing reliable imports (rice imports are already duty free) and increasing domestic productivity for rice

cultivation(Dorosh 2012). Additionally, the rapidly growing population adds pressure to the industry to continue to improve yields, and self-sufficiency in rice production is a politically important goal.

Rice productivity expanded rapidly during the green revolution, with the spread of high yielding variety seeds, which required higher levels of irrigation and fertilizer usage (Alam et al 2011; Anam 2014; BBS 2012). However, productivity has since waned and the Food and Agriculture Organization of the UN (FAO) has highlighted the importance of fertilizer management in improving rice yield (Sattar 2000).Despite the large gains in productivity and intensive use of inputs, a gap remains between potential yield and actual yield achieved by farmers, known as the yield gap (Alam 2010; Begum et al 2010; Ganesh-Kumar et al 2012). While the national average for boro rice production is 4.35 tons per hectare, the yield of boro rice at experimental stations ranges from 5.37 to 6.88 tons per acre depending on the environment. This yield gap is particularly significant, given that boro rice accounts for nearly half of Bangladesh's rice production (Sattar 2000).

The use of fertilizers in Bangladesh has increased by 400 percent in the last 30 years (Alam et al 2011; Anam 2014; BBS 2012; Kafiluddin et al 2008). **Urea, a source of nitrogen that is needed for plant growth, is used almost universally by rice farmers and it makes up over 65% of total fertilizer used in the country** (Jahiruddin et al 2009; Kafiluddin et al 2008). Traditionally,urea has been heavily subsidized. The price of urea in the country is fixed by the governmentand is generally lower than world prices.

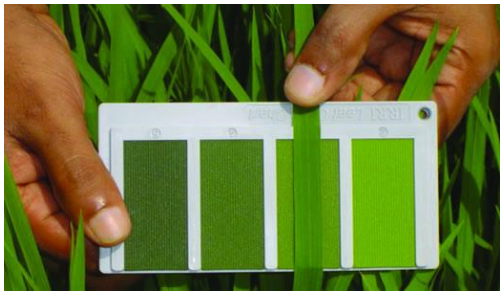
Despite significant experience in using the fertilizer, farmers may fail to use urea efficiently. Farmers must learn about the right quantity of urea to apply, timing for application, and number of applications, as urea is volatile and quickly depleted from the soil if unused (Chowdhury & Kennedy 2004, 2005; Koenig et al 2007). After a urea application, the nitrogen introduced in the soil constantly cycles among its various forms, including ammonia, nitrate and ammonium. Much of the nitrogen can be lost from the conversion of ammoniaand nitrate to nitrogen gas, as well as from leaching downwards and run-off away from the roots. The rate of lossdepends on soil pH, temperature, moisture and other soil properties, and it can vary across plots and seasons.

Rice can best absorb the urea when nitrogen levels are somewhat deficient, which is when the leaves are lighter in color. While underuse of fertilizers results in nutrient-deficient soil and threatens the long-run sustainability of farms,overuse of fertilizers can result in lower current and future yields, in addition to imposing additional costs on farmers. Overuse also has negative externalities for the environment: run-off of urea into water bodiescan cause eutrophication of surface water, the enrichment of water with plant nutrients. This results in oxygen depletion to the detriment of some animal species. There is no evidence, however, of whether this is a significant problem in Bangladesh, where rainfall is high and may counterbalance oxygen depletion(Ongley 1996), but further research is required.Nonetheless, evidence from other countries such as South Africa demonstrates that increased water pollution due to irrigated agriculture increased infant mortality (Walker 2014).

Typically government recommendations on fertilizer usage are based on regional (not plot-specific) soil and climate conditions, and therefore their usefulness is limited. Farmers would greatly benefit from plot-specific information on which fertilizers to use, when to use them, and how much to apply.

The Intervention: Leaf Color Charts

A Leaf Color Chart (LCC) is a high-quality plastic strip (which costs less than USD1) with four panels displaying different shades of green. Farmers are instructed to take ten healthy leaf samples, and assess the average color. By comparing the color of the leaf with the panels, one can determine if nitrogen fertilizer is needed in rice crops.



LCCs were developed jointly by the Philippines Rice Research Institute and the International Rice Research Institute (IRRI). After testing for efficacy through field trials, an LCC with standardized color formulation has been developed and is available from IRRI for distribution to Bangladeshi farmers (Alam et al 2005).

This study conducted a randomized control trial in which the treatment included a free LCC, with instructions on the back, and training on LCC usage. Training encouraged checking leaf color more frequently, applying a smaller amount of urea per application, and possibly applying urea more frequently, depending on the results of LCCs.Farmers were told to start checking leaf colors in their field 21 days after planting to determine if they need to apply urea, which is a later starting date compared to what we observe among farmers. After applying urea on any date, farmers were instructed to check back in 10 days, to determine whether additional urea was needed. If the chart indicated that urea was not needed, farmers were told to check again in 5 days. During each application, they were advised to apply 9 kilograms of urea per 33 decimals of land (0.27 kg/decimal), which is lower than the mean application at baseline. The Bangladesh Rice Research Institute estimated that with an LCC, most farmers would apply urea four times instead of the recommended three times. Farmers were also instructed to stop at flowering, which the baseline data suggests is common practice among farmers.

Theory of Change and Existing Evidence

The literature demonstrates that the quantity of fertilizer applied by farmers differs from official recommendations; one reason may be that official recommendations are not profitable (Duflo et al. 2008). Duflo et al. (2008) studied low fertilizer use in Kenyan maize cultivation. They used a series of field trials to explore whether fertilizer and hybrid seeds were unprofitable to small farms in real-world, non-model conditions. They found a high mean rate of return, similar to those found on model farms. However, they found that the Ministry of Agriculture recommendations were unprofitable to sampled farms (Duflo et al. 2008). Thus, official usage of experimental plots for recommendations may be less useful if individual plot characteristics are important to production.

There is variation in soil quality even within a village, so blanket recommendations on fertilizer usage may not apply to individual farmers. Leaf color charts are an alternative way for farmers to use nitrogen fertilizers more efficiently and accurately. LCC provides a real-time signal on whether more nitrogen fertilizer is needed, and the cardis designed to be easy to use. Therefore, farmers get an immediate, clear signal, improving the efficiency of urea use (Buresh, 2010; Witt et al, 2005). The decision of how much and when to apply fertilizer is typically based on rules of thumb. Instead, with an LCC, before the fertilizer is applied, farmers can compare the color of the paddy leaf to the chart..

Alam et al. (2005) found that nitrogen management through LCC-use improved rice yields and profits compared to usual practices. The literature on LCCs identify increased returns due to either yield improvements or substantial reductions in nitrogen fertilizer waste (Alam et al. 2006; Alam et al.

2005; Balasubramanian et al. 2000; Islam et al. 2007; Singh et al. 2002; Haque et al.s 2003).Though these studies have shown the benefit of LCCs for agricultural production on test plots, which are monitored by agricultural specialists, few studies have rigorously examined the real life usage and impact of LCCs.

It is unclear whether farmers would adopt and correctly use LCCs without incentives or supervision. A series of economic studies have examined constraints to technology adoption. While some farmers may not know that their use of urea is not efficient due to rational reasons, others may not pay attention to to relevance of leaf colors due to behavioral constraints such as limited attention, as found in other related contexts (Hanna 2014). Farmers may be unware of the device or reluctant to use technology unless they have seen it used by their peers, or they may not predict a benefit to higher yield if there are inefficiencies in the input or output markets. Finally, increased fertilizer usage may be costly or have negative externalities for other agricultural inputs (Jack 2011). Understanding constraints to correct usage can shed light on target groups for distribution, partners in implementation, and important aspects of training.

In short, the provision of low-cost LCCs may allow for superior fertilizer usage recommendations by using plot-level data. However, rational and behavior constraints may limit the adoption and usage of the technology.LCCs are relatively cheap and the intervention provides the treatment group with a free card and training. Thus, the difference in take-up by the treatment and control group is a measure of (1) the effectiveness and perceived effectiveness of LCCs and (2) constraints in access and information on LCCs. This project evaluated the average effects of providing household access to LCCs. It also examined variation in technology adoption and utilization over a farmer's risk preferences and cognitive ability. Moreover, this study calculated average take-up regardless of market inefficiencies, as these issues are faced by both the treatment and control groups.

Evaluation Implementation

To explore these questions we implemented a randomized control trial across 8 districts in Bangladesh with over 2000 farmers (see Figure 1). The main goal of the study was to examine whether providing farmers access to LCCs and basic training on how to use the tool would result in an increase in the efficiency of urea use and higher returns for farmers. We implemented the study using a strategy that is scalable. Specifically, we were interested in observing whether farmers take up the LCC once they are given access, and in understanding average returns for such as program. We were also interested in understanding whobenefits the most from LCC usage and whether income, cognition and other individual characteristics determine the returns to LCCs (see Table 8). Prior to starting this study, Mahnaz Islam, a PhD candidate at Harvard University, ran a pilot with 174 farmers and spent time in the field conducting interviews and focus groups with farmers and partner organizations to finalize the design.

Partners

Our implementing partner, the Center for Development Innovation and Practices (CDIP), operateswith 70 branches in 13 districts in Bangladesh. It is primarily a microfinance lender and its 100,000 clients are mostly smallholder farmers. CDIP also runs a primary school remedial program, hiringfemale teachers from within the community to tutor children after school. They work primarily in rural areas, and the majority of their clients are from agricultural households. Currently they have 2,325 education centers, all in rural areas. Although they do not work directly in agriculture extension, CDIP has some experience with agricultural interventions: in the past, they have provided agricultural training sessions through extension workers from the Department of Agricultural Extension (DAE). Given their stable and extensive penetration into these rural communities, they were in an excellent position to implement all operational aspects of both interventions.

The project received generous funding from USAID DIV ($99,985,) and ATAI($186,895,) that allowed for a rigorous evaluation of LCCs. Research advice and support were provided by Evidence for Policy Design (EPoD), a network of scholars, practitioners, staff, and students at the Harvard Kennedy School's Center for International Development.

Research grants from the South Asia Initiative and the Joseph Crump Fellowship also provided support primarily towards the baseline survey. The USAIDDIV funding was budgeted for endlineand other core costs. ATAI funding has been used for features such as cognition surveys, and a midline survey on time use. It will also be used for a follow-up survey to measure long term effects of LCC distribution and training.

Most of the midline surveys as well as the endline survey were conducted electronically using smartphones. mPower Social Enterprises Limited, based in Bangladesh, developed the software for the surveys. Pathways Consulting Services of Bangladesh provided support in conducting the endline survey.

Study Locations

The study was implemented in 105 villages under 20 CDIP branches spread across 21 sub-districts in the 8 districts of Brahmanbaria, Chandpur, Comilla, Gazipur, Lakhipur, Munshiganj, Naranganj and Noakhali. A map of Bangladesh identifying the districts is shown in Figure 1. Table A1 presents some summary statistics for the districts. Among the districts, Narayanganj is less agricultural as it is close to the capital, Dhaka, and has a higher concentration of industries. However, the villages from Narayanganj included in this study have a high prevalence of agricultural activity. All locations are rural without the presence of a major market in the village.

