Did you really get the message? Using text reminders to stimulate adoption of agricultural technologies

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Abstract
This paper provides evidence from a randomized control trial (RCT) conducted among potato farmers in Northern Ecuador about the impact of receipt of text message reminders on farmer knowledge about and adoption of integrated pest management (IPM) practices. The paper provides novel empirical evidence of the potential roles of reminders as post-training follow-ups in an agrarian setting. Using psychological constructs, we examine competing explanations for non-standard decision making such as low adoption of beneficial agricultural technologies. Farmers who received text messages have significantly higher knowledge scores and are more likely to adopt most IPM practices than those in the control group. The experiment provides evidences that text messages lead to behavioral changes by reducing inattention and sub-optimal heuristics in the case of complex decisions.

Keywords: Technology adoption, agricultural extension, information and communication technology, program evaluation

JEL codes: O13, Q12, Q13

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Introduction

A key challenge facing public agricultural extension in developing countries is how to change behavior in the most cost-effective manner. Messages delivered in-person or through mass media can stimulate adoption and spread of new agricultural technologies, particularly technologies where yield gains are not large or not immediately evident. Many extension systems in Latin America underwent substantial changes due to the debt crisis in the 1980s and structural adjustments in the 1990s. In Mexico, Brazil, Chile, Ecuador and other countries, centralized public agricultural extension systems were disbanded and extension services were either decentralized to local government or outsourced to projects and private providers. Relatively recent spikes in food prices combined with a growing awareness of the need to stimulate agricultural productivity to meet projected population needs in Latin America has renewed calls to reinvigorate agricultural extension services (Zeigler and Truitt Nakata, 2014).

Integrated pest management (IPM) is a system of practices to manage agricultural pests and diseases while minimizing use of harmful chemicals. Despite its demonstrated effectiveness at raising profitability and lowering environmental and health damages associated with chemical use, spread of IPM in developing countries has been slow (Parsa, et al., 2014). IPM is among a group of "orphan technologies" such as conservation agriculture where benefits are not directly visible through yield increases, may take a long time to emerge, or are diffuse. Orphan technologies do not attract private sector actors to promote them and often have to compete with more lucrative alternatives. For example, IPM technology faces direct competition from chemical sales agents where the profit motive is strong.

Parsa, et al. (2014) blame insufficient training and technical support as a basic cause of limited adoption of IPM; an institution is needed to champion the orphan technology. The complexity of some IPM practices has led to investment intensive training programs such as farmer field schools (FFS), but even these have not been associated with broad spread among non-participants (Feder, et al., 2004, Godtland, et al., 2004). Recent evidence shows that FFS are not generally effective when taken to scale (Waddington, et al., 2014). Despite extensive experimentation with alternative outreach measures, IPM adoption remains limited in many developing countries. As extension systems are reconstituted, cost-effective means of diffusing relatively complex orphan technologies such as IPM need to be identified.

Information and communications technology (ICT) offer the potential for low-cost delivery of extension messages. Evidence shows that access to cell-phone services affect outcomes such as choice of market (Jensen, 2007, Urquieta and Alwang, 2012), price dispersion and market efficiency (Aker, 2011, Aker and Fafchamps, 2014, Jensen, 2007). Access to cell-phone signals also has been shown to improve producer and consumer well-being (Aker, 2011). Cell-phones are now ubiquitous in developing countries and competition has driven the cost of text messages to near zero. This low cost invites the possibility of using text messages to deliver information, and the ease of randomizing recipients into treatment and control groups makes message-based measures appropriate for investigation using randomized control trials (RCTs).

The mechanism by which cell-phone technologies change farmer behavior is still not well-understood. The examples of impact mentioned above all result from push receipt of modest information content. But, cell-phones can also pull content. In Bolivia, for example, women use cell-phones to gather potato price information from different markets (Urquieta and Alwang, 2012); in India, cell phones are effective in gathering price information from spatially separated fish markets (Jensen, 2007). Cell-phones can be used to transmit simple messages, such as information about prices in markets, but evidence about their effective use to provide information about a complex technology such as IPM is more limited. Text messaging may be more limiting than telephone communications and use of SMS to stimulate behavioral change is limited by the inflexibility of the medium.

In agriculture, findings from RCTs about the effectiveness of text message programs to effect behavioral change depend on the context. In general, researchers have found that receipt of text messages influences a farmer's decision of where to sell crops, but, in India, market prices received by farmers who received text messages were not statistically significantly higher than prices received by control farmers (Fafchamps and Minten, 2012). Also in India, farmers randomly selected to participate in a mobile-based agricultural consulting service were more likely to use appropriate pesticides and fewer hazardous ones. Researchers found, however, that the while participating in the program promoted adoption of better agricultural practices, farmer's knowledge of these practices did not increase, suggesting that the farmers accepted the agricultural advice without understanding the evidence that substantiated it (Cole and Fernando, 2012). In Peru, farmers randomly selected to receive text messages with market price information received significantly higher prices for some crops. Statistically significant differences were found mainly for perishable crops, highlighting the importance of receipt of timely information and tailoring the message to the appropriate point in the season (Nakasone, 2013). In some contexts, receipt of text information has not had significant impacts on crop value-added, crop losses or likelihood of changing cultivation practices (Fafchamps and Minten, 2012). Improved yields were, however, associated with receipt of text messages in a study of sugar cane producers in Kenya (Casaburi, et al., 2014). In that study, the texts contained messages tailored to the specific timing of the farming operation.

The literature on effectiveness of text message receipt on different outcomes is nuanced. Karlan, et al. (2012) found that general text messages were not effective in increasing repayment rates for microfinance loans in the Philippines, but those with specific mention of the loan officer's name increased repayment significantly. Karlan, et al. (2016) found, in a three-country study, that the content of a text message affects the impact on increased savings among those enrolled in a commitment savings plan. Their study was designed to examine the mechanism by which message receipt induces behavioral change and they found that message receipt helped overcome the tendency to procrastinate and limited attention of savers.

