INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

IFPRI

IFPRI Discussion Paper 01517

March 2016

Can Information Help Reduce Imbalanced Application of Fertilizers in India?

Experimental Evidence from Bihar

Ram Fishman

Avinash Kishore

Yoav Rothler

Patrick S. Ward

Shankar Jha

R. K. P. Singh

South Asia Office

Environment and Production Technology Division

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

AUTHORS

Ram Fishman is an assistant professor in the Department of Economics at George Washington University, Washington, DC and the Department of Public Policy at Tel Aviv University, Israel.

Avinash Kishore is a research fellow in South Asia Office of the International Food Policy Research Institute (IFPRI), New Delhi.

Yoav Rothler is a consultant with the Department of Public Policy at Tel Aviv University, Israel.

Patrick S. Ward is a research fellow in the Environment and Production Technology Division of IFPRI, Washington, DC.

Shankar Jha is an assistant professor in the Department of Soil Science at Rajendra Agricultural University, Bihar, India.

R. K. P. Singh is a retired professor in the Department of Economics at Rajendra Agricultural University, Bihar, India.

Notices

Contents

Abstract	v
Acknowledgments	vi
1. Introduction	1
2. Context	4
3. Experimental Design, Data, and Empirical Strategy	5
4. Results	9
5. Why Did Farmers Ignore the Soil Health Card?	13
6. Conclusion	19
References	20

Tables

3.1 Descriptive statistics of control and treatment farmers 6

3.2 Timeline of soil health card intervention and data collection activities 7

4.1 Soil test ratings for different soil nutrients 9

4.2 Actual fertilizer application and (A) baseline calibrated recommendations and (B) target yield recommendations 10

4.3 Determinants of application-recommendation gap 11

4.4 Effect of soil health card intervention on subsequent application of three main fertilizers 12

5.1 Self-reported rationales for over- and underapplying fertilizers relative to recommended application 14

5.2 Characterization of subsample groups for zinc BDM 16

5.3 Comparison of WTP between subsample groups from BDM 16

5.4 Determinants of WTP for zinc 16

5.5 Correspondence between farmers' memory of SHC and actual SHC recommendations (percent) 17

5.6 Respondents' trust in information sources (percent) 18

5.7 Correspondence between farmers' self-reported knowledge of zinc sufficiency/deficiency and actual sufficiency/deficiency based on soil analysis 18

Figures

3.1 Location of sample districts 6

3.2 Example of blank soil health card presented to study participants 8

ABSTRACT

The imbalanced application of chemical fertilizers in India is widely blamed for low yields, poor soil health, pollution of water resources, and large public expenditures on subsidies. To address the issue, the government of India is investing in a large-scale, expensive program of individualized soil testing and customized fertilizer recommendations, with the hope that scientific information will lead farmers to optimize the fertilizer mix. We conducted a randomized controlled trial in the Indian state of Bihar in what we believe to be the first evaluation of the effectiveness of the program as currently implemented. We found no evidence of any impact of soil testing and customized fertilizer recommendations on actual fertilizer use or the willingness to pay for lacking nutrients (elicited using a Becker-DeGroot-Marschak mechanism). Several factors could be driving these results, including a lack of understanding, lack of confidence in the information's reliability, or the costs of the recommended fertilizer mixes. We provide evidence that suggests lack of confidence is the main factor inhibiting farmers' response.

Keywords: soil testing, fertilizers, India, randomized controlled trial, Becker-DeGroot-Marschak mechanism

ACKNOWLEDGMENTS

This work has benefited from financial support from the International Growth Centre's India (Bihar) Program; the Tel Aviv University Manna Center Program for Food Security and Safety; the Tel Aviv University Boris Mints Institute for Strategic Policy Solutions to Global Challenges; the Indian Council of Agricultural Research (ICAR); the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS); the International Food Policy Research Institute's Strategic Innovations Fund; George Washington University; the Bill and Melinda Gates Foundation and the United States Agency for International Development (the latter two through the Cereal Systems Initiative for South Asia). We would like to thank Vartika Singh and Sourav Kumar for their assistance in data collection efforts, and Jyotsana Dua and Lorena Danessi for administrative assistance.

1. INTRODUCTION

The nation that destroys its soil destroys itself.—Franklin D. Roosevelt (1937)

Soil testing and its conservation are the most essential. Everything is based on the soil only.—Nitish Kumar, Chief Minister, Bihar (2014)

On World Soil Day we reaffirm our commitment to making our soil healthier. When soil is in good health, our farmers get more wealth.—Narendra Modi, Prime Minister of India (2015)

Fertilizer consumption in India increased remarkably during the second half of the 20th century and into the first decade of the 21st century, rising from roughly 66,000 tons[1] in the 1950–1951 agricultural year to more than 26 million tons in 2009–2010 (Mujeri et al. 2012). While food grain production increased significantly during the same time period, the increase in total food grain production failed to keep pace with the dramatic increases in fertilizer application, resulting in low and deteriorating fertilizer use efficiency. At the end of the century, overall fertilizer use efficiency was as low as 50 percent, while nitrogenous (N) and phosphatic (P) fertilizer use efficiencies were an estimated 30–35 percent and 20–25 percent, respectively (Awasthi 1999).[2] Early on in this period, the government recognized the importance of chemical fertilizers and introduced the Fertilizer Control Order under the Essential Commodity Act to regulate the production, trade, distribution, and prices of fertilizers to ensure that these essential commodities were both available and affordable. Global shortages of fertilizers led to increased prices in global markets, which subsequently increased budgetary pressures in India. To alleviate some of these pressures, prices for phosphatic and potassic (K) fertilizers (for example, diammonium phosphate, known as DAP, and potash) were deregulated in the early 1990s, leading to sharp increases in the prices of these fertilizers. As a result, while the absolute price of urea increased by about 50 percent from 1992–1993 to 1999–2000, the relative price (vis-à-vis DAP and potash prices) declined dramatically, resulting in a subsequent imbalance in fertilizer application rates.

To date, the imbalanced application of different types of chemical fertilizers remains a widespread problem in India. The government is also faced with the rising costs of fertilizer subsidies, which now account for nearly 1 percent of India's gross domestic product. The lion's share of this public expenditure is for urea, the most commonly used fertilizer in India, though other fertilizers also receive much lower levels of subsidy. Farmers often apply too much heavily subsidized urea while seldom, if ever, applying secondary nutrients (for example, sulfur, calcium, and magnesium) or micronutrients (for example, zinc, iron, copper, boron, molybdenum, and manganese).[3] The overapplication of urea has resulted in a highly skewed NPK application ratio of 8.2:3.2:1, compared with the broadly recommended ratio of 4:2:1 (India, Ministry of Agriculture and Farmers Welfare 2015). This imbalance is thought to affect soil fertility, crop productivity, and even farmers' net profits, while also ultimately resulting in diminished biodiversity and widespread pollution of water resources (Ongley 1996). The declining vitality of Indian soils and the resultant threat to food security has already been accepted as a crisis by Indian policymakers (Gopikrishna 2012).

Under the leadership of the Food and Agriculture Organization of the United Nations and the Intergovernmental Technical Panel on Soils, the world celebrated 2015 as the International Year of Soils in an attempt to raise awareness of the importance of soils for food security (Lal and Stewart 2010) and essential ecosystem functions (Kibblewhite, Ritz, and Swift 2008), as well as to promote the sustainable use and preservation of this valuable nonrenewable resource. In India, the International Year of Soils was celebrated with the launch of a massive—and massively ambitious—program that aims to provide *soil*

[1] Tons are metric tons (1,000 kg) throughout the text.

[2] The most common nitrogenous and phosphatic fertilizers are urea and diammonium phosphate (DAP), respectively. The estimates in Awasthi (1999) do not refer explicitly to these fertilizers but refer only to the primary elements.

[3] The overuse is compared with what agriculture experts recommend for different crops and soil types.

health cards (SHCs) to all of the nation's 145 million farmers. At a total program cost of 568 crore[4] rupees (that is, Rs 5.68 billion, roughly equivalent to US$85 million at prevailing exchange rates at the time), the program promises to conduct individualized laboratory tests of soil composition for each farmer's land and provide a detailed analysis of the availability of various nutrients and other compounds in the soil as well as recommendations for fertilizer application based on a target yield. If the program runs as planned, farmers will receive these cards every three years.

Faced with declining fertilizer use efficiency, threats to food security, and increasing subsidy burdens, the government is therefore pinning its hopes on this SHC program. It is hoped that the successful implementation of this program will result in a more balanced and judicious use of plant nutrients, including a 20 percent reduction in the use of chemical fertilizers, fostering a significant increase in the productivity of selected local crops. In an interview, the honorable Minister of Agriculture, Shri Radha Mohan Singh, had this to say about the program:

> *We are issuing Soil Health Cards to help him [the farmer] know exactly how much fertilizer is needed. We will set up soil health labs across the country and even provide mobile labs. This will have dual benefit. Urea subsidy is Rs 80,000 crore. Its consumption will come down by 20–25 percent after farmers know they do not need to use too much of it. Secondly, with proper use of fertilizers and better seeds, production can increase by 50 percent to 100 percent.*—Cited in Watts and Sally (2014).