Beneficiaries

CDIP selected 20 of their branch offices to participate in the study and we selected approximately 100 farmers from villages covered by each branch. Within each branch, approximately, one-third of the sample was drawn from CDIP micro-finance clients and the remaining two-thirds were drawn from farmers residing in villages with a CDIP school. Further details on sampling are discussed in the Appendix.

Table 1 shows summary statistics and checks for balance across the treatment and control groups at baseline. Columns (1) and (2) show summary statistics for the control and treatment groups. On average, farmers in the control group were 45 years old, had 5.9 years of schooling, cultivated rice on 2.37 plots in the *Boro* season, and had a monthly non-agricultural household income of Tk 10,330 (USD 132). The average plot area was 29 decimals, and 1.01 kilograms of urea were applied per decimal, which produced an average yield of 26.22 kilograms per decimal.

The traditional division of labor in agricultural households in Bangladesh is that men work in the fields while women conduct post-harvest work. However, these roles have been evolving with women becoming involved in different aspects of farming. Although the main analysis will be at the household level, we also collected information about involvement of individual household members in agricultural activities in the field. This allowed the project to analyze whether there was a relationship between our outcomes and the involvement of women in agriculture in the household.

Data and Intervention

We conducted a baseline survey in September-October 2012, for 1440 farmers. We collected data at the plot level on all crops grown in the past year by season. The survey focused on the *Boro* season of 2012, and included information for the season on all prices and all inputs including fertilizers. A short survey was conducted with an additional 603 farmers in December 2012.[3] CDIP staff conducted the baseline surveys in their program locations, after I provided training to CDIP staff.

Treatment farmers were invited to attend a training session in their village in January 2013. The training session was organized by local CDIP staff and led by an extension worker or agriculture officer invited from the Department of Agricultural Extension (DAE). During the session, each farmer received an LCC and instructions on how to use the chart. CDIP staff conducted home visits for farmers who did not attend the training, to provide the LCC and instructions. The training sessions were generally held just before or around the time of planting. CDIP staff also conducted an informal refresher training (individually with farmers or in small groups) a few weeks after the main training (before the time urea is generally applied). Figure A2 in the Appendix shows a timeline for the study.

CDIP staff conducted four short midline surveys electronically on about 67% of the sample.[4]These surveys focused on time use by farmers. A midline survey focusing on the timing of urea applications was conducted on all farmers. An endline survey was conducted for all farmers after harvest from June to August 2013. I implemented the endline survey through an independent survey company (Pathways), that had not been involved in the interventions or previous data collection to reduce the probability of bias. The survey was similar to the long-form baseline survey, and collected detailed plot-level information for all farmers in the study. We were able to track 97.5% of the households and about 75.7% were still involved in rice cultivation.[5]

Randomization &Methodology

We measured urea use and yields before and after the intervention and assigned farmers into a treatment or a control groupthrough a lottery. Farmers in the treatment group received an LCC and basic training on how to use it, while farmers in the control group received no intervention. The experimental design of the study helps to obtain an unbiased estimate of the impact of receiving LCCs on use of urea fertilizers and yields. Random assignment to treatment and control groups ensured that no observed or unobserved differences between the treatment group and control groups (such as prices of alternate fertilizers, externalities, and land market inefficiencies which constrain technology adoption (Jack 2011)), other than getting access to the treatment, could lead to differential changes in urea use or yield. Thus, the design overcame issues with access and local market failures to isolate the take-up and impact of LCCs.

We randomly assigned farmers into either a treatment or a control group, from a list of participants that included basic information about the farmer and the household.[6] To assign the farmers, we stratified the sample by CDIP branch and by type of sub-sample (CDIP microfinance clients and farmers from villages

[3] Due to delays in receiving funding for the project, I could not conduct the longer baseline survey for all farmers, since the intervention had to be completed by January 2013. New farmers were added to the study by including additional CDIP branches and by following the same guidelines in selecting farmers.

[4] Sample size was limited by funding constraints. I selected the locations randomly after excluding some areas with expected staff shortages in that time period.

[5] Overall, 91.3% were still involved in agriculture.

[6]Random assignment was conducted after the baseline survey was completed, but not before all the baseline data had been entered.

with CDIP schools) in the branch, and then randomized at the individual level.[7] Since we randomized at the individual level, each village in the study had both treatment and control group farmers, although the proportion varies. This design increased statistical power compared to the alternative of randomizing at the village level, and as discussed in the section on results, cross-overs do not appear to be a concern in this setting.See Section A1 in the Appendix for the power calculations utilized in this study.

Table 1 shows summary statistics and checks for balance across the treatment and control groups at baseline. Column (3) shows estimates from regressions of each baseline variable on a treatment dummy and strata fixed effects. There are no significant differences between the two groups for average age, years of schooling, number of plots farmed, non-agricultural income of the household, total plot area cultivated, urea use, yield, revenue or costs. A joint test reveals that the coefficients are not jointly significant. Figure A2 in the Appendix illustrates a timeline for the study and a detailed timeline is also provided below.

Timeframe

Details of the Study		
Date	Activity	Details
Sept-Nov 2012	Baseline "Long" Survey	Before Boro rice planting period, collected data on household demographics and income; agricultural activities from the past year, inputs, expenses, yields Total 1440 farmers (50% Treatment; 50% Control)
Dec 2012	Baseline "Short" Survey	Out of concern for statistical power, added 500 participants to the study. As time was limited, a reduced set of questions was asked and plot-level data on urea use and yields in previous season were collected. Total 603 farmers (50% Treatment; 50% Control)
Jan-Feb 2013	LCC Training	Distribution of LCC and training on LCC usage during planting season; organized by local CDIP branch and lead by DAE extension worker
Feb 2013	Refresher training	CDIP staff also conducted a more informal refresher training (individually with farmers or in small groups) a few weeks after the main training (around the time of first urea application)
Feb-April 2013	Midline Surveys	Time use diaries (67% of farmers) 7 day recall of time use (67% of farmers) Urea application dates by plot (all farmers)
June-Aug 2013	Endline Survey	After harvest period, collected data on household demographics and income; agricultural activities from the past year, inputs, expenses, yields
Forthcoming	Follow-up Survey	Purpose: assess medium term impact

[7]The choice of stratification was determined by preferences stated by CDIP to have an equal number of treatment and control group farmers in each branch, and in each type of sample within the branch.

Challenges in Evaluation: *Threats to Data quality & methodological limitations*

A challenge in implementation included very staggered and delayed planting dates for farmers compared to the norm due to (1) a cold winter (2) seed shortages and (3) water shortages in some areas. Refresher trainings were also held by CDIP staff to refresh farmers' memories on the key points. *We have not separated the treatment farmers into two groups where the refresher trainings would be split between CDIP staff and DAE workersas suggested earlier* because of (1) feasibility concerns – in many cases DAE workers and CDIP staff both lived in close proximity to the farmers and farmers went to both for advice without us arranging for help, so it would be difficult to interpret and separate the results; (2) concerns about statistical power in splitting the treatment group and (3) importance of the refresher training in ensuring that the instructions farmers received were standardized.

Take up was lower than what administrative records show, largelybecause primary farmersdid not attend the training in these instances.Qualitative interviews with some of the farmers revealed that the primary farmer was often away from the village or working in an additional occupation during the training, and a family member attended instead as his representative. As CDIP records indicate almost full attendance, however, it appears the representative often failed to effectively explain LCC usage tothe farmer.

Since some of the midline surveys were conducted on a sub-sample and there was also some attrition at endline, we also conduct randomization checks for the midline and endline samples as shown in Table A3.I selected the locations for the midline surveys randomly after excluding some areas with expected staff shortages in that time period. There are no differences at baseline for the midline sample. For the endline sample (farmers who remained in rice cultivation), revenue and costs were marginally lower (significant at 10% level) but the estimates had similar magnitudes to the estimates for the baseline sample. The coefficients were not jointly significant. Treatment farmers were invited to the training in January around the time of planting and did not know about their treatment status before then. Farmers make decisions on rice cultivation before planting, as seedlings are grown separately during initial generation until they are transplanted to the plots at planting. Therefore, decisions on whether to cultivate rice or what varieties to cultivate will not be related to treatment.

In practice, a few members of the control group attended training and received an LCC. The probability of a farmer stating that they received an LCC is 68.4 percentage points higher for the treatment groups farmers compared to the control group farmers. About 75% of the treatment group statedthat they received an LCC. 7.8% of the control group also statedthat they received an LCC, most likely through government extension workers. Although CDIP staff was instructed not to allow additional participants into the training, in a few cases other farmers came. CDIP records and qualitative work show that the control group farmers who have an LCC, usually received it from the DAE representative outside the training or in a few cases if they attended the training. The primary farmer in the household is the person interviewed at the endline survey and only 59% reported attending the DAE training session. Fifty-six percentof the treatment farmers stated they used the LCC compared to 5.5% of the control group farmers.

Findings

Note that details on findings can be found in Islam (2014). As results were similar for regressions with and without controls, we only include regression results that consider controls. However, results of regressions without controls can be found in Islam (2014).

Table 2 shows several estimates for the take-up of leaf color charts, indicating that the treatment group farmers were much more likely to receive the LCC, attend training, use the LCC and show the LCC itself to enumerators. During the endline survey, farmers were asked whether they received an LCC, whether they attended the main training, whether they used the LCC during the season, and they were

also asked to show their LCC. The estimates are similar with or without controls for individual and household characteristics.

Table 3 demonstrates that on average, urea use declined while yield increased for the treatment group relative to the control due to the intervention. Table 4 shows the effects of obtaining an LCC on urea used and yields attained by farmers, and demonstrates that results are robust across two specifications: without individual and household controls and after including controls for individual, household and plot-level variables. The unit of observation is a plot, resulting in an analysis of 8,144 plots, and all regressions are clustered at the household level and include strata fixed effects. Details of the empirical strategy are in Section A2 in the Appendix.

Column (2) shows that having access to leaf color charts results in a decrease in urea use of 0.079 kilograms per decimal (significant at the 5% level). This is equivalent to an 8% decrease in urea use on average compared to mean use at baseline. Average area cultivated by farmers is about 66 decimals, therefore back-of-the-envelope calculations reveal that farmers in the treatment group save about 5.2 kilograms of urea on average, which is a savings of Taka 104 (USD 1.33) over the season. The estimates in Column (1) without household and plot-level controls are similar.

Column (4) shows that getting access to LCCs leads to an increase in yields of 1.757 kilograms per decimal (statistically significant at the 5% level), which is an increase of 6.8% from the mean baseline yield. As the mean price of rice is Tk 15 per kilogram, there is a gain of Tk 1739 in revenue (USD 22.3) for the average plot holding of 66 decimals. The estimates in Column (3) without household and plot-level controls are consistent with the estimates in Column (4). For the remaining tables, only estimates for the specification including the controls are presented since estimates with and without controls are consistent. The results are available in the working paper Islam 2014.