In the health arena, text-based programs primarily use text messages as reminders for patients, though some also provide information. Programs include those for diabetes management, smoking cessation and increasing physical activity (Fjeldsoe, et al., 2009, Hurling, et al., 2007, Rodgers, et al., 2005). Text message programs have been found to be effective in improving health outcomes and increasing adherence to drug regimens (Da Costa, et al., 2010, Strandbygaard, et al., 2010, Vervloet, et al., 2012). The credibility of these assessments is furthered through the use of RCTs to cleanly identify the treatment effect. RCTs allow researchers to establish causal links between short-term positive behavioral outcomes and the receipt of text messages in the areas of smoking cessation, physical activity and diabetes treatment (Fjeldsoe, et al., 2009). For example, an RCT involving smokers in New Zealand used daily tailored text messages to encourage smoking cessation. Messages included advice, support and distractions. The messages proved effective in the short-term, with 28% of recipients reporting not smoking after 6 weeks, compared to 13% of individuals in the control. However there was no significant difference in the cessation rates of participants at the conclusion of the study at 26 weeks (Rodgers, et al., 2005).

Evidence shows that text messages are especially suitable for changing behavior through targeted, low-content messages, often in the form of reminders. In the context of orphan technologies, the issue is whether text messages can complement or substitute for more intensive training measures. Two questions are particularly salient: (i) Are text messages effective at increasing farmer knowledge? Or (ii) do they effect change by reminding farmers to do something? The psychology literature highlights the importance of different factors in leading to non-standard decision making; in the context of adoption of orphan agricultural technologies, farmers might be overwhelmed by the complexity of the decision or might, due to inattention, default to the familiar option (DellaVigna, 2007).

This paper provides evidence from an RCT conducted among potato farmers in Northern Ecuador about the impact of receipt of text message reminders on farmer knowledge about and adoption of IPM practices. The paper provides novel empirical evidence of the potential roles of reminders as post-training follow-ups in an agrarian setting. Our experimental design allows us to identify the role of reminders relative to knowledge gain in affecting use of IPM practices. We are able to distinguish between competing psychological explanations for the impacts of message receipt on adoption.

The paper is organized as follows. The next section presents a framework for disentangling the mechanisms by which text messages can change behavior. Different effects of reminder versus knowledge building are identified; these differences are later used to identify the relevant behavioral mechanism. The subsequent section discusses the field experiment and data. Empirical models and estimation results are presented next. The paper concludes with a discussion of implications and limitations.

Conceptual framework

In the context of decisions about agricultural management, consider the stylized model (DellaVigna, 2007, Rabin, 2002) where individual i at time t=0 maximizes expected utility from management decisions subject to a probability distribution p(s) of the states of the world:

$$max_{v_i^t} \sum_{t=0}^{\infty} \delta^t \sum_{s_t} p(s_t) U(v_i^t | s_t) \quad (1)$$

Utility is defined over the payoff (v) from management decisions at time t based on different states of nature and returns are discounted back to the decision period. DellaVigna (2007) discusses several deviations from this standard model associated with psychological constructs. These deviations include nonstandard preferences, nonstandard beliefs about the state of nature, and nonstandard decision making. Deviations of these sorts can lead to behavior that fails to conform to predictions of standard economic models. In the case of nonstandard decision making, people with utility U(v|s) and beliefs p(s) make decisions based on differences in how the decisions or options are framed, based on social pressure or on emotions. Two examples that are particularly germane to orphan technologies are decisions characterized by limited attention and use of sub-optimal heuristics when multiple options are available.

A simple model of attention as a scarce resource can be used to illustrate decision-making impacts of psychological phenomena (DellaVigna, 2007). Consider a management action whose value V (inclusive of cost of implementation) is determined by the sum of two components. The first component is visible and easily known and remembered by the decisionmaker (v). The second component, which is more opaque and requires more "effort" or "attention" to perceive, is called o. The total value of the management action is V = v + o. Inattention causes the producer to perceive the value as $V^* = v + (1 - \theta)\, o$, where $\theta \in [0, 1]$ reflects "inattention" of the decision maker. The parameter θ is interpreted as follows: each individual has the opportunity to see the opaque information, but processes it only partially, to the degree θ. Various factors affect θ, including salience $s \in [0, 1]$ of o and of the number of competing stimuli N: $\theta = \theta\,(s,N)$.

With a randomly assigned text message, the impact of inattention on decision making can be identified by experimentally varying o. By computing how the valuation V^* responds to a change in o; the derivative $\partial V^*/\partial o = (1 - \theta)$ can be compared to $\partial V^*/\partial v = 1$ to test for limited attention. This approach was followed by Hossain and Morgan (2006) and Chetty, et al. (2007). A second means of identification is by noting that v^t may be time-sensitive and we would expect that messages for time-sensitive operations that are timed to be delivered at the appropriate time would have a greater effect on valuation because the inattention parameter θ is itself time-sensitive. Define θ_t as the time-sensitive inattention parameter and θ as the time-insensitive parameter. For properly sequenced messages, we would expect $\partial V^{t*}/\partial o = (1 - \theta_t) > \partial V^*/\partial o = (1 - \theta)$, that is, time-sensitive inattention is lower than the time-insensitive variety, or, conversely, that a timely reminder provides more value when actions are time-sensitive.

The phenomenon of use of sub-optimal heuristics when decision makers are faced with a large menu of decisions has been commonly documented in the economics literature. The general finding is that more choices are, paradoxically, not welfare-improving for the decision maker. Responses to complex choice sets include excess diversification, preference for the familiar, and preference for the default option (see DellaVigna for references). IPM packages typically involve complex choices as producers face numerous pests, can manage them before or after they appear, and use labor- or capital-intensive control mechanisms (Norton, et al., 2005). Some practices require input purchases and, often, IPM-recommended inputs such as less toxic chemicals are not available. Practices requiring input purchases could be affected differentially by the presence of sub-optimal heuristics.

