Uganda Coffee Agronomy Training Impact Evaluation Report

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

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Contents

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Executive summary

This report describes the methods and findings of a randomized controlled trial evaluating the impact of coffee agronomy training and phone-based advisory services on farmer practices and observed coffee yield. In-person training was provided in randomly selected villages over the course of two years by Hanns R. Neuman Stiftung (HRNS) and TechnoServe in two separate regions of Western Uganda encompassing six districts. Messages reinforcing this training were sent to a subset of farmers in villages where training was offered by Precision Development (PxD), and standalone messages were sent to a subset of farmers in villages where no training was offered. The program period spanned the onset of the COVID-19 pandemic and associated lockdowns, which significantly affected how training could be delivered and likely reduced its impact.

Coffee yield per tree was measured for the fourth main harvest after the start of training. The number of coffee cherries per tree was estimated for three trees per farm by removing and weighing green cherries by size category ahead of harvest. This number was multiplied by the weight per ripe cherry during harvest time to arrive at an estimate of the ripe yield weight. Coffee practices were observed at the same time as green cherry measurement. We find that coffee yield per tree was 4.1% higher in villages where HRNS offered training compared to in villages where no training was offered, and 10.5% higher in villages trained by TechnoServe among a sample of farmers who showed initial interest in training. As only about half of farmers in treatment villages were verified to have attended a significant amount of training, yield impacts on *trained* farmers could be as high as 8.2% and 18.1% for HRNS and TechnoServe, respectively. That the regions where the two implementers worked were quite different, so these differences may be due at least partially to context, as opposed to trainer programming.

Farmers' use of recommended coffee practices increased in line with the observed yield impact. Knowledge of these practices was also improved by training. However, practices about which knowledge improved the most were not always those for which the greatest physical changes were seen. This suggests that there are other constraints to adoption of recommended practices, and that training can serve as a reminder and encouragement to implement practices of which farmers are already aware. There is no evidence that the improvement in coffee yield was offset by a decline in households' cash income from other sources or less food crop production, or that it reduced women's income sources controlled by women. Nor did training affect women's control over coffee income, which remained low.

In contrast to impacts on the directly observed outcomes of yield, practices, and knowledge, we do not find statistically significant impacts on farmers' reported coffee revenues, costs, or profits. We attribute this to the difficulty of accurately recalling expenditures and income related to coffee, both of which occur over several months, and to the discrepancy in time periods covered by recall data on coffee costs and sales, versus prospective yield estimates.

Sending farmers recorded phone messages that reinforced training content resulted in a near-statistically significant impact on practices equivalent to a 3.1 percent increase in yield in HRNS training villages, but no impact in the TechnoServe sample. This implies a total combined yield increase of 5.5 percent for farmers who received both HRNS training and reinforcement messages, and a 2.7 percent increase for those who did not. There is suggestive evidence that a standalone mobile phone-based intervention may have had a similar impact on coffee practices, though this is measured with less statistical precision.

Yield gains of in-person training translate to an annual return on investment of between 15% and 44% depending on the region and implementer. The total ROI depends crucially on whether these yield impacts are sustained over time. A previous evaluation for which farmer practices were observed at multiple points post-training found persistent effects. Based on results from that study, we estimate a total 14-year net ROI of between 19% and 251% (by region and implementer) beyond recovery of the initial investment.

Using the imprecisely estimated impacts of the phone-based interventions, and projecting yield effects based on farm practices, we calculate annual ROIs for these of between 225% and 335%, assuming they are deployed at a scale of one million farmers.

1. Introduction

Yields among Ugandan smallholder coffee farmers are estimated at less than 30% of their agronomic potential (Wang, 2015). Increased coffee production is a key strategy of the Government of Uganda for boosting both national earnings of foreign exchange and improving the livelihoods of the country's 1.8 million small-scale coffee farmers, who produce 90% of the country's coffee (UCDA, 2021; World Coffee Research, 2024).

Achieving this goal will require that farmers adopt yield-enhancing management practices including pruning, rejuvenation, weeding, and integrated pest and disease management. Many of these practices require only knowledge and labor to implement. Training and provision of information on recommended practices could potentially have large impacts on the coffee farmers' practices and yields.

This report describes the results of an impact evaluation of an in-person coffee agronomy training program, reminders of key coffee practice recommendations sent via mobile phone to farmers in villages where training was offered, and standalone recommendations sent to farmers in villages where training was not offered. The interventions were conducted in six districts of Western Uganda. To maximize the potential impact of the interventions, these districts were selected based on their relative lack of prior access to similar programing.

We evaluate the impact of in-person coffee agronomy training program, as well as mobile phone-based reinforcement of this training, and a stand-alone phone-based extension intervention. In-person training was delivered by Hanns R. Neumann Stiftung in Kagadi, Kibaale, and Kyenjojo districts, and by TechnoServe in Mbarara, Ntungamo, and Sheema districts. Both HRNS and TechnoServe provided monthly in-person training sessions focused on one or more coffee practices over a period of 26 months, including up to 3 months during which training was halted due to the COVID-19 pandemic, and up to 8 additional months when training was restricted to individual farmers or small groups.

The phone-based interventions were implemented by Precision Development (PxD). Farmers assigned to the mobile reinforcement intervention were called and, if they answered, heard pre-recorded messages containing key content from the in-person training sessions offered in their region. This intervention was delivered concurrently with in-person training in each region, after a three- to four-month lag in initiation.

The standalone mobile extension intervention similarly delivered pre-recorded phone messages containing agronomy advice. In addition, farmers assigned to this intervention were given a phone number which they could call and leave specific questions, which would then be answered (via recorded message) by a PxD agronomist. Farmers could also access recorded messages they had previously been sent through this number.

2. Sample

Between September of 2018 and February of 2019, HRNS and TechnoServe assembled a list of villages in the study districts in which at least 20 households were growing coffee. Based on GPS coordinates of the approximate center of these villages, 360 per region were selected that were at least 1.9 KM (HRNS region) or 1.4 KM (TechnoServe region) apart from one another for inclusion in the study.[1]

Prior to the initiation of the interventions to be evaluated, the HRNS and TechnoServe conducted training sessions on coffee harvest and post-harvest practices in all 720 of the study villages. Study participants were selected from the group of farmers who attended these sessions, with a target of 12 coffee farming households per treatment village, and 18 per control village.[2]

The logic underlying this sample selection procedure was that farmers who attended the initial training would also be likely to attend subsequent training on coffee agronomy, should it be offered in their village. This approach was shown in a pilot study to result in a much higher rate of training attendance, and thus statistical power to evaluate the effect of the training intervention, compared to standard population-based sampling (Hoffmann, Doan and Harigaya, 2023). The primary outcomes assessed in this evaluation (coffee yield based on harvesting by the research team; pre-harvest practices) are not expected to be affected by training on harvest or post-harvest practices.

Due to low attendance at some of the pre-intervention training sessions, and failure to find some of the farmers who had attended these sessions as well as loss to follow-up, the sample of recruited farmers fell short of the original target. A total of 4,679 farmers in the districts served by HRNS, and 5,279 in the area where TechnoServe provided training, were recruited into the evaluation.

3. Study design

Experimental assignment proceeded in two steps, first at the village level for the assignment of in-person agronomy training, and then, after the baseline survey, at the household level for assignment to mobile phone-based interventions. Figure 1 summarizes the design.

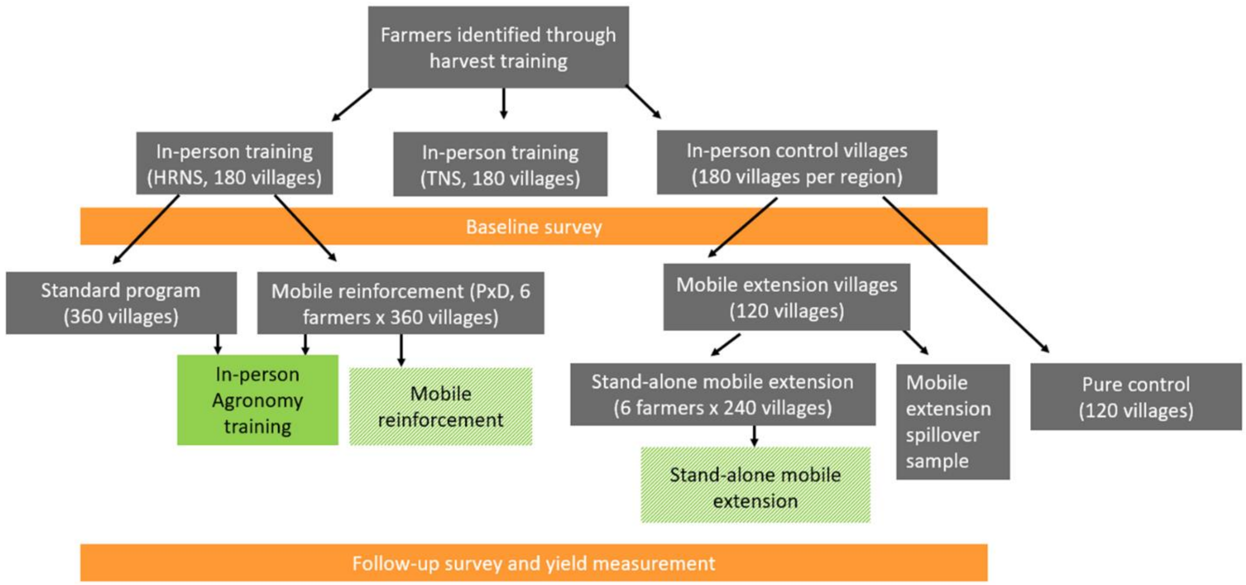
Village-level randomization to in-person coffee agronomy training program

The 720 study villages were stratified into 180 geographically defined clusters of 4 villages each. Within each cluster, 2 villages were randomly assigned to receive in-person agronomy training. This resulted in 360 villages (180 per implementer region) assigned to receive in-person agronomy training, and 360 nearby villages assigned to serve as controls.

[1] The difference in minimum distance arose due to the different sizes of the two regions.

[2] Additional farmers were recruited in control villages to enable the evaluation of the PxD standalone mobile intervention in these villages.

Figure 1. Experimental design



Baseline survey

A baseline survey was administered to all study households in November-December of 2018 (HRNS region) and April-May of 2019 (TechnoServe region) prior to the initiation of the interventions. Due to time constraints between the end of harvest training and the beginning of the randomized intervention, and an implementer's need for data on a subset of farmers using their standard observational coffee practice survey tool, three different versions of the survey instrument were used to collect baseline data: Standard, Limited (shorter), and Observational (longer, partially in-field). A subset of Standard surveys also included a module on gender roles and women's income sources. Randomization to a survey version was conducted at the same time as sample selection.

