Understanding Technology Adoption: Fertilizer in Western Kenya
Preliminary Results from Field Experiments
(EXTREMELY PRELIMINARY AND INCOMPLETE)
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1. Introduction

Maize is the staple food in most of Eastern and Southern Africa. Although a relatively new crop, the production of maize has expanded so fast that maize has become the dominant food crop in that region. In Kenya, maize accounts for 80% of the national production of cereals (Hassan 1998, p.164) and provides 40% of calorie consumption for Kenyans who consume more 125 kilograms of maize per person each year (Byerlee, 1997 p.16).

Maize is also a crop which has been subject to relatively successful technological improvements such as the use of fertilizer and new hybrid seeds. In developing countries outside of Africa, the use of fertilizer accounted for 50-75% increase in the crop yields from the mid 1960s (Viyas, 1983). Many believed that this new technology in maize production with its high-yield potential would lead Africa to replicate the success of Asia's Green Revolution. However, this hope did not materialize. Fertilizer use in Africa is still very low and has been stagnating since the 1980s.

Meanwhile, with rapid population growth, Africa can no longer be viewed as a land-abundant region where food crop supply could be increased by the expansion of land used in agriculture (Byerlee, 1997). Large areas in Africa are marginal for agriculture and arable land is scarce in many African countries. One of those countries is Kenya, which surpasses major Asian countries in intensity of land use (Binswanger and Pingali 1988). This makes the need for intensification of land use through the use of land-saving technologies such as fertilizer, critical for achieving food security. Yet, the rate of increase in fertilizer use has been substantially lower than in Asia and Latin America (Byerlee, 1997).

In rural Western Kenya, the Ministry of Agriculture recommends the use of hybrid seeds and fertilizer to increase maize yields. This recommendation is based on evidence from experimental farms that fertilizer substantially increases yield. However, according to surveys we have conducted over several years with a random sample of farmers, just 40.3% of farmers had ever used fertilizer, and just 31.6% had used fertilizer in the year prior to the survey. This paper seeks to understand why so many people do not use fertilizer even though it appears to have the potential to improve yields considerably, thus improving poor farmers' lives as well as improving food security in the country.

Models of technology adoption in agriculture suggest three broad categories of explanations. First, fertilizer may not be appropriate in this region. Second, it may be appropriate, but farmers either do not know it, or do not know how to use fertilizer. There may be an inefficiently low level of experimentation if there are externalities in learning. Finally, there is the issue of financing profitable investments. As technology adoption, information acquisition and diffusion, and the financing of investments are all fundamental questions in development economics, the lessons from this project have the potential to extend far beyond the specific example of fertilizer.

In this project, we employ a series of randomized field trials to investigate several hypotheses that might explain why farmers do not use fertilizer: fertilizer is not profitable given the conditions on real farms; it is profitable but farmers do not know how to use it, or do not know how profitable it is; or, farmers have difficulty financing the investment, perhaps because they are unable to save.

In a series of randomized field experiments, we have explored these three hypotheses. Our main results suggest that: (1) fertilizer is profitable; (2) providing information goes part of the way towards increasing fertilizer adoption, and part of the low fertilizer adoption may be explained by the complete absence of diffusion of technological innovation; but (3) programs that help the farmers commit at the point where they have money to use fertilizer in the future also have a large impact on future fertilizer adoption.

This project has taken place in Busia, a relatively poor rural district in Western Kenya. The majority of Busia district is classified as a moist mid-altitude agro-ecological zone and maize is the main staple food. Soil fertility is low and the Kenyan Agricultural Research Institute and Ministry of Agriculture recommend use of fertilizer.

Since the summer of 2000, International Child Support (ICS), a Dutch NGO which has been working in Busia district for ten years, has conducted a series of small-scale pilot programs in order to understand the barriers to fertilizer adoption for farmers growing maize. In order to evaluate the impact of these programs, beneficiaries were randomly selected and data was collected. While the experiments have already been completed, the last wave of data collection is currently ongoing; this paper presents the experiments and the results that have been obtained so far, as well as some open questions.

A. Fertilizer is profitable

A natural hypothesis to explain the low level of adoption of fertilizer is that it is not a profitable investment for the average farmer. While agricultural experts have found that fertilizer greatly increases yield in test plots, it may not be profitable if it requires substantial investment in complementary inputs, is difficult to use in real-world situations, or cannot easily be used by typical farmers. For example, Foster and Rosenzweig (1995) found that uneducated farmers have negative profits in the first year they adopted HYV seeds. Beginning in the summer of 2000, a series of 6 pilot projects (over 3 years) were designed to ascertain the profitability of fertilizer in the actual conditions experienced by farmers.

ICS first randomly selected 30 farmers from a list of parents of students enrolled at local schools.[1] At each farmer's farm, a field officer from ICS measured 3 adjacent 30 square meter plots (this is a very small fraction of a typical farm). One plot was randomly assigned to receive Calcium Ammonium Nitrate (CAN) fertilizer to be applied as top dressing (when the plant is knee high). On the second plot, hybrid seeds were used instead of traditional varieties and Di-Ammonium Phosphate (DAP) fertilizer was supplied for planting along with CAN for top dressing. The latter combination is the full treatment recommended by the Ministry of Agriculture. The third plot was a comparison plot on which farmers farmed as usual with traditional seeds and with no fertilizer. ICS paid for the cost of the extra inputs (fertilizer and hybrid seed) and ICS field workers applied fertilizer and seeds with the farmers, followed the farmers throughout the growing season, harvested with them, and weighed the maize yield from each plot. Aside from these visits, the farmers were instructed to farm their plots just as they would have otherwise. Interviews with the farmers and field observation suggest that they did this.