The presence of use of sub-optimal heuristics when IPM decisions are made will be examined as follows. First, decision makers with more IPM knowledge are less likely to be overwhelmed by complex choice sets and are, hence, less likely to choose the default option. Second, this knowledge effect is likely to be greater for complex compared to simple technologies; better-informed decision makers are likely to be more willing to adopt complex practices and employ practices requiring input purchases. Third, since the text message is intended to help sort out complex information (i.e. messages improve IPM knowledge) the effect of receipt of text messages on IPM use is likely to be less pronounced for more knowledgeable decision makers. Finally, the effect of receipt of a message is likely to have a smaller effect on adoption of simple compared to complex technologies. These propositions are formalized when the testing regime is presented below.

The experiment

Potato farmers in Carchi, Ecuador were invited to one of three day-long training sessions on IPM—a farmer field day (FFD). Invitation to the FFDs was generalized—the trainings were advertised using mass media, through word of mouth spread by employees of the Ministry of Agriculture, through local governments, and through NGOs working on agriculture in the Carchi area. During the FFDs, participants were exposed to different teaching stations where IPM practices for potatoes were demonstrated. Attendees also received an information workbook covering the main pests and their management. At the FFDs, half the participants were randomly selected to receive 2-3 text messages per week over a 10-week growing season providing further information and reminders about IPM practices. Eligibility for the message program included ownership of a cell-phone, ability to read text messages (basic literacy), and willingness to participate.

Messages were tailored to the time of the potato growing season based on the reported stage of the main potato crop at the time of the FFD. Some messages were intended to be reminders, others provided additional information. At times, the messages referred to a page in the information booklet. Baseline and follow-up surveys were fielded for 354 farmers (188 treated, 165 control); to control for possible spillovers, randomization was at the community level. The baseline survey, conducted during the FFDs, was light; it asked about basic household demographics, mobile phone number and characteristics, stage of the primary potato crop, and collected information used to localize the farmer in the follow-up survey. Among other things, the follow-up questionnaire asked about adoption of 12 IPM practices of varying complexity and input requirements for their implementation. A knowledge test was included asking about potato pests, their management, and particular details about IPM practices covered in the FFD.

Measures of adoption and IPM knowledge were constructed from the survey responses. IPM practices vary in their complexity and this variation is used in the empirical analysis to examine competing explanations for non-adoption. Practices were categorized as simple and complex, were distinguished by whether their implementation requires a purchase, and by whether their implementation is time sensitive. Table 1 presents the different practices and criteria used to categorize adoption; table 2 shows the 23 knowledge questions and criteria used to generate the IPM knowledge scores.

Empirical model

The analysis focuses on three broad issues: (i) whether receipt of a text message affects adoption of IPM; (ii) whether receipt affects farmer knowledge about IPM; and (iii) the mechanism by which the message affects behavior. The final issue is important because text messages, if effective, can be tailored to overcome cognitive barriers outlined in the conceptual framework. For example, if time-sensitivity is not found to be important, messages may not have to be constructed with detailed knowledge of the agricultural calendar. If sub-optimal heuristics are found to affect the relationship between the treatment and the outcome, messages might be simplified to reduce the cognitive burden on the farmer. Conversely, messages can be differentiated by farmer skill level.

To address these issues several steps are followed. We first examine differences in individual and household attributes across treatment assignment. This step will establish statistical balance or whether the randomization worked and treatment and control groups are equalized on observable variables. While this step is often taken in randomized controlled trials, it is not necessary for making valid inferences about a treatment effect (Senn, 1994). We next compare mean adoption rates for IPM overall and specific IPM technologies across the treatment assignment. Since the survey assignments are random, we abstract from unobserved heterogeneity in individual, household, and village characteristics. We also compare IPM knowledge scores by treatment assignment.

In a third step, we formally estimate the marginal treatment effects using the following specification:

$$y_{ij} = f(X_{i}, T_{i}; \alpha_{j}, \beta_{Xj}, \beta_{Tj}) + \varepsilon_{cj} \quad (2)$$

Where y_{ij} are outcomes such as adoption of specific classes of practices (indexed by j, these include simple and complex, time-sensitive, and purchase-reliant practices) and the knowledge scores. T is the treatment assignment, X is a vector of individual and household covariates, and ε_{cj} is the error term, clustered at the community level. We first run grouped regressions (i.e., not separating by the j); we then examine whether different classes of practices and knowledge are affected in different ways. Summary statistics are presented in tables 3, 4, and 5.

Several variants of this model are estimated; a fractional probit regression is used for the adoption (aggregating over a number of practices) and knowledge scores, which are measured in terms of percent of adopted IPM practices[1] and correct responses to the knowledge questions. The different behavioral explanations presented above suggest specific regression models. The theory of inattention suggests three hypotheses: (i) the impact of treatment on IPM adoption is significant when knowledge is controlled for in the regression; (ii) the marginal effect of the treatment on adoption of time sensitive practices is greater than for non-time sensitive practices; and (iii) the marginal impact of receipt of the reminder text message is greater for practices that do not require an input purchase compared to those requiring an input purchase. The theory of simple heuristics in the face of complex choices suggests: (i) the marginal effect of knowledge and the receipt of treatment on adoption of complex practices is greater than the effect of knowledge and receipt of the treatment on adoption of simple practices; and (ii) the impact of receipt of the treatment is smaller for high-knowledge respondents compared to low-knowledge ones. These hypotheses are examined by running variants of the general regression model presented above.

Results

Adoption of IPM

[1] Two IPM practices (chemical control for weevil and tuber moth) should be adopted only contingent on observing the pest. Thus, the total number of potential IPM practices that should be adopted differ across farmers. For this reason, we quantify adoption in terms of percent.