Assignment to mobile extension treatments

Assignment to the two mobile extension treatments (standalone and reinforcement) was conducted after the baseline survey. The mobile reinforcement intervention was randomly assigned to 50% of farmers in each In-person training village.

A subset of farmers in 240 of the 360 villages where no in-person training was to be offered were assigned to receive the standalone mobile extension intervention as follows. These 240 villages were selected as follows. First, one control villages in each of the 90 geographical clusters per region was randomly selected. Second, the remaining 90 control villages in each region were grouped into terciles based on the village-level mean of an index of agronomy practices as reported or observed in the baseline data. Ten villages per tercile (30 villages in total per region) were then randomly selected and combined with the 90 already selected. These 120 villages constituted those from which farmers would be assigned to the standalone mobile extension treatment.

In the HRNS implementation area, the 6 farmers assigned to the limited survey group were automatically assigned to the standalone treatment group in mobile extension villages. The village-level randomization described above was repeated in the HRNS sample until p-values of tests for equality of means of the agronomy practice index between farmers assigned to the mobile extension versus those not assigned to this intervention was > 0.6. In the TechnoServe implementation area, the index of practices was found to be imbalanced between those farmers to whom the limited survey had been administered, versus others. In this region, therefore, both the village-level and farmer-level random assignments were repeated to achieve balance in the practice index (also at $p > 0.6$) across groups.

Follow-up data collection

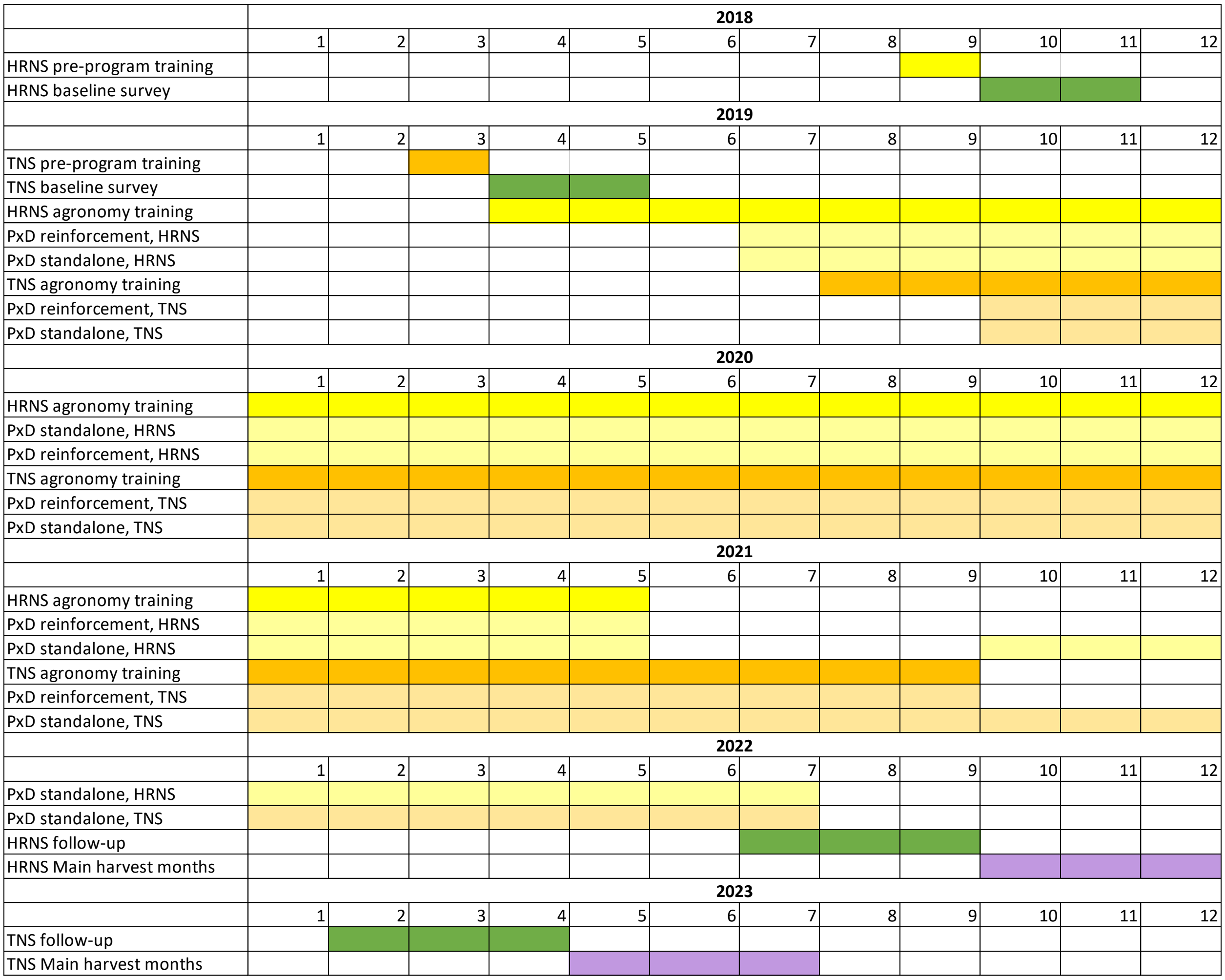
Follow-up survey data and physical measurement of coffee were collected preceding the fourth main coffee harvest after the start of training in each region (July to September 2022 in the region served by HRNS, and February to April 2023 in the region served by TechnoServe). Data on weight per ripe cherry was collected 2-3 months later during the peak harvest period in each region. In both regions, over a year elapsed between the end of the interventions and the start of data collection.

Study timeline

Figure 2 shows the timeline of the evaluation. Baseline data collection preceded the evaluated training activities by 2 to 4 months. PxD interventions were initiated within 2 to 4 months of in-person training in both regions. Reinforcement messages were sent up until the end of in-person training, while standalone messages continued until the start of August 2022 in both regions. In the HRNS region, there was a four-month interruption of the standalone intervention due to changes in the timing of follow-up data collection and uncertainty associated with the funding available to extent this component of the program.

Due to COVID-19 related disruptions, midline data collection, originally planned to occur while the training interventions were ongoing, was cancelled. While in-person training is typically assumed (and in fact shown) to have durable effects on farmer practices, this is not the case for the light-touch mobile phone-based interventions implemented by PxD. The 13- to 16-month lag between the end of the reinforcement intervention in both regions, and the 6-month lag between the end of the standalone intervention and follow-up data collection in the TechnoServe region may have reduced the measurable impact of these programs.

Figure 2. Evaluation timeline



Attrition

Table 1 shows the study sample by implementer region, the number of farmers successfully reinterviewed at endline, and the number for which yield measures were obtained, along with attrition rates. In both regions, just over 90% of farmers were re-interviewed. The primary reasons for loss to follow-up were respondent lack of availability even after multiple attempts (28% of attriters) and relocation of the household (19%). Refusals constituted 11% of attrition cases (105 farmers). In addition, physical yield data could not be observed for a further 5% of baseline sample farmers in the HRNS region and 12.6% in the TechnoServe region who were re-interviewed. The most common reasons for missing yield data were having pre-sold coffee ahead of harvest and thus not having the authority to allow the research team to take coffee (30.5%), followed by simple refusal (21.6%), and having just harvested (14.1%). The full set of reasons for survey attrition and missing yield data are provided in Tables A1 and A2, respectively.

As shown in Appendix tables A3 and A4, loss to follow-up for both interview and yield measurement was generally similar across in-person training treatment groups, implying that comparisons of outcomes across groups at endline can be interpreted as due to program effects, and not treatment-induced sample selection. Differences of up to 6 percentage points in attrition are observed across mobile intervention groups. These differences are significant at the 90% level for both the PxD reinforcement and PxD standalone intervention spillover comparisons in the pooled sample, implying that estimated impacts of these interventions could potentially be influenced by non-random selection of the sample for which follow-up data is available.

Table 1: Study sample and attrition

	HRNS	TNS	Total
Overall study sample	4679	5279	9958
Re-interviewed	4219	4758	8977
Lost to follow-up	460	521	981
Survey attrition rate	0.098	0.099	0.099
Study sample for yield	3789	4211	8000
Yield data available	3229	3263	6492
Lost to follow-up	327	381	708
No yield data	233	567	800
Yield attrition rate	0.148	0.225	0.189

4. Baseline statistics and balance across experimental groups

Appendix tables A5 through A8 present descriptive statistics of the evaluation sample at baseline. For each variable and comparison, means by experimental group are shown in the first two columns of the first row. In the following row, standard deviations are shown below group means, followed by the standard error of the adjusted difference. For the mobile reinforcement and mobile standalone comparisons, only the 90% of farmers from whom phone numbers were obtained at baseline, and who gave their consent to receive recorded messages, are included in these comparisons.[3] Analysis of the impact of these interventions is likewise restricted to this sub-sample.

The third column shows the adjusted difference in mean values for each variable between experimental groups.[4] The probability of observing each adjusted difference by chance (p-value) is shown in the fourth column for each comparison. Adjusted differences with p-values below 0.05 are indicated with an asterisk in these tables. By definition, variables will differ at this threshold of significance around 5% of the time, but a larger proportion of low p-values values could be cause for concern that the randomization failed to produce statistically equivalent experimental groups.

Demographics and education

The individual identified by the household as primarily responsible for growing coffee was male over 80% of the time; this proportion was higher in the region served by HRNS, at 86%. Female-headed households

[3] Consent to potentially receive messages was obtained from all farmers at baseline, including those subsequently assigned to the control group.

[4] Adjusted differences are computed by regressing the variable on the treatment indicator, as well as indicators for baseline survey type X region, stratification bins, and whether an observation was drawn from the back-up sample.

constituted 9% of the sample, and the average household consisted of just over 6.5 members. The primary coffee farmer was between 46 and 47 years old. Overall, just over half of male farmers and 65% of female farmers had less than a primary school education. Secondary school education or higher was rare, attained by 4% of men and 3% of women. That said, 85% of male farmers in the full sample, and 70% of female farmers could read and write in at least one language. Education attainment and literacy were generally lower in the region served by HRNS.

Asset ownership

Most households in the sample owned radios (80%) and mobile phones (90%), and many owned more than one phone. However, 32% of households did not own a pair of closed-toed shoes for each member. The average total landholding was just over 5 acres, of which around one and a third acres was under coffee. Livestock holdings amounted to 1.45 tropical livestock units (TLU) on average, an aggregate measure in which poultry are assigned a value of 0.01 goats and sheep a value of 0.1, cattle are worth 0.7, donkeys 0.5, and pigs 0.2. Asset ownership and housing quality were generally higher in the region where TechnoServe implemented training. Total landholdings were higher in the HRNS region, but less land was devoted to coffee.