[1] Comprehensive lists of households of this area are not available but fertility and primary school enrollment rates in this area are both high, so while this is not a representative sample it should not be that atypical either.

At the end of a growing season, the maize was harvested, dried, and weighed with the farmer. In order to calculate the value of the extra maize from the treatment plot, it was necessary to take some care in measuring the yield. After maize is harvested, it must be dried and shelled, and the kernels must be left to dry for several days before it is ready for consumption or for sale in the marketplace. In later pilots, we attempted to determine the amount of weight that is lost as the maize dries by offering farmers incentives to carefully dry their harvested maize at their home. We then returned to measure the weight of the dried kernels and the ratio of the weight of the dry kernels to the weight at harvest and used these figures to calculate estimates for the earlier pilots.

The program was continued for the next five growing seasons, with small differences from season to season. After the second pilot, ICS stopped using full treatment, and the amount of top dressing fertilizer used per hole varied from season to season. Most notably, some pilots used ½ teaspoon per hole, and others used 1 teaspoon, since the Kenya Agricultural Research Institute recommends 1 teaspoon per hole (KARI, 2000), while other authorities recommend ½ teaspoons or even less (Salasya, et al., 1998; Ouma, et al., 2002). In the fifth and sixth pilots, different quantities of fertilizer were used on different plots. The size of the demonstration plots also varied from pilot to pilot.

In total, six pilot projects were conducted over three years (Kenya has two growing seasons per year), with sample sizes ranging from 29 to 97 farmers. Surveys suggest that there were no differences in farmer-provided inputs, including labor inputs, such as time spent weeding, between the plots.

Table 1 presents the mean and median rate of return obtained for each farmer by taking the difference between the value of the output of the treated plot and the value of the output for the comparison plot, and dividing by the cost of the inputs. Because the price of maize fluctuates considerably during the season and the price of fertilizer does not seem to, the calculations below are done for two prices, 25 Kenyan shilling (Ksh) per goro/goro (a volume measurement which is used for measuring maize at the market), which is the price at harvest, and 40 Ksh per goro/goro which is the price of maize at its maximum price over the season. These figures are based on local prices during the three years ICS has been collecting data, but these numbers are consistent with a much longer historical time series of prices in Nairobi and in cities closer to Busia.

Even at the conservative estimate of 25 Ksh per goro-goro fertilizer yields an average return of 39.6% to ½ teaspoon of top dressing fertilizer per hole over a 4-month period (280% annualized). The valuation of 40 Ksh per goro-goro yields an average return of 123.4% for a 13-month investment (110% annualized). These preliminary results suggest that using the correct amount of top dressing fertilizer is quite profitable, so that low rates of usage cannot be explained purely by unsuitability to African soils, as suggested by Voortman et al. (2000).

In contrast, the official full package recommended by the Ministry of Agriculture is actually unprofitable on average, largely because the seeds may not germinate, causing a complete failure (recall that top dressing is applied only after seeds have germinated). Moreover, the rate of return to 1 teaspoon of top dressing fertilizer is consistently less profitable than ½ teaspoon, which suggests that an important part of the learning process is the amount of fertilizer to be used. This suggests that Jovanovic and Nyarko's (1996) target input model of technology adoption, which is also the model employed by Foster and Rosenzweig (1995) is a good framework to model learning and adoption. This is an environment in which learning *how* to use fertilizer may be as important as learning about rates of return, and therefore an environment where we could see learning by doing as well as learning from others. There is also considerable variability in the rate of returns to fertilizer.

B. Learning

The extent to which people learn from each other is a central question in development economics. In particular, the diffusion of new technologies through social networks (neighbors, friends, etc.) has been and continues to be intensively studied (see Munshi (2005) for a recent review of the work in the area). The impact of learning on technology adoption in agriculture has been studied particularly extensively. Besley and Case (1994) show that in India, adoption of HYV seeds by an individual is correlated with adoption among their neighbors. While this could be due to social learning, it could also be the case that common unobservable variables affect adoption of both the neighbors. To partially address this problem, Foster and Rosenzweig (1995) focus on profitability. During the early years of the green revolution, returns to HYV were uncertain and dependent on adequate use of fertilizer. In this context, the paper shows that profitability of HYV seeds increased with past experimentation, by either the farmers or others in the village. Farmers do not fully take this externality into account, and there is therefore underinvestment. In this environment, the diffusion of a new technology will be slow if one neighbors' outcomes are not informative about an individual's own conditions. Indeed, Munshi (2003) shows that in India, HYV rice, which is characterized by much more varied conditions, displayed much less social learning than HYV wheat.