Twelve IPM practices promoted during the field day, included in the workbook, and reinforced through the text messages are analyzed. Farmers who received text messages (treatment group) adopt 6 of the 12 IPM practices at a significantly higher rate than control farmers (table 3). Subsequently, individual IPM practices are grouped into seven adoption scores. The first adoption score includes the 12 IPM practices while the other scores are created based on the nature of the IPM practices, i.e. whether the practice is simple or complex, purchase-reliant or non-purchase reliant, and time sensitive or not. The adoption scores indicate the percentage of IPM practices adopted within a given category. There are important differences in adoption rates across categories. For the sample as a whole, the highest adoption rate is found for adoption of simple practices while complex practices are the least adopted. This supports the theory that farmers can get overwhelmed by complex decisions, leading to suboptimal heuristics. Farmers in the treatment group have significantly higher adoption rates for all adoption scores, with the exception of the adoption of time-insensitive practices. These findings suggest that the treatment provided a stimulus to recipients and subsequently induced them to adopt different IPM practices. The difference in adoption rates between the control and treatment group is the largest for the adoption of practices that do not require purchases. The treatment boosted the adoption of these practices by 11 percentage points, suggesting that text messages have a reminder effect. However, when looking at the percent change, the different is the greatest for adoption of complex practices. Farmers in the control group adopted on average 17% of the complex practices compared to 23% for those in the treatment group, a 37% increase.

IPM knowledge

Statistics for the knowledge questions indicate the percentage of farmers who correctly answered the IPM-related questions (table 4). Farmers in the treatment group on average performed significantly better on 19 of the 23 knowledge questions than farmers in the control group. The overall knowledge score includes all knowledge questions while the other knowledge scores include a subset of the questions relating directly to the adoption scores; knowledge scores represent the proportion of questions answered correctly. All the knowledge scores are statistically greater among treated farmers compared to those in the control group. This provides clear evidence that, in addition to serving as a reminder, text messages and subsequent behavioral responses (we do not observe whether the farmer consulted the IPM workbook following receipt of the messages) have a measurable effect on knowledge creation. In fact, the largest knowledge difference between treatment and control farmers is for knowledge related to complex IPM practices.

Balance of covariates

Balance is achieved for about half of the covariates, i.e. for age and education of the respondent and land devoted to potato production[2]. Farmers in the control group have larger household sizes and own more land while farmers in the treatment group own more cows and reside at higher altitudes. Farmers in the treatment reported observing leaf miner and rhizoctonia more frequently in the potato production cycle studied compared with those in the control group. This relative lack of balance may affect the validity of the unconditional comparisons made above, but should not be an issue in a multivariate formulation.

Regression results

[2] We also created an overall wealth index using principal component analysis. This index includes ownership of durable goods, type of toilet facilities, and source of drinking water. Treatment and control households were not statistically different in this measure, but, since the variable is not used in the regressions, it is not included here.

Fractional probit response models were estimated because the dependent variables are continuous variables bounded between 0 and 1. Standard errors are clustered at the community levels. Canton fixed effects are included in the all regressions.

<u>Impact of the treatment on knowledge about pest management</u>

Knowledge is assumed to be a function of *the treatment* and household socio-economic characteristics: age and education of the participant (the person who received the text messages or would have received them had she been selected), where education is a dummy variable equal to one when the respondent completed secondary education, number of household members 15 years old and above, and land and cow ownership (the last two variables capture wealth and the importance of farming to the decision maker). The eight knowledge scores (see table 2 and 4 for definitions) are regressed on these variables (marginal effects shown in table 6).

Results show that the treatment always has a positive impact on knowledge; receiving regular text messages through the potato growing season increases knowledge scores by 18 to 23 percentage points. As first suggested in the comparisons of means presented above, the treatment seems to build IPM knowledge, even controlling for education level of the participant. Having completed secondary education increases knowledge scores by 5 to 10 percentage points, so in terms of specific knowledge about an orphan technology, provision of low-cost test messages over the growing season is more effective than other forms of education.

<u>Impact of treatment on adoption</u>

Adoption of IPM is modeled as a function of the treatment and household socio-economic characteristics. The same variables as in the knowledge regressions are included, plus altitude (in meters), and five dummy variables indicating whether the farmer observed the following pests/diseases during the potato production cycle: 1) weevil, 2) tuber moth, 3) leaf miner, 4) late blight, 5) rhizoctonia. These variables represent pest pressure which could be positively associated with IPM adoption. Seven adoption scores (overall, simple, complex, purchase reliant, non-purchase reliant, time sensitive and non-time sensitive) are considered and their marginal effects are presented in table 7.

Exposure to the treatment has a positive and significant impact of all adoption scores with the exception of practices that are not time sensitive. This evidence is consistent with a behavioral model of inattention—the text message has a reminder effect. There are only two practices considered that are not time-sensitive: use of IPM-recommended chemicals (i.e., chemicals that are less toxic) to prevent/control tuber moth and rhizoctonia. Farmers face several options when it comes to choosing chemical controls (IPM recommended or not) and thus the use sub-optimal heuristic behavior is likely to be strong for this category. When significant, the treatment increases the adoption scores by 5 to 9 percentage points. The marginal effect of the treatment on adoption of simple practices is smaller than the marginal effect of the treatment on adoption of complex practices, a finding that provides additional evidence that the treatment contributes to knowledge building, and is consistent with the hypothesis of simple heuristics in the case of complex decisions. The theory of simple heuristics holds that information provision has more value in the face of complex decisions, and the finding supports the theory. Consistent with the idea of the reminder effect, the marginal effect of the treatment is the greatest for adoption of practices that do not require a separate purchase of inputs. Farmers can put in practice right away the recommendation provided in the text messages so the immediate reminder effect is confirmed.