Coffee practices, knowledge, and network

Coffee practices at baseline were assessed based on farmers' self-reports against implementer definitions of best practices, as described in Table 6 below. While most farmers were already managing their coffee in accordance with some recommendations – 76% reported weeding at least twice per year using a method other than digging under the tree canopy, and 64% avoided intercropping coffee with nitrogen-hungry maize or root crops whose harvest could damage the coffee root system – use of other recommended practices was less common. Just over a fifth of farmers applied at least one fertilizer to their coffee, a third reported applying mulch, 30% reported the recommended that their trees generally had four stems or fewer, and 8% knew at least 3 recommended pest and disease management techniques. Most farmers (77%) were able to correctly describe how coffee could be rejuvenated by removing stems.

Farmers recognized the names of an average of fewer than 2 out of 24 coffee farmers living in the three nearest study villages assigned to the opposite treatment group. Most coffee trees were an average of 10 to 11 years old.

In the region where TechnoServe implemented training, coffee farms were more established, with trees around 14 years old on average, compared to under 8 years in the HRNS region. The proportion using recommended practices was also higher, and respondents were more likely to know coffee farmers in other villages.

Income sources

Coffee was the most important income source for study households at baseline, at 29% of total income overall. Coffee made up a larger share of income in the districts where TechnoServe operated (39%) compared to those where HRNS was active (20%). Other important sources of household income were banana or matoke (22% in the TechnoServe region), maize (13% in the HRNS region) beans and other legumes (9% overall), and non-farm businesses (8% overall).

Coffee costs, revenues, and plans

Nearly 40% of farmers reported paying for labor to work on their coffee farm. Transportation was the next most frequently reported category of coffee expense, at 26%, followed by pesticides at 24%. Relatively few farmers reported spending money on any type of fertilizer (12%) and even fewer purchased inorganic fertilizer (4%). Mulch was purchased by 12% of farmers.

Over 20% of households overall, and nearly 30% in the region where TechnoServe implemented training, took payment for coffee prior to harvest. Average coffee revenue over the past 12 months was just over $163 US overall, or $119 US per acre. Both total revenue and revenue per acre were higher in the TechnoServe region, at $259 and $173, compared to the HRNS region, where the respective values were $82 and $78.

Balance across experimental groups

Differences between groups at baseline were generally small in magnitude and occurred at rates expected under random assignment. In the full sample, farmers in villages where coffee training was offered lived in slightly lower-quality housing and had slightly less land under coffee (1.27 vs. 1.38 acres). Coffee constituted 1% more of total household income for farmers in training villages, and root crops were less important by the same margin. The proportion of farmers reporting expenses for inorganic fertilizer was lower (3% vs. 4%) in villages assigned to receive training, while the proportion who reported coffee equipment or other coffee expenses was higher (28% vs. 24%; 1% vs. 0%). More of farmers in treatment villages (24%, vs. 21% in control villages) took payment for coffee ahead of harvest. Some of these differences were also apparent in training versus control villages in the HRNS and TechnoServe sub-samples. In the HRNS region, treatment group farmers were more likely to be following the best practice for coffee nutrition. In the TechnoServe region, the households of treatment group farmers included slightly fewer adults and adolescents.

Farmers in training villages who were assigned to receive PxD reinforcement messages had a higher mean household size (6.9 vs. 6.5 members) than those who received training only, and the female farmers in these households were more likely to have completed secondary school (1% vs. 0%). These farmers were also more likely to earn income from casual labor (4% vs. 3%) and to report pesticide and inorganic fertilizer expenses for coffee (26% vs. 23%). Within HRNS training villages, farmers who received reinforcement messages tended to have more coffee plots (1.6 vs. 1.49). In TechnoServe villages, farmers assigned to the reinforcement treatment were less likely to report coffee equipment expenses. Ownership of closed-toed shoes was slightly higher among farmers in the reinforcement group within the TechnoServe sub-sample.

Among those in the pooled sample who were assigned to the standalone mobile phone intervention, show ownership was higher relative to other farmers within the same village, as was the number of coffee plots (2.01 vs. 1.85). These farmers also tended to know more farmers in neighboring treatment villages (1.47 vs. 1.4). The adjusted difference in mobile phone ownership was 2% lower in the mobile standalone treatment group relative to farmers in pure control villages.

Variables most closely related to the primary study outcomes of coffee yield (measured at baseline as revenue per acre of coffee) and the coffee practice index were balanced across all treatment groups. Farmers who received the standalone PxD intervention were more likely to report following best practice for intercropping than other farmers in the same village, but other baseline coffee practices and knowledge were statistically equivalent across these groups.

5. Interventions and farmer engagement

One training session conducted by each trainer (40 for HRNS and 25 for TechnoServe) was observed by data collection staff. Most observations occurred in July of 2019 for HRNS, and November 2019 for TechnoServe, the fourth month of training for each implementer.[5] Table 2 describes presents mean values of training session duration, attendance, practices, and farmer engagement, by implementing organization.

Table 2. Training session characteristics and quality, by implementer

	HRNS	TNS	Overall
Duration and attendance			
Total duration (hours)	1.6	1.8	1.7
Duration of content	0.83	1.3	1.1
# Female farmers	3.6	6.7	4.8
# Male farmers	9.2	10	9.5
Training practices and farmer engagement			
# Demonstrations conducted	1.4	2.4	1.8
Any visual aid used	0.57	0.88	0.69
# Female farmers engaged in discussion	0.97	2.9	1.7
# Male farmers engaged in discussion	3.5	5.7	4.4
# Female farmers engaged in activities	0.1	9.7	3.8
# Male farmers engaged in activities	1.2	16	6.9
Observer assessment			
Trainer was enthusiastic	0.72	0.6	0.68
Trainer was engaging	0.7	0.88	0.77
Trainer provided clear instructions	0.85	1.0	0.91
Farmers were engaged	0.95	1.0	0.97

[5] Two HNRS trainers who could not be observed in July were observed in December of the same year, and three of the TechnoServe observations occurred in January 2020.

Duration and attendance

The total duration of training, including attendance-taking and planning the next meeting, was 1.6 hours for HRNS and 1.8 hours for TechnoServe. The delivery of content accounted for just over half of the HRNS training duration, at 0.83 hours, and most (1.3 hours) of the TechnoServe training. Female farmers constituted 28% of attendees in HRNS sessions, and 40% in TechnoServe sessions, which also included more farmers overall, at just under 17 on average versus 13 at HRNS sessions.

Training practices and farmer engagement

Demonstrations and visual aids were used by both implementers, with a higher average number of both types of teaching tool used per session by TechnoServe trainers.

Both male and female farmers were more likely to engage in group discussions during TechnoServe trainings compared to those run by HRNS. The contrast was particularly strong for female farmers, who participated on average once during HRNS trainings, compared to 3 times during TechnoServe trainings. This reflects both the higher numbers of women in TechnoServe sessions and a higher participation rate among those present.

Female farmers almost never participated in activities during HRNS trainings, reflecting the lower number of activities involving farmers generally in these trainings. In contrast, the number of instances of active participation by both women and men during TechnoServe trainings outnumbered the number of each group present.

Observer assessment

At the end of the training session, observers were asked to rate the trainer's performance and the level of farmer engagement. Ratings of trainers were generally high for both implementers, with 68% of trainers rated as enthusiastic or very enthusiastic, 77% judged as engaging, and 91% assessed as providing clear instructions. Similarly, farmers were rated by observers as engaged or very engaged in 97% of training sessions.

Attendance

Training attendance data is available from two sources. For farmers in treatment villages, implementers kept records of the training attendance of all farmers in the study sample who had attended the pre-intervention session used to identify the study sample. It was not feasible to collect such attendance data for all control farmers in nearby villages, or for treatment farmers who attended training sessions outside of their village. Summary statistics based on implementer records are shown in Table 3.

Table 3. Training attendance of study farmers, from implementer records

	HRNS	TNS	Pooled
Attended any trainings	0.82	0.86	0.84
Attended 5+ trainings	0.77	0.77	0.78
Attended 10+ trainings	0.55	0.29	0.41
Observations	1786	1953	3739

In addition, both treatment and control farmers were asked a series of questions during the follow-up survey about their attendance of coffee agronomy training during the period this was offered, and their recollection of key details about the training. Farmers who both indicated they had attended training and were able to recall the name of the trainer, local training mobilizer, or farmer group, are considered as having attended training. Table 4 presents the proportion of farmers who attended training, based on this measure, by treatment and control group.

Attendance of training verified in this way is significantly lower than based on implementer records. One potential reason for the difference is that the individual interviewed was not aware of other household members' attendance of training, which was captured at the household level by implementers. In the cost effectiveness analysis conducted below, training costs are measured at the village level and outcomes are based on results among farmers with access to and expressed interest in training, rather than on training completion rates. Our estimates of cost effectiveness are therefore unaffected by uncertainty about the true rate of training attendance.

The last two rows in Table 4 show the proportion of farmers who report having learned at least one new coffee practice from another farmer during the study period, and then the proportion who reported this type of learning or whose attendance of training was confirmed. In both regions, farmers in control villages were 3 percentage points more likely than those in training villages to report learning about new coffee practices from other farmers. When combining verified training and reported peer learning, a sizeable difference in farmers' exposure to information about coffee practices remains: 41% in the HRNS region, and 50% in the TechnoServe region. This difference indicates that the randomized training intervention resulted in a meaningful change in access to the information disseminated through agronomy training, based on which we estimate treatment effects on practices, yields, and related outcomes.

Table 4. Survey-based measures of attendance, recollection of topics, and reported learning from others

	HRNS			TechnoServe		
	Control	Treatment	T-C	Control	Treatment	T-C
Self-reported attendance	0.32	0.73	0.41	0.36	0.80	0.44
Confirmed attendance (recalls specific info)	0.05	0.54	0.50	0.06	0.64	0.58
Recalls any training topic	0.30	0.70	0.40	0.34	0.78	0.44
Number of training topics recalled	0.85	2.51	1.66	1.13	3.14	2.00
Learned coffee practice from another farmer	0.17	0.14	-0.03	0.16	0.13	-0.03
Confirmed attendance OR learned from farmer	0.21	0.62	0.41	0.21	0.71	0.50

Among the 90% of farmers assigned to the mobile phone interventions who provided the research team with a mobile phone number at baseline and agreed to receive messages, the average proportion of recorded messages played was 59% for the reinforcement intervention and 62% for the standalone phone-based extension intervention, as of June 2021 when analysis of PxD engagement data was conducted (Table 5).