All these results could still be biased in the presence of spatially correlated profitability shocks. Using detailed information about social interactions, Conley and Udry (2005) distinguish geographical neighbors from “information neighbors”, the set of individuals from whom an individual neighbor may learn about agriculture. They show that pineapple farmers in Ghana imitate the choices (of fertilizer quantity) of their information neighbors when these neighbors have a good shock, and move further away from these decisions when they have a bad shock. Conley and Udry try to rule out that this pattern is due to correlated shocks by observing that the choices made on an established crop (maize-cassava intercropping), for which there should be no learning, do not exhibit the same pattern.

All these papers try to solve what Manski (1993) has called the “reflection problem”: outcomes of neighbors may be correlated because they face common (unobserved) shocks, rather than because they imitate each other. This problem can be solved, however, with an experimental design in which part of a population is subject to a program that changes their behavior. The ideal experiment to identify social learning is to exogenously affect the choice of technology of a group of farmers and to follow subsequent adoption by themselves and their neighbors, or agricultural contacts.

The current setup is ideal to test the proposition that lack of information about either the rate of return to fertilizer, or its proper use, discouraged the farmers from using fertilizer, as well as the strength of network effects: since the farmers participating in each pilot were randomly selected from the parents of a school list, participating in the trials is randomly assigned within a school, and parents from the same schools that were not selected form a control group. Moreover, by comparing the “contacts” of the treatment farmers to the “contacts” of the comparison farmers, we can investigate whether knowledge is transmitted within networks.

B1. The trials as agricultural extension

The trials can be thought of as a particularly intense form of agricultural extension. After the harvest, we discussed the results of the experiment in detail with each farmer, and helped him to work through a calculation of costs and benefits of using fertilizer, using his own data as well as the data for all the farmers who participated in the trials. If the farmers lacked information either about costs or about the proper way to use fertilizer, this intervention should have provided that to them.[2]

After each pilot, we have been following each farmer to see if he chose to use fertilizer or any other inputs on his own in subsequent seasons. Table 2 presents the results. Panel A present the results without control variables, while panel B present the results controlling for school and gender. The odd columns show the effect of participating in the pilot program on fertilizer adoption, while the even column shows the effects on adopting either fertilizer or hybrid seeds. The results are presented for up to 3 seasons following the pilot. Adoption is about 10 percentage points (or 57%) higher the season after the pilot, and the effect drops to zero the following season: Farmers seem to have been convinced use of fertilizer, but the impact is short lasting.

B.2 Learning by doing

The trials gave the farmers the opportunity to experiment with fertilizer in their own farm, but it also provided them with additional inputs: the fertilizer was applied with an ICS field officer, who also visited the farmers regularly, and who helped them compute their rate of return and gave information on results obtained by others at the end of the intervention. To distinguish the effect of learning by doing from the effect of the additional information provided, ICS implemented two separate programs in different samples.

The first program was designed to evaluate the impact of learning by doing. In this program, each farmer was provided with a “starter kit”, consisting of a small quantity of fertilizer or fertilizer and hybrid seeds (for a sub-sample) sufficient for a 30-square-meter plot. Farmers were instructed that the kit was sufficient for this amount of space, and were given twine to measure two plots of the relevant size. Beyond this, there was no monitoring of whether or not (and how) the farmers used the starter kit. Starter kits have been used elsewhere; for instance, the Malawian government distributed 2.86 million such packs beginning in 1998 (Masters et al., 2000). In the ICS program, field staff explained how to use the inputs but did not formally monitor or measure the yields.

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[2] We have collected data on farmers’ belief about fertilizer costs and benefits both in treatment and comparison groups. The analysis of this data is not yet complete, however.

Fertilizer adoption for this group is shown in Table 3. Fertilizer use was 7 percentage points higher among starter-kit farmers in the year after the program, and they were 11 points more likely to use either fertilizer or hybrid seeds. The effects about as large as those of the on-farm trials, and moreover, they are more persistent. Farmers who were given starter kits were still 10% more likely to use fertilizer the next season.

In this sample, which remains limited, starter kits therefore appear to be as effective as on-site agricultural extension. To test whether the impact of starter kits is robust when starter kits are distributed in a "mass" scale, ICS has distributed starter kits to all parents of one randomly selected class in 16 randomly selected schools (this program was coupled with a demonstration program that will be described below). We do not yet have the data on adoption of fertilizer or seeds of those who received a starter kit for the following season.

B.3 Learning by Watching

The other component of the agricultural trial was regular contact with a field officer who demonstrated how to use fertilizer, and guided the farmers through computation of rate of returns for themselves and for other farmers in the same area. To evaluate the impact of this component, in two of the trials, ICS asked the farmer to name 3 people with whom they regularly discuss agriculture. They then invited one farmer randomly selected from this set to the key stages of the trial (notably, planting, harvest, and the discussion of profitability).

The impact on subsequent adoption of fertilizer amongst these farmers is presented in Table 4. The first two columns compare the adoption of fertilizer of the farmers who were invited to watch the trial on their friend's farm to adoption among other contacts of the pilots and contacts of the comparison farmers. After one season, adoption of some treatment is 10 percentage points higher in the first group (with school controls). This suggests that the effect of watching a demonstration on someone else's plot is as large as the effect of experimenting on one's own plot. It is possible to learn from others.