<u>Impact of treatment and knowledge on adoption</u>

Additional regressions were run to explain IPM adoption scores while including knowledge as an explanatory variable. These regressions should be interpreted with caution as the causal flow is uncertain—adoption might in fact lead to more IPM knowledge. Moreover, as shown above knowledge is strongly influenced by the treatment. Knowledge of IPM is closely correlated with adoption of practices, but when knowledge is included in the regression the impact of the text message treatment becomes insignificant (table 10). The marginal effect for the knowledge score on adoption ranges from 0.187 (for non-time sensitive practices) to 0.404 (for practices that do not rely on purchases). The strong and positive impact of knowledge on adoption supports the theory of sub-optimal heuristics; as knowledge about IPM increases, farmers are less likely to be overwhelmed by the complexity of the technology, and less likely to resort to default practices. The fact that knowledge has a greater impact on adoption of practices that do not rely on an input purchase is an additional indicator of the reminder effect. Doing something also increases knowledge. The impact of the treatment is the greatest for adoption of non-purchase reliant practices, meaning that farmers increased the use of these practices the most, and thus are getting more knowledgeable. Based on the theory of simple heuristics in the face of complex choices, we would expect knowledge to have a greater effect on the adoption of complex than simple practices. Our results indicate that the marginal effect of knowledge on adoption of simple practices is greater than on adoption of simple practices, however, the marginal effects are not statistically different.

Conclusions

The revolution in information and communications technology can have important implications for programs designed to promote adoption of agricultural technologies. Use of these technologies has, however, lagged far behind potential, and agricultural extension services struggling with limited budgets might make better use of these low-cost means of information transfer. IPM adoption has also lagged behind that of conventional (mainly varieties) technologies and proponents of IPM and other orphan technologies need to know how to best structure information transfer to effect behavioral change.

This paper, which evaluated the impacts of receipt of text messages on knowledge and adoption of IPM among potato producers in Carchi, Ecuador, shows clearly that text messages both improve farmer knowledge and encourage adoption. The use of an RCT allowed clean identification of the treatment effect and the design of the experiment enabled analysis of the mechanisms behind behavioral change. Treated farmers had significantly higher knowledge scores and were more likely to adopt most IPM practices. The behavioral theory was largely confirmed by the results: all the predictions of the model of inattention were born out and most of the predictions of the model of use of sub-optimal heuristics were also confirmed in the analysis.

These results imply that text messages are a promising tool to promote adoption of even complex orphan technologies. Timing, message content, and farmer ability, however, all should be considered—the reminder effect can be exploited mainly for simple technologies that can be applied at different time. More complex messaging is needed to overcome use of sub-optimal heuristics and poorly trained or unskilled farmers will need a different package of messages, especially when the targeted practices are complex. An additional caveat is that delivery of the messages was preceded by a formal training session, so the results here cannot be extrapolated to untrained farmers. This warning is especially germane when considering the context: Carchi is an area where IPM training had occurred for many years, although widespread formal training ended in 2004 (Carrión Yaguana, et al., 2015). As a result of this training, baseline IPM knowledge is higher than it would be in other parts of the country, so that similar messaging programs might not work as well elsewhere.

Despite these warnings, the message is one of cautious optimism about the potential use of ICT to promote orphan agricultural technologies.

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Table 1: Description of potato IPM practices and their categorization to generate adoption scores

12 IPM Practices	IPM Adoption Scores						
	Overall	Simple	Complex	Purchase-Reliant	Non-Purchase Reliant	Time sensitive	Not time sensitive
Use of traps for weevil	✔		✔		✔	✔	
Use of bait plants for weevil	✔		✔	✔		✔	
Use of IPM chemical control for weevil (contingent on observation)	✔	✔		✔			✔
Solarize seeds to prevent tuber moth	✔	✔			✔	✔	
Application of Bacu-Turin to prevent tuber moth	✔		✔	✔		✔	
Hilling to prevent tuber moth	✔	✔			✔	✔	
Use of IPM chemical control for tuber moth (contingent on observation)	✔	✔		✔			✔
Use of fixed traps for leaf miner	✔		✔	✔		✔	
Use of mobile traps for leaf miner	✔		✔	✔		✔	
Disinfect seeds to prevent Rhizoctonia	✔		✔	✔		✔	
Use of IPM chemical control for Rhizoctonia	✔	✔		✔		✔	
Remove yellow plants to maintain seed quality	✔	✔			✔	✔	

Note: Bacu-Turin is a locally manufactured biological control used to prevent tuber moths during potato seed storage

Table 2: Description of IPM knowledge questions and their categorization to generate knowledge scores

	IPM Knowledge Scores							
23 knowledge questions	**Overall (23)**	**Related to practices included in the overall adoption score (15)**	**Related to practices included in the simple adoption score (7)**	**Related to practices included in the complex adoption score (8)**	**Related to practices included in the purchase-reliant adoption score (10)**	**Related to practices included in the Non-Purchase Reliant adoption score (5)**	**Related to practices included in the Time sensitive adoption score (13)**	**Related to practices included in the Not time sensitive adoption score (2)**
Recommended distance between Weevil traps	✔	✔		✔		✔	✔	
Insecticide used in Weevil traps	✔							
Insecticide used for bait plants	✔	✔		✔	✔		✔	
Recommended distance between bait plants	✔	✔		✔	✔		✔	
IPM Recommended Insecticide for Weevil	✔	✔	✔		✔			✔
Solarization time to prevent weevil infestation	✔	✔	✔			✔	✔	
Recommended quantity of bacu-turin to use prevent tuber moth	✔	✔		✔	✔		✔	
Storage location of seeds after use of Bacu-turin	✔	✔		✔	✔		✔	
Correct hilling technique to prevent the tuber moth	✔	✔	✔			✔	✔	
Reason why hilling prevent tuber moth damage	✔	✔	✔			✔	✔	
IPM recommended insecticide for tuber moth	✔	✔	✔		✔			✔
Timing of fixed trap installation	✔	✔		✔	✔		✔	
Timing of mobile trap passing	✔	✔		✔	✔		✔	
Part of the plant that leaf miners attack	✔							
Timing of leaf miner chemical control for adult leaf miners	✔							
Timing of leaf miner chemical control for larva	✔							

IPM recommendations to prevent and control late blight	✔							
Reason for using chemicals with different active ingredients when controlling for late blight	✔							
IPM recommendations to control rhizoctonia	✔							
Seed disinfection process to control for Rhizoctonia	✔							
IPM recommended chemical to disinfect seeds	✔	✔		✔	✔		✔	
IPM recommended chemical to prevent Rhizoctonia	✔	✔	✔		✔		✔	
Recommended seed quality maintenance techniques	✔	✔	✔			✔	✔	