Table 5. Engagement with PxD interventions (among treatment farmers with phones) up to June 2021

	Mean	25th Percentile	Median	75th Percentile	N
Share of reinforcement messages played	59%	32%	73%	88%	1915
Share of standalone messages played	62%	40%	70%	85%	1233

Impact of COVID-19

In March 2020, 11 months into the two-year HRNS program, and 7 months into TechnoServe's activities, in-person training was halted by both implementers for over two months, due to the COVID-19 pandemic. As restrictions on travel eased in June 2020, both implementers resumed on-farm training, but with significant modifications. Visits to individual farms fully replaced TechnoServe's group training sessions for 6 full months, and were used in combination with smaller group trainings during an additional 2 months. Individual and small group trainings were likewise the primary means of farmer engagement used by HRNS during the latter half of their program. For both implementers, the rate of progress through training topics during the COVD-19 period was far slower than usual due to restrictions on the size of gatherings. The implementers also reported that peer-to-peer learning opportunities were negatively impacted. Two months were added to the training duration compensate for this disruption.

6. Outcome variable definitions and descriptive statistics

Coffee practices

Coffee agronomy practice variables are based on a combination of on-farm observations and farmers' responses to survey questions. Definitions of best practices are provided in Table 6, and average rates of best practice adoption at endline for farmers in the no training and training groups in the pooled sample are shown in Figure 3.[6]

[6] Coffee practices were directly observed for all farmers at endline, but were assessed based on farmer reports for most farmers at baseline, leading to discrepancies in practice adoption rates across rounds. Definitions were also updated slightly between baseline and endline in response to implementer feedback. Analysis of treatment impact

Table 6. Practice definitions and weights in the practice index

Practice	Best practice definition at endline	Best practice definition at baseline	Weight in index
Weeding	1. Main method used for weeding under the canopy is NOT digging. *AND* 2. Farmer weeds twice or more per year *AND* 3. There are few or no weeds under the canopy *AND* 4. If there are few weeds, they are less than 30cm tall	1. Farmer has NOT exclusively dug under the tree canopy to weed *AND* 2. Farmer weeds twice or more per year *AND* 3. There are few or no weeds under the canopy (observational surveys) *AND* 4. If there are few weeds, they are less than 30cm tall (observational surveys)	0.30
IPDM	1. Farmer uses at least 2 out of 9 IPDM methods	1. Farmer can name at least 3 out of 9 IPDM methods	0.30
Rejuvenation	1. Most trees have 4 main stems or fewer AND 2. The oldest main stems on the majority of the plot are 8 years or younger	1. Most trees have 4 main stems or fewer *AND* 2. The oldest main stems on the majority of the plot are 8 years or younger (observational surveys)	0.40
Pruning	1. Trees have been pruned using 3 of the 4 following methods listed - Centres opened - Unwanted suckers removed - Dead and broken branches removed - Branches touching the ground removed	Same as endline for observational surveys; not available for others	0.35

presented in this report is therefore limited to differences between randomly assigned treatment groups at a given point in time.

Coffee Nutrition	1. At least one of the following are used: compost, manure, NPK, Foliar Feeds, Lime and DAP. If foliar feed is used only count if this is zinc/boron based *AND* 2. IF fertilizer is applied to the soil, the fertilizer has been applied using a measure, and is not broadcast *AND* 3. Nearly all leaves are dark green	1. At least one of the following are used: compost, manure, NPK, Foliar Feeds, Lime and DAP. If foliar feed is used only count if this is zinc/boron based ***AND*** 2. IF fertilizer is applied to the soil, the fertilizer has been applied using a measure, and is not broadcast ***AND*** 3. Nearly all leaves are dark green (observational surveys)	0.4
Mulching	1. Farmer has applied mulch *AND* 2. Mulch is more than 2cm thick *AND* 3. Mulch has been applied to at least 25% of the coffee plot	1. Farmer has applied mulch ***AND*** 2. Mulch is more than 2cm thick (observational surveys) ***AND*** 3. Mulch has been applied to at least 25% of the coffee plot (observational surveys)	0.25
Erosion Control	1. At least one erosion control method observed	Same as endline for observational surveys; not available for others	0.20
Shade	1. There is 20% shade or more	Same as endline for observational surveys; not available for others	0.20
Intercropping	1. The two main crops grown with coffee are NOT maize, cassava, or root crops	1. Coffee is not grown exclusively with one, or any combination of, the following crops: maize, cassava, potato, other root crops. 2. Whether the farmer grows **any of** maize, cassava, or a root crop in combination with coffee will be included among the candidate control variables	0.125

An index of coffee practices was constructed by applying weights to binary practice indicators, with weights corresponding to the median of the expected effect of each practice on yield as assessed by 15 coffee agronomists based in East Africa. These weights are shown in the last column of Table 6. Below, we refer to this index of practices as the practice index.

Figure 3. Adoption rates of coffee best practices by training treatment group at endline

Yield per tree

Measurement of yield per tree was assessed using the following protocol:

Pre-harvest yield measurement: Yields were measured by harvesting all green cherry from three trees in the plot where the farmer indicated at baseline that new practices would be implemented first. These trees were equidistant from the edges of the plot and each other, along a diagonal transect of the coffee plot. To avoid purposive selection of trees with certain characteristics by enumerators (for example, those with few cherries or low branches), trees were selected and marked during an initial visit by one team and harvested by a separate team the following day. Photographs were taken by both teams, and by the second team pre- and post-harvest, to enable visual back-checks.

Cherry count estimate: The number of cherries per tree was estimated using the green cherry collected ahead of harvest time. Green cherries were brought back to a central location and sorted into four size categories (> 14 mm, 12.5-14 mm, 9-12.5 mm, 6-9 mm), using sieves. The total weight of each size group was measured, and the average weight per cherry in each size category was estimated using a 100-cherry sample. Using these estimates, the average number of cherries per tree was calculated.

The total weight of the green coffee cherries harvested per team was measured independently by the harvest team and a separate sorting team as a check on data quality.

Ripe cherry weight: At the peak of the harvest immediately following pre-harvest yield measurement, 500 grams of ripe cherries were collected from a minimum of 10 coffee trees, with the use of a visual aide to ensure peak ripeness. From these, a representative sample of 100 cherries was sub-sampled using a cherry board and used to calculate the mean weight per cherry.

Estimation of ripe cherry yield.

The estimated number of cherries (from the green cherry harvest) was multiplied by the average weight per ripe cherry to come to an estimate of the total ripe cherry harvest weight per tree in kg. This method provides a consistent estimate of yield across farms and treatment arms and can therefore be used to assess the impact of the intervention on harvest per tree, in terms of a percentage difference. We note that the resulting weight per tree estimates are higher than would be expected during a single harvest, as the range of green cherries included in this estimate are expected to ripen over two successive harvest seasons, and some may not ultimately mature.

Figure 4. Coffee yield estimation methods, from left to right bottom: a coffee tree marked by Team A for harvest by Team B, mesh used by Team C to sort unripe coffee cherries by size, confirming ripeness of cherries using a visual guide, taking a photo of the weight reading for 100 ripe coffee cherries.

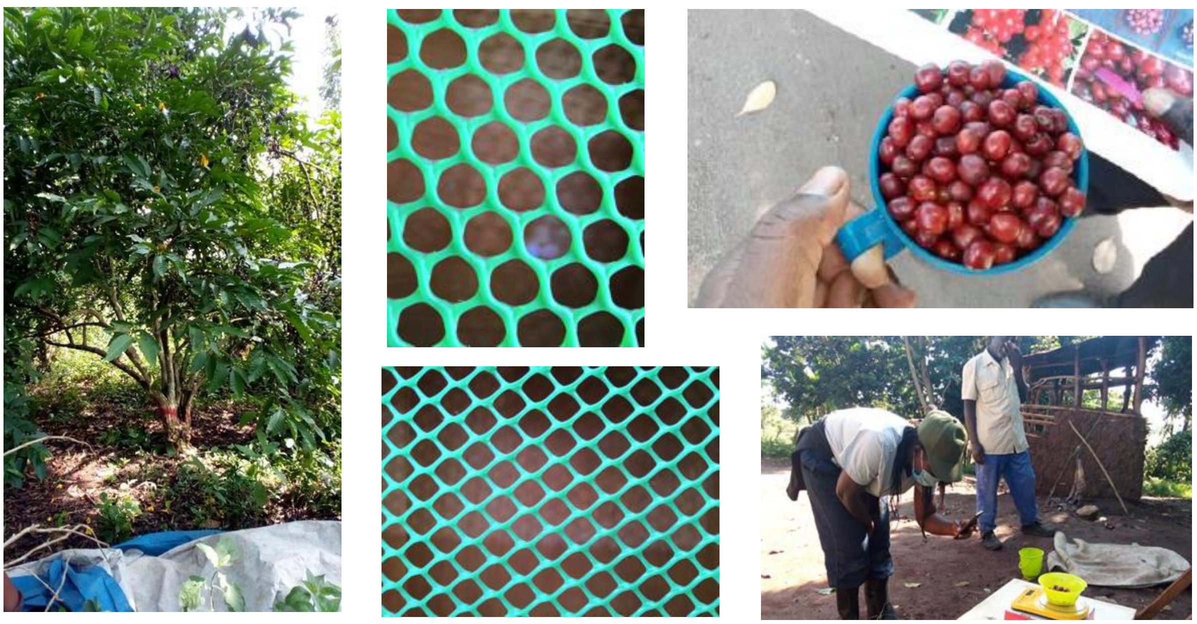
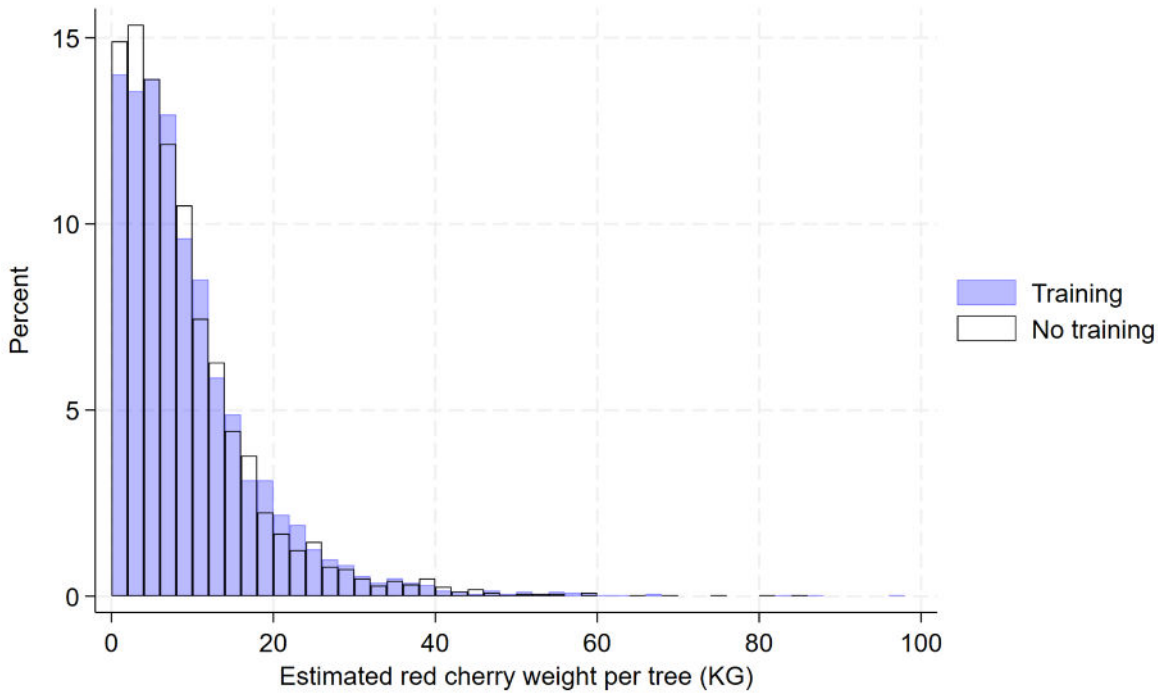