On another occasion, he argued the following:

> *Once you provide farmers proper irrigation facility and basic counseling through such [soil health] cards for using or not using certain fertilizers for certain crops in certain areas, it will improve productivity and cut down costs. .*—Cited in Mohan (2014).

These hopes are based on several implicit assumptions. First, it is assumed that smallholder farmers, many of whom are illiterate, will be able to understand the contents of the SHC. Second, even if farmers understand the contents, it is assumed they will trust the quality and reliability of the information that is provided, or perhaps more crucially, the source of that information. Third, it is assumed that the information, even if accepted, will alter their *preferred* use of fertilizers. And fourth, it is assumed that they will be *able* to act on these altered preferences, that is, that their choices are not constrained by other factors that dictate fertilizer choices, such as cost or liquidity, among others.

Given these multiple assumptions, the multimillion-dollar question remains: will SHCs prompt farmers to adjust their fertilizer use, and if so, how? Despite much fanfare surrounding the launch of this program, these important questions do not have immediate answers. To provide some of the first empirical evidence on this matter and test the validity of the assumptions underlying India's flagship SHC scheme, we carried out a randomized controlled trial in the Indian state of Bihar that approximated the government's SHC intervention. Specifically, soil samples were collected from treated farmers' fields and sent to a certified laboratory for testing and analysis. Treated farmers were then provided with SHCs that reported the soil test results and provided recommendations for the required dosage of different fertilizers and micronutrients to be applied to rice and wheat—by far the most prevalent crops grown in Bihar, and in India more generally. The recommendations of the SHCs were markedly different from farmers' baseline fertilizer application, as determined by laboratory analysis. On the one hand, baseline urea application was almost twice as much as the recommended dosage. On the other, soil tests indicated deficiencies in some micronutrients (such as zinc), which farmers typically do not apply at all. Despite these gaps, however, a comparison of treatment with control farmers (who did not have their soils tested or receive SHCs containing fertilizer recommendations) does not reveal any evidence that the distribution of SHCs affected farmers' fertilizer application decisions.

[4] A *crore* is a commonly used unit in India, equal to 10,000,000 (10 million).

We also attempted to determine which of the program's assumptions linking the receipt of soil information to actual changes in fertilizer use fail to hold and may be ultimately responsible for the lack of observed response. First, we conducted a Becker-DeGroot-Marschak valuation elicitation exercise with farmers from both our treatment and control groups in order to elicit revealed willingness to pay (WTP) for zinc, an important micronutrient that was deficient in a substantial fraction of our sample (based on soil sample analysis), but that is scarcely applied by sample farmers. We compare the WTP for zinc between (1) farmers whose SHC indicated zinc deficiency and those whose SHC indicated zinc sufficiency, (2) farmers whose SHC indicated zinc deficiency and control farmers (who did not receive SHCs), and finally, (3) farmers with zinc-deficient soil who were randomly reminded of their SHC results and others who were not. Even though only this last comparison is purely experimental, the lack of any appreciable difference between the WTP of farmers in all of these comparison groups allows us to conclude that that the information in the SHC simply did not affect farmers' fertilizer preferences to a significant degree. In fact, the WTP for zinc across all groups was quite close to the market price. To differentiate further between lack of understanding and lack of trust, we examined farmers' familiarity with the information contained in the SHC and compared it with their own subjective beliefs about the conditions of their soils. The results revealed that although repetition of the SHC information can improve what is an initially low level of information assimilation, farmers did not use the information to update their beliefs about the condition of their soils, suggesting that perhaps a lack of trust is the principal factor behind the lack of response to the SHC program.

From strictly a policy perspective, our results cast serious doubts on the viability—and ultimately the cost-effectiveness—of India's SHC program, at least in the manner it is currently planned and administered. But we willingly acknowledge two important shortcomings of the present study. First, although we have attempted to maintain a high degree of internal validity, essentially modeling our intervention on the government model, our sample is far from representative, leaving the experimental results and subsequent policy implications susceptible to challenges regarding external validity. Second, our results provide strong evidence that at least in the context of rural Bihar, the proposed method of providing SHCs does not work. At this stage, we are not, however, able to shed much light on alternative mechanisms that may prove to be more successful in changing fertilizer preferences toward a more balanced application. Our suggested response in light of both of these shortcomings is to encourage the ongoing generation of evidence. Given the large public expenditures in question, we believe additional experimental studies in other parts of the country—in terms of both testing the efficacy of the existing program design and exploring alternative or complementary interventions that can yield the desired effect—are needed to provide evidence on the external validity of these results as well as to improve the overall design of the program. Specifically, our results suggest finding ways to build farmers' trust in the SHC recommendations may be a vital aspect of the program that requires substantial improvement from current levels.

This study also contributes to the growing literature on technology adoption by smallholder farmers in developing countries. There are several important strands of this literature, but one thread explores the role of several factors that may constrain the adoption of optimal practices, including lack of information, resource constraints, and behavioral factors such as limited attention and information processing strategies (Hanna, Mullainathan, and Schwartzstein 2014; Duflo, Kremer, and Robinson 2008, 2009). Providing information about soil nutrient composition has unique informational aspects that have only recently begun to attract the attention of development economists (Islam 2014). As an intervention, the provision of soil information is akin to (or indeed a specific component of) traditional agricultural extension programs, but is unique in that it offers individualized, site-specific information on what are often highly heterogeneous conditions. If this heterogeneity constrains the diffusion of improved practices, these types of individualized interventions might offer an advantage over more traditional extension messaging. At the same time, our results suggest that this heterogeneity can also become a weakness of these kinds of programs whenever farmers lack trust in the quality of information or in the information provider, which may lead to their resisting recommendations that run contrary to a widespread perception of the "average" need.

2. CONTEXT

Cultivation of Wheat and Fertilizer Use in Bihar

Bihar is among the poorest and most populous states of India. Nearly 90 percent of the state's 104 million people live in rural areas and depend upon agriculture for their livelihood. According to the 2011 Demographic Census, 70 percent of all main workers in Bihar and 78 percent of workers in rural Bihar reported cultivation or agricultural labor as their principal occupation. Rice is the predominant kharif (rainy season) crop, while wheat is the predominant rabi (dry, winter season) crop, accounting for nearly 60 percent of gross sown area. Next to rice, wheat is the second most important crop in terms of cropped area, production, and household consumption. Unlike rice, which benefits from the annual monsoon rainfall, wheat is grown mainly under irrigated conditions, reducing year-over-year yield variability compared with rice. Wheat is therefore key to the food and income security of farmers in Bihar.

Fertilizer use has increased rapidly in Bihar over the last three decades. In 1981–1982, the average NPK (the combined amount of the three main nutrients of nitrogen, phosphorous, and potassium) application rate was 21.54 kg/ha of gross cropped area (GCA) in Bihar, compared with the all-India average of 34.34 kg/ha. By 2012–2013, the fertilizer use intensity in Bihar had increased to 212.23 kg of NPK per 1 ha of GCA, compared with the national average of 128.34 kg/ha of GCA. Despite higher fertilizer use in Bihar than in the rest of India, crop productivity is significantly lower (2.2 T/ha, compared with the national average of 3.0 T/ha). This difference is likely the result of a range of socioeconomic factors, but it also suggests a suboptimal use of fertilizers in the state.

Soil Testing and Soil Health Cards in India

India's soil testing program began in 1955–1956 with the establishment of 16 soil testing laboratories under the Indo-US Operational Agreement for the Determination of Soil Fertility and Fertilizer Use. The program benefited from a substantial revival in the 11th five-year plan (2007–2012), when the National Project on Management of Soil Health and Fertility was launched with an outlay of Rs 429.85 crore (approximately US$65 million at the prevailing exchange rate) to set up new laboratories and strengthen existing laboratories with micronutrient testing facilities. The program was expanded further in the 12th five-year plan (2012–2017), when all states adopted the system of preparing and issuing soil analysis–based SHCs to farmers along with associated fertilizer use recommendations.

The recently launched flagship SHC program will give a major fillip to ongoing soil testing efforts. This program aims to provide SHCs to all farmers across the country every three years. States like Gujarat have already implemented a similar program whereby farmers received crop-specific fertilizer application recommendations for all plots of land in the state. Bihar, on the other hand, has been a laggard in testing soil and issuing SHCs. In our sample of more than 800 farmers in three districts, not a single farmer reported ever having had his or her soil tested. However, this status is set to change under the flagship program. In Bihar, the program aims to analyze nearly 1.31 million soil samples and provide more than 11 million SHCs to farmers within three years. The government of India released more than Rs 25 million to the state government during 2014–2015 for implementing the program, and nearly Rs 14 million has been allocated for 2015–2016.[5]

---

[5] Information from a response given on July 31, 2015, by Mohanbhai Kundaria, minister of state for agriculture, to a question posed in the upper house of the Parliament of India.