Table 3: Descriptive statistics of IPM adoption practices and scores

Description	Sample Mean (%)	Control Mean (%)	Treatment Mean (%)	p-value
Adoption of IPM practices				
Use of traps for weevil	16.71	12.74	19.90	0.068
Use of bait plants for weevil	17.56	8.28	25.00	0.000
Use of IPM chemical control for weevil	48.71	52.94	45.41	0.163
Solarize seeds to prevent tuber moth	62.04	49.04	72.45	0.000
Application of Bacu-Turin to prevent tuber moth	10.76	10.19	11.22	0.755
Hilling to prevent tuber moth	86.97	81.53	91.33	0.009
Use of IPM chemical control for tuber moth	65.71	63.40	67.53	0.424
Use of fixed traps for leaf miner	8.50	8.92	8.16	0.802
Use of mobile traps for leaf miner	6.23	6.37	6.12	0.924
Disinfect seeds to prevent Rhizoctonia	61.47	54.14	67.35	0.012
Use of IPM chemical control for Rhizoctonia	38.81	31.85	44.39	0.015
Remove yellow plants to maintain seed quality	52.97	50.32	55.10	0.373
Adoption scores (see table 1 for definition of adoption scores)				
Overall	39.60	35.61	42.79	0.000
Simple practices	59.04	54.55	62.64	0.001
Complex practices	20.21	16.77	22.96	0.004
Purchase-reliant practices	32.03	29.16	34.32	0.011
Non-purchase reliant practices	54.67	48.41	59.69	0.000
Time sensitive practices	36.20	31.34	40.10	0.000
Non-time sensitive practices	56.68	57.37	56.12	0.759
Number of observations	353	157	196	

Table 4: Descriptive statistics for IPM knowledge questions and scores

Description	Sample Mean (%)	Control Mean (%)	Treatment Mean (%)	p-value
Knowledge questions				
Recommended distance between Weevil traps	43.91	27.39	57.14	0.000
Insecticide used in Weevil traps	57.79	45.86	67.35	0.000
Insecticide used for bait plants	45.61	27.39	60.20	0.000
Recommended distance between bait plants	28.90	12.10	42.35	0.000
IPM recommended insecticide for weevil	47.59	41.40	52.55	0.037
Solarization time to prevent weevil infestation	40.51	30.57	48.47	0.001
Recommended quantity of Bacu-turin to use prevent tuber moth	1.98	2.55	1.53	0.509
Storage location of seeds after use of Bacu-turin	45.04	32.48	55.10	0.000
Correct hilling technique to prevent the tuber moth	56.94	43.95	67.35	0.000
Reason why hilling prevent tuber moth damage	82.15	76.43	86.73	0.014
IPM recommended insecticide for tuber moth	46.18	32.48	57.14	0.000
Timing of fixed trap installation	30.88	21.02	38.78	0.000
Timing of mobile trap passing	30.59	18.47	40.31	0.000
Part of the plant that leaf miners attack	93.20	88.54	96.94	0.003
Timing of leaf miner chemical control for adult leaf miners	47.31	32.48	59.18	0.000
Timing of leaf miner chemical control for larva	44.19	27.39	57.65	0.000
IPM recommendations to prevent and control late blight	35.69	32.48	38.27	0.259
Reason for using chemicals with different active ingredients when controlling for late blight	31.16	38.85	25.00	0.006
IPM recommendations to control Rhizoctonia	18.41	10.83	24.49	0.001
Seed disinfection process to control for Rhizoctonia	29.46	19.75	37.24	0.000
IPM recommended chemical to disinfect seeds	20.11	14.01	25.00	0.009
IPM recommended chemical to prevent Rhizoctonia	23.23	17.20	28.06	0.014
Recommended seed quality maintenance techniques	26.91	25.48	28.06	0.587
Knowledge scores (see table 2 for definition of knowledge scores)				
1-Overall Knowledge	40.34	31.27	47.60	0.000
2-Knowledge related to overall adoption practices	38.04	28.20	45.92	0.000
3-Knowledge related to simple practices	46.22	38.22	52.62	0.000
4-Knowledge related to complex practices	30.88	19.43	40.05	0.000
5-Knowledge related to purchase reliant practices	32.01	21.91	40.10	0.000
6-Knowledge related to non-purchase reliant practices	50.08	40.76	57.55	0.000
7-Knowledge related to time sensitive practices	36.67	26.85	44.54	0.000
8-Knowledge related to non-time sensitive practices	46.88	36.94	54.85	0.000
Number of observations	353	157	196	

Table 5: Balance of covariates

Description	Sample Mean	Control Mean	Treatment Mean	p-value
Socio-economic characteristics				
Age of the respondent	42.31	42.59	42.08	0.686
Education of the respondent (years)	8.82	8.52	9.06	0.187
Household size	**4.37**	**4.60**	**4.19**	**0.004**
Number of household members 15 years old and above	**3.05**	**3.24**	**2.90**	**0.007**
Land owned (ha)	**10.44**	**11.25**	**9.79**	**0.062**
Land devoted to potato production (ha)	2.79	2.81	2.77	0.879
Number of cows owned	**5.00**	**3.66**	**6.08**	**0.001**
Altitude (meters)	**2942.48**	**2899.19**	**2977.15**	**0.000**
Pest pressure and damage				
Farmer observed weevil in production cycle (1=yes)	0.85	0.83	0.87	0.392
Farmer observed tuber moth in production cycle (1=yes)	0.80	0.78	0.83	0.250
Farmer observed leaf miner production cycle (1=yes)	**0.85**	**0.80**	**0.89**	**0.030**
Farmer observed late blight in production cycle (1=yes)	0.89	0.87	0.90	0.462
Farmer observed rhizoctonia in production cycle (1=yes)	**0.50**	**0.44**	**0.54**	**0.059**
Number of observations	353	157	196	