Photo credit: Priscah Cheruiyot and *Enveritas*

The distribution of yields by treatment group is shown in Figure 5. Just under 3% of farmers, including those that had stopped growing coffee, had zero yields at the time of follow-up data collection. The median red cherry weight per tree was 7.09 kg, and the mean was 9.4 kg. These translate to approximately 1 kg and 1.34 kg of dried green beans respectively, using a conversion factor of 7 to 1. We note that because unripe cherries as small as 6 mm in length were included in the yield measure, the estimated weight per tree represents at least the annual, rather than seasonal, harvest amount. Further, as many of these small cherries may never reach maturity, the yield estimates presented here can be thought of as an upper bound on the mature harvest weight. Even with these caveats in mind, some of the yield values are larger than typically encountered for coffee trees, with the 95th and 99th percentile of yields at 25.7 and 42.2 kg of estimated ripe cherry weight (3.7 kg and 6 kg of dried green bean equivalent) respectively. Cases of very high yield estimates were investigated by survey team supervisors. The typical explanation for trees with extremely high yields was that the tree had many branches and resembled a cluster of trees rather than a typical coffee tree.

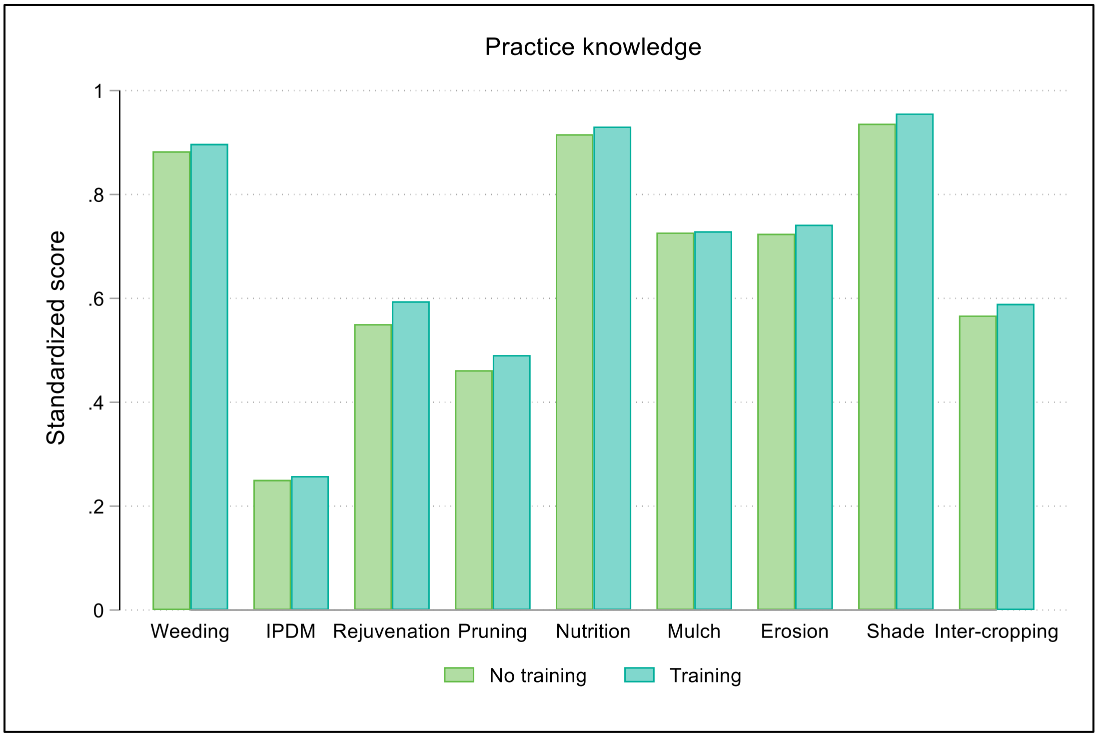
Figure 5. Coffee yield by training treatment group at endline



Knowledge

Correct responses to the knowledge questions in Appendix 2 were aggregated by the practice to which they relate based on item response theory. Endline knowledge scores by training treatment group for the pooled sample are shown in Figure 6. For each practice, the knowledge score varies between zero and one. The knowledge index used in the regression analysis below (but not shown in Figure 6) is constructed from these scores using the same yield-based weights as used in the practice index, and then standardized to have a mean of zero and a standard deviation of one.

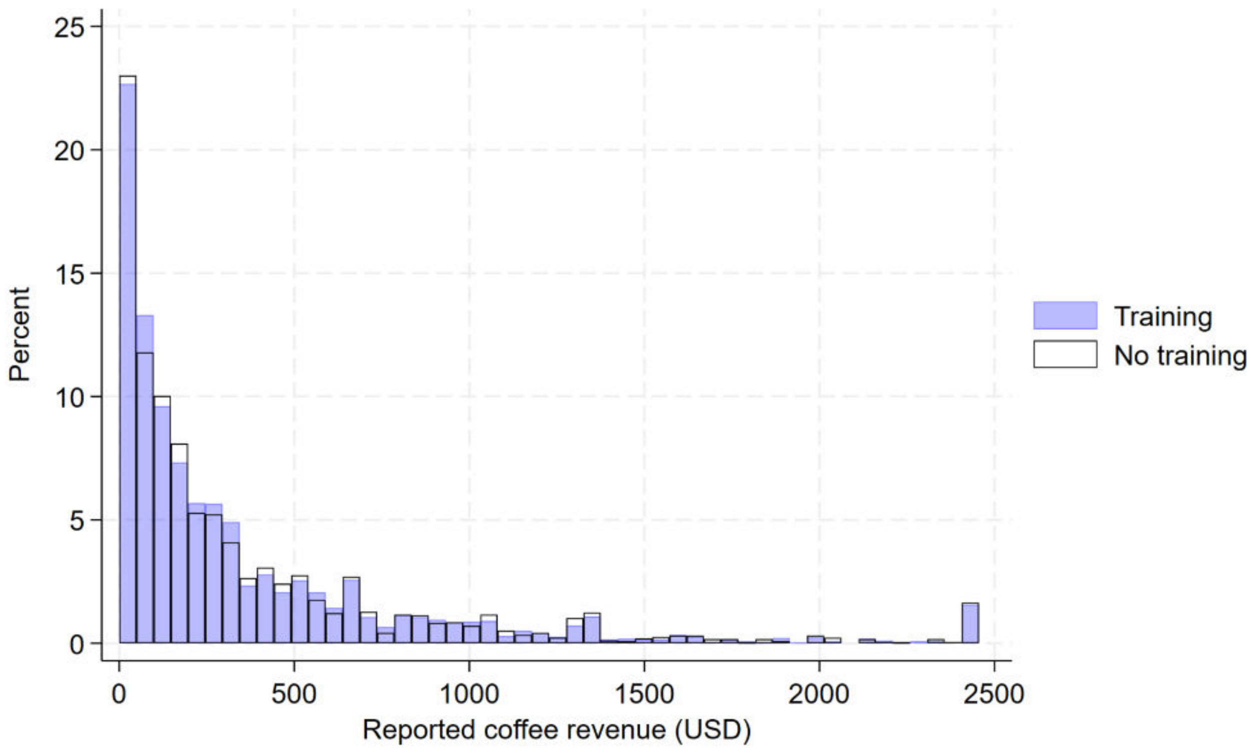
Figure 6. Knowledge of coffee best practices by training treatment group at endline



Coffee revenue, costs, and profit

Coffee revenue is the total of each farmer's reported total coffee revenue for each of the periods during which coffee was harvested over the 12 months preceding the follow-up survey. This survey was conducted at the same time as the pre-harvest yield assessment, and so covers approximately the third full year after the start of training, and the first full year after the end of training. Figure 7 shows the distribution of reported coffee revenue at endline by treatment group. Six percent of households in the study reported no coffee revenue in the year preceding the endline survey, and 23% reported revenue of less than $50 US. The 1.6% of observations that exceeded the sample mean plus 3 standard deviations were considered outliers and assigned this cut-off value ($2,522).

Figure 7. Coffee revenue by treatment group



Coffee costs are the total of farmers' expenditures on all cash inputs used on coffee. Following previous literature, the value of household labor is not included due to difficulty with assigning a monetary value to non-wage work (Beaman et al., 2023). In the analysis below, impacts on the number of days spent by household members on coffee production are presented separately. Figure 8 graphs the share of total coffee costs for all farmers (both regions, treatment and control farmers) at endline. Weed control constitutes the greatest share of costs, at 37% of the total, followed by 15% for harvesting, 14% for post-harvest costs, and 13% for pest and disease management. All other costs make up for 6% or less of the total, with mulch and nutrition each constituting 6%, followed by marketing at 4%, pruning at 3%, and the remaining practices less than 1% each of total costs.

Twenty-one percent of coffee farmers reported zero coffee costs over the past year, and 62% had costs of less than $50 US (Figure 9). Some farmers, however, had significant costs, with the top 1% spending over $1,000 US on coffee production related expenses.

Coffee profit is calculated as coffee revenue minus costs. The distribution of this variable by treatment group is shown in Figure 10.