Based on these results, ICS experimented with a school-based demonstration intervention. They randomly selected 8 of 16 schools for this treatment. In those 8 schools, they selected one grade, and they invited all the parents to participate on a demonstration plot on the school ground (schools have typically space to grow a small maize farm). The demonstration followed the same protocol as the demonstration on the pilot farm: 2 plots were set up (though they were significantly larger than the previous demonstration plots), and one of them received fertilizer. Parents of this grade, and of one randomly selected grade in the next school, also received a starter kit at the beginning of the next season.

The results on these experimental plots were disappointing, however: in many cases, the maize was not properly taken care of, and in some plots the crop was entirely destroyed (by animals) or stolen. Even in plots that were harvested, the returns to fertilizer were low. As a result, the plots had negative returns for most of the 8 plots. At the post-harvest de-briefing, parents were told that the returns on their plot and that of the other school in this season were negative, but that other trials conducted in the area had shown positive results.

Nevertheless, one season later, ICS field officers collected adoption data among the parents of these schools. The results are shown in table 5, column 1: parents who have a child in class selected for the demonstration plot are actually *less* likely to adopt than those who are not (when the school is controlled for). Though this coefficient is insignificant, it suggests that parents may have actually learnt from the experiment, that using fertilizer may not be as good as they expected

This also suggest that while agricultural trials may be effective in diffusing information, on-farm agricultural trials are expensive, while community based trials may not deliver expected results. This implies that trials may not be a cost effective to diffuse technology, unless these technology diffuses rapidly once it is introduced. This is what we turn to now.

B.4 Learning from others

We studied diffusion, by following both the neighbors (geographical network) and the people named as agricultural contacts (actual network) of the pilot and the comparison farmers. Diffusion of agricultural technology has been studied before (Foster and Rosenzweig, 1995; Munshi, 2004; Udry and Conley, 2005), but this setup allows us to provide experimental evidence that does not suffer from omitted variable or simultaneity bias.

Table 6 shows the results for agricultural contacts (panel A) and neighbors (panel B). In each of these panels, we compare the friends (or the neighbors) of the pilot farmers with the friends (or the neighbors) of the comparison farmers. Panel A shows no evidence of the diffusion of the use of fertilizer: The difference between the friends of the pilot farmers and the friends of the comparison farmers is 3.6% for fertilizer without control for school dummies, and very close to 0% with school dummies. Panel B's result is even more surprising: There seems to be a negative and significant impact of being the neighbor of a pilot farmer on the probability for adopting fertilizer in the year of the adoption. However, this result loses significance when introducing school dummies, and it is restricted to the neighbors of only one set of pilot farmers. It may therefore not prove robust.

These results do suggest that farmers do not discuss much about agriculture: if they did, they would probably be able to learn from each other's experience, as the other experiments show. To verify this, we interviewed farmers about their neighbors and cross-checked their answers. Indeed, there seems to be considerable uncertainty regarding the activities of the neighbors: 39% farmers agree about whose harvest was better. Only 46% of farmers correctly state when their neighbor planted. Pilot farmers and their neighbors do not have more accurate information about each other than comparison farmers and their neighbors

Overall, what may be surprising about these effects is that all the learning effects are quite small: adoption increases from 18% to 28% the season after a pilot, and then moves back to where it was. There is no diffusion to the neighbors, though we have shown that this does not stem from an inability to learn. It seems that something else is preventing farmers to adopt fertilizer.

C. Savings, Commitment, and Reminders

C.1 Pilot Programs

These results suggest that knowledge both about how to use fertilizer and the returns to fertilizer are a factor in future adoption. However, even after participating in the experiment, more than half the farmers do not use fertilizer. A possible explanation is that farmers are unable to save the money they need to buy fertilizer, despite their desire to do so. This suggests that a savings mechanism in which to hold their money could help them invest in agricultural inputs. To explore this issue, we set up the Savings and Fertilizer Initiative (SAFI) in 2001, a program which provides a commitment device for those farmers who wanted to use fertilizer.

The main idea behind the SAFI program is that farmers would like to use fertilizer, but do not have the money on hand when fertilizer is needed (at planting or top dressing). The general principle of the SAFI program is that the farmer is visited right after harvest (when maize and, potentially, money is relatively plentiful), and is offered the option of purchasing a voucher for fertilizer. ICS then delivers the fertilizer at the time of planting. The program is therefore a commitment device, akin to a 401(k) program. We have tried out several variants of the program, in order to distinguish the role of the commitment device from other services the program may offer. Table 7 presents the take up of various versions of the program.

In the first version of the program (SAFI 2), a group of farmers were randomly selected, and visited right after harvest. They were visited twice, once to ask them whether they wanted to participate in the program, and one other time, a few days later, to collect the money. Sixty-six percent of the farmers expressed interest, and 22.6% eventually purchased fertilizer. In the subsequent versions of the program (SAFI 3, 4, and 5), we combined SAFI with the pilot program: pilot farmers were asked whether they wanted to use some of the maize that they had just harvested to purchase fertilizer. Moreover, in SAFI 4, we had asked them to sell us part of their harvest anyway. In either case, we asked them to make a decision and give us the money right away, so that they had no chance to procrastinate.