Table 6: Marginal effects of treatment and covariates on knowledge scores

	Knowledge score 1 Overall		Knowledge score 2 Adoption overall		Knowledge score 3 Adoption simple		Knowledge score 4 Adoption complex	
	dy/dx	z	dy/dx	z	dy/dx	z	dy/dx	z
Treatment	**0.184*** **	**5.33**	**0.193*** **	**4.74**	**0.183*** **	**4.42**	**0.201*** **	**4.59**
Secondary education (1=Yes)	0.073**	2.14	0.070**	2.16	0.090**	2.51	0.050	1.59
Age	-0.001	-0.99	-0.001	-0.97	-0.002	-1.10	-0.001	-0.75
Nb of HH members 15 years old & +	0.023***	2.68	0.025***	2.87	0.029***	2.89	0.021**	2.37
Land owned (ha)	0.000	-0.03	-0.001	-0.61	-0.001	-0.33	-0.002	-0.80
Nb of cows owned	0.004**	1.97	0.004*	1.94	0.003	1.10	0.005***	2.59
Canton (Base = Bolivar)								
Espejo	-0.147***	-4.27	-0.126***	-2.91	-0.192***	-4.54	-0.059	-1.20
Huaca	-0.101	-1.37	-0.092	-1.10	-0.082	-0.96	-0.087	-1.02
Mira	0.262***	3.32	0.241***	2.87	0.119	1.31	0.358***	3.05
Montufar	-0.024	-0.61	-0.021	-0.44	-0.065	-1.41	0.027	0.48
Tulcan	-0.071	-1.56	-0.063	-1.18	-0.130**	-2.42	0.004	0.06

	Knowledge score 5 A. Purchase-reliant		Knowledge score 6 A. non-purchase reliant		Knowledge score 7 A. time sensitive		Knowledge score 8 A. non-time sensitive	
	dy/dx	z	dy/dx	z	dy/dx	z	dy/dx	z
Treatment	**0.193*** **	**4.46**	**0.195*** **	**4.63**	**0.187*** **	**4.84**	**0.232*** **	**3.50**
Secondary education (1=Yes)	0.059*	1.65	0.089**	2.57	0.065**	2.18	0.101*	1.66
Age	-0.001	-0.83	-0.002	-1.17	-0.001	-0.75	-0.003	-1.54
Nb of HH members 15 years old & +	0.025***	2.76	0.024**	2.29	0.023***	2.73	0.037**	2.23
Land owned (ha)	-0.001	-0.31	-0.002	-1.08	-0.002	-1.06	0.004	1.15
Nb of cows owned	0.004*	1.68	0.005**	2.22	0.005**	2.51	-0.002	-0.42
Canton (Base = Bolivar)								
Espejo	-0.124**	-2.56	-0.127***	-3.31	-0.110***	-2.77	-0.224***	-3.05
Huaca	-0.099	-1.01	-0.075	-1.18	-0.081	-1.09	-0.161	-1.03
Mira	0.277***	2.64	0.174	1.58	0.234**	2.53	0.302***	3.48
Montufar	0.007	0.14	-0.075	-1.58	-0.018	-0.41	-0.027	-0.35
Tulcan	-0.035	-0.60	-0.121**	-2.45	-0.057	-1.13	-0.101	-1.14

Table 7: Marginal effects of treatment and covariates on adoption scores

	Overall adoption		Adoption (simple practices)		Adoption (complex practices)	
	dy/dx	z	dy/dx	z	dy/dx	z
Treatment	**0.063*** **	**2.62**	**0.047***	**1.83**	**0.075*** **	**2.71**
Secondary education (1=Yes)	0.031	1.52	0.031	1.30	0.033	1.29
Age	0.000	-0.41	0.001	1.12	-0.002**	-2.00
Nb of HH members 15 years old & +	-0.003	-0.51	-0.010	-1.08	0.004	0.54
Land owned (ha)	-0.002*	-1.70	-0.003**	-2.25	-0.001	-0.53
Nb of cows owned	0.002*	1.68	0.002*	1.69	0.002	0.97
Altitude (m)	0.000**	2.07	0.000**	1.99	0.000	1.62
Observed weevil (1=Yes)	0.064**	2.15	0.091***	2.96	0.034	0.83
Observed tuber moth (1=Yes)	0.082	1.62	0.143***	2.61	0.005	0.10
Observed leaf miner (1=Yes)	-0.012	-0.26	0.039	0.85	-0.068	-1.10
Observed late blight (1=Yes)	0.063	1.58	0.045	0.80	0.078**	2.31
Observed Rhizoctonia (1=Yes)	0.070***	3.54	0.023	1.02	0.119***	5.68
Canton (Base = Bolivar)						
Espejo	-0.103***	-2.67	-0.050	-1.57	-0.156***	-2.59
Huaca	-0.109***	-2.83	-0.046	-1.39	-0.168***	-2.90
Mira	0.219***	3.66	0.210***	2.99	0.182*	1.82
Montufar	0.100**	2.07	0.140***	4.10	0.041	0.57
Tulcan	-0.054	-1.34	0.003	0.07	-0.113**	-2.01

Table 7: Marginal effects of treatment and covariates on adoption scores (CON'T)