Figure 8. Coffee cost shares by practice

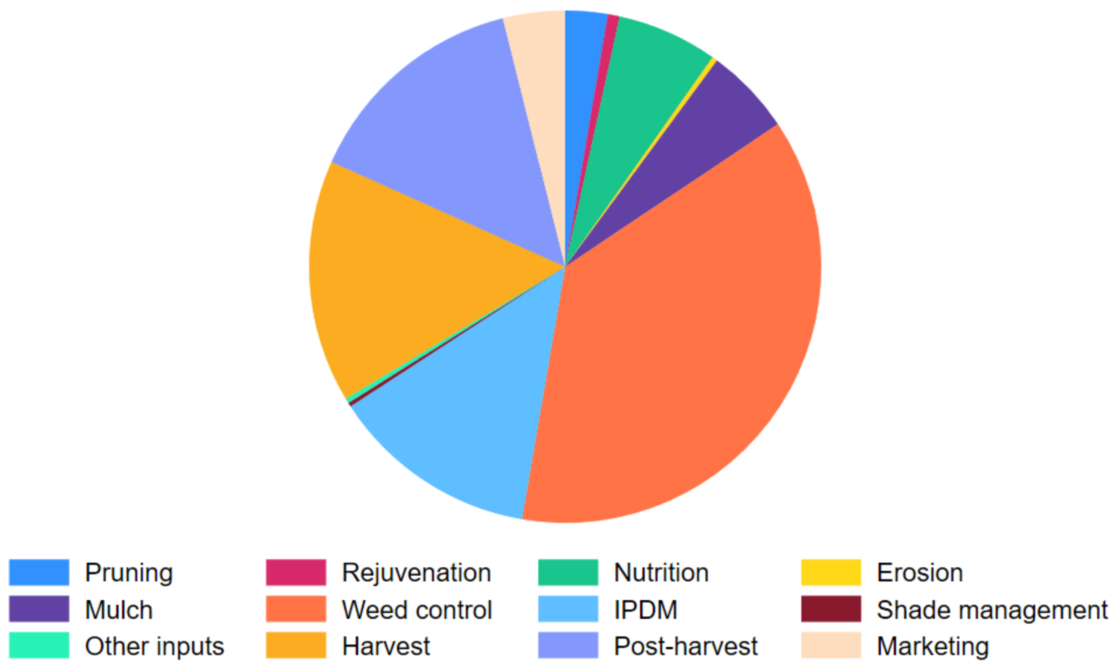


Figure 9. Coffee costs by treatment group

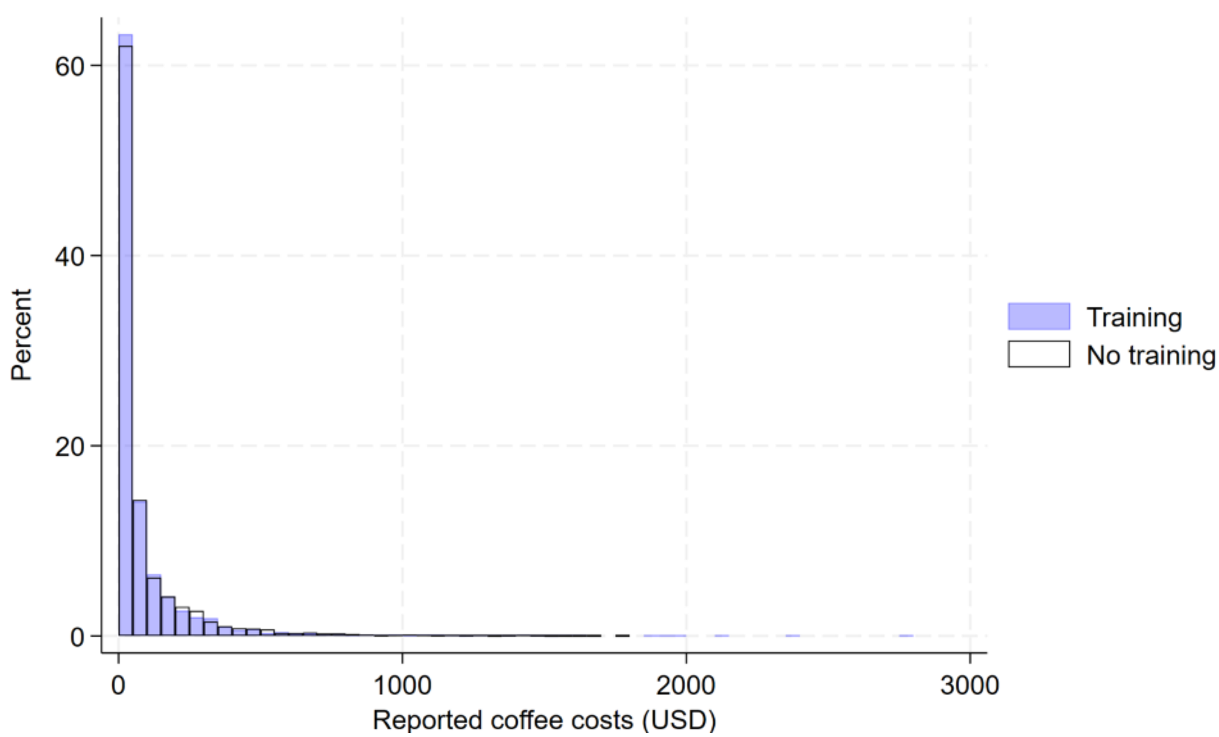
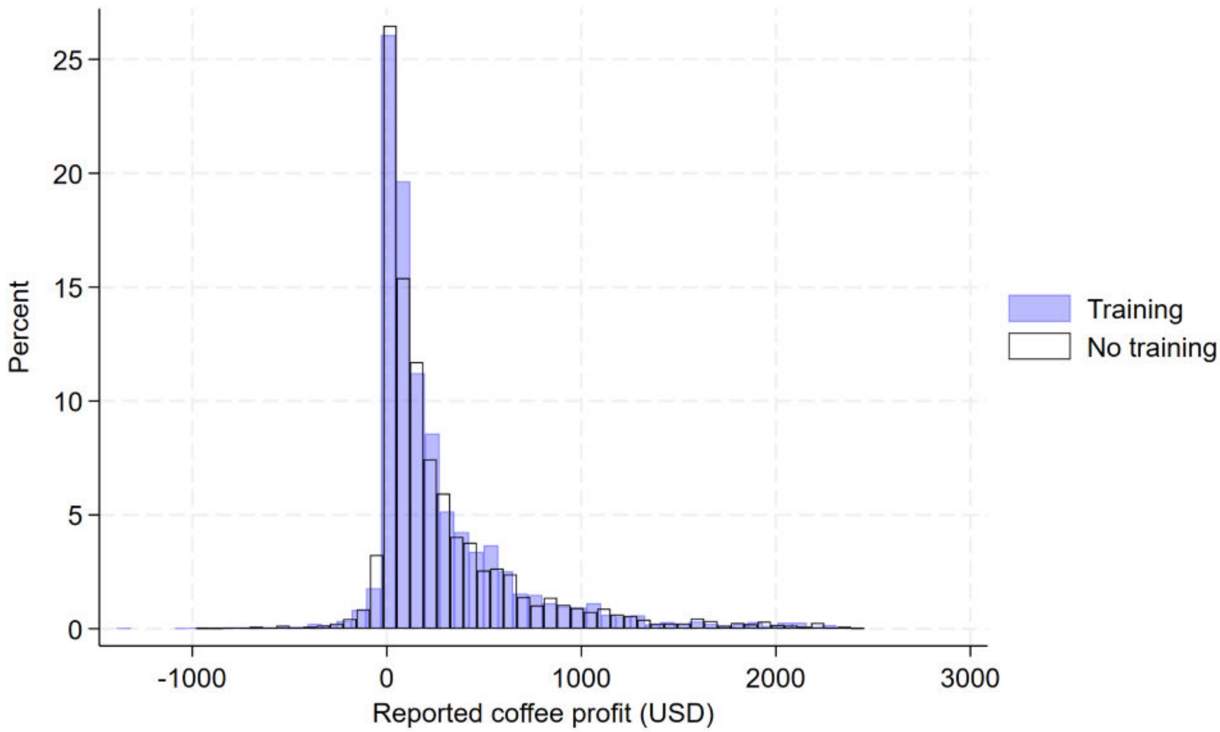


Figure 10. Coffee profit by treatment group



Non-coffee income, women's control over income, and food production

Without access to credit, smallholder farmers' productive resources, including land, labor, and cash, can be thought of as fixed. Increasing coffee production by increasing the time or inputs applied to this crop may therefore come at the cost of reducing the production of other crops, or cutting back on other income-generating activities. It is therefore crucial to measure the impact of the training intervention not only on coffee yield and profits, but also on other sources of household income.

To this end, we assess the impact of the in-person training intervention on the change since baseline in household income from non-coffee sources. We construct a qualitative index equal to the sum of a set of variables indicating the directional change in income for each non-coffee income source. Potential income sources include non-farm businesses; casual wages; salaries; and sales of specific non-coffee crops, livestock products, and livestock. Each income source is assigned a value of 0 if there was no change in the amount of income from the source over the four between baseline and endline, a value of 1 if income from that source increased, and a value of -1 if income from that source decreased. These values are then added up across all income sources.

A particular risk of encouraging households to focus on coffee production relates to the fact that revenue earned from this crop is typically controlled by men. In fact, the ratio of female farmers versus households who report income from coffee is lower than for any other crop or income source (Doan and Hoffmann, 2021). Unless coffee training also leads to greater control of coffee income by women, there is a risk that women's control over household income may fall as resources are redirected toward coffee, and away from income-generating activities over which she has more say.

We assess the effect of the training program on women's control over income through two variables: an index of changes to non-coffee income under women's control over the past four years, and an index of women's control over coffee income. The index of changes in women's control over non-coffee income is calculated similarly to the measure of changes in non-coffee income at the household level, except that it is restricted to income sources reported as controlled primarily by the female head (in the case of single female-headed households, this applies to all household income sources).

The index of women's control over coffee income is constructed as the mean of responses to a set of questions about the female head's role in the decision to spend coffee income on various items, including school fees, food / general household expenses, repayment of debt, reinvestment in coffee, agricultural activities or assets, non-farm business expenses, improvements to the home, consumer durables, and medical expenses. Responses to each of these questions is coded as 0 if the decision is primarily made by the male head, 0.5 if the decision is shared, and 1 if the decision is primarily made by the female head.

Finally, we test for changes in the amount of food crops grown by the household, with changes per food crop coded as 1 (positive change), 0 (no change), and -1 (decrease), and then averaged at the household level.

7. Analytical methods

We follow the pre-analysis plan registered on the American Economic Association's registry for randomized controlled trials prior to the research team's access to follow-up data.[7] Deciding on the statistical methods to be followed ahead of data analysis prevents researchers from selecting methods based on results and is widely considered a best practice for the analysis of randomized controlled trials (Christensen and Miguel, 2018).