Table 4 demonstrates that revenue was significantly higher for the treatment group. Profits and costs were higher for the treatment group, but the differences were not statistically significant. As discussed in the methodology section, price data of inputs and details on quantities used for non-fertilizer inputs are only available at the baseline for the ``long survey'' sample of farmers. Thus, we estimate two sets of regressions. Columns (1) to (3) of Table 5 show the difference-in-difference estimates for revenue, total cost and profits for farmers for the ``long survey'' sample. The difference between the treatment and control groups at endline are estimated for all farmers in the study and columns (4) to (6) shows the estimates for revenue, costs and profits.

After controlling for individual, household characteristics and rice variety, the “long survey” sample exhibits an increase in revenue of Tk 34.4 per decimal (significant at 5% level), suggesting additional revenue of Tk 2270 for the average plot holding of 66 decimals. Total cost is higher by Tk 16 per decimal and profits are higher by Tk 18 per decimal, but results for both cost and profits are not significant.

Table 5 indicates that the treatment group was more likely to delay the first urea application to a higher-return period of the season and that that they also applied significantly less urea (per application) during the low-return period. Treatment farmers also applied urea significantly more often (with greater frequency) during the high-return period, although this effect was small. The last round of the midline survey collected data at the plot level for all farmers on urea application dates and quantities applied on each date. We used this data to identify changes in behavior by farmers in the timing of urea applications. We also estimated whether farmers spent more time in their fields, as LCCs may have encouraged farmers to check leaf colors more frequently.

Table 5estimates the difference between treatment and control group farmers for urea application patterns from the midline data. The interval between 21 days after planting until flowering is considered a period of higher returns to urea. Although there may be returns to urea application before 21 days, the returns are lower. There are no returns to urea use after flowering. In the training, farmers were instructed to start checking the leaf colors with the LCC to determine whether they should start applying urea.They were also instructed to stop using urea after flowering. Thus, we examinedwhether there is movement by treatment farmers to the period of optimal use, i.e. whether farmers waited until 21 days to start applying urea and whether they stopped urea applications after flowering. The table shows that farmers in the treatment group were significantly more likely to have waited until 21 days to start urea application compared to the control group: about 11.9% of farmers in the control group waited 21 days, and this increased by 4 percentage points in the treatment group. Farmers in the treatment group were significantly less likely to apply urea after flowering, in the low-return period; although these results come from a very small number of farmers who made this mistake.

The Bangladesh Rice Research Institute estimates that with an LCC most farmers will apply urea four times instead of the recommended three applications under traditional practices.We found that there was no significant difference in the frequency of urea applications overall, but the coefficient was positive and significant at the 10% level in the high-return period. The coefficient on treatment for the number of applications at the low-return period was negative but not significant. The coefficients on treatment in urea usage per application were negative but not significant in the high-return period. **In the low-return period, there was a significant decline in urea usage per application of 0.03 kilograms per decimal. This was a 6% decrease compared to the control group.**

Table 6 reveals that farmers in the treatment group visited the field significantly more often. On average, they spent more time on specific activities than the control group. However, the difference in time use was not significant for any one activity. In the second and fourth rounds of the midline surveys, a sub-sample of farmers was asked about time spent on various agricultural activities in the last seven days. The results are shown in Table 6. Since the variables are highly censored at zero, we utilized Tobit estimates of treatment on time use. The dependent variable in Column (1) is the number of days in the last week, the farmer visited his fields. The other dependent variables are total number of minutes spent in the last seven days on fertilizer application, weeding, applying pesticides and other activities in the field. Most of the coefficients were positive but not precise, partly due to insufficient statistical power because these data are from a smaller sample, however, it shows that treatment farmers visited their plots 0.13 times more often (significant at the 10% level).

The results from Tables 5 and 6 provide indirect evidence that the higher yields observed on average were driven by a better ability by farmers to match urea applications with nitrogen needs of the crop in the high-return period. Urea use in the low-return period declined while urea use in the high return period did not increase and yield was overall higher. The results in these two tables also show that farmers were more likely to apply urea more frequently in the high-return period and visit their fields more often, which provides supporting evidence that the treatment farmers may have paid more attention to the correct timing of urea application and improved the timing in the high-return period which led to improved yields.

Figure 2explores non-linearity in treatment effects and shows that urea usage was significantly lower at all levels of the urea usage distribution from baseline. The largest treatment effects on yield came from farmers with the highest yields at baseline. An LCC will encourage farmers who underuse to use more urea and farmers who overuse to use less urea. Thus, we expected non-linear responses. To explore how the distributions of urea use and yield changed with access to LCCs, we estimated quantile regressions for both. The regressions controlled for individual, household and plot characteristics and strata fixed effects and clustered errors at the household level. Figure 2 shows the results of the quantile regressions, and reports coefficients at 0.1 quantile intervals from 0.1 quantile to 0.9 quantile. The figure shows that the full distribution of urea use shifted downwards for the treatment group. We cannot rule out that the coefficients were significantly different from one another. There was no significant change in the distribution of yield. However, the largest increase occurred at the highest end of the distribution. These results suggest that there is potential to save urea without sacrificing yields at all levels of the distribution. It also shows that the largest treatment effects came from farmers with the highest yields at baseline.

Table 7 shows a cost-benefit analysis of the program. The cost of the LCC, training, distribution, and intervention totaled $2.60 per farmer, while the benefits in urea saved and yield gained amounted to $23.60. This produced a cost-effectiveness estimate of 9.10 in one boro rice growing season, for the first dollar spent on LCCs per farmer.Each LCC costs US $1.3 including shipping from Philippines and indirect fees. The expenses for the intervention included honorariums for DAE trainers, refreshments during training sessions, transportation costs and direct expenses incurred by CDIP workers to arrange the local training sessions and printing expenses for training materials. After including these expenses, the total cost per LCC was approximately $2.60.

To estimate benefits, we used treatment effects on urea and yield to compute back-of-the-envelope estimates of urea saved and yield gained for the mean farmer. Average farmers cultivate rice on 66 decimals of land. Using the official price of urea and the average reported price of rice at the endline survey, we estimated that farmers saved $1.34 on average from reducing urea use. This amount is larger than the cost of one LCC. We also estimate that the average farmer gained $22.34 additional returns from higher yields. Combining both, the total benefit is $23.68. Overall, the cost-effectiveness of the intervention was 9.10, i.e. every $1 spent on the intervention generated a return of $9.10. The cost-effectiveness was much higher when we considered the fact that the costs were a one-time expense: the LCC is durable and can be used by the farmer for many years. Moreover, these estimates show returns during the Bororice season, but the LCC can also be used for other rice varieties, such as Aman rice which is grown in a different season. However, one must note that returns may be lower, as average yields are lower in the Aman season than the Boro season. Follow-up surveys will allow analysis of the

longer-term impact of LCCs, the persistence of behavior, and the presence of spillover to other farmers and rice varieties.

We used estimates for treatment effects on yields rather than treatment effects on revenue and profits, since we do not have data on revenue for all farmers, and costs and profits are imprecisely estimated. The cost-effectiveness estimate for one season will be higher ($11.6) if we use the estimated treatment effect on revenue. Profits are positive but not statistically significant, but using the point estimate for profits, the cost-effectiveness estimate over one season is $6.12. If we assume an extreme scenario in which returns were zero andthe only treatment effect came from savings in urea of $1.34 (which was persistent), the program is cost-effective if the LCC was used in two seasons.

It is important to note that the cost-effectiveness calculations do not take into account any benefits to the environment either short-term or long-term. As discussed above, overuse or inefficient use of urea can result in water pollution that can have health costs. Based on the available literature we do not have clear evidence or estimates of the extent of water pollution due to urea fertilizer use, however, if it is non-negative it will increase the cost-effectiveness of LCCs. Moreover, there may be long term negative impact on soil fertility due to imbalanced fertilizer use.

The magnitude of impact from the treatment did not differ with measures of patience, mathematical ability, schooling, or non-agricultural income (see Table 8).

We also examined if treatment effects on yield and urea varied by characteristics of the primary farmer or characteristics of the household. Though we hypothesized that (1) farmers with less patience may be less likely to check their fields regularly, (2) farmers with higher cognitive ability may use the LCC tool more effectively, and (3) low-income farmers may not be able to take-up this tool or react to recommendations of the LCC. A farmer's patience was measured by asking farmers if they would prefer receiving Tk 1000 today or a larger amount one month later. A farmer's cognitive ability was measured by a short mathematical test, a Raven's test, and level of education. Nonagricultural income at baselinewas used as a proxy for a farmer's income level.

The sample sizes were smaller since these measures were collected at endline and the response rate was lower compared to the other modules in the survey. Overall, after including controls, no differences were found in treatment effects on urea or yield for any of these measures suggesting that treatment effects were the same across the distribution of farmers for these characteristics. This suggests that LCCs are easy to use and cost-effective for all income levels. To learn more, see the academic study supporting this report[2].

Table 9 shows that households in the treatment group with female farmers were less likely to use the LCC. There is low participation of women in agriculture in this sample. At the endline survey, data were collected on the participation of household members in agriculture. Only 4.3% of households had a female as the primary farmer in the household. Overall, in 84% of the households, there was no stated participation in agriculture (working in or supervising activities in the field) by any female members.

[8]Based on the data collected we construct variables on whether the primary farmer was female, whether there was any female participation in agriculture in the household, and the fraction of farmers in the household who are female, which we use to investigate any different gender effects on the take-up of LCCs and treatment effects. The results should be interpreted with caution due to the low number of households with female participation.

Table 9 shows that within the treatment group, households with any female farmer are less likely to have stated to use an LCC. Households with a higher fraction of female who participate in agriculture in the fields are also less likely to use an LCC. Table A5 looks at treatment effects by each of these variables. The treatment effect is marginally negative for households with a higher fraction of female farmers. This is due to the facts that yields on average were lower at endline compared to baseline yields and that these households are less likely to use the LCC, therefore facing lower yields. Within the treatment group, households with a higher fraction of females in agriculture who used the chart have positive treatment effects as can be seen in Table A6.

Policy Implications

Results of the randomized control trial clearly suggest that the dissemination of LCCs is a cost-effective tool for encouraging farmers to use plot-level data in decision-making. The use of LCCs had the average effect of reducing urea usage, increasing rice yield, delaying the start date for urea application, and increasing the frequency of urea application during high-return periods.

Thus, we encourage organizations such as USAID to scale-up LCC usage through their affiliations with governmental and non-governmental organizations. Dissemination could also be more effective if it was profitable and propagated by a private entity. Thus, USAID could provide seed funding to a social entrepreneur, and allowthe entrepreneur to take advantage of USAID's network of implementers for LCC promotion. If demand for LCC should increase, private or public actors could engage local shops or fertilizer dealers in sale of LCCs.