The take up of SAFI 3 and 4 was very high: Among those who were offered SAFI 3 or 4, over 80% of farmers did indeed purchase fertilizer. The interpretation of these results is complicated by two facts. SAFI 3 was offered only to farmers who had done particularly well in the experiments (we therefore need to compare take up of fertilizer between farmers who were offered SAFI and those who were not among those who had done well in the experiment). For SAFI 4, all Pilot 4 farmers were asked to sell part of their maize anyway: farmers may have been happier to hold on to maize than to hold on to cash, if they thought that cash was more likely to be dissipated rapidly. Nevertheless, these results are quite striking, and do suggest that the farmers make use of the commitment device, at least when they have an unexpectedly high harvest or an extra amount of cash available.

We offered the SAFI program again in the following year to a subset of the farmers who had been offered SAFI 4. They still had the option of selling us maize to buy fertilizer. However, since they were not compelled to sell maize for some other reason, they were left the option of taking a few days to collect the money. The take up of SAFI 4 exhibits the same pattern as the take up for

SAFI 2: Most (81.8%) of the farmers initially expressed interest, but after a few days, only 30% eventually purchased for fertilizer. This is still substantially higher than the fraction of farmers who are using fertilizer in the control group, which suggest that, even if all the farmers who were going to use fertilizer anyway purchased fertilizer from us, the program increased the fraction of people who are using fertilizer.

SAFI 5 explicitly explored the value of the commitment device. All Pilot 5 farmers were asked to sell a small quantity of maize for the experiment. They were then divided into three groups. The first group was offered the same program as before: They had the option of buying fertilizer right away, paying either in cash or by selling maize. The second group were offered the program, but were told that we would come back in a few days to collect the money. The third group was asked whether they wanted us to come back at the time of top dressing with fertilizer that they would then pay for (either in cash or in maize). The contrast between the three groups is striking: In all cases, about 50% of farmers expressed interest in the scheme. However, the actual take up decreases from 50% when the money is collected on that day to 29% when the money is collected a few days later, to 0% when the money is collected at the time of top dressing.

The results from Pilot 4 suggested that individuals may be more willing to invest in fertilizer after harvest if they hold wealth in a liquid asset like cash instead of maize. Pilot 6 explored this issue further, by offering two SAFI variants. In the first, farmers were encouraged to sell their maize to ICS so that they would have more cash on hand; the second was of the standard SAFI variety. Seventy-one percent of those that were encouraged to sell maize took up SAFI compared to 50% of the standard SAFI group, suggesting that the cash had some effect on take-up.

Table 8 shows that these programs led to a net increase in fertilizer adoption (which is not surprising, since the average fraction of people who purchased fertilizer under the different program, 36% is higher than the number of people who use fertilizer in a given season). The average increase in the season where the SAFI program was offered (always one season after the pilot) is 16%, and strongly significant. Subsequent data collection suggest, furthermore, that this may be an underestimate: the fertilizer used under SAFI was not always used on the land of the respondent to the initial survey, and when it was used on the husband's or another wife's plot, the respondent is not always aware of what had actually happened. To address this problem, we are currently collecting data on all the plots of a household to address this problem.

However, as shown in table 8, the SAFI program has no lingering effect: it increases take up only in the year it was offered. Its effects seem to be closely linked to the financing.

C2. SAFI, Subsidy, and Free delivery

The results from the different take up suggest that SAFI was successful in encouraging fertilizer adoption. However, the samples in the different versions of SAFI were small and not necessarily comparable. We therefore set up, in conjunction with ICS, a large scale SAFI experiment conducted over two seasons.

The questions and hypotheses the experiments set out to answer or test were as follows, First, the main hypothesis is that SAFI leads to higher adoption because of the *timing* at which people are offered to buy fertilizer, not only because, by offering to deliver fertilizer at home, the NGO is strongly endorsing fertilizer or because the free deliver was convenient. And is timing is what matter, how does the elasticity of fertilizer purchase compare to that with respect to price?

Second, there are some questions which have to do with the design of SAFI: is SAFI more valuable when the individual as cash on hands? Does it vary with previous exposure to fertilizer? Does it vary if people can chose in advance the timing at which the offer should be made: are they sophisticated enough to request an early visit, rather than a late visit?

In order to answer this question, we set up a two-year large scale SAFI experiment in the 16 schools that form the treatment and the control for the subsidy program. The experiment started in the season following the demonstration plots experiment. In this season (the 2004 Long Rains), a simple SAFI program (no choice of timing, the offer is a take it or leave it offer) was offered to 244 farmers after stratifying by school and class (i.e. whether or not the farmer received a starter kit). As shown in Table 9, the results from this SAFI was very similar to those of earlier variants: farmers offered the SAFI used on average 13.5% more fertilizer in the season following the program.

In the following season (the 2004 Short Rains), the experimental design was more complex.

First, a set of farmers was asked to sell some maize at an increased price (“buy” condition)

SAFI was then offered to randomly selected farmers, stratifying by school, starter kit status, prior SAFI status, and “buy” status. Two kinds of SAFI were offered:

- No choice condition: the farmer must buy a voucher immediately if he wishes to participate (offered at harvest time)
- Choice condition: the farmer can decide *before harvest* when he would like the field officer to come back to offer the SAFI. The farmer could request that the field officer return at harvest, at planting, or at top dressing time.