Treatment effects of the in-person training intervention are estimated by regressing each outcome on a binary variable indicating whether the farmer lived in a village where training was offered, and a set of binary variables indicating the geographical clusters that constituted the randomization strata. The sample for this analysis excludes those farmers within control villages who were assigned to the standalone mobile extension treatment. To increase the precision of the estimated differences between treatment groups, a machine learning algorithm, post-double selection lasso (Belloni, Chernozhukov, and Hansen, 2014) is used to select control variables measured at baseline that are correlated with both treatment assignment and the outcome of interest. Baseline survey type indicators are interacted with baseline control variables for comparisons in which the share of respondents administered a given survey type at baseline differed significantly across experimental groups.[8] The estimated treatment effect of training is the average effect for farmers in treatment villages, some of whom also received reinforcing phone messages. Following an intent-to-treat approach (ITT), farmers who lived in training villages but did not attend training are considered part of the treatment group.

[7] https://www.socialscienceregistry.org/trials/9765. Deviations from this analysis plan are noted in the text.

[8] The exception to this rule is tropical livestock units, which, when interacted with baseline survey type, prevent model convergence.

As described in Section 5, only 54% of study farmers in villages where HRNS offered training and 64% of those in villages where TechnoServe did so were confirmed to have attended training to the extent that they could recall the name of the trainer, farmer group, or find their name on the list of attendees. Moreover, 5% to 6% farmers who lived in nearby control villages also attended. If we make the assumption that farmers only received benefits of the intervention if they attended training, and did not, for example, also learn about coffee recommendations from their neighbors who attended training, then we can calculate the impact of training on those who actually attended as the estimated treatment. This 'treatment on the treated' (ToT) effect is equal to the intent-to-treat estimate (reported in the tables below), divided by the difference between the proportion of farmers trained in treatment versus control villages. For HRNS, the ToT effect (based on our definition of confirmed attendance) can be calculated as the estimated ITT treatment effect divided by 0.5. For TechnoServe, the ToT effect is the ITT estimate divided by 0.58.

Treatment effects of the mobile phone-based interventions are similarly estimated by regressing outcomes on an indicator for the farmer's assignment to each of these interventions (reinforcement or standalone mobile extension), along with randomization strata indicators (villages for the reinforcement intervention; geographical clusters and practice terciles for the standalone intervention), baseline control variables, and interactions with survey type as for the in-person training intervention. If an outcome differed significantly across experimental groups at baseline, the baseline value of that outcome is also included as a control to minimize potential bias (Frison and Pocock, 1992). In practice, this applies only to the intercropping best practice for the comparison of farmers who received standalone messages against within-village controls. As noted above, we estimate effects of the phone-based interventions among the subset of farmers who provided phone numbers and consented to receive recorded messages.

We account for the re-randomization of the standalone mobile extension treatment assignment by using randomization inference (permutation tests) to estimate the statistical significance of results (Young, 2019). The intent-to-treat approach we follow means that farmers who never listened to any of the messages sent are still considered as treated in this analysis.

Impacts on continuous outcomes are estimated using linear regression models. Impacts on binary outcomes (individual practices) are estimated using logistic regression models and marginal impacts at the sample mean are presented. Impacts on outcomes that are approximately log-normally distributed (yield per tree, coffee revenue, coffee costs, coffee profit) are log-transformed.

Two primary outcomes were specified in the registered pre-analysis plan: the practice index, and yield per tree. Pre-specifying primary outcomes guards against the over-interpretation of results when impacts on many outcomes are tested, as some of these may, by chance alone, be correlated with treatment assignment. Other outcomes can provide supporting evidence of impact and may shed light on the mechanisms behind impact.

8. Impact of interventions

8.1 Reading results tables

In tables showing estimated impacts of the interventions, outcomes are indicated at the to top of each column. The values in first row of the table, in the same line as the intervention description (for example "In-person training") are coefficients on the treatment indicator. These indicate the adjusted mean difference in the value of the outcome between farmers assigned to an intervention and those assigned to the comparison group.

	HRNS			TechnoServe		
	Control	Treatment	T-C	Control	Treatment	T-C
Self-reported attendance	0.32	0.73	0.41	0.36	0.80	0.44
Confirmed attendance (recalls specific info)	0.05	0.54	0.50	0.06	0.64	0.58
Recalls any training topic	0.30	0.70	0.40	0.34	0.78	0.44
Number of training topics recalled	0.85	2.51	1.66	1.13	3.14	2.00
Learned coffee practice from another farmer	0.17	0.14	-0.03	0.16	0.13	-0.03
Confirmed attendance OR learned from farmer	0.21	0.62	0.41	0.21	0.71	0.50

The second row of values, shown in parentheses, are the standard errors of these mean differences. For estimates of the impact of in-person training and reinforcement interventions, standard errors are related to confidence intervals as follows: the bounds of 95% confidence intervals are equal to the mean difference, plus or minus 1.96 times the standard error. Because randomization inference was used to account for the re-randomization of treatment assignment for the standalone mobile phone intervention, confidence intervals for those estimates cannot be calculated.

The third row of values are p-values. These represent the probability that the mean difference across intervention and comparison groups is due to chance. A p-value of less than 0.05 means there is less than a one in twenty chance that the difference between groups has occurred due to chance. This is the standard threshold for a statistically significant finding, though when a specific direction of impact is hypothesized, as was the case for this study, outcomes with p-values of less than 0.1 may also be considered statistically significant. In the tables below, * indicates an estimated effect with statistical significance of p<0.1, ** indicates that p<0.05, and *** means that p<0.01.

The second to last row in each table shows the mean value of the outcome in the control group. Finally, the sample size (including intervention and control farmers) is shown in the last row.

We present impacts of the in-person training interventions first, then those of the mobile phone-based interventions. In each case, we begin with impacts on the pre-specified primary outcome variables of the coffee practice index and, for in-person training, yield per tree. We then describe impacts on farmers' knowledge of best practices, as an expected pathway through which the interventions were expected to affect practices. For in-person training, we describe impacts on reported coffee revenue, costs, and profit, as well as on other earnings, changes in food crops, and women's control over income.

8.2 Impacts of in-person training

Impacts of in-person training on the adoption of recommended coffee practices are shown in Table 7. In the pooled sample, the estimated effect of training on the yield-based index of practices is a 6 percentage-point increase (column 1, first panel). This implies that based on the median assessment of the 15 agronomists interviewed, the changes in practices induced through the training intervention would be expected to increase coffee yields by six percent. The estimated effect on the practice index is slightly higher, at 7 percentage points in the TechnoServe sample, though the impacts of the two implementers on this outcome do not differ statistically.

In the pooled sample, training significantly increases the share of farmers who follow best practices on integrated pest and disease management, pruning, coffee nutrition, and erosion control. The patterns of effects on specific practices are similar across the two regions.

Differences in estimation sample size across practices are due to the fact that when all of the farmers in a particular geographical cluster either do, or do not, adopt a practice, information from that cluster of villages cannot be used to estimate the outcome, and all observations in the cluster drop out of the statistical model. This occurs more often when the proportion of farmers who adopt an outcome is close to either 1 or 0, as is the case for the mulching best practice.

As observed at baseline, coffee practices among control group farmers at endline were generally better in the districts where TechnoServe implemented training compared to those where HRNS operated. Relative patterns of adoption across practices were similar across regions, with most farmers following recommended intercropping and weeding practices, an intermediate share following recommended pruning, erosion, shade, and IPDM practices, and lower levels of adoption of recommended mulching, nutrition, and rejuvenation practices.

Table 7. Effect of in-person training on coffee agronomy practices

	Pooled Sample									
	Practice Index	Weeding	IPDM	Re-juvenation	Pruning	Nutrition	Mulching	Erosion control	Shade	Inter-cropping
In-person training	0.06***	0.03	0.09***	0.01	0.03*	0.06**	0.03	0.05***	-0.01	0.01
	(0.01)	(0.02)	(0.01)	(0.08)	(0.02)	(0.03)	(0.04)	(0.01)	(0.02)	(0.02)
p-value	[0.000]	[0.137]	[0.000]	[0.887]	[0.095]	[0.048]	[0.493]	[0.000]	[0.561]	[0.731]
Control mean (endline)	0.67	0.49	0.24	0.11	0.32	0.12	0.04	0.27	0.40	0.86
Observations	7235	7235	7235	7235	7235	6907	5297	7235	7235	7075
	HRNS									
	Practice Index	Weeding	IPDM	Re-juvenation	Pruning	Nutrition	Mulching	Erosion control	Shade	Inter-cropping
In-person training	0.06***	0.02	0.09***	0.05	0.05**	0.05	-0.03	0.04	-0.02	-0.02
	(0.01)	(0.03)	(0.02)	(0.03)	(0.02)	(0.05)	(0.07)	(0.03)	(0.03)	(0.04)
p-value	[0.000]	[0.508]	[0.000]	[0.153]	[0.040]	[0.326]	[0.691]	[0.120]	[0.468]	[0.640]
Control mean (endline)	0.58	0.35	0.18	0.13	0.27	0.07	0.03	0.21	0.43	0.87
Observations	3437	3437	3437	3437	3437	3109	2267	3437	3437	3364
	TechnoServe									
	Practice Index	Weeding	IPDM	Re-juvenation	Pruning	Nutrition	Mulching	Erosion control	Shade	Inter-cropping
In-person training	0.07***	0.03	0.08***	0.02	0.03	0.06	0.04	0.06***	-0.00	0.02
	(0.01)	(0.03)	(0.03)	(0.04)	(0.03)	(0.04)	(0.05)	(0.01)	(0.03)	(0.04)
p-value	[0.000]	[0.196]	[0.008]	[0.558]	[0.278]	[0.125]	[0.400]	[0.000]	[0.982]	[0.555]
Control mean (endline)	0.75	0.61	0.28	0.09	0.36	0.16	0.04	0.33	0.36	0.86
Observations	3798	3798	3798	3798	3798	3798	3030	3798	3798	3711

Yield effects are generally modeled as multiplicative: when two farmers, one with low and one with high yields, each change their practices in a particular way, for example by starting to use chemical fertilizer, we would expect each of them to experience a proportional increase in yield – increasing production by, say, 40%, rather than an additive increase of, for example, 500 g of coffee per tree. To model yield effects this way, it is necessary to estimate the impact of an intervention on the *logarithm* of yield, rather than its level. The logarithmic transformation has the additional benefit of compressing the range of values, which in turn reduces the influence of very high values on mean outcomes. The downside of using the logarithm of coffee yield as the outcome is that the logarithmic transformation of zero is undefined, so farmers with zero yield cannot be included in this analysis.