Mahnaz Islam, the researcher for this study, plans to present the paper at seminars throughout the US. She also plans to share a policy brief and conduct workshops with the Center for Development Innovation and Practices (CDIP) and affiliated organizations in Bangladesh. Due to excitement over the study, CDIP has already disseminated 1000 LCCs with plans for more. Findings will be publicized on the websites for the Agricultural Technology Adoption Initiative (ATAI) and Evidence for Policy Design (EPoD) at the Center for International Development at the Harvard Kennedy School.

Finally, the study served as a pilot for LCC dissemination. Thus, we developed an understanding of implementation and areas for future research. We must note that these findings are experiential, and not rigorously tested. However, we will share them here in the event that they can be beneficial to interested policy makers,implementers, and researchers.

[8] Since going to the fields is essential for using leaf color charts, we define participation in agriculture as working in the plots or supervising agricultural activities in the plots. Women who only participate in post-harvest activities are not included by this definition.

Engaging Stakeholders

Any LCC dissemination should survey existing stakeholders. While involving the Department of Agriculture Extension (DAE) in Bangladesh improved the credibility of our initial training, involving CDIP improved our data collection and allowed us to not over-tax the DAE. CDIP's network allowed for a geographically and demographically diverse network of households to study. As many CDIP teachers lived in the surveyed villages, follow-up was less costly and more data could be collected. In short, the infrastructure of the existing organization allowed for easy, low-cost adoption of a program. These networks, and the engagement of influential farmers, may improve the awareness and use of agricultural tools.

The government ran a large-scale pilot of disseminating LCCs, which ended around the time this study began. To our knowledge, although the pilot was found to be effective it has not been scaled up and LCCs are not available in the local markets. Sharing the results of this study with interested stakeholders such as NGOs similar to CDIP, in addition to relevant government agencies may help promote interest and encourage larger-scale dissemination. Further investigation is necessary to determine why the government did not scale its LCC pilot, and how the findings of this research could provide useful information to re-launching a government LCC program.

As farmers at all levels of baseline urea use decreased the amount of urea used (see Figure 2), and effects did not differ significantly by time preferences, cognition, and household income (see Table 8), it appears that LCCs should be distributed to all farmers and no targeting is necessary.

Training and Follow-Up

It is technically feasible for LCCs to be disseminated with fertilizer bags or through mobile phones. However, our experience suggests that LCCs will be less effective without training. **Training gave farmers hands-on experience and increased attention on fertilizer usage. Our team also made several adaptations to the training.** First, trainers simplified instructions to engage a wider audience. Instead of asking farmers to calculate averages for 10 leaf samples, trainers asked farms to count the number of leaves that were light or dark according to the chart; if over six leaves were light, the farmer was instructed to apply fertilizer. Finally, after noticing that agriculture extension trainers often encouraged farmers to always reduce fertilizer usage, CDIP trainers were instructed to emphasize that the LCC would direct farmers to use more if they were underusing and use less if they were overusing. It appeared that farmers reacted more favorably, possibly because they felt more empowered to self-regulate. This approach also reduced potential bias in fertilizer usage.

It also appears that farmers required little supervision in LCC usage. As we realized that there was variation in the information provided in the first training, we offered farmers a refresher-training after planting. This provided farmers with more simple information and allowed them to ask questions about an immediately relevant concern. After the refresher training, the study included no direct follow-up on LCC usage until the endline survey. However, our questionnaires did ask farmers about urea usage and application, which may have increased their attention to fertilizer usage in general. As the same questions were asked of both the treatment and control group, the treatment effects are the result of the LCC alone. However, both treatment and control groups may have altered outcomes by paying more attention to fertilizer usage. Thus, minimal engagement on fertilizer usage by implementers may still lead to beneficial to farming outcomes.

Replicability

The environment, practices, and market structure in the study are unique to Bangladesh, so results on urea usage and yield may not be applicable outside of the country. However, analytical methodology, details of the training, and methods of dissemination may be readily applied elsewhere.

Agricultural researchers have found that LCCs have been useful in rice, wheat, and corn/maize cultivation. While LCC effectiveness has been researched in countries ranging from the United States to Iran to India, LCCs have been distributed to countries ranging from Rwanda to China to Nigeria. Several ongoing studies are assessing the applicability of LCCs to other crops. However, no other experimental study, to our knowledge, has considered the impact of LCCs on usage in a real-world environment. Though the results for urea usage and yield are not readily applicable to other countries, a more simple research design may be enough to demonstrate LCC impact.

As our study was conducted in a variety of districts, it is likely that most findings can be applied to the rest of Bangladesh, with significant impact given the size of the rice industry. The Department of Agricultural Extension in Bangladesh has been engaged in efforts to introduce LCCs through agriculture extension workers in a national level pilot project where they distributed 500,000 LCCs to local agricultural extension workers and groups of farmers (DAE 2011).

As discussed in the findings of the research, the cost of the LCC itself, the distribution, and training totaled $2.60 per farmer, while savings from urea and revenues from yield totaled $23.60, resulting in a cost-effectivness ratio. Though we observed that the treatment group visited the field significantly more times, the amount of time used was not significantly higher for the treatment group than the control group. The low cost of this intervention, and the unmeasured additional impact from future year of LCC usage and environmental benefits, makes LCCs a low-cost, easily-replicated tool.

The Need for Future Research

During our detailed research of LCC usage, additional research questions arose. While our researchers have the funding to engage in some research on soil testing and the longer term impacts of LCCs, we suggest that multilateral organizations and governments encourage research on (1) the relative importance of the LCC itself versus training on first urea application date, (2) externalities of LCC usage, (3) information dissemination networks and technology adoption, and (4) the role of additional plot-level data collection for improving agricultural outcomes.

From implementation, it appears that many farmers did not know that they could wait 21 days until urea application. As our treatment included both LCCs and training about waiting 21 days, we are not able to disentangle the two interventions. It may be useful to separate these two sources of information in research, as providing one of them may be more cost-effective.

While we found that the cost-effectiveness ratio of LCCs was 9.10, this analysis only considered costs and benefits from one season of rice cultivation. We do not know the extent to which treatment effects persist or amplify. Thus, long term impacts may be larger due to greater learning and positive externalities or smaller due to unforeseen behaviors and expenses. We have funding from ATAI to analyze the long terms aspects of LCCs and give us some understanding of externalities regarding agricultural inputs. However, analyzing the environmental externalities for urea usage in farming was beyond the scope of this study.

Finally, additional research is required on information networks and the diffusion of technology adoption. Engaging a microfinance institution as a partner appeared to increase the reach and credibility of our study in the eyes of farmers. This may have helped us overcome some behavior constraints to technology adoption, such as the risks of unknown technologies. The social networks of organizations or the engagement of "influential" farmers may assist the spread of development tools, as supported by literature in economics and sociology (Rogers 1962, Conley and Udry 2010, Foster and Rosenzweig 1995). Mushfiq Mobarak's ongoing study will shed light on information diffusion based on the choice of agricultural extension partners.

Conclusion

Overall, the treatment effects of LCCs and training are substantial, particularly in savings of urea. Back of the envelop calculations show large quantities of savings of urea and higher revenue. This implies inefficiencies exist in the way urea is applied by the average farmer. With better information or signals, which farmers obtain with the LCC, they are now able to both save urea and benefit from higher yields.

The results on changes in timing of urea applications suggest that the reduction in overall urea use comes from a reduction in urea used during the low-returns period (the period between planting and 21 days after planting, and the period after flowering). The delay in start date for urea application is not sufficient to explain an increase in yield, as applying urea before the third week will not harm the crop. However, an increase in yield can be explained if farmers improve timing of urea application within the period of high returns (the period between 21 days after planting and the time of flowering). There is some evidence that the treatment group farmers visit their fields more often and apply urea more frequently in the high-returns period, and these results provide suggestive evidence that treatment farmers may learn to improve the timing of urea use and spend more time on fertilizer application to ensure that returns to urea are higher.

Bibliography

Alam, M. J., Van Huylenbroeck, G., Buysse, J., Begum, I. A., & Rahman, S. (2011). Technical efficiency changes at the farm-level: A panel data analysis of rice farms in Bangladesh. African Journal of Business Management, 5(14), 5559-5566.

Alam, M.M., Ladha, J.K., Khan, S.R., Foyjunnessa, Harun-ur-Rashid, Khan, A.H., & Buresh, R.J. (2005). Leaf color chart for managing nitrogen fertilizer in lowland rice in Bangladesh. Agron. J, 97, 949959.

Alam, Shahe, M. Minimization of rice yield gap." The Daily Star 29 Aug. 2010. Web. 9 July 2014. http://archive.thedailystar.net/newDesign/printnews.php?nid=152635

Anam, Tahmina. Bangladesh's Rotten-Mango Crisis." The New York Times 2 July 2014: sec. The Opinion Pages.Web. 9 July 2014. http://www.nytimes.com/2014/07/03/opinion/tahmima-anam-bangladeshs-rotten-mango-crisis.html

Bishwajit, G., Sarker, S., Kpoghomou, M. A., Gao, H., Jun, L., Yin, D., & Ghosh, S. (2013). Self-sufficiency in rice and food security: a South Asian perspective. *Agriculture & Food Security*, *2*(1), 10.

Balasubramanian, V., Morales, A.C., Cruz, R.T., Thingarajan, T.M., Nagarajan, R., Babu, M., Abulrachaman, S., Hai, I.H. (2000). Adoption of chlorophyll meter (SPAD) technology for real-time nitrogen management in rice: a review. International Rice Research Notes, 25 (1), 48.

Bangladesh Bureau of Statistics (BBS). (2010). Report on Labor Force Survey 2010. Retrieved from http://203.112.218.66/WebTestApplication/userfiles/Image/Latest%20Statistics%20Release/LFS%20Report%202010.pdf.

Bangladesh Bureau of Statistics (BBS) (2009). Preliminary Report on the Agricultural Census of Bangladesh 2008. Retrieved from http://www.bbs.gov.bd/dataindex/Pre-report-Agri-census-2008-Final.pdf

Bangladesh Bureau of Statistics (BBS) (2012). Yearbook of Agricultural Statistics of Bangladesh. Bangladesh Bureau of Statistics, Statistics Division, Ministry of Planning, Government of People's Republic of Bangladesh, Dhaka

Begum, M. E. A., & D'Haese, L. (2010). Supply and demand situations for major crops and food items in Bangladesh. Journal of the Bangladesh Agricultural University, 8(1), 91-102.

Buresh, R.J. (2010). Nutrient best management practices for rice, maize, and wheat in Asia. World Congress of Soil Science, 16, Brisbane, Australia

Choudhury, A. T.MA., & Kennedy, I. R. (2005). Nitrogen fertilizer losses from rice soils and control of environmental pollution problems. Communications in Soil Science and Plant Analysis, 36(11-12), 1625-1639.

Conley, T., & Udry, C. (2010). Learning about a New Technology: Pineapple in Ghana. The American Economic Review, 100(1), 35-69.

Department of Agricultural Extension. (2011). Programme Completion Report (PCR) of Popularizing Leaf Color Chart for Saving Urea.