In total, 417 farmers were offered SAFI in this program.

In addition, a set of farmers that were not sampled for SAFI were visited at planting time during the same (2004 Short Rains) season. These farmers were sampled using the same stratified sampling method as for SAFI and were offered fertilizer either at full price (but with free delivery) or at half price. Thus those offered fertilizer at full price were saved travel costs and were offered an implicit “endorsement” of fertilizer usage, while those offered fertilizer at half price were offered these incentives plus a subsidy on the price.

The main results of these interventions are summarized in Table 9. The average take up in the “visit” group (those offered fertilizer at planting time at full price) was 21%; that is, 21% of those visited at planting did buy fertilizer for planning. The average take up in the 50% “subsidy” group was 46.2%. The average take up in the SAFI group was 40.4%. The difference in take-up between those offered fertilizer at full price and the SAFI and subsidy groups is significant, but the average difference between SAFI and the 50% subsidy is not. This suggests that SAFI increases fertilizer purchase over and above “endorsement” and “convenience,” and that its effect on purchase of fertilizer is roughly equivalent to that of a 50% subsidy.

This result confirms that the timing of the SAFI offer is what makes it popular. One more result is important to understand the role that the offer of buying fertilizer at this particular moment for the farmer means: in the group that was asked before the harvest (in the lean season) whether and when the field officer should come back to sell them fertilizer, and if when at what time, the eventual purchase of fertilizer was *as large* as in the group that did not have the choice. This is because a large fraction of farmers (46.8%) in the choice condition asked the field officer to come back immediately after harvest. This suggest that the decision to buy fertilizer when the farmers were “flushed” do not correspond to an impulse purchased prompted by the cue given by the field officer. If this were the case and fertilizer were not purchase that the farmer know they would want to make, when visited before harvest they would ask the field officer to come back at planting, and would end up not purchasing fertilizer. In fact, they ask them to come early, and they do buy fertilizer when they come.

This could be a simple story of commitment device (such as the one told by Ashraf, Karlan and Yin (2004)). There is, however, a very puzzling fact lingering in the background: the farmers are asked when they want the fertilized to be delivered. In most cases, they want it right away (i.e. much before they will actually use it). This is reasonable, since they may not trust ICS to conserve their money for a long period of time, and fertilizer keeps well over a period of a few weeks. But given this, and the fact that they seem to know their limitation, why don't they buy fertilizer themselves right after harvest? It seems that a sophisticated farmers (which many seem to be) has the ability to do exactly what we did for them. Yet, almost nobody (even among the people who use fertilizer) buys fertilizer in advance.

We do not yet have a very good answer to this question. One possibility is that the farmers know they have an inconsistent time preference problem, but they procrastinate dealing with it, because they have to pay a small cost today, which they may be reluctant to do, precisely because they have time inconsistent time preferences. If this were the case, a small discount on the price of fertilizer today, but with a strong deadline (expiring shortly around harvest) would induce farmers to buy fertilizer at harvest time. We have tried this idea on a pilot basis, by distributing farmers in one school coupons to buy fertilizer at a 6 shilling (15%) discount. The coupons could be redeemed at any of the three stores in the villages. The take up of this program was quite high, at 29.8%. This suggests that the story we just told may be right. This also suggests a way to transform the SAFI program into a cost effective development intervention: while it is costly and logistically difficult to visit all the farmers exactly at the time of harvest, the coupons program would be relatively easy to generalize.

We have also visited a sample farmers at harvest time and reminded them that buying fertilizer at harvest time is possible, and that many farmers who want to use fertilizer do not end up doing it if they don't buy it at harvest time. This will tell us whether the only role of the SAFI program is to remind farmers of their time inconsistency problem: if the reminder intervention is as effective as SAFI, it will suggest that all SAFI is doing is to remind people to act now.

D. Conclusion

The problem of fertilizer adoption is both important in itself and because it embodies all the problems of technology adoption that we encounter in developing countries: from computers, to deworming drugs, to condoms. We have set up a series of randomized experiment to try to understand the determinants of fertilizer adoption. We conclude that while information matters, it only goes part of the way, and whatever information is provided seems to be forgotten fast and not diffused to friends and neighbors in the mean time. Other things seem important as well, in particular the ability to finance the purchase of fertilizer, which for many farmers, is synonymous with the ability to buy fertilizer at the time of harvest. We have seen that if farmers are offered to buy fertilizer at the time of harvest, many do, and this lead to substantial increases in adoption. We are still to resolve why they do not do it themselves, and why the market is not proactively seeking this opportunity.