3. EXPERIMENTAL DESIGN, DATA, AND EMPIRICAL STRATEGY

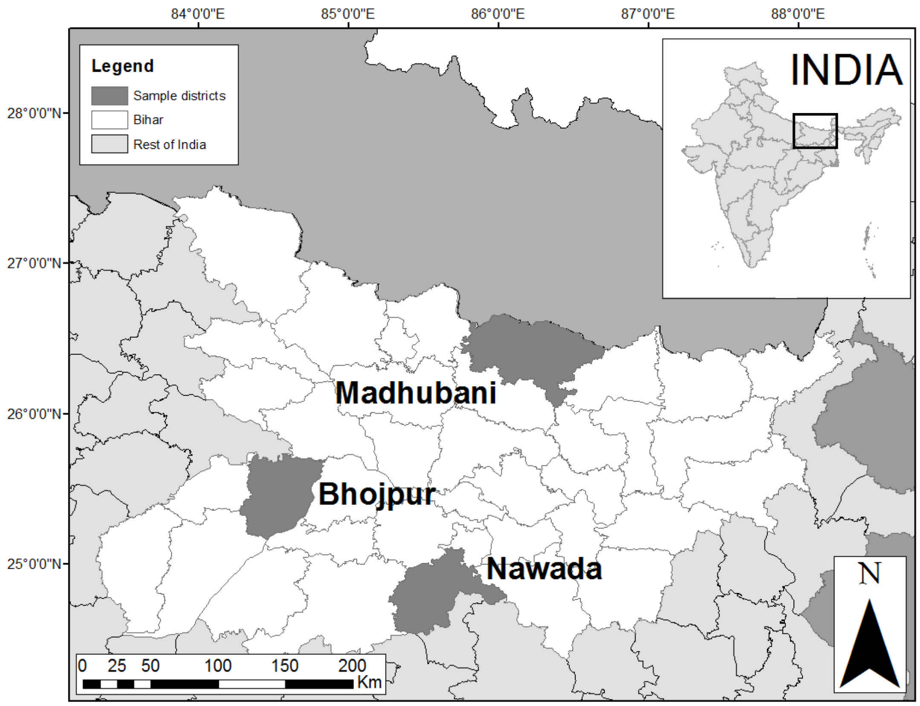
Study Area and Randomization

The study was conducted in partnership with the Department of Soil Science of Rajendra Agricultural University (RAU), Bihar, the oldest and most prestigious institution for agricultural research and extension in the state. We used a multistage sampling approach to form our survey sample. In the first stage, we selected three districts with a predominant rice-wheat cropping system from which to sample households: Bhojpur, Madhubani, and Nawada (Figure 3.1). These three districts span two distinct agroecological zones and have varying levels of agrarian dynamism. In the second stage, we selected 16 high-rice-producing blocks (subdistrict administrative units) across the three districts, with the number of blocks drawn from each district proportional to the share of rice production attributable to that district.[6] Seven blocks were selected from Bhojpur, 3 from Nawada, and 6 from Madhubani. Within each of these 16 blocks, we randomly selected 2 villages from which to draw households for treatment and 1 village from which to draw households for a control group. From each of these 48 villages, we randomly selected 18 rice- and wheat-growing households from village rosters prepared by enumerators through door-to-door listing. After eliminating households for which data were missing, our treatment group consists of 213 households from Bhojpur, 189 households from Madhubani, and 89 households from Nawada. Similarly, the control group consists of 132 households from Bhojpur, 107 households from Madhubani, and 54 households from Nawada.

We conducted a baseline survey in April–May 2014 prior to collecting soil samples for subsequent analysis. The baseline survey covered both treatment and control households, and collected data on farmer characteristics (such as age, gender, education, caste membership, and total landownership), use of fertilizers (including number and quantity of applications of different types of fertilizers) and other inputs, and yield realized in crops harvested during 2012–2013. Table 3.1 presents summary statistics from the baseline survey and examines the balance between the control and treatment groups based on t-tests of sample means. In our sample, 90 percent of the respondents were male, and their average age was 46 years. Nearly 40 percent of respondents were illiterate. Average wheat yield in the previous season (rabi 2012–2013) was 2.6 T/ha. The summary statistics reported in this table suggest that the randomization process resulted in a balanced sample in terms of farmer characteristics, productivity, and fertilizer application.

[6] We had originally planned to carry out the intervention during the rice-growing season. However, because of the slow pace of soil testing in the RAU laboratory, we were forced to delay distribution of SHCs until just prior to the wheat-growing season. Limited soil testing capacity remains a major challenge for the successful implementation of the soil testing program all over India, and delays are common. Fortunately for this study, almost all farmers in our study area also grow wheat on more than 90 percent of their gross cultivated area during the winter (rabi) season.

Figure 3.1 Location of sample districts



Source: Authors.

Table 3.1 Descriptive statistics of control and treatment farmers

Variable	Total	Control	Treatment	T - C	Standard error	t-stat
Plot 1 yield in previous season (kg/ha)	2,602	2,601	2,602	1.88	90.51	-0.02
Age (years)	45.58	45.11	45.84	0.73	0.95	-0.77
Gender (0 = male; 1 = female)	0.09	0.08	0.10	0.02	0.02	-0.76
Literacy (0 = illiterate; 1 = literate)	0.60	0.58	0.61	0.04	0.04	-0.95
Total land cultivated (ha)	0.93	0.87	0.96	0.09	0.46	-0.92
Plot 1 size (ha)	0.20	0.21	0.19	-0.01	0.01	1.08
Rice plot 1 urea application (kg/plot)	117.64	120.21	116.10	-4.11	9.31	0.44
Rice plot 1 DAP application (kg/plot)	60.49	60.74	60.34	-0.40	4.75	0.08

Source: Authors.
Note: T – C = absolute difference in means between Treatment (T) and Control (C) sub-samples; DAP = diammonium phosphate.

SHC Intervention and Data Collection

Table 3.2 illustrates the timeline of our SHC intervention and related data collection activities undertaken during the life-span of the present study. Following the baseline survey (May–June 2014), we collected soil samples from one plot of every treatment farmer.[7] Eight graduates of local agricultural universities with experience in farming received a three-day training from experts at RAU and the regional office of the Indian Council of Agricultural Research on procedures for collecting soil samples for testing. These agents then visited each of the 493 treatment households, collected soil samples according to the

[7] The plot from which samples were collected was randomly selected from a list of farmers' two most important plots.

recommended practices, and deposited them with the soil testing laboratory at RAU. This execution of soil testing and its delivery to the laboratory was meant to approximate the intended execution of the SHC government program.

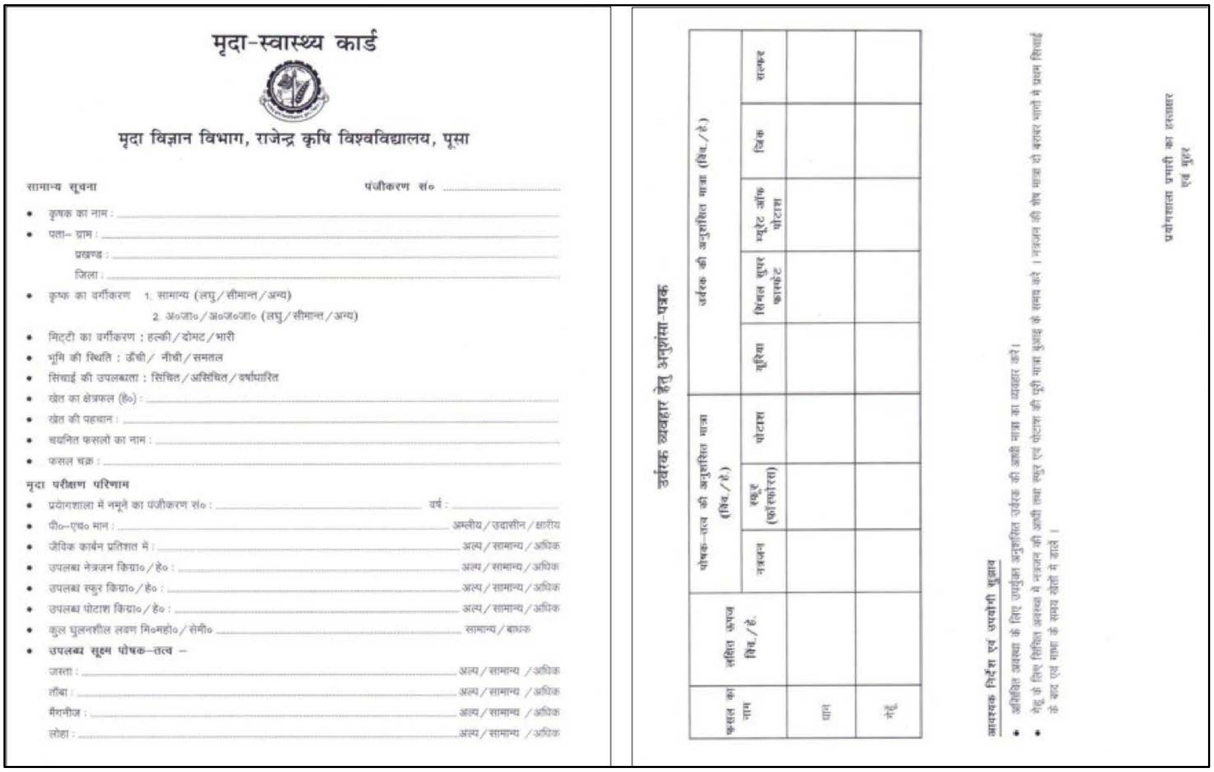
Table 3.2 Timeline of soil health card intervention and data collection activities

	2014									2015						
Activity	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**
Kharif/rabi season			Kharif season							Rabi season						
Soil sampling																
Baseline survey																
SHC distribution																
Pre-rabi survey																
Endline survey																
BDM survey																

Source: Authors.
Notes: BDM = Becker-DeGroot-Marschak valuation elicitation exercise; SHC = soil health card.