Dorosh, P. A., & Rashid, S. (2012). Bangladesh Rice Trade and Price Stabilization. IFPRI Discussion Paper 1209 Washington, DC: International Food Policy Research

Duflo, E., Kremer, M., & Robinson, J. (2008). How high are rates of return to fertilizer? Evidence from field experiments in Kenya. *The American Economic Review*, 482-488.

Foster, A., & Rosenzweig, R. (1995). Learning by Doing and Learning from Others: Human Capital and Technical Change in Agriculture. Journal of Political Economy, 103(6), 1176-1209.

Ganesh-Kumar, A., Prasad, S. K., & Pullabhotla, H. (2012). Supply and Demand for Cereals in Bangladesh, 20102030. IFPRI Discussion Paper 01186.

Gruhn, P., Goletti, F., Yudelman, M. (2000). Integrated nutrient management, soil fertility, and sustainable agriculture: current issues and future challenges. Food, Agriculture, and the Environment Discussion Paper 32, International Food Policy Research Institute, Washington, D.C.

Hanna, R., Mullainathan, S., & Schwartzstein, J. (2012). Learning through noticing: theory and experimental evidence in farming (No. w18401). National Bureau of Economic Research.

Haque, M. A., Husain, M. M., Jharna, D. E., Uddin, M. N., & Iqbal Hussain, A. S. M. (2003). A comparative study of leaf color chart based and farmer's practice of nitrogen fertilizer application on rice under on-farm conditions of Bangladesh. *Pakistan J Biol Sci*, *6*, 1685-1688.

Hussain, Sayed S. (2013). Bangladesh Grain and Feed Annual. Global Agricultural Information Network Report BG3004. Retrieved from http://gain.fas.usda.gov/Recent%20GAIN%20Publications/Grain %20and%20Feed%20Annual_Dhaka_Bangladesh_3-28-2013.pdf).

International Rice Research Institute. (1997). Bangladesh: Rice is Life. Retrieved from http://www.worldbank.org/html/cgiar/newsletter/june97/9bang.html.

Islam, Z., B. Bagchi, & M. Hossain, (2007). Adoption of leaf color chart for nitrogen use e_ciency in rice: Impact assessment of a farmer-participatory experiment in West Bengal, India. Field Crops Research, 103, 70-75.

Jack, K. (2011). Market inefficiencies and the adoption of agricultural technologies in developing countries. *White paper, Agricultural Technology Adoption Initiative (Abdul Latif Jameel Poverty Action Lab/MIT, Cambridge, MA*.

Jahiruddin, M., Islam, M. R., & Miah, M. M. (2009). Constraints of farmers access to fertilizer for food production. Final Report. National Food Policy Capacity Strengthening Programme. FAO. Dhaka.

Kafiluddin, A., & Islam, M. S. (2008). Fertilizer distribution, subsidy, marketing, promotion and agronomic use efficiency scenario in Bangladesh. International Fertilizer Industry Association (IFA), Melbourne, Australia.

Koenig, R. T., Ellsworth, J. W., Brown, B. D., & Jackson, G. D. (2007). Management of urea fertilizer to minimize volatilization. Montana State University Extension.

Ongly, Edwin (1996). Fertilizers as Water Pollutants. In *Control of Water Pollution From Agriculture (Chapter 3)*. Food and Agriculture Organization. Retrieved from http://www.fao.org/docrep/w2598E/w2598e06.htm

Raman and Hassan 2011 http://www.banglajol.info/index.php/JBAU/article/viewFile/8755/6492

Rogers, E. M., & Cartano, D. G. (1962). Living Research Methods of Measuring Opinion Leadership. *Public Opinion Quarterly*, *26*(3), 435-441.

Sattar, Sheikh A. (2000). Bridging the Rice Yield Gap in Bangladesh. In Minas K. Papademetriou, Frank J. Dent, & Edward M. Herath (Eds.), *Bridging the Rice Yield Gap in the Asia-Pacific Region (Chapter 3)*. Food and Agriculture Organization. Retrieved from http://www.fao.org/docrep/003/x6905e/x6905e07.htm.

Singh, B., Singh, Y., Ladha, J. K., Bronson, K. F., Balasubramanian, V., Singh, J., & Khind, C. S. (2002). Chlorophyll meter–and leaf color chart–based nitrogen management for rice and wheat in Northwestern India. *Agronomy Journal*, *94*(4), 821-829.

Walker, E. (2014). Irrigation Dams, Water and Infant Mortality: Evidence from South Africa. Job Market Paper.

Witt, C., Pasuquin, J.M.C.A., Mutters, R., Buresh, R.J., (2005). New leaf color chart for effective nitrogen management in rice. Better Crops 89, 3639

Tables and Figures

Figure 1: Districts of Bangladesh Covered by Randomize Control Trial

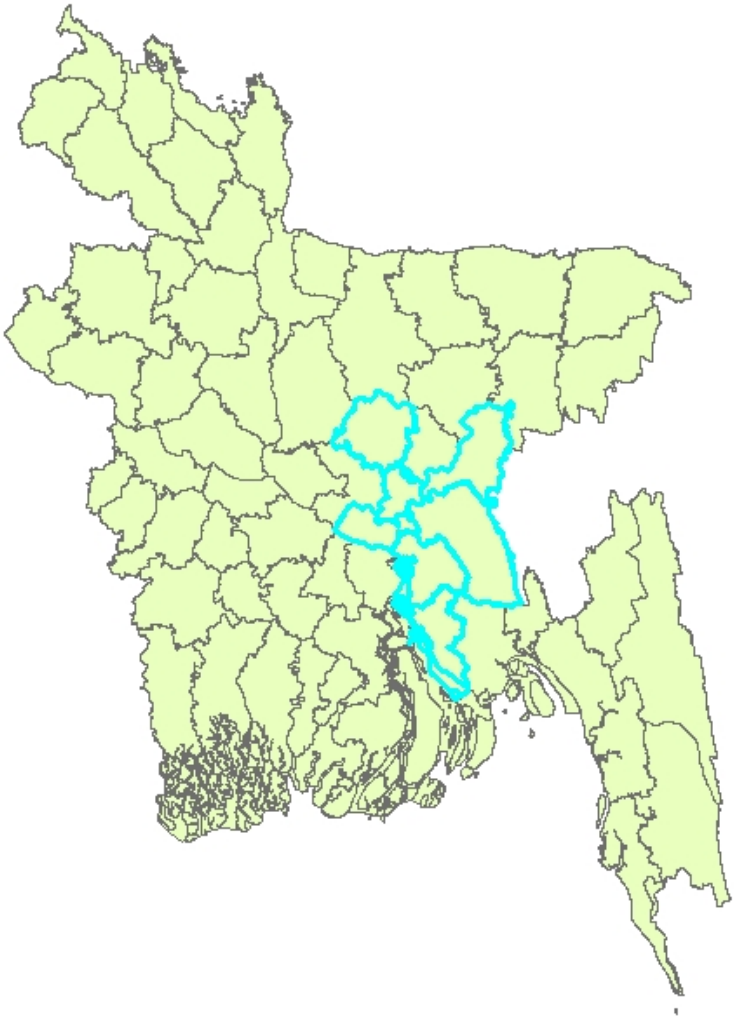
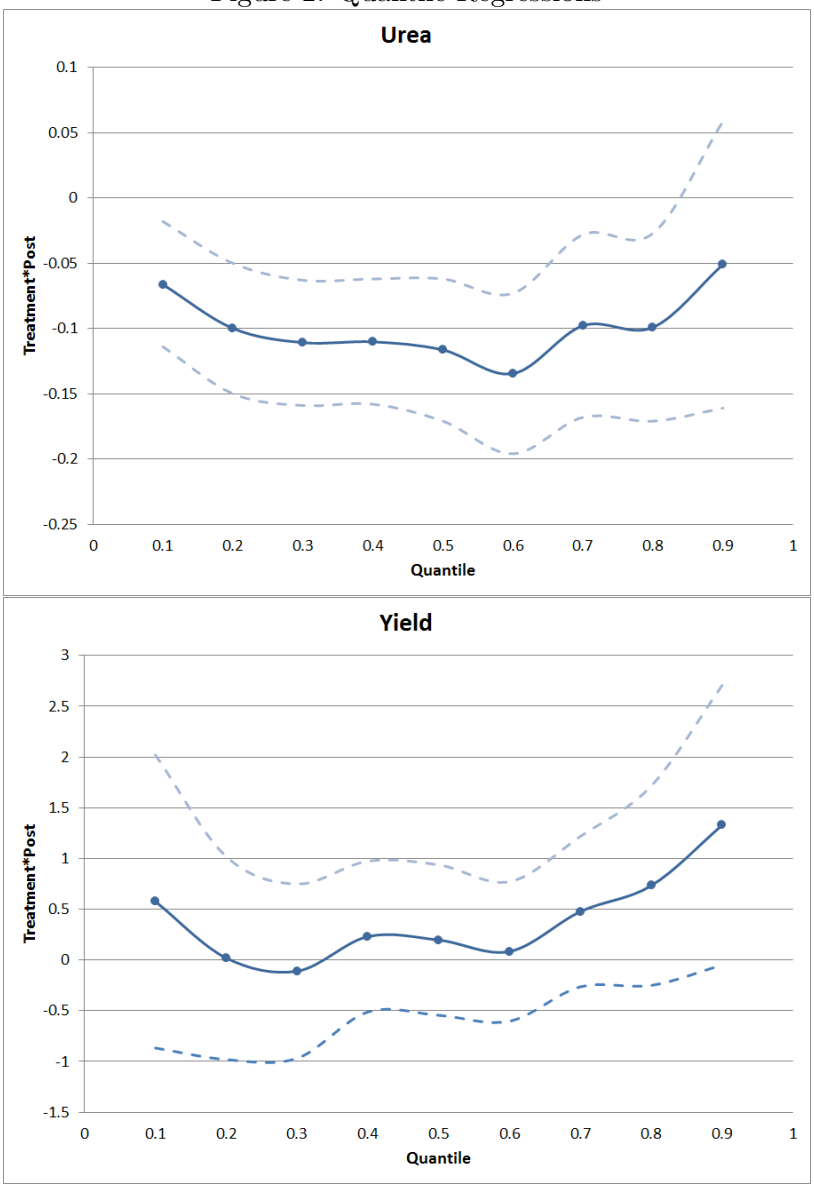


Figure 2: Quantile Regressions



Notes: The figures report estimates from quantile regressions of urea use and yield on $Treatment_h * Post_t$. The regressions also included covariates for $Treatment_h$, $Post_t$, controls for age, schooling, income and total plot area, rice variety and strata fixed effects. Standard errors are clustered at the household level. The quantiles are from 0.1-quantile to 0.9-quantile at 0.1-quantile intervals. 95% confidence intervals are shown. The dotted line shows the estimate of the corresponding OLS coefficient.