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Table 1: Returns to Fertilizer

	Top dressing 1/4 teaspoon			Top dressing 1/2 teaspoon			Top dressing 1 teaspoon			Full treatment		
	mean	median	obs	mean	median	obs	mean	median	obs	mean	median	obs
Panel A: Not Annualized												
25 Ksh per goro-goro	0.108	-0.173	117	0.396	0.164	203	-0.254	-0.428	275	-0.476	-0.494	85
40 Ksh per goro-goro	0.772	0.322	117	1.234	0.862	203	0.194	-0.084	275	-0.161	-0.191	85
Panel B: Annualized												
25 Ksh per goro-goro	0.506	-0.533	117	2.799	0.835	203	-0.690	-0.893	275	-0.925	-0.935	85
40 Ksh per goro-goro	0.696	0.294	117	1.100	0.775	203	0.178	-0.078	275	-0.150	-0.178	85

Table 2: Adoption for Farmers Participating in Demonstration Plot

	1 season later		*2 seasons later*		*3 seasons later*	
Panel A. No Controls	(1)	(2)	(3)	(4)	(5)	(6)
	fertilizer	*any treatment*	*fertilizer*	*any treatment*	*fertilizer*	*any treatment*
Demonstration Plot Farmer	0.102	0.109	0.053	0.004	0.011	0.007
	(0.041)***	(0.045)***	(0.048)	(0.051)	(0.061)	(0.067)
Constant	0.176	0.237	0.197	0.251	0.16	0.213
	(0.022)**	(0.024)**	(0.025)**	(0.026)**	(0.029)**	(0.033)**
Observations	468	466	374	373	210	210
Panel B. Controlling for School and Gender (coefficients not shown)						
	(1)	(2)	(3)	(4)	(5)	(6)
	fertilizer	*any treatment*	*fertilizer*	*any treatment*	*fertilizer*	*any treatment*
Demonstration Plot Farmer	0.116	0.131	0.077	0.034	-0.002	0.002
	(0.043)**	(0.047)**	(0.050)	(0.052)	(0.065)	(0.073)
Observations	468	466	374	373	210	210

Standard errors in parentheses

* significant at 10%; *** significant at 5%; ** significant at 1%

Table 3: Adoption for Farmers Offfered Starter Kits

	1 season later		2 seasons later		3 seasons later	
Panel A. No Controls	(1)	(2)	(3)	(4)	(5)	(6)
	fertilizer	*any treatment*	*fertilizer*	*any treatment*	*fertilizer*	*any treatment*
Starter Kit Farmer	0.073	0.107	0.097	0.064	0.046	0.039
	(0.049)	(0.054)***	(0.044)***	(0.056)	(0.060)	(0.065)
Constant	0.155	0.194	0.037	0.11	0.159	0.205
	(0.035)**	(0.038)**	(0.030)	(0.038)**	(0.041)**	(0.045)**
Observations	252	252	157	157	166	166
Panel B. Controlling for School and Gender (coefficients not shown)						
	(1)	(2)	(3)	(4)	(5)	(6)
	fertilizer	*any treatment*	*fertilizer*	*any treatment*	*fertilizer*	*any treatment*
Starter Kit Farmer	0.044	0.082	0.107	0.072	0.04	0.035
	(0.049)	(0.054)	(0.045)***	(0.058)	(0.062)	(0.068)
Observations	252	252	157	157	166	166

Standard errors in parentheses

* significant at 10%; *** significant at 5%; ** significant at 1%

Table 4: Adoption for Agricultural Contacts Invited to Witness Treatment

	1 season later	
Panel A. No Controls	(1)	(2)
	fertilizer	*any treatment*
Invited Agricultural Contact	0.018	0.039
	-0.041	-0.044
Constant	0.211	0.26
	(0.023)**	(0.024)**
Observations	484	481
Panel B. Controlling for School and Gender (coefficients not shown)		
	(1)	(2)
	fertilizer	*any treatment*
Invited Agricultural Contact	0.091	0.103
	(0.051)*	(0.055)*
Observations	484	481

Standard errors in parentheses
* significant at 10%; *** significant at 5%; ** significant at 1%

Table 5: Adoption for Parents Sampled for School-Based Demonstration

	1 season later	
Panel A. No Controls	(1)	(2)
	fertilizer	*any treatment*
Parents sampled to participate on Demonstration Plots	0.037	0.026
	(0.035)	(0.038)
Constant	0.3	0.509
	(0.019)**	(0.020)**
Observations	866	866
Panel B. Controlling for School (coefficients not shown)		
	(1)	(2)
	fertilizer	*any treatment*
Parents sampled to participate on Demonstration Plots	-0.002	-0.004
	(0.046)	(0.048)
Observations	866	866

Standard errors in parentheses

* significant at 10%; *** significant at 5%; ** significant at 1%

Table 6: Adoption for Other Contacts of Demonstration Plot Farmers

	1 season later	
Panel A: Agricultural Contacts of Demonstration Plot Farmers		
No Controls		
	(1)	(2)
	fertilizer	*any treatment*
Pilot Friend (not invited to treatment)	0.036	0.025
	(0.046)	(0.050)
Constant	0.198	0.251
	(0.028)**	(0.030)**
Observations	336	334
Controlling for School and Gender (coefficients not shown)		
	(1)	(2)
	fertilizer	*any treatment*
Pilot Friend (not invited to treatment)	0	-0.034
	(0.063)	(0.067)
Observations	336	334
Panel B. Neighbors of Demonstration Plot Farmers		
No Controls		
	(1)	(2)
	fertilizer	*any treatment*
Pilot Neighbor	-0.144	-0.095
	(0.070)***	(0.075)
Constant	0.282	0.302
	(0.045)**	(0.048)**
Observations	143	144
Controlling for School and Gender (coefficients not shown)		
	(1)	(2)
	fertilizer	*any treatment*
Pilot Neighbor	-0.075	-0.035
	(0.081)	(0.087)
Observations	143	144