Scientists at RAU analyzed the soil samples and recommended appropriate doses of different types of fertilizers for rice and wheat crops. In the normal soil testing procedure, a soil sample is tested for macronutrients (nitrogen, phosphorus, and potash), electrical conductivity (to measure soil salinity), and pH value (to know if the soil is acidic, alkaline, or neutral). For an additional cost, testing can also include an analysis of and recommendations on secondary nutrients and micronutrients. Because Bihari soils are widely believed to suffer from sulfur and zinc deficiencies (Singh 2008), and because both of these micronutrients are considered to be important for soil health and crop yields, we included this additional information in the laboratory analysis and SHCs (Indian Institute of Rice Research 2011). The results of the soil test and resulting recommendations for appropriate fertilizer use were printed (in Hindi) on SHCs for each farmer in a format that closely followed the standard format used in Bihar (Figure 3.2). The front side of the SHC contains information on soil nutrients and their levels, categorized as low, medium, or high, and the back side provides farmers with information on how much of different fertilizers to apply to their various crops. We explain the structure of the information in the SHC in the following section.

Figure 3.2 Example of blank soil health card presented to study participants



मृदा-स्वास्थ्य कार्ड

मृदा विज्ञान विभाग, राजेन्द्र कृषि विश्वविद्यालय, पूसा

सामान्य सूचना — पंजीकरण सं० ....

- कृषक का नाम : ______
- पता– ग्राम : ______
  प्रखण्ड : ______
  जिला : ______
- कृषक का वर्गीकरण 1. सामान्य (लघु/सीमान्त/अन्य)
  2. अ०जा०/अ०ज०जा० (लघु/सीमान्त/अन्य)
- मिट्टी का वर्गीकरण : हल्की/दोमट/भारी
- भूमि की स्थिति : ऊँची/ नीची/समतल
- सिंचाई की उपलब्धता : सिंचित/असिंचित/वर्षाधारित
- खेत का क्षेत्रफल (है०) : ______
- खेत की पहचान : ______
- चयनित फसलों का नाम : ______
- फसल चक्र : ______

मृदा परीक्षण परिणाम

- प्रयोगशाला में नमूने का पंजीकरण सं० : ______ वर्ष : ______
- पी०–एच० मान : ______ अम्लीय/उदासीन/क्षारीय
- जैविक कार्बन प्रतिशत में : ______ अल्प/सामान्य/अधिक
- उपलब्ध नेत्रजन किग्रा०/है० : ______ अल्प/सामान्य/अधिक
- उपलब्ध स्फुर किग्रा०/है० : ______ अल्प/सामान्य/अधिक
- उपलब्ध पोटाश किग्रा०/है० : ______ अल्प/सामान्य/अधिक
- कुल घुलनशील लवण मि०म्हो०/सेमी० ______ सामान्य/बाधक
- उपलब्ध सूक्ष्म पोषक–तत्व –
  जस्ता : ______ अल्प/सामान्य /अधिक
  ताँबा : ______ अल्प/सामान्य /अधिक
  मैंगनीज : ______ अल्प/सामान्य /अधिक
  लोहा : ______ अल्प/सामान्य /अधिक

उर्वरक व्यवहार हेतु अनुशंसा-पत्रक

फसल का नाम	अपेक्षित उपज क्वि./हे.	पोषक-तत्व की अनुशंसित मात्रा (कि./हे.)			उर्वरक की अनुशंसित मात्रा (कि./हे.)				
		नत्रजन	स्फूर (फास्फोरस)	पोटाश	यूरिया	सिंगल सुपर फास्फेट	म्यूरेट ऑफ पोटाश	जिंक	सल्फर
धान									
गेहूँ									

आवश्यक निर्देश एवं उपयोगी सुझाव

प्रयोगशाला प्रभारी का हस्ताक्षर एवं मुहर

Source: Authors.

The agents were also trained by RAU on how to interpret soil test results and explain fertilizer use recommendations to farmers. As previously stated, our experimental protocol simulated the operational guidelines followed by the government's own soil testing program. The SHCs were delivered to farmers, in person, in November 2014, weeks before the sowing of the wheat crop, when farmers had yet to purchase fertilizers. An additional survey was carried out following the distribution of the SHCs (December 2014–January 2015) to collect information on cultivation habits, fertilizer application, and wheat yields from the previous rabi season (2013–2014). Finally, an endline survey was conducted after the subsequent wheat harvest (June–July 2015) to collect information on farmers' fertilizer application and production.

In order to further analyze the underlying reasons for farmers' fertilization choices and the apparent lack of response to the SHCs, an additional interaction was conducted to elicit farmers' WTP for zinc (June–July 2015). A simplified Becker-DeGroot-Marschak mechanism was implemented, allowing us to compare zinc valuation by farmers whose land is zinc deficient with zinc valuation by those whose land is zinc sufficient (both in the treatment group), as well as zinc valuation by those whose specific land characteristics are undetermined (that is, farmers in the control group).

4. RESULTS

Soil Test Results and Recommendations

Table 4.1 presents a summary of the soil test results. Nearly half of the soil samples were low in organic carbon, and all but one had low levels of available phosphorus. One in four soil samples showed potassium deficiency. In our analysis of secondary nutrients and micronutrients, sulfur and zinc deficiency was rather common, while iron, manganese, and copper were available in medium or high concentrations in most samples. Soil salinity was not found to be especially problematic, and most samples were relatively neutral (that is, were neither acidic nor alkaline).

Table 4.1 Soil test ratings for different soil nutrients

	Soil nutrient composition (relative to recommended levels)			
Nutrient	Low	Medium	High	Total samples tested
Organic carbon	241	208	47	498
Phosphate	497	1	0	
Potassium	129	369	0	
Sulfur	161	48	289	
Zinc	179	124	195	
Iron	5	63	430	
Copper	7	47	434	
Manganese	10	24	464	

Source: Authors.

The recommended doses of different fertilizers are partly determined on the basis of available concentrations of different nutrients as found in the analysis of soil samples, but are also conditioned by a target yield that is specific to a particular crop. One way to think about the recommendations is that they provide advice on the application of nutrients required to achieve a target yield, once the availability of nutrients in the soil is taken into consideration. The basic recommended dose was based on a target wheat yield of 4 T/ha. With this target yield, the recommended dose of urea varied from 232 to 297 kg/ha. For phosphate (DAP), the recommended application varied from 100 to 240 kg/ha, and for potash, from 34 to 122 kg/ha. In our sample, 137 farmers received a recommendation to apply 20 kg/ha of sulfur, and 180 farmers received a recommendation to apply zinc at the rate of 25 kg/ha. Once applied, zinc remains available to crops for up to three cropping seasons, though marginal returns on the application of zinc are higher if it is first applied to the rice crop in a rice-wheat cropping system. While the recommendations provided by RAU assumed a target yield of 4 T/ha, in reality, target yields vary across farmers because of other factors constraining productivity, such as irrigation. We therefore also provided farmers with recommendations that were recalibrated on the basis of their self-reported wheat yields. In what follows, we therefore present results for these two calibrations: (1) recommendations based on a target yield of 4 T/ha, and (2) calibrated recommendations based on farmers' actual achieved yields, determined from baseline or endline data.

Table 4.2 compares the recommendations with data on actual fertilizer use from the baseline survey. Calibrated recommendation results show that more than 80 percent of farmers in our sample apply more than the recommended dose of urea. We also find that overapplication of DAP is common, with more than 75 percent of farmers applying more than the recommended dose. During the 2013–2014 rabi season, urea and DAP application was higher than the calibrated recommendations by 72 and 36 percent, respectively. Farmers generally applied less potash than the recommended dose, with average applications 69 percent less than the calibrated recommendations. While RAU scientists recommended that most farmers in our sample apply potash to their wheat crop at an average rate of 43 kg/ha, only 143 treatment farmers applied potash to wheat.