Table 1:
Baseline Characteristics

	(1)	(2)	(3)
	Summary Statistics		Randomization Checks
	Control Group	Treatment Group	Treatment
Farmer & Household Characteristics:			
Age (years)	45.02	45.78	0.663
	(12.73)	(12.40)	(0.546)
	[994]	[1001]	[1995]
Schooling (years)	5.86	5.72	-0.136
	(4.38)	(4.28)	(0.189)
	[948]	[970]	[1918]
Number of Plots	2.37	2.36	-0.015
	(1.18)	(1.18)	(0.046)
	[1008]	[1017]	[2025]
Non-agricultural income (Tk)	10329.70	9657.928	-674.164
	(10759.79)	(10392.05)	(455.634)
	[936]	[940]	[1876]
Total Plot Area (decimals)	65.30	67.09	1.215
	(43.42)	(43.62)	(1.763)
	[1008]	[1017]	[2025]
Number of Household Assets	4.28	4.34	0.042
	(2.23)	(2.17)	(0.106)
	[708]	[714]	[1422]
Plot Level Variables):			
Plot Area (decimals)	28.87	30.18	1.125
	(20.72)	(22.97)	(0.740)
	[2252]	[2260]	[4512]
Urea (kg/decimal)	1.01	1.01	-0.001
	(0.69)	(0.62)	(0.025)
	[2253]	[2263]	[4516]
Yield (kg/decimal)	26.22	25.25	-1.093
	(19.71)	(15.81)	(0.764)
	[2253]	[2263]	[4516]
Revenue (kg/decimal)	361.86	342.71	-21.641
	(278.02)	(205.08)	(13.198)
	[1682]	[1702]	[3384]
Total Cost (Tk/decimal)	245.92	233.87	-14.236
	(230.93)	(159.76)	(8.884)
	[1684]	[1704]	[3388]
Profit (Tk/decimal)	115.99	109.03	-7.455
	(292.69)	(209.38)	(12.658)
	[1682]	[1702]	[3384]
Joint Test (chi-squared)			2.51
p-value			(0.1130)

Notes: For columns (1) & (2), standard deviations are shown in parentheses and sample sizes are shown in square brackets. Column (3) reports the coefficients for regressions of each dependent variable on *Treatment* and strata fixed effects. Robust standard errors for regressions with individual/household level variables and standard errors clustered at household level for regressions with plot level variables are shown in parentheses. Sample sizes are shown in square brackets. The joint test used a chi-squared test to estimate whether the coefficients are jointly significant.
*** p<0.01, ** p<0.05, * p<0.1.

Table 2:
Take-up & Stated use of LCCs

	(1) Received LCC	(2) Attended Training	(3) Used LCC	(4) Could Show LCC
Treatment	0.682***	0.529***	0.489***	0.579***
	(0.018)	(0.020)	(0.020)	(0.019)
Age (years)	0.000	0.001	0.001	-0.000
	(0.001)	(0.001)	(0.001)	(0.001)
Schooling (years)	-0.006***	-0.006**	-0.005**	-0.004*
	(0.002)	(0.003)	(0.003)	(0.003)
Total plot area	0.000	0.000	0.001**	0.000*
	(0.000)	(0.000)	(0.000)	(0.000)
Income (Non-agri)	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Mean of Control Group	0.0788	0.0604	0.0604	0.0723
Observations	1,526	1,526	1,526	1,526

Notes: The dependent variables are dummy variables that respectively take on values of 1 if farmers state receiving a leaf color chart, attending the training, using the chart and if they can show the chart to the enumerator, and 0 otherwise. Robust standard errors are shown in parentheses. All regressions include strata fixed effects
*** p<0.01, ** p<0.05, * p<0.1.

Table 3:
Full Sample: Treatment Effects on Urea & Yield

Urea & Yield in Kilograms per Decimal

	Urea		Yield	
	(1)	(2)	(3)	(4)
Treatment*Post	-0.074**	-0.079**	1.823**	1.757**
	(0.035)	(0.034)	(0.867)	(0.849)
Treatment	-0.001	0.001	-1.103	-1.035
	(0.025)	(0.025)	(0.772)	(0.759)
Post	0.059**	0.084***	-3.416***	-3.238***
	(0.026)	(0.026)	(0.677)	(0.697)
Controls	No	Yes	No	Yes
Mean at Baseline	1.011	1.011	25.73	25.73
Observations	8,144	8,144	8,144	8,144

Notes: This table shows treatment effects on urea use and yield. Control variables include age, schooling, total plot area cultivated, income, rice variety.
Standard errors clustered at the household level are shown in parentheses. All regressions include strata fixed effects.
100 decimals = 1 acre
*** p<0.01, ** p<0.05, * p<0.1.

Table 4:
Revenue, Cost & Profits

All dependent variables in Takas per decimal

	Long Survey Sample			Full Sample		
	(1)	(2)	(3)	(4)	(5)	(6)
	Revenue	Total Cost	Profit	Revenue	Total Cost	Profit
Treatment*Post	34.412**	15.998	18.414			
	(15.454)	(16.873)	(20.001)			
Treatment	-19.615	-11.429	-8.186	10.035**	5.213	4.950
	(13.164)	(8.982)	(12.894)	(4.626)	(10.672)	(11.636)
Post	-28.206**	42.406***	-70.612***			
	(13.348)	(11.193)	(14.531)			
Means (Baseline/control group)	352.3	240.0	112.3	344.0	289.1	54.92
Observations	6,102	6,102	6,102	3,632	3,632	3,632

Notes: Regression includes controls age, schooling, total plot area cultivated, non-agricultural income and rice variety.
Standard errors clustered at the household level are shown in parentheses. All regressions include strata fixed effects.
100 decimals = 1 acre
*** p<0.01, ** p<0.05, * p<0.1.

Table 5:
Changes in Behavior in Using Urea

	Overall Change			Change in Frequency			Change in Quantity		
	(1) Applied First Urea After 21 days	(2) Applied Urea After Flowering	(3) Mean Interval between Applications (days)	(4) # Times Urea Applied	(5) # Times Urea Applied High-return Period	(6) # Times Urea Applied Low-return Period	(7) Urea per application (kg/decimal)	(8) Urea/app. High-return Period (kg/decimal)	(9) Urea/app. Low-Return Period (kg/decimal)
Treatment	0.040***	-0.009***	-0.551*	0.020	0.047*	-0.027	-0.011	-0.007	-0.030***
	(0.014)	(0.003)	(0.295)	(0.028)	(0.029)	(0.026)	(0.009)	(0.015)	(0.012)
Control Group Mean	0.119	0.0132	20.75	2.419	1.250	1.169	0.508	0.423	0.496
Observations	3,541	3,541	3,107	3,541	3,541	3,541	3,541	3,541	3,541

Notes: This table shows changes in urea application patterns overall, as well as within periods of high-returns and low-returns to urea. The high-return period is defined as 21 days after planting until 60 days after planting (expected time of flowering). The low return period is defined as any application within 21 days after planting or after 60 days of planting. Control variables include age, schooling, income, total plot area and baseline urea.
Standard errors, shown in parentheses, are clustered at household level. All regressions include strata fixed effects.
*** p<0.01, ** p<0.05, * p<0.1.

Table 6:
Tobit Estimates of Time Use by Farmers (7 day recall)

	(1) #Times in Field	(2) Fertilizer Application (minutes)	(3) Weeding (minutes)	(4) Pesticide Application (minutes)	(5) Other Activities (minutes)
Treatment	0.134*	7.949	10.047	9.245	2.200
	(0.079)	(10.186)	(18.639)	(14.903)	(9.130)
Control Group Mean	2.700	50.31	57.35	4.471	38.85
Observations	2,066	2,066	2,066	2,066	2,066

Notes: This table shows Tobit estimates of treatment effects on on time use by farmers using data from Rounds 2 and 4 of the midline surveys. The dependent variables in Columns (2) to (5) are total time spent in minutes in the last seven days on different agricultural activities. Control variables include age, schooling, total plot area cultivated and non-agricultural income.
Standard errors clustered at the household level are shown in parentheses. All regressions control for survey round and strata FE.
*** p<0.01, ** p<0.05, * p<0.1.

Table 7:
Cost-Benefit Analysis of Program

Costs:	
Cost of 1000 LCCs[1]	$1,100
Costs of Training & Distribution[2]	$1,500
Total cost of intervention	$2,600
Direct Cost per LCC	$1.10
Total Cost per LCC	$2.60
Benefits:	
Savings in Urea for Mean Farmer	$1.34
(0.079 kg/dec. urea saved *66 decimals of land*Tk 20/kg of urea*$0.012/Tk)	
Increase in Returns for Mean Farmer	$22.34
(1.76 kg/dec yield gain.*66 decimals of land*Tk 15/kg of rice*$0.012/Tk)	
Total Benefit per farmer per season	$23.68
Cost-Effectiveness (Benefits/Costs):	9.10

Note: [1]Includes cost of importing 1000 LCC from the Philippines, including shipping ($1000) and bank and agent fees ($100).
[2]Includes honorarium for DAE trainers, refreshments during training, transport of LCCs, additional training costs for CDIP staff and printing.
I use the DD estimates of treatment effects of urea and yield from Table 3.
The average land area cultivated for rice is 66 decimals, price of urea is Tk 20/kg (official price) and mean reported price of rice is Tk 15/kg.
I use an exchange rate of 1 USD = Tk 78 to convert returns to dollars.

Table 8:
Treatment Effects by Time Preferences, Cognition and Baseline Household Income

Urea & Yield in Kilograms per Decimal

	(1) Urea	(2) Yield	(3) Urea	(4) Yield	(5) Urea	(6) Yield	(7) Urea	(8) Yield	(9) Urea	(10) Yield
Time Preference (Low Stakes)*Treatment*Post	0.026	0.706								
	(0.021)	(0.443)								
Time Preference (High Stakes)*Treatment*Post			-0.015	0.077						
			(0.021)	(0.494)						
Math Score*Treatment*Post					-0.010	-0.263				
					(0.030)	(0.799)				
Ravens Score*Treatment*Post							0.051	0.654		
							(0.036)	(1.086)		
Non-agricultural Income*Treatment*Post									0.002	-0.039
									(0.003)	(0.074)
Mean at Baseline	1.011	25.73	1.011	25.73	1.011	25.73	1.011	25.73	1.011	25.73
Observations	7,080	7,080	7,080	7,080	7,080	7,080	7,080	7,080	7,468	7,468

Notes: Controls include age, schooling, total plot area cultivated and rice variety. Regressions in columns (1)-(6) also control for non-agricultural income. Coefficients not shown for the variables Treatment, Post, Treatment*Post, the specific characteristic variable in each column as well as the interactions of the variable with the Treatment and Post variables. Standard errors clustered at the household level are shown in parentheses. All regressions include strata fixed effects.
Time preference variables range from 0 (most patient) to 6 (least patient)
Math scores and Raven's score measure the number of correct answers and range from 0 to 7 and 0 to 8 respectively.
Non-agricultural income is the reported month non-agricultural income in 1000 Takas per month as reported at the baseline survey.
100 decimals = 1 acre
*** p<0.01, ** p<0.05, * p<0.1.