Standard errors in parentheses
* significant at 10%; *** significant at 5%; ** significant at 1%

Table 7: Take-up of Various Commitment Savings Products (SAFI Program)

option	description	safi2	safi3	safi4	safi4b	safi5	safi6	total
option 1: take-it-or-leave-it	offered SAFI		10			17	27	54
	initially accepted		9 (90 %)			8 (47.05 %)	13 (48.14 %)	30 (55.55 %)
	actually paid		9 (90 %)			8 (47.05 %)	13 (48.14 %)	30 (55.55 %)
option 2: take-it-or-leave-it	offered SAFI			35			14	49
(with cash effect)	initially accepted			29 (82.85 %)			10 (71.42 %)	39 (79.59 %)
	actually paid			29 (82.85 %)			10 (71.42 %)	39 (79.59 %)
option 3: return in a few days	offered SAFI				33	17		50
to collect the money	initially accepted				27 (81.81 %)	8 (47.05 %)		35 (70 %)
	actually paid				10 (30.30 %)	5 (29.41 %)		15 (30 %)
option 4: return in a few months	offered SAFI	53				18		71
to collect the money	initially accepted	35 (66.03 %)				9 (50 %)		44 (61.97 %)
	actually paid	12 (22.64 %)				0 (0 %)		12 (16.90 %)

Table 8: Adoption for Farmers offered SAFI Program

	1 season later		*2 seasons later*		*3 seasons later*	
Panel A. No Controls						
	(1)	(2)	(3)	(4)	(5)	(6)
	fertilizer	*any treatment*	*fertilizer*	*any treatment*	*fertilizer*	*any treatment*
Sampled for SAFI Program	0.169	0.164	0.069	0.066	0.016	0.15
	(0.060)**	(0.065)***	(0.078)	(0.074)	(0.095)	(0.099)
Demonstration Plot Farmer	0.052	0.062	0.036	0.007	-0.068	-0.089
	(0.050)	(0.055)	(0.056)	(0.058)	(0.080)	(0.092)
Constant	0.181	0.249	0.19	0.227	0.155	0.205
	(0.028)**	(0.031)**	(0.030)**	(0.032)**	(0.037)**	(0.045)**
Observations	421	421	303	318	136	158
Panel B. Controlling for School and Gender (coefficients not shown)						
	(1)	(2)	(3)	(4)	(5)	(6)
	fertilizer	*any treatment*	*fertilizer*	*any treatment*	*fertilizer*	*any treatment*
Sampled for SAFI Program	0.173	0.151	0.044	0.038	0.037	0.068
	(0.063)**	(0.067)***	(0.081)	(0.080)	(0.095)	(0.100)
Demonstration Plot Farmer	0.013	0.023	0.028	-0.008	-0.067	-0.146
	(0.052)	(0.055)	(0.059)	(0.060)	(0.083)	(0.094)
Observations	421	421	303	318	136	158

Standard errors in parentheses

* significant at 10%; *** significant at 5%; ** significant at 1%

Table 9: Adoption for Parents Sampled for SAFI (Long Rains 2004)

	1 season later	
Panel A. No Controls	(1)	(2)
	fertilizer	*any treatment*
Selected for SAFI	0.144	0.091
	(0.038)**	(0.041)***
Constant	0.279	0.496
	(0.018)**	(0.019)**
Observations	866	866
Panel B. Controlling for School (coefficients not shown)		
	(1)	(2)
	fertilizer	*any treatment*
Selected for SAFI	0.135	0.081
	(0.038)**	(0.040)***
Observations	866	866

Standard errors in parentheses
* significant at 10%; *** significant at 5%; ** significant at 1%

Table 10: Purchase of Fertilizer Through SAFI and Subsidy Programs, Short Rains 2004

	purchased fertilizer through program	
	(1)	(2)
Parent in Demonstration Plot School	-0.024	-0.025
	(0.049)	(0.050)
Offered SAFI for Long Rains 2004	-0.004	0.03
	(0.042)	(0.091)
Offered SAFI for Short Rains 2004	0.197	0.187
	(0.046)**	(0.069)**
Offered Subsidy for Short Rains 2004	0.255	0.307
	(0.055)**	(0.079)**
Bought Maize	-0.102	-0.081
	(0.043)***	(0.093)
Parent in Treatment Standard in Demonstration Plot School	0.129	0.132
	(0.057)***	(0.096)
SAFI LR04 * Subsidy		-0.118
		(0.128)
SAFI Long Rains 2004 * SAFI Short Rains 2004		-0.02
		(0.106)
Bought Maize * Subsidy		-0.133
		(0.131)
Bought Maize * SAFI Short Rains 2004		0.005
		(0.126)
Parent in Treatment Standard in Demonstration Plot School		0.048
* Subsidy		(0.127)
Parent in Treatment Standard in Demonstration Plot School		-0.014
* SAFI in Short Rains 2004		(0.105)
choice_safi_sr04		0.036
		(0.047)
Constant	0.207	0.192
	(0.046)**	(0.060)**
Observations	710	710

Standard errors in parentheses

* significant at 10%; *** significant at 5%; ** significant at 1%