Table 4.2 Actual fertilizer application and (A) baseline calibrated recommendations and (B) target yield recommendations

	Fertilizer		
Variable	**Urea**	**DAP**	**Potash**
Average baseline application (kg/ha)	210.8	136.1	13.2
A. Baseline calibrated recommendations			
Average recommendation (kg/ha)	122.9	100.4	43.1
Average gap (kg/ha)	87.9	35.7	-29.9
Gap/recommendations (percent)	72	36	-69
Farmers who overapply (percent)	82.6	75.9	9.0
Average absolute gap (kg/ha)	104.8	53	32.7
Absolute gap/recommendations (percent)	85	53	76
B. Target yield recommendations			
Average recommendation (kg/ha)	245	164.6	81.5
Average gap (kg/ha)	-33.6	-28.5	-68.3
Gap / recommendations (percent)	-14	-17	-84
Farmers who overapply (percent)	34.2	32.4	0.69
Average absolute gap (kg/ha)	75.9	46.9	68.6
Absolute gap/recommendations (percent)	31	28	84

Source: Authors.
Note: DAP = diammonium phosphate.

While target recommendations seem to be closer to the actual fertilizer application, the calibrated recommendations are probably a more relevant measure of what amounts of fertilizer were actually necessary to achieve the given yield. For example, on average, farmers substantially overapplied nitrogen fertilizers given the yield they received.

It is widely argued that the high subsidy on urea could be one of the reasons for its excessive use. We note, however, that although DAP is no longer subsidized, a good number of farmers were found to have applied excessive amounts of DAP. In fact, DAP is not only costly, but when applied in excess, it gets fixed into the soil and is not available to plants.[8] The application of secondary nutrients and micronutrients was found to be very rare among sample farmers. For example, one in four soil samples were found deficient in zinc and sulfur, but few farmers had applied zinc or sulfur in the previous season. Based on a simple linear regression of the application-recommendation gap (for different macronutrients) on various household observable characteristics, there does not appear to be any systematic variation in these gaps (Table 4.3).

[8] This is one reason why most soil samples were found deficient in available phosphorus in spite of overapplication of DAP.

Table 4.3 Determinants of application-recommendation gap

Dependent variable: application / recommendation gap in:			
Independent variable	**Urea**	**DAP**	**Potash**
Constant	122.5***	54.98***	-19.46**
	(20.450)	(12.110)	(9.464)
Age (years)	-0.0181	0.117	-0.126
	(0.340)	(0.222)	(0.110)
Gender (female = 1)	-7.673	5.172	-6.217
	(14.110)	(10.580)	(5.401)
Literacy (literate = 1)	-19.35	-4.648	-2.221
	(11.020)	(9.488)	(3.505)
Area cultivated (ha)	2.309	2.209	1.88
	(3.607)	(2.596)	(1.724)
Observations	370	375	376
Adjusted R^2	0.311	0.22	0.195

Source: Authors.

Notes: * Significant with 10 percent probability of Type I error; ** significant with 5 percent probability of Type I error; *** significant with 1 percent probability of Type I error. Standard errors (adjusted for clustering at village level) in parentheses. Each regression contains block fixed effects. DAP = diammonium phosphate.

Did the SHCs Influence Farmers' Fertilizer Use?

The randomized design of the intervention allows us to estimate the causal impacts of the delivery of SHCs through a comparison of mean fertilizer use between the treatment and control groups. More specifically, we estimate a regression

$$F_{ijk} = \alpha + \beta T_j + \gamma X_i + \theta B_k + \phi A_l + \varepsilon_{ijk,} \tag{1}$$

where F_{ijk} is a measure of fertilizer application in terms of kilograms per unit of land (the local unit of land is a *katha*, of which there are approximately 55 per hectare) by farmer i at village j in block k. The variable T, defined at the village level, is a binary indicator of treatment; its coefficient, β, is the coefficient of interest, capturing the effect of receipt of an SHC on subsequent fertilizer application. Given that every farmer assigned to the treatment group received an SHC, there is no need to distinguish between assignment to the treatment group and actual receipt of the treatment. This regression also controls for farmer attributes X, including gender, age, literacy, landholding size, size of the treated plot, and baseline levels of fertilizer application. In addition, we include block fixed effects B (recall that randomization was carried out within blocks). Because farmers may have felt obligated to adhere to the SHC recommendation, and self-reported use could have been sensitive to the identity of the enumerator, we also include enumerator fixed effects A in the regression. In other words, we compare fertilizer use between treated and control farmers who are in the same block and interviewed by the same enumerator. Finally, ε_{ijk} is an error term that is distributed identically, though we relax the independence assumption and allow the errors to be correlated among members from the same village. In the subsequent econometric analysis, we adjust the standard errors to account for this clustered sampling design.

Table 4.4 reports the results for estimating equation (1) by ordinary least squares, using the application rates of the three major fertilizers in use by local farmers in the wheat season as the dependent variables in a series of such regressions. Across the three regressions, the treatment coefficients are of a generally small magnitude, representing 2–6 percent of the average level of fertilizer application in the control group (reported at the bottom of the table), and they are statistically insignificant. Furthermore, the point estimate on urea use is positive (though not statistically significant) whereas, as noted above, the average recommended dose of urea was much lower than the baseline use. These results suggest that receipt of an SHC had no effect on subsequent urea application, or if it did, it produced the perverse effect of increasing urea application above the already excessive level. A similar narrative applies to application of DAP: on average, the SHC recommendations suggested a reduction in DAP, yet we fail to find evidence that receipt of SHC recommendations affected DAP application (that is, though the treatment coefficient is negative, it is not statistically significant). When it comes to potash, the recommendations tended to suggest an increase in use, but here again, the point estimate is the opposite of what would be expected if the SHC produced the appropriate response. Since the majority of farmers did not apply potash at all, we also estimated a linear probability model to test for the effect of SHC receipt on a binary indicator of potash use. While the point estimate of the treatment effect is positive, it is small in magnitude, and furthermore statistically insignificant.

Table 4.4 Effect of soil health card intervention on subsequent application of three main fertilizers

Dependent variable	Urea (kg/katha)	DAP (kg/katha)	Potash (kg/katha)	Potash dummy (yes/no)
Constant	3.171***	1.467***	0.143	0.198
	(0.349)	(0.296)	(0.091)	(0.137)
Treatment	0.189	-0.06	-0.035	0.0157
	(0.129)	(0.086)	(0.023)	(0.030)
Baseline application rate (kg/katha)	0.034	0.0283	-0.0262	
	(0.041)	(0.028)	(0.028)	
Baseline application indicator (yes = 1)				0.0322
				(0.055)
Baseline plot size (katha)	0.00979	-0.000379	-0.0000485	0.00149
	(0.006)	(0.004)	(0.001)	(0.002)
Literate (yes = 1)	-0.245	0.0514	-0.0157	-0.019
	(0.148)	(0.111)	(0.036)	(0.044)
Age	-0.00364	-0.000092	-0.000663	-0.000752
	(0.004)	(0.003)	(0.001)	(0.001)
Gender (female = 1)	0.0802	-0.234**	-0.0117	0.0177
	(0.151)	(0.101)	(0.050)	(0.067)
Observations	520	565	527	527
Adjusted R^2	0.059	0.216	0.575	0.552
Control group mean	3.07 kg/katha	1.67 kg/katha	0.277 kg/katha	35.3% used potash

Source: Authors.
Notes: * Significant with 10 percent probability of Type I error; ** significant with 5 percent probability of Type I error; *** significant with 1 percent probability of Type I error. Standard errors (adjusted for clustering at village level) in parentheses. Each regression contains block fixed effects. DAP = diammonium phosphate.

5. WHY DID FARMERS IGNORE THE SOIL HEALTH CARD?

Our results suggest that the SHC recommendations did not affect farmers' fertilizer application in our treatment sample. In this section we attempt to gain insight into the reasons behind this lack of response. In the first part of this section, we report farmers' own explanations for why they over- or underapplied different fertilizers relative to the recommended doses. This self-reporting generally points toward an adherence to traditional fertilizer use, reflecting a lack of confidence in the information contained in the SHCs. We propose three possible explanations for the lack of response. The first is that farmers simply did not understand the contents of the SHC; we should not expect farmers to change their behavior on the basis of recommendations that they do not understand. The second is that farmers understood the contents of the SHC but did not find the soil analysis and fertilizer recommendations to be reliable or compelling. The third is that farmers did in fact internalize recommendations, and the information did alter their preferred fertilizer mix, but other factors (such as cost, liquidity, or timely availability of specific fertilizers) prevented them from acting on these preferences by shifting their actual application. In the second part of this section, we examine this latter potential explanation. We find no relationship between farmers' elicited WTP for an underused fertilizer and the SHC recommendations, and we interpret this as evidence against the third explanation. In the third part of this section, we use survey results to distinguish lack of understanding from lack of confidence or "belief" in the results, and we find the evidence points to the latter.

Self-Reported Explanations

In the endline survey, farmers were asked whether they had retained the SHCs given to them before the rabi season and whether they had consulted them in making fertilizer application decisions. While 93 percent of farmers claimed to have kept the SHCs, only 56 percent were able to locate the SHCs and show them to enumerators, and only 25 percent reported having consulted the SHCs.