Table 9:
Take-up of LCCs by Female Participation in Agriculture in Treated Households

	(1) Received LCC	(2) Attended Training	(3) Used LCC	(4) Could Show LCC
Panel A:				
Primary Farmer Female	0.012	-0.086	-0.142	0.020
	(0.086)	(0.097)	(0.095)	(0.088)
Mean for households with male primary farmers	0.76	0.59	0.56	0.64
Observations	759	759	759	759
Panel B:				
Any Female Farmer	-0.068	-0.062	-0.095*	-0.042
	(0.051)	(0.055)	(0.054)	(0.053)
Mean for households with no female farmers	0.77	0.59	0.56	0.65
Observations	765	765	765	765
Panel C:				
Fraction of Female Farmers	-0.099	-0.140	-0.166*	-0.050
	(0.080)	(0.086)	(0.085)	(0.082)
Mean for households with no female farmers	0.77	0.59	0.56	0.66
Observations	761	761	761	761

Notes: The dependent variables are dummy variables that respectively take on values of 1 if farmers state receiving a leaf color chart, attending the training, using the chart and if they can show the chart to the enumerator, and 0 otherwise. Robust standard errors are shown in parentheses. All regressions includes controls for age and schooling of primary farmer, total plot area cultivated, non-agricultural household income and strata fixed effects
*** p<0.01, ** p<0.05, * p<0.1.

Appendix

A1. Power calculations:

Assumptions: $t_{(1-k)} = 0.253$; $t_{\alpha} = 1.96$; N (LCC) = 2000

The mean and standard deviations of yield and urea (in kilograms per decimal) are from the LCC baseline survey data for the project. We will be able to detect an impact of 4.25% change in yields for the LCC intervention and of 6.01% change in yields for the PST intervention, which we think are sufficient based on the literature and pilot data for LCCs.

	Yield		**Urea**	
Mean	25.788		1.037	
Standard Deviation	15.587		0.813	
	R2=0.2	R2=0	R2=0.2	R2=0
LCC (N=2000)				
MDE	1.096	1.226	0.0572	0.0639
MDE (%)	4.25%	4.75%	5.51%	6.16%

A2. Sample Selection

CDIP selected 20 of their branch offices to participate in the study and we selected approximately 100 farmers from villages covered by each branch. Within each branch, approximately, one-third of the sample was drawn from CDIP micro-finance clients and the remaining two-thirds were drawn from farmers residing in villages with a CDIP school.[1] The second group of farmers may or may not be directly connected with CDIP.[2] For the first sub-sample, we randomly selected four micro-finance groups from the list provided by CDIP for each branch, and then randomly selected 10 rice farmers from each group. For the second sub-sample, two villages were selected by CDIP in each branch. We conducted a census of farmers in those villages and then randomly selected 30 rice farmers from each village.[3]To be included in the study, the farmer had to meet the following criterion: (1) agree to participate, (2) have cultivated rice in the 2012 *Boro* season, (3) at the time of the survey expect to cultivate rice in 2013 and (4) cultivate no greater than five plots in the 2012 season. We did not conduct a census for the short survey, but farmers were selected by CDIP based on the criterion above. In all cases, the primary farmer in the household was interviewed, and multiple farmers were never selected from the same household. At the time of the survey, if the enumerator realized that we had earlier received the name of the household head instead of the main agricultural decision maker, then he or she interviewed the primary farmer instead. Therefore, the household can be considered to be the unit of analysis.

[1]The total number of farmers and proportion of CDIP clients in the sample varied in some branches due to logistical constraints or in branches with fewer rice producing areas.

[2]Sample drawn this way for logistical purposes, based on preferences stated by CDIP.

[3]The number of villages or micro-credit groups in each branch sometimes varied based on availability of CDIP staff.

A3. Empirical Strategy

We estimate the intent-to-treat effect of getting access to an LCC. A simple difference specification is estimated (Equation 1) for outcomes for which data are not available at baseline. This specification is used to estimate changes in urea application patterns using data in the midline surveys.

$$y_{ph} = \alpha_0 + \alpha_1 \text{Treatment}_h + \rho X_h + \delta Z_{ph} + \gamma_s + \varepsilon_{ph} \qquad (1)$$

y_{ph} is a urea application pattern in plot *p* by household *h*. Treatment_h takes a value of *1* for households in the treatment group and is *0* otherwise and $X_h$includes controls for household and individual specific characteristics including age and years of education completed by the farmer interviewed (primary farmer in household), total plot area cultivated by household, non-agricultural household income. Z_{ph}includes plot level variables such as variety of rice. γ_s controls for strata fixed effects and $\varepsilon_{ph}$is the error term. Standard errors are clustered at the household level. The coefficient $\alpha_1$estimates the difference between the treatment and control groups during the season.

For outcomes such as urea use and yields, for which data are available at baseline and endline, I estimate treatment effects using a difference-in-difference estimator (Equation 2).

$$y_{ph} = \alpha_0 + \alpha_1 \text{Treatment}_h + \rho X_h + \delta Z_{ph} + \gamma_s + \varepsilon_{ph}$$

$$y_{pht} = \beta_0 + \beta_1 \text{Treatment}_h + \beta_2 \text{Post}_t + \beta_3 \text{Treatment}_h * \text{Post}_t + \rho X_{ht} + \delta Z_{pht} + \gamma_s + \varepsilon_{pht} \qquad (2)$$

y_{pht} the outcome in plot *p* for household *h*at time*t*. $Post_t$is*1* for the observations from the endline survey and *0* if it is from the baseline. Other variables are the same as above. Standard errors are clustered at the household level. Since assignment to receive an LCC was random, $\beta_3$estimates the causal effect of gaining access to an LCC.

Appendix

Figure A1:
Timeline for Rice Cultivation during *Boro* Season

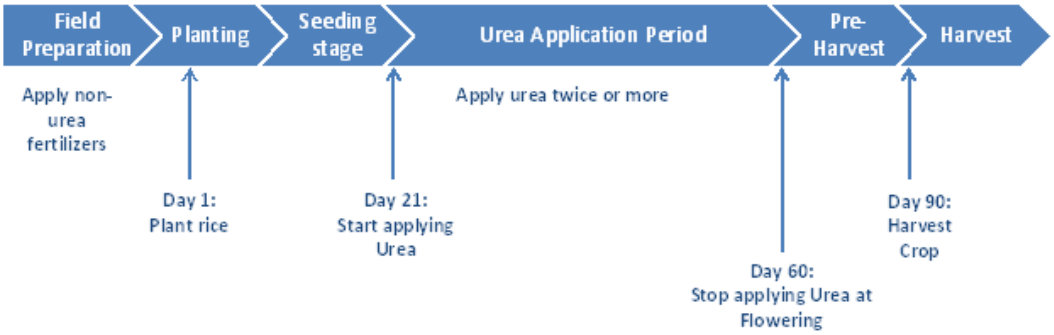


Figure A2:
Timeline of Study

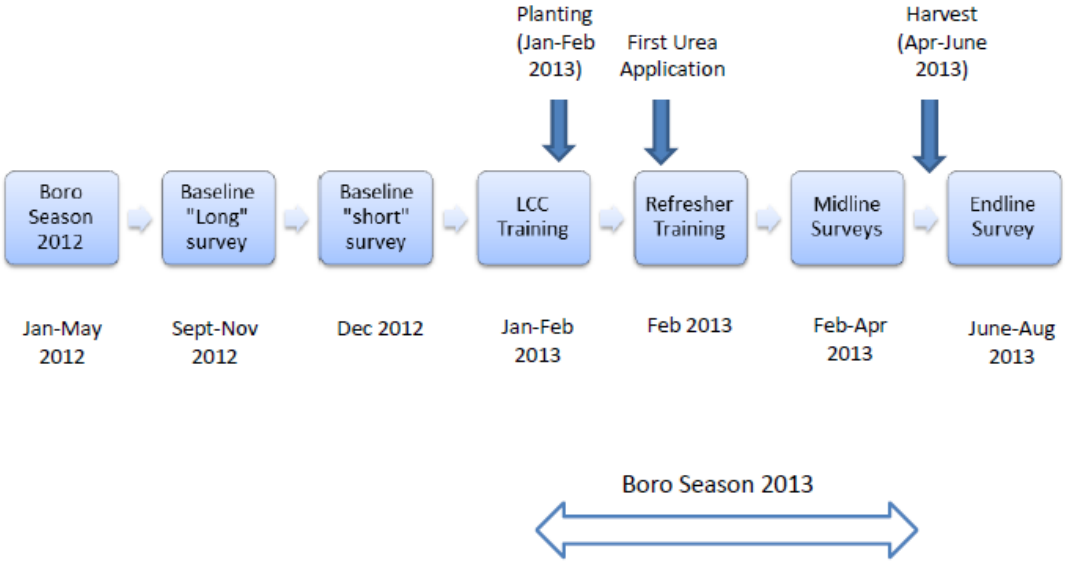


Table A1:
Descriptive Statistics for Districts in Study Area

District	% Population in Rural Areas	% Population in Agriculture	Average Household Size (Rural)	Urbanization (%)	Literacy Rate (%)
Brahmanbaria	84.21	30.02	5.28	15.79	45.3
Comilla	84.40	30.54	5.10	15.60	53.3
Chandpur	81.97	25.56	4.76	18.03	56.8
Gazipur	69.52	24.02	4.14	30.48	62.5
Lakhipur	84.79	25.10	4.71	15.21	49.4
Munshiganj	87.13	13.29	4.56	12.87	56.1
Narayanganj	66.46	6.30	4.40	33.54	57.1
Noakhali	84.02	19.61	5.20	15.98	51.3
Bangladesh	**76.70**	**23.85**	**4.46**	**23.3**	**51.8**

Note: Source: Bangladesh Bureau of Statistics.
% Urbanization, Literacy rate obtained from Community Reports for each district from the Bangladesh Population & Housing Census 2011. % Population in rural areas computed from total rural population and total population for each district from the same source.
% Population in Agriculture computed from total population and total population in agriculture obtained from Statistical Yearbook of Bangladesh, 2010.
All data obtained online at http://www.sid.gov.bd/

Table A2:
Instructions to Use LCCs

Five Most Important Information

1. Check leaf color with LCC every 10 days, starting 21 days after planing until flowering (If urea is not needed on a day when you check with the LCC, check back again in 5 days).
2. Every time you check leaf color with an LCC, pick out 10 healthy leaf samples (Walk diagonally across the field from one end to the other to pick 10 bunches).
3. For each bunch of leaves, select the topmost fully developed leaf and place it on the LCC to match a color. Compare in the shade of your body.
4. Out of the 10 samples, if 6 or more are light in color (it matched the first two panels of the LCC) then apply 9 kilograms of urea every 33 for decimals of land. Check leaf color with LCC again in 10 days.
5. If urea is not needed on the day you measure (out of the 10 leaf samples, 4 or fewer are light), then check the leaf color again in 5 days with the LCC to see if urea needs to be applied.