	Adoption purchase reliant practices		Adoption non-purchase reliant practices		Adoption time sensitive practices		Adoption non-time sensitive practices	
	dy/dx	z	dy/dx	z	dy/dx	z	dy/dx	z
Treatment	**0.053****	**2.07**	**0.086*****	**2.97**	**0.071*****	**3.08**	**0.022**	**0.50**
Secondary education (1=Yes)	0.036	1.62	0.026	0.84	0.025	1.19	0.056	1.59
Age	0.000	-0.49	0.000	-0.18	-0.001	-1.31	0.003**	2.43
Nb of HH members 15 years & +	0.003	0.57	-0.015	-1.45	-0.005	-0.70	0.013	1.04
Land owned (ha)	-0.001	-0.84	-0.004**	-2.16	-0.003**	-2.09	0.002	0.92
Nb of cows owned	0.000	-0.25	0.007***	3.62	0.004***	2.85	-0.007***	-2.74
Altitude (m)	0.000*	1.78	0.000*	1.78	0.000**	2.46	0.000	0.08
Observed weevil (1=Yes)	0.101***	2.96	0.008	0.17	0.001	0.03	0.415***	13.51
Observed tuber moth (1=Yes)	0.123**	2.53	0.003	0.04	0.025	0.43	0.365***	6.35
Observed leaf miner (1=Yes)	-0.068*	-1.91	0.093	0.96	-0.007	-0.11	-0.027	-0.60
Observed late blight (1=Yes)	0.075**	2.43	0.041	0.58	0.059	1.24	0.126***	3.50
Observed Rhizoctonia (1=Yes)	0.089***	4.16	0.029	1.10	0.088***	4.28	-0.029	-0.78
Canton (Base = Bolivar)								
Espejo	-0.107***	-2.60	-0.101**	-2.28	-0.099***	-2.65	-0.130*	-1.96
Huaca	-0.170***	-4.40	0.031	0.61	-0.023	-0.57	-0.503***	-8.44
Mira	0.174*	1.87	0.290***	6.91	0.234***	4.71	0.108	1.12
Montufar	0.113**	2.03	0.094	1.62	0.108**	2.09	0.049	0.91
Tulcan	-0.055	-1.34	-0.059	-1.30	-0.056	-1.41	-0.04	-0.80

Table 8: Marginal effects of treatment, knowledge, and covariates on adoption scores

	Overall adoption		Adoption simple practices		Adoption complex practices	
	dy/dx	z	dy/dx	z	dy/dx	z
Treatment	-0.001	-0.05	-0.015	-0.68	0.012	0.62
Secondary education (1=Yes)	0.004	0.23	-0.001	-0.05	0.014	0.64
Age	0.000	0.12	0.002*	1.75	-0.001*	-1.96
Nb of HH members 15 years old & +	-0.011**	-2.19	-0.019**	-2.31	-0.002	-0.35
Land owned (ha)	-0.002*	-1.69	-0.003**	-2.23	0.000	-0.20
Nb of cows owned	0.001	0.92	0.002	1.12	0.000	0.19
Canton (Base = Bolivar)						
Espejo	-0.058**	-2.07	0.016	0.59	-0.128***	-2.81
Huaca	-0.071**	-1.96	-0.013	-0.36	-0.129***	-2.58
Mira	0.148***	2.77	0.182***	2.69	0.053	0.62
Montufar	0.096***	2.81	0.156***	5.12	0.017	0.32
Tulcan	-0.030	-1.10	0.050	1.63	-0.106***	-2.75
Altitude (m)	0.000**	2.44	0.000***	2.61	0.000	1.64
Observed weevil (1=Yes)	0.068***	3.00	0.094***	3.14	0.040	1.28
Observed tuber moth (1=Yes)	0.092***	3.20	0.145***	4.03	0.019	0.55
Observed leaf miner (1=Yes)	-0.019	-0.62	0.038	1.17	-0.081	-1.64
Observed late blight (1=Yes)	0.006	0.19	-0.003	-0.08	0.017	0.51
Observed Rhizoctonia (1=Yes)	0.065***	3.67	0.015	0.72	0.119***	6.40
Knowledge -overall adoption	**0.330*****	**11.15**				
Knowledge of simple practices			**0.332*****	**10.25**		
Knowledge of complex practices					**0.300*****	**8.10**

Table 8: Marginal effects of treatment, knowledge, and covariates on adoption scores (Con't)

	Adoption purchase reliant practices		Adoption non-purchase reliant practices		Adoption time sensitive practices		Adoption non-time sensitive practices	
	dy/dx	z	dy/dx	z	dy/dx	z	dy/dx	z
Treatment	0.003	0.17	0.005	0.19	0.003	0.19	-0.018	-0.47
Secondary education (1=Yes)	0.016	0.88	-0.013	-0.48	-0.002	-0.12	0.034	1.09
Age	0.000	-0.18	0.000	0.32	-0.001	-1.05	0.004***	3.08
Nb of HH members 15 years old & +	-0.004	-0.63	-0.024***	-2.67	-0.013**	-2.04	0.005	0.40
Land owned (ha)	-0.001	-0.87	-0.003*	-1.71	-0.002*	-1.81	0.001	0.64
Nb of cows owned	-0.001	-0.94	0.006***	3.29	0.002**	2.46	-0.007**	-2.38
Canton (Base = Bolivar)								
Espejo	-0.068**	-2.08	-0.049	-1.27	-0.055**	-2.05	-0.084	-1.49
Huaca	-0.138***	-4.29	0.069	1.35	0.014	0.38	-0.467***	-8.56
Mira	0.107	1.51	0.243***	4.62	0.152***	3.31	0.064	0.56
Montufar	0.106**	2.40	0.106**	2.22	0.100***	2.77	0.051	1.13
Tulcan	-0.041	-1.39	-0.006	-0.18	-0.033	-1.24	-0.026	-0.55
Altitude (m)	0.000*	1.79	0.000***	2.58	0.000***	2.98	0.000	0.03
Observed weevil (1=Yes)	0.111***	3.87	-0.005	-0.13	0.004	0.17	0.421***	13.00
Observed tuber moth (1=Yes)	0.136***	4.11	-0.010	-0.21	0.032	0.97	0.380***	6.92
Observed leaf miner (1=Yes)	-0.071***	-2.59	0.079	0.97	-0.014	-0.36	-0.027	-0.51
Observed late blight (1=Yes)	0.017	0.58	0.012	0.22	0.001	0.02	0.078*	1.75
Observed Rhizoctonia (1=Yes)	0.087***	4.35	0.023	0.97	0.086***	4.49	-0.043	-1.28
Knowledge of purchase reliant practices	**0.261*** **	**7.72**						
Knowledge of non-purchase reliant practices			**0.404*** **	**9.07**				
Knowledge of time sensitive practices					**0.358*** **	**10.59**		
Knowledge of not time sensitive practices							**0.187*** **	**5.73**