Farmers were then asked to report how much of different fertilizers they had applied: the recommended amount, more than the recommended amount, or less than the recommended amount. Farmers that reported having applied more or less than the recommended amount were then asked why they did so. The results, presented in Table 5.1, suggest that trust in their own habits (or rules of thumb) over the recommendations is a crucial factor, with most farmers indicating a belief that their preferred amount was the correct amount and that the scientific recommendations were incorrect. For example, 66 percent of the farmers who reported having used more than the recommended amount of urea and 58 percent of those who used less than the recommended amount of urea said they did so because they did not want to change their behavior from previous seasons. Similar trends were observed for DAP and potash. A similar proportion of farmers that reported having used more than the recommended amount of fertilizers said they believed yields would be reduced if they applied less.

Farmers that reported having applied less than the recommended amount also cited fertilizer cost as a factor, especially for DAP and potash, which are not subsidized and hence more expensive. Liquidity constraints also appear to be a barrier to more balanced fertilizer application. For example, 38 percent of farmers that used less than the recommended amount of DAP and potash said they did so because they did not have enough money or because these fertilizers were too expensive. Interestingly, despite the high urea subsidy's often being blamed for the overapplication of urea, only 3 percent of farmers who applied more than the recommended dose of urea said they did so because it was inexpensive.

Table 5.1 Self-reported rationales for over- and underapplying fertilizers relative to recommended application

Reason for over/underapplication of fertilizers	Urea		DAP		Potash	
	Freq.	Percent	Freq.	Percent	Freq.	Percent
Why used more than recommended?						
Fertilizer cost is low	5	3	0	0	0	0
Using less will reduce yields	46	30	27	52	7	54
Believe the usual amount is the right amount	101	66	25	48	7	46
Why used less than recommended?						
Fertilizer cost is high	7	5	62	31	86	27
Does not have enough money	9	7	14	7	27	9
Yields would not increase by using more	8	6	4	2	10	3
Returns would not increase by using more	4	3	12	6	7	2
Using more would damage the crop	7	5	8	4	13	4
Believe usual amount is the right amount	76	58	92	46	152	48
Fertilizer is not available	9	7	1	1	10	3
Other	11	8	5	2	12	4

Source: Authors.

Notes: Farmers were asked how much fertilizer they used in comparison with the recommendations (more than, less than, or recommended amount). Farmers who reported having applied more or less of the recommended amount were then asked why they did so. DAP = diammonium phosphate.

Revealed WTP for Zinc

To gain further insight into the reasons behind farmers' seeming lack of responsiveness to the SHC, we implemented a simplified Becker-DeGroot-Marschak (BDM) valuation elicitation exercise following the conclusion of the endline survey. The exercise was conducted in order to reveal farmers' WTP for fertilizers they are underusing (specifically zinc) and to determine whether the information obtained from the SHC affected this WTP. That is, we are interested in whether farmers whose SHC indicated zinc deficiency and recommended application of zinc were willing to pay more for zinc than farmers whose SHC indicated that their soils were zinc sufficient or who did not know the status of their soil health. This distinction is important because the lack of SHC impact on farmers' actual fertilizer application can be interpreted as indicating that the information did not affect their preferences or, alternatively, that it did affect preferences but that other factors, such as costs, prevented farmers from acting on them. Exploring differences in WTP helps to disentangle these competing explanations.

Within our sample of treatment farmers, 180 soil samples analyzed were found to be deficient in zinc, yet zinc is scarcely applied by Bihari farmers. The lack of zinc application is troubling, since zinc is the fourth most important yield-limiting nutrient for crops in India (Arunachalam, Kannan, and Govindaraj 2013). Applying zinc to deficient soils is thought to increase crop productivity and crop quality while also reducing zinc deficiency in humans (Bevis 2015). The BDM mechanism is widely used in experimental economics as an incentive-compatible procedure for eliciting the WTP for a good or a service. In a BDM, each subject submits an offer price to purchase the good. Afterwards, a binding sale price is randomly drawn from a distribution of prices ranging from a very low value to a price greater than the anticipated maximum possible WTP among bidders. Any bidder who submits a bid greater than the sale price receives a unit of the good and pays an amount equal to the sale price. If the bid is lower than the sale price, the bidder gets nothing. The dominant strategy for the bidder is to truthfully reveal his or her preferences.

Before administering the BDM exercises, we randomly allocated farmers with zinc-deficient soil into two groups. The protocol informed all farmers of the potential impact of zinc deficiency for crops and the expected gains from application of zinc to deficient soils. This information was conveyed in very general terms, without explicit reference to the farmers' actual conditions. However, farmers in the first group (group 1) were also shown their SHCs and reminded of their zinc deficiency and the scientific recommendation to apply zinc in their fields. Farmers in the second group (group 2) received no such reminder. Among farmers in the treatment group whose soil was determined to be zinc sufficient (that is, their SHC indicated no deficiency and no need to apply zinc), half were randomly selected to take part in the valuation exercise as well (group 3). A fourth group (group 4) consisted of control farmers, for whom no soil testing was conducted. Farmers in this group were notified by agents that there was no information on whether they needed zinc or not. Due to logistical constraints, the BDM exercises in Madhubani district included only farmers from the first three groups, whereas those in Bhojpur and Nawada districts included farmers from the control group as well. Half of the farmers in each control village in Bhojpur and Nawada were randomly selected to be part of the fourth group.

A comparison between groups 1 and 2 sheds light on the value farmers place on nutrient deficiency information contained in the SHCs. A comparison of the composite group consisting of groups 1 and 2 with group 3 sheds light on the value of information indicating deficiency vis-à-vis sufficiency, while a comparison of the composite group consisting of groups 1, 2, and 3 with group 4 provides evidence on the impact of having SHC-based information at all. However, we stress that only the comparison of group 1 with group 2 yields a proper counterfactual, because farmers in other groups have or potentially have different soil characteristics that might be correlated with other attributes affecting the WTP.

After explaining the way the valuation elicitation exercise would be implemented, we conducted two practice rounds, with one practice round entailing a real bidding process (essentially open-ended contingent valuation) with an actual transaction of money for a good of a relatively lower value than zinc (a 250 g pack of lentils). In the actual zinc valuation exercise, farmers were offered 1 kg packs of zinc sulfate ($ZnSO_4$) fertilizer. The binding sale price (which was randomly drawn) ranged from Rs 10 to Rs 60 (the prevailing market rate) for a 1 kg pack. A farmer with a stated WTP above the randomly selected price was then bound to purchase the packet of zinc sulfate, with an option to purchase a quantity up to the recommended dose for his or her tested plot at the random sale price.[9]

Table 5.2 reports the revealed WTP for zinc for the different groups in the BDM exercises. Treatment farmers were willing to pay 41.2 Rs/kg on average, regardless of whether their soils were determined to be zinc deficient (groups 1 and 2) or zinc sufficient (group 3). Statistical tests of sample mean WTPs in Table 5.3 indicate there are no significant differences between the WTPs in any of the intergroup comparisons. Also, estimates of differences between the groups, based on a linear regression of WTP on group dummy variables reported in Table 5.4, are small and statistically insignificant. The WTP for zinc in Madhubani (which is generally a zinc-deficient region) is indeed higher than in Bhojpur or Nawada (generally zinc-sufficient regions)—42.8 Rs/kg versus 41 Rs/kg, respectively—but even that difference is not statistically significant. The relatively modest gap between market price (60 Rs/kg) and the elicited WTP through the BDM exercise suggests that costs may not be the main impediment to applying zinc, although it is important to note that farmers mostly chose to purchase small quantities of zinc that would be insufficient to apply throughout their entire field.

[9] One possible concern is that farmers may purchase the zinc in order to resell it to other farmers below market. We cannot rule out this possibility entirely, but we note that use of zinc is so uncommon in the study area that finding a buyer may not be easy.

Table 5.2 Characterization of subsample groups for zinc BDM

Group	Detail	Number of farmers	Madhubani (Rs/kg)	Bhojpur & Nawada (Rs/kg)	Mean WTP (Rs/kg)	Standard deviation
Group 1	Zinc deficient, shown SHC	82	42.5	41.8	42.3	21.2
Group 2	Zinc deficient, not shown SHC	81	41.2	44.4	42.2	21.0
Group 3	Zinc sufficient	176	43.7	40.4	41.7	20.3
Group 4	Control farmers	67	-	37.5	37.5	26.7
Total		406	42.8	41.0	41.2	21.7

Source: Authors.
Notes: DM = Becker-DeGroot-Marschak (BDM) valuation elicitation exercise; Rs = rupees; SHC = soil health card; WTP = willingness to pay.

Table 5.3 Comparison of WTP between subsample groups from BDM

T-tests of WTP	Detail	Difference in WTP (Rs/kg)	t-stat
Group 1 versus group 2	Value farmers place in information on deficiency contained in the SHC	0.096	0.030
Group 1 + 2 versus group 3	Value of information on deficiency vis-à-vis sufficiency	0.476	0.214
Group 1 + 2 + 3 versus group 4	Value of having any information at all	-4.424	-1.533

Source: Authors.
Notes: BDM = Becker-DeGroot-Marschak (BDM) valuation elicitation exercise; Rs = rupees; SHC = soil health card; WTP = willingness to pay.