Table A3:
Randomization Checks after Attrition

Differences at Baseline for Midline & Endline Samples

	Individual/Household level Variables				Plot level Variables						
	(1) Age	(2) Schooling (years)	(3) Non-agri. Income (Tk)	(4) Total Plot Area (dec.)	(5) Plot Size (dec.)	(6) Urea (kg/dec)	(7) Yield (kg/dec)	(8) Revenue (Tk/dec)	(9) Total Cost (Tk/dec)	(10) Profit (Tk/dec)	(11) Chi-squared Test
Panel A: Midline (Time Use) Sample											
Treatment	0.006	-0.163	-521.520	-0.327	0.865	-0.010	-0.956	-5.675	-9.178	3.977	0.67
	(0.744)	(0.268)	(661.530)	(2.188)	(0.929)	(0.028)	(0.847)	(10.825)	(10.794)	(13.563)	(0.4138)
Control Mean	45.84	6.077	12934	78.04	45.84	1.069	26.81	362.9	251.8	109.9	
Observations	1,062	1,013	1,016	1,080	2,548	2,488	2,488	2,327	2,346	2,327	
Panel B: Endline Sample											
Treatment	0.361	-0.172	-797.780	1.594	1.237	-0.006	-1.291	-23.644*	-18.369*	-4.293	2.41
	(0.629)	(0.213)	(549.472)	(2.126)	(0.869)	(0.027)	(0.801)	(12.115)	(9.413)	(13.387)	(0.1205)
Control Group Mean	46.25	5.973	10985	80.51	46.25	1.005	26.23	354.6	241.7	111.4	
Observations	1,524	1,477	1,428	1,549	3,638	3,567	3,566	2,703	2,724	2,703	

Notes: This table shows randomization checks for the midline (time-use) sample and the endline sample after attrition. It reports coefficient of *Treatment* for regressions of each dependent variable on *Treatment* and strata fixed effects for the midline time-use surveys. Robust standard errors for regressions with individual/household level variables and standard errors clustered at household level for regressions with plot level variables are shown in parentheses.
The joint test used a chi-squared test to estimate whether the coefficients are jointly significant.
*** p<0.01, ** p<0.05, * p<0.1.

Table A4:
Changes in Urea Application Intervals over the Season

	(1) # Days from Planting to 1st Application	(2) # Days between 1st and 2nd Applications	(3) # Days between 2nd and 3rd Applications	(4) # Days between 3rd and 4th Applications	(5) # Days between 5th and 6th Applications	(6) # Days from Last Application to Flowering
Treatment	0.435	-0.598**	0.164	0.489	0.930	-0.346
	(0.372)	(0.298)	(0.527)	(1.030)	(4.699)	(0.711)
Control Group Mean	13.27	20.72	19.66	17.42	19.40	32.30
Observations	3,541	3,115	1,481	96	13	3,541

Notes: This table shows differences in urea application over the season between the treatment and control groups. Control variables include age, schooling, non-agricultural income and total plot area.
Standard errors, shown in parentheses, are clustered at household level. All regressions include strata fixed effects.
*** p<0.01, ** p<0.05, * p<0.1.

Table A5:
Treatment Effects by Gender

Urea & Yield in Kilograms per Decimal

	(1) Urea	(2) Yield	(3) Urea	(4) Yield	(5) Urea	(6) Yield
Primary Farmer Female*Treatment*Post	-0.006	-3.768				
	(0.209)	(2.824)				
Any Female Farmer*Treatment*Post			0.017	0.761		
			(0.065)	(1.239)		
Fraction Female Farmers*Treatment*Post					-0.056	-5.300*
					(0.173)	(2.853)
Mean at Baseline	1.011	25.73	1.011	25.73	1.011	25.73
Observations	7,136	7,136	7,184	7,184	7,151	7,151

Notes: Controls include age, schooling, total plot area cultivated, non-agricultural income and rice variety. Coefficients not shown for the variables Treatment, Post, Treatment*Post, the specific characteristic variable in each column as well as the interactions of the variable with the Treatment and Post variables. Standard errors clustered at the household level are shown in parentheses. All regressions include strata fixed effects.
100 decimals = 1 acre
*** p<0.01, ** p<0.05, * p<0.1.

Table A6:
Effects of Using LCC by Gender within Treatment Group

Urea & Yield in Kilograms per Decimal

	(1) Urea	(2) Yield	(3) Urea	(4) Yield	(5) Urea	(6) Yield
Primary Farmer Female*Used LCC*Post	-0.137	6.872				
	(0.368)	(4.471)				
Any Female Farmer*Used LCC*Post			0.123	3.192		
			(0.151)	(2.524)		
Fraction Female Farmers*Used LCC*Post					0.114	6.663
					(0.293)	(4.211)
Mean at Baseline	1.011	25.73	1.011	25.73	1.011	25.73
Observations	3,515	3,515	3,543	3,543	3,521	3,521

Notes: Controls include age, schooling, total plot area cultivated, non-agricultural income and rice variety. Coefficients not shown for the variables Used LCC, Post, Used LCC*Post, the specific characteristic variable in each column as well as the interactions of the variable with the Used LCC and Post variables. Standard errors clustered at the household level are shown in parentheses. All regressions include strata fixed effects.
100 decimals = 1 acre
*** p<0.01, ** p<0.05, * p<0.1.

Table A7:
OLS Estimates of Time Use by Farmers (7 day recall)

	(1) #Times in Field	(2) Fertilizer Application (minutes)	(3) Weeding (minutes)	(4) Pesticide Application (minutes)	(5) Other Activities (minutes)
Treatment	0.112	3.921	5.827	0.786	1.349
	(0.071)	(3.436)	(4.554)	(0.866)	(3.032)
Control Group Mean	2.700	50.31	57.35	4.471	38.85
Observations	2,066	2,066	2,066	2,066	2,066

Notes: This table shows OLS estimates of treatment effects on on time use by farmers using data from Rounds 2 and 4 of the midline surveys. The dependent variables in Columns (2) to (5) are total time spent in minutes in the last seven days on different agricultural activities. Control variables include age, schooling, total plot area cultivated and non-agricultural income.
Standard errors clustered at the household level are shown in parentheses. All regressions control for survey round and strata FE.
*** p<0.01, ** p<0.05, * p<0.1.

Table A8:
Costs Breakdown (Long Survey)

All costs are in Takas per decimal

	(1) Fertilizers	(2) Manure	(3) Pesticides	(4) Other Expenses	(5) Labor
Treatment*Post	6.771	0.840	0.882	7.151*	-2.560
	(6.836)	(1.204)	(1.148)	(3.769)	(5.401)
Treatment	-7.810	0.488	-0.719	-4.834	0.322
	(6.502)	(0.450)	(0.632)	(3.073)	(3.563)
Post	9.759*	-0.456	-2.680***	2.241	13.737***
	(5.282)	(0.516)	(0.991)	(3.207)	(3.927)
Mean at Baseline	35.22	1.974	7.013	84.28	111.7
Observations	6,096	5,164	5,705	6,102	6,102

Notes: Controls variables include age, schooling, total plot area cultivated, non-agricultural income and rice variety.
Standard errors clustered at the household level are shown in parentheses. All regressions include strata fixed effects.
100 decimals = 1 acre
*** p<0.01, ** p<0.05, * p<0.1.

Milestone 8

Project Update:

The project is progressing well overall based on the plan described in the previous document (Milestone 7) we submitted. We have finished conducting a survey to look at medium-term effects of leaf color charts in June 2015, which was funded by the Agricultural Technology Adoption Initiative (ATAI) for the full Leaf Color Chart Sample. We included additional sections relevant for a Soil Testing baseline (funding by USAID-DIV) including a detailed agricultural section focusing on the *Aman* season which we are targeting for the Soil Testing intervention. We will use a sub-sample of farmers from the Leaf Color Chart sample and cross-randomize the Soil Testing treatment and controls groups across the Leaf Color Charts treatment and control groups.

Milestone 8 completion:

- The soil testing baseline survey has been completed.
    - We tried to track and conduct the survey for all 2045 farmers in the leaf color charts sample, and were able to track and conduct the survey for 1,877 households
    - The survey was completed very recently so we are in the process on cleaning the data, however, some preliminary summary statistics are shown in Tables 1-4 below.
- Soil testing has begun.
    - Enumerators were asked to collect soil samples from farmers whenever environmental conditions allowed. Early and heavy rainfall has been a challenge in some locations and soil samples could not be collected from all farmers targeted (as soil samples cannot be collected if the plot is completely submerged under water). However, 664 soil samples have been successfully collected and are being tested in the lab.
    - Enumerators will return to collect soil samples from additional farmers once environmental conditions allow.

Table 1: Seasons at Baseline

Details	**%**
Percentage of farmers cultivating any crop in Boro season 2015	82.53
Percentage of farmers cultivating any crop in Aman season 2014	29.40

Table 2: Fertilizer Use in Aman Season 2014

Fertilizer Type	**%**
Urea	95.83
Triple super phosphate (TSP)	72.05
Muriate of Potash (MoP)	67.15
Gypsum	3.45
Zinc	3.63

Manure	8.89
Boric acid	0.00

Table 3: Mean Use of Major Fertilizers in Aman Season 2014 for farmers using the Fertilizer

Type of Fertilizer use in Kilograms per Decimal	**Kg/dec**
Urea	0.59 (0.28)
Triple super phosphate (TSP)	0.42 (0.27)
Muriate of Potash (MoP)	0.28 (0.12)

Notes: 100 decimals = 1 acre; Standard deviation shown in parentheses

Table 4: Prices of Major Fertilizers, Price of Rice and Estimated Profits in Aman 2014

Mean Prices of Major Fertilizers (Taka/kilogram)	**Taka/unit**
Urea	19.43 (1.46)
Triple super phosphate (TSP)	31.22 (3.48)
Muriate of Potash (MoP)	18.43 (2.07)
Mean price of Rice (Taka/mon)	697.5 (94.0)
Mean profit for household (Takas)	4292.0 (6578.8)

Grant No. AID-OAA-F-13-00016
Title: Reducing Imbalanced Fertilizer Use in Bangladesh
Principal Investigator(s): Rohini Pande and Mahnaz Islam

Milestone 9

Project Update:

We successfully completed collection of soil samples from 570 farmers in July 2015. The lab results from these soil samples were collected and used to compile individual and union council level fertilizer recommendations. We distributed the recommendations to farmers based on their treatment status at the end of August 2015. A third of the farmers received plot specific recommendations, another third received the union council level recommendation, and the remaining farmers were in the control group.

Challenges:

We faced difficulty in soil sample collection for two reasons. Firstly, in order to evaluate the treatment impact over the course of the Aman season (Sep-Dec 2015), we needed to ensure that farmers were not leaving their land fallow during this time. This was not the case for all farmers, so we could only potentially go to the farmers who reported an intention to cultivate for this season.

Secondly, due to early start of the monsoon this year, plots were under water starting in June. Since we can collect soil sample only if the plot is dry, we had to make several attempts to collect soil samples when the plot was dry and were not successful in some cases.