Table 5.4 Determinants of WTP for zinc

Dependent variable	WTP for zinc (Rs/kg) (I)	(II)	(III)
Constant	42.54***	41.73***	41.73***
	(1.62)	(1.63)	(1.63)
North/south (south = 1)	-2.344		
	(2.16)		
Group 1		0.523	
		(2.89)	
Group 2		0.428	
		(2.91)	
Group 1 + 2			0.476
			(2.35)
Group 4		-4.196	-4.196
		(3.11)	(3.10)
Observations	406	406	406
Adjusted R^2	0	-0.002	0.001
Average WTP		41.2 Rs/kg.	

Source: Authors.
Notes: * Significant with 10 percent probability of Type I error; ** significant with 5 percent probability of Type I error; *** significant with 1 percent probability of Type I error. Standard errors in parentheses. Omitted dummy: group 3 (zinc sufficient). Rs = rupees; WTP = willingness to pay.

Did Farmers Understand the SHC?

In the first part of this section, we discussed farmers' explanations for over- or underapplication of various fertilizers. A comparison of their subjective beliefs about whether they had used more or less than the recommended dose of a given fertilizer with the actual difference shows no significant correlation, suggesting that farmers exhibited a poor awareness of the recommendations. Only 40 percent of the farmers who overapplied urea (that is, those farmers whose self-reported application was more than the recommended dose from the SHC) believed that they had used more than the recommended dose. Similarly, of the farmers who overapplied DAP and potash, only 16 percent and 4 percent, respectively, believed that they had used more of these fertilizers than recommended by the SHCs. In contrast, the results seem to suggest that farmers are more prone to believe they have underapplied these fertilizers.

We also carried out a telephone survey among treatment farmers in the course of the 2015 wheat cultivation season, not long after the SHCs were distributed, in order to further examine whether farmers understood the SHC recommendations issued to them. Treatment farmers were asked if they remembered whether their SHC recommended the use of some fertilizers that are less common in the study area, namely potash, zinc, and sulfur. These took the form of simple yes/no questions. The results of the phone survey show a very weak correlation between the actual recommendations and those recalled by the farmers. On average, 74–78 percent of farmers with nutrient-deficient soil correctly stated that the SHC recommended applying the relevant fertilizers. However, 67–68 percent of farmers with nutrient-sufficient soil wrongly stated that the SHC recommended applying the relevant fertilizers. Again, these results support the notion that farmers generally have a bias toward assuming that the SHCs recommended using more fertilizers.

In sum, these results suggest that a lack of understanding of the SHC is very prevalent. However, we also found that this gap can be rectified substantially by repetition of the SHC information in a more salient context. During the BDM exercise, zinc sufficiency/deficiency was specifically stressed to the farmers. In the follow-up telephone survey, farmers were asked (again) whether the SHC recommended that they apply zinc. Table 5.5 shows that in this instance, farmers were much better informed of the actual SHC recommendations: 81 percent of those with zinc-deficient soil correctly stated that the SHC recommended applying zinc, and only 8 percent of those with zinc-sufficient soil incorrectly stated that the SHC recommended applying zinc.

Table 5.5 Correspondence between farmers' memory of SHC and actual SHC recommendations (percent)

	Farmer's memory of SHC		
Actual SHC recommendations	**Zinc deficient**	**Zinc sufficient**	**Don't know**
Zinc deficient	81	3	16
Zinc sufficient	8	69	23

Source: Authors.
Note: SHC = soil health card.

Lack of Understanding or Lack of Trust?

Another potential explanation for the general lack of compliance with the SHC recommendations is a lack of confidence in the quality of the information received from the SHC, which may reflect a general lack of trust in external information sources. In the course of the endline survey, we asked farmers several trust questions, and we report the results in Table 5.6. While farmers reported that they trust their family (61 percent place a lot of trust in family members), they tend to mistrust information or recommendations given by strangers and extension workers (70 percent have little trust in extension agents or do not trust them at all).

Table 5.6 Respondents' trust in information sources (percent)

Trust level	Strangers	Extension agents	Family
No trust at all	17	13	5
A little trust	76	57	12
Quite a bit of trust	6	28	22
A lot of trust	1	2	61

Source: Authors.

As we saw above (Table 5.3), WTP for zinc among farmers with zinc-deficient soil was unaffected by whether they were shown the SHC prior to making their decision on how much to bid for zinc. Furthermore, farmers with zinc-sufficient soil (group 3) were willing to pay an amount similar to that of farmers whose soil was zinc deficient. We also saw above that soon after the valuation exercise, farmers were accurately aware of whether the SHC had indicated sufficiency or deficiency in zinc. To assess whether trust in the quality of this information can explain these results, we also asked farmers in the Madhubani district (a largely zinc-deficient region) to report their own assessment of the zinc status of their soils. The results, reported in Table 5.7, show that even though, as we saw above, most farmers were clearly aware of the SHC indication (Table 5.5), it seems that they preferred to ignore it: while 96 percent of the farmers with zinc-sufficient soil according to the SHC recommendations believed their soils to be zinc deficient, only 2 percent of those with zinc-sufficient soil believed their soils to be zinc sufficient. In other words, even when they are aware of the SHC contents, farmers seem to adhere to their own beliefs about the condition of their soils, a belief that tends to assume deficiency.

Table 5.7 Correspondence between farmers' self-reported knowledge of zinc sufficiency/deficiency and actual sufficiency/deficiency based on soil analysis

	Farmer’s knowledge		
SHC Recommendations	Zinc deficient	Zinc sufficient	Don't know
Zinc deficient	94%	0%	6%
Zinc sufficient	96%	2%	2%

Source: Authors.
Note: SHC = soil health card.

6. CONCLUSION

The government of India recently launched an ambitious program of providing SHCs based on individualized soil tests to promote balanced use of fertilizers in agriculture throughout India. The program is expected to deliver more than 145 million SHCs covering all plots and farmers in India, with farmers expected to receive a new SHC every three years. Implementing a program on this scale requires large amounts of funding and labor, not to mention technical capacity, and policy makers expect it to deliver large gains—a significant increase in crop yields, restoration of soil health, and a 25 percent reduction in fertilizer subsidies. These anticipated gains, however, will be realized only if the SHC recommendations influence farmers' fertilizer use.

To evaluate the feasibility of this program and test its potential effectiveness, we conducted a randomized controlled trial in three districts of Bihar in which we mimicked the operational approach of the government's SHC program. Our experimental approach enabled us to test whether farmers would change their fertilizer use pattern after receiving fertilization recommendations based on soil tests from their own farm plots. Our results suggest that farmers largely ignore the soil test results and fertilizer use recommendations contained in the SHCs. The impact of the SHCs on fertilizer application was insignificant, both for farmers who applied more than the recommended dose of fertilizers and for those who applied less. Thus, even farmers who could have saved money on fertilizers by following scientific recommendations did not do so. This suggests that credit or liquidity constraints are not a major reason for not attending to the scientific recommendations, and points toward informational factors as the primary culprit.

In order to understand the possible reasons behind this result, we undertook a series of additional exercises, including a BDM valuation elicitation exercise (in order to assess farmers' WTP for zinc) and short quizzes to test farmers' knowledge of the contents of the SHCs. These exercises revealed that most farmers did not trust the recommendations and therefore were not willing to change their existing practices. Many farmers believed that changing their fertilizer according to the SHC recommendations could lead to yield losses. Moreover, many farmers also struggled to internalize the soil test results and recommendations, despite receiving the SHC in their native language and having its contents explained to them in detailed, one-to-one sessions by trained personnel, which could reflect lack of interest or difficulty in absorbing information of this kind.

Our evidence from Bihar casts serious doubts on the ability of the ongoing soil card program to achieve its expected gains, at least in its current form. Our results suggest that the existing program potentially requires several modifications to become effective. First, we suggest rigorously testing different ways to inspire farmers' trust in the soil test results and fertilizer use recommendations. For example, making local input dealers a part of the soil testing program may help win farmers' trust because farmers often seek input dealers' advice on farming practices and technologies. Second, since many farmers struggle to understand and remember the information in the SHC, follow-up visits by trained extension agents to discuss the SHC results and recommendations may help increase compliance. Third, as previous research in this area has shown (Ward and Singh 2015), farmers are often risk averse. Farmers may benefit from some form of risk management that allows them to cover or transfer downside risks arising from altering their fertilizer application, which may encourage greater compliance with the scientific recommendations. We recommend using a series of randomized controlled trials to test a number of different approaches to making SHCs more effective tools for the promotion of balanced fertilizer use in Indian agriculture. Evidence generated from such experiments will help improve the soil testing program not only in India but also potentially in other parts of the world where imbalanced use of fertilizer is a serious problem.

REFERENCES

Arunachalam, P., G. P. Kannan, and M. Govindaraj. 2013. "Zinc Deficiency in Indian Soils with Special Focus to Enrich Zinc in Peanut." *African Journal of Agricultural Research* 8 (50): 6681–6688.

Awasthi, U. S. 1999. *Challenges to the Fertilizer Industry.* Fertilizer Industry Annual Review 22. Mumbai: The Amalgamated Press.

Bevis, L. E. M. 2015. "Soil-to-Human Mineral Transmission with an Emphasis on Zinc, Selenium and Iodine." *Springer Science Reviews* 31 (1): 77–96.

Duflo, E., M. Kremer, and J. Robinson. 2008. "How High Are Rates of Return to Fertilizer? Evidence from Field Experiments in Kenya." *The American Economic Review* 98 (2): 482–488.

———. 2009. *Nudging Farmers to Use Fertilizer: Theory and Experimental Evidence from Kenya*. Working Paper 15131. Cambridge, MA, US: National Bureau of Economic Research.

Gopikrishna, S. R. 2012. "Soil Health and Support Systems." *Economic and Political Weekly* 47 (29): 24–26.

Hanna, R., S. Mullainathan, and J. Schwartzstein. 2012. *Learning through Noticing: Theory and Experimental Evidence in Farming*. Working Paper 18401. Cambridge, MA, US: National Bureau of Economic Research.

India, Ministry of Agriculture and Farmers Welfare. 2015. *Operational Guidelines for Implementation of Centrally Sponsored Scheme: Soil Health Card*. New Delhi. http://agricoop.nic.in/imagedefault/GSHC3.pdf.

Indian Institute of Rice Research. 2011. "Rice Knowledge Management Portal." Accessed on April 8 2013. http://14.139.94.101/fertimeter/Soil%20Resources3.aspx.

Islam, M. 2014. *Can a Rule-of-Thumb Tool Improve Fertilizer Management? Experimental Evidence from Bangladesh.* Job Market Paper. Cambridge, MA, US: Harvard University.

Kibblewhite, M. G., K. Ritz, and M. J. Swift. 2008. "Soil Health in Agricultural Systems." *Philosophical Transactions of the Royal Society B* 363: 685–701.

Kumar, N. 2014. "Roadmap to a Nutrition Secure Bihar." Keynote speech at the IFPRI-ANSISS workshop, "A Food Secure Bihar: Challenges and Way Forward," New Delhi, August 6.

Lal, R., and B. A. Stewart. 2010. *Food Security and Soil Quality.* Boca Raton, FL, US: CRC Press.

Narendra, M. Narendra Modi Twitter post. December 4, 11:11 p.m. https://twitter.com/narendramodi.

Mohan, S. 2014. "Govt Plans 'Soil Health Cards' for All Farmers." *Times of India*, June 17. http://timesofindia.indiatimes.com/india/Govt-plans-soil-health-cards-for-all-farmers/articleshow/36689371.cms.

Mujeri, M. K., S. Shahana, T. T. Chowdhury, and K. T. Haider. 2012. *Improving the Effectiveness, Efficiency, and Sustainability of Fertilizer Use in South Asia*. Global Development Network Policy Research Paper 8. New Delhi: Global Development Network.

Ongley, E. D. 1996. *Control of Water Pollution from Agriculture*. Irrigation and Drainage Paper 55. Rome: Food and Agriculture Organization of the United Nations.

Roosevelt, F. D. 1937. "Letter to All State Governors on a Uniform Soil Conservation Law." In *The American Presidency Project,* compiled by G. Peters and J. T. Woolley. www.presidency.ucsb.edu/ws/?pid=15373.

Singh, M. V. 2008. *Micronutrient Fertility Mapping for Indian Soils*. Bhopal: Indian Institute of Soil Science.

Ward, P. S., and V. Singh. 2015. "Using Field Experiments to Elicit Risk and Ambiguity Preferences: Behavioural Factors and the Adoption of New Agricultural Technologies in Rural India." *Journal of Development Studies* 51 (6): 707–724.

Watts, H., and M. Sally. 2014. "Cost of Cultivation Will Come Down When Farmers Get Educated, Says Agriculture Minister Radha Mohan Singh." *The Economic Times,* September 12. http://articles.economictimes.indiatimes.com/2014-09-12/news/53851093_1_soil-health-Urea-subsidy-farmers.

RECENT IFPRI DISCUSSION PAPERS

For earlier discussion papers, please go to www.ifpri.org/pubs/pubs.htm#dp.
All discussion papers can be downloaded free of charge.

1516. *Pakistan's fertilizer sector: Structure, policies, performance, and impacts.* Mubarik Ali, Faryal Ahmed, Hira Channa, and Stephen Davies, 2016.

1515. *Agriculture-nutrition linkages and child health in the presence of conflict in Nepal.* Elizabeth Bageant, Yanyan Liu, and Xinshen Diao, 2016.

1514. *"As a husband i will love, lead, and provide": Gendered access to land in Ghana*. Isabel Lambrecht, 2016.

1513. *Formal versus informal: Efficiency, Inclusiveness, and financing of dairy value chains in India.* Pratap S. Birthal, Ramesh Chand, P. K. Joshi, Raka Saxena, Pallavi Rajkhowa, Md. Tajuddin Khan, Mohd Arshad Khan, and Khyali R. Chaudhary, 2016.

1512. *Measuring women's disempowerment in agriculture in Pakistan*. Nuzhat Ahmad and Huma Khan, 2016.

1511. *The impact of conditional cash transfer programs on indigenous households in Latin America: Evidence from PROGRESA in Mexico*. Esteban J. Quiñones and Shalini Roy, 2016.

1510. *Why some are more equal than others: Country typologies of food security.* Eugenio Díaz-Bonilla and Marcelle Thomas, 2016.

1509. *Empowerment and agricultural production: Evidence from rural households in Niger.* Fleur Wouterse, 2016.

1508. *Is access to tractor service a binding constraint for Nepali Terai farmers?* Hiroyuki Takeshima, Rajendra Prasad Adhikari, and Anjani Kumar, 2016.

1507. *Determinants of chemical fertilizer use in Nepal: Insights based on price responsiveness and income effects.* Hiroyuki Takeshima, Rajendra Prasad Adhikari, Basu Dev Kaphle, Sabnam Shivakoti, and Anjani Kumar, 2016.

1505. *Volatile volatility: Conceptual and measurement issues related to price trends and volatility.* Eugenio Díaz-Bonilla, 2016.

1504. *Changes in Ghanaian farming systems: Stagnation or a quiet transformation?* Nazaire Houssou, Michael Johnson, Shashidhara Kolavalli, and Collins Asante-Addo, 2016.

1503. *Returns to agricultural public spending in Ghana: Cocoa versus Noncocoa subsector.* Samuel Benin, 2016.

1501. *Challenges in implementing a small-scale farmers' capacity-building program: The case of the food production, processing, and marketing project in the Democratic Republic of Congo.* Catherine Ragasa, Ephraim Nkonya, John Ulimwengu, and Josée Randriamamonjy, 2016.

1500. *Leveling the field for biofuels: Comparing the economic and environmental impacts of biofuel and other export crops in Malawi.* Franziska Schuenemann, James Thurlow, and Manfred Zeller, 2016.

1499. *Farm transition and indigenous growth: The rise to medium- and large-scale farming in Ghana.* Nazaire Houssou, Antony Chapoto, and Collins Asante-Addo, 2016.

1498. *The impact of agricultural extension services in the context of a heavily subsidized input system: The case of Malawi.* Catherine Ragasa, John Mazunda, and Mariam Kadzamira, 2016.

1497. *Ghana's macroeconomic crisis: Causes, consequences, and policy responses.* Stephen D. Younger, 2016.

1496. *Temporary and permanent migrant selection: Theory and evidence of ability–search cost dynamics.* Joyce J. Chen, Katrina Kosec, and Valerie Mueller, 2015.

1495. *The effect of insurance enrollment on maternal and child healthcare use: The case of Ghana.* Gissele Gajate-Garrido and Clement Ahiadeke, 2015.

1494. *Stories of change in nutrition: A tool pool.* Stuart Gillespie and Mara van den Bold, 2015.

1493. *Optimal tariffs with smuggling: A spatial analysis of Nigerian rice policy options.* Michael Johnson and Paul Dorosh, 2015.

1492. *Smallholders and land tenure in Ghana: Aligning context, empirics, and policy.* Isabel Lambrecht and Sarah Asare, 2015.

1491. *Returns to agricultural public spending in Africa South of the Sahara*. Samuel Benin, 2015.

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

www.ifpri.org

IFPRI HEADQUARTERS

2033 K Street, NW
Washington, DC 20006-1002 USA
Tel.: +1-202-862-5600
Fax: +1-202-467-4439
Email: ifpri@cgiar.org

IFPRI NEW DELHI

NASC, DPS Road, Opp Todapur, Pusa
New Delhi 110-012 India
Tel.: 91 11 2584-6565
Fax: 91 11 2584-8008 / 2584-6572
Email: ifpri-newdelhi@cgiar.org