Table 8 presents estimated effects of coffee agronomy training first on the probability of non-zero coffee yield based on a probit model (first three columns), and then on the logarithm of coffee yield among those farmers with any positive yield (second three columns). Estimated effects on the logarithm of yield are roughly equal to proportional effects on yield.[9,10] Farmers who did not grow coffee or did not have any fruit-bearing coffee trees at the time of sampling are considered to have zero yield. Farmers with zero yield account for 3 percent of the sample in control villages overall, and a similar share in villages where training was offered in the pooled and HRNS samples. In the region where TechnoServe implemented training, most observations drop out of the regression estimating the occurrence of any yield because all farmers in most of the geographical clusters within which villages were randomized harvested some coffee. Within those clusters in the TechnoServe region where some farmers had positive yield and others had zero yield, those assigned to the treatment were 1 percentage point more likely to have zero yield. Assuming no effect of the intervention on the probability of harvesting coffee in villages where all farmers harvested implies an effect size of 0.46 percentage points (= 1 percentage point x 46% of the sample included in the estimation) for the TechnoServe sub-sample. This small difference could potentially be attributed to higher rates of uprooting and replanting, or rejuvenation involving the removal of all stems, in training villages.

Transforming the impacts on log yield to percentage effects, in the pooled sample, farmers who lived in treatment villages and harvested any coffee had yields per tree 7.3% higher than farmers in control villages with non-zero coffee yield. The estimated impact is over twice as high in the TechnoServe region, at 10.5%, versus 4.1% and not significantly different from zero in the HRNS region. These yield impacts, however, do not differ statistically across implementers. Assuming yields only increased for those farm households whose members attended training themselves, we can divide the coefficient estimates by the proportion of farmers who were induced by the treatment to attend training to arrive at effects for those who attended. Doing so, and then transforming to a percentage impact, the 'treatment on the treated' yield effect of training in the HRNS region is 8.3%, while in the TechnoServe region it is 18.8%.

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[9] Coefficients on log yield can be transformed to percentage impacts by taking the exponential of the coefficient on log yield and then subtracting one: percentage $\%\ impact = e^{\beta} - 1$.

[10] The results of running these two separate models, first estimating the treatment effect on the probability of a non-zero outcome, and then estimating the treatment effect on the subset of cases with a non-zero outcome, are identical to those obtained from running an exponential hurdle model (which estimates both components in a single procedure). The hurdle model was specified in the pre-analysis plan but fails to converge for some outcomes. Survey type X baseline control interactions are omitted from the probit models estimating the impact of training on non-zero yield, revenue, and costs due to collinearities that prevent these models from converging.

Table 8. Effect of in-person training on coffee yield per tree

	Non-zero coffee yield			Log coffee yield, among those with any		
	Pooled sample	HRNS	Techno-Serve	Pooled sample	HRNS	Techno-Serve
In-person training	-0.01	-0.00	-0.01**	0.07**	0.04	0.10***
	(0.01)	(0.01)	(0.00)	(0.03)	(0.04)	(0.03)
	[0.265]	[0.628]	[0.036]	[0.010]	[0.336]	[0.002]
Control mean (endline)	0.97	0.96	0.98	9.12	6.66	11.49
Observations in model	4065	2574	1491	6267	3090	3177
Observations in data	6492	3229	3263	6267	3090	3177

Training could affect coffee practices and ultimately yield through two potential channels. First, training can improve farmers' knowledge of training recommendations. Second, training can serve as a reminder and encouragement to adopt practices about which farmers are already knowledgeable.

We test for the effect of training on both aggregated and practice-specific knowledge scores using data from the endline survey. Table 9 shows impacts on farmers' knowledge scores by practice, as well as on a standardized knowledge index. Positive impacts on knowledge are apparent for most practices in both regions. Only for mulching was farmers' knowledge not significantly improved in the pooled sample. Overall, farmers' knowledge of coffee agronomy practices was increased by 0.23 standard deviations of the knowledge index; effects were similar in the HRNS and TechnoServe regions.

For some practices, such as rejuvenation, shade, and intercropping, impacts on knowledge did not translate into better practices, suggesting other barriers to adoption. For others, such as IPDM, nutrition, and erosion control, practices changed more than might be expected based on the modest changes in knowledge observed, pointing to the possibility that training also served to remind and encourage farmers to implement known practices.

Table 9. Effect of in-person training on coffee agronomy knowledge

	Knowledge index	Weeding	IPDM	Rejuvenation	Pruning	Nutrition	Mulching	Erosion control	Shade	Inter-cropping
Pooled Sample										
In-person training	0.23***	0.01***	0.01***	0.05***	0.03***	0.02***	0.00	0.02***	0.02***	0.02***
	(0.02)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)
	[0.000]	[0.005]	[0.000]	[0.000]	[0.000]	[0.000]	[0.356]	[0.000]	[0.000]	[0.000]
Control mean (endline)	0.00	0.89	0.25	0.55	0.46	0.92	0.73	0.72	0.93	0.57
Observations	7235	7235	7235	7235	7235	7235	7235	7235	7235	7235
HRNS										
	Knowledge index	Weeding	IPDM	Rejuvenation	Pruning	Nutrition	Mulching	Erosion control	Shade	Inter-cropping
In-person training	0.24***	0.01	0.01***	0.06***	0.03***	0.02***	0.00	0.02**	0.01	0.02**
	(0.04)	(0.01)	(0.00)	(0.00)	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)
	[0.000]	[0.182]	[0.000]	[0.000]	[0.000]	[0.000]	[0.582]	[0.026]	[0.101]	[0.040]
Control mean (endline)	0.00	0.80	0.22	0.43	0.43	0.87	0.69	0.71	0.96	0.59
Observations	3437	3437	3437	3437	3437	3437	3437	3437	3437	3437
TechnoServe										
	Knowledge index	Weeding	IPDM	Rejuvenation	Pruning	Nutrition	Mulching	Erosion control	Shade	Inter-cropping
In-person training	0.26***	0.02***	0.00***	0.04***	0.02***	0.01***	-0.00	0.02***	0.03***	0.03***
	(0.03)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.876]	[0.005]	[0.002]	[0.001]
Control mean (endline)	0.00	0.97	0.28	0.66	0.49	0.95	0.75	0.73	0.92	0.55
Observations	3798	3798	3798	3798	3798	3798	3798	3798	3798	3798

We next investigate impacts on reported coffee revenue, costs, and profit.. We do not observe statistically significant impacts on any of these outcomes, whether measured in logarithms, levels, or levels per acre (Table 10). Moreover, the directions of the estimated treatment effects are unstable across the way these outcomes are defined. The number of days spent by household members on coffee production is likewise unaffected.

One potential reason for the discrepancy between a strong yield impact and the null results for revenue reported here is poor data quality due to recall error. Coffee production activities and sales both occur throughout the year, and farmers may have found it difficult to recall all costs and revenues over the 12 months leading up to the survey.

A second source of potential discrepancy relates to the different time periods covered by our measures of coffee revenue and yield cover. Revenue data is based on coffee income over the past year, whereas our measure of yield is based on coffee that has not yet been harvested. Farmers' adoption of practices may have occurred over time; with less of a change in practices in the year preceding follow-up data collection, the effect on yield and thus revenue may have been weaker. Further, some of the newly adopted practices may have affected yields with a lag, and others, such as rejuvenation, could have had a negative effect on yield in the short-term but reached positive impact by the time of forward-looking yield measurement.

Next, we consider impacts of coffee training on non-targeted outcomes that may have been incidentally affected by the intervention due to a greater focus of household resources on coffee production.

As shown in Table 11, coffee training had no discernible impact on income earned from other sources, though the negative mean values of this index in the control group indicates that overall, households earned less income from sources other than coffee at endline than at baseline. The decline is equivalent to one household in five earning less income from one non-coffee activity. Production of food crops for own consumption was likewise unaffected by coffee training, but we again see an overall negative trend in the extent to which households in both treatment and control groups grew their own food since baseline. The overall sample mean in the control group can be interpreted as the average household reducing the amount of 1 in 4 of the food crops it grows.

Women's control over non-coffee income fell slightly in training villages relative to control villages, but not by much, and not at conventional levels of significance. The change of -0.01 in the qualitative index used to measure this variable implies that on average, one woman per hundred earned less income from a source over which she had primary control at baseline, and there is a 14% chance that this difference occurred by chance.

Finally, the direction of estimated treatment effects on women's control over coffee income is inconsistent across training regions and not statistically significant. On average across the sample, women's say over how coffee income was spent was equivalent to them having an equal share in decision-making authority for just over half of the types of spending out of coffee income mentioned in the survey, and primary decision-making authority over none of these expenses.

Table 10. Effect of in-person training on coffee revenue, costs, and profit

	Non-zero outcome		Log of outcome			Level of outcome			Level per acre		
Pooled sample	Revenue	Costs	Revenue	Costs	HH Labor	Profit	Revenue	Costs	Profit	Revenue	Costs
In-person training	-0.01	0.01	0.02	-0.00	-0.00	-5.41	1.12	5.29	5.04	-1.70	-9.32
	(0.01)	(0.01)	(0.03)	(0.03)	(0.02)	(8.27)	(9.01)	(3.61)	(12.52)	(8.10)	(10.69)
p-value	[0.411]	[0.439]	[0.486]	[0.943]	[0.957]	[0.513]	[0.901]	[0.143]	[0.687]	[0.834]	[0.384]
Control mean (endline)	0.94	0.78	368.65	92.56	125.90	276.17	368.65	92.56	265.61	366.13	100.46
Observations	5604	7292	6806	5721	7175	7287	7287	7292	7227	7227	7232
HRNS											
In-person training	-0.00	0.01	0.06	0.02	-0.01	6.74	8.85	3.77	-6.02	-6.16	-1.10
	(0.01)	(0.01)	(0.04)	(0.04)	(0.04)	(7.55)	(7.79)	(3.79)	(9.66)	(9.79)	(5.34)
p-value	[0.602]	[0.431]	[0.161]	[0.639]	[0.724]	[0.373]	[0.257]	[0.319]	[0.534]	[0.530]	[0.837]
Control mean (endline)	0.90	0.71	184.79	53.23	87.43	133.25	186.83	53.82	179.67	239.21	59.48
Observations	3350	3462	3100	2513	3408	3457	3457	3462	3431	3431	3436
TechnoServe											
In-person training	-0.01	-0.01	-0.05	-0.01	-0.00	-18.44	-5.29	4.86	19.16	0.36	-19.66
	(0.01)	(0.01)	(0.04)	(0.04)	(0.03)	(14.77)	(16.22)	(6.13)	(23.55)	(13.14)	(20.77)
p-value	[0.351]	[0.495]	[0.140]	[0.745]	[0.961]	[0.213]	[0.745]	[0.429]	[0.416]	[0.978]	[0.345]
Control mean (endline)	0.97	0.85	531.28	127.28	160.32	404.01	531.28	127.28	342.41	479.56	137.15
Observations	2254	3830	3706	3208	3767	3830	3830	3830	3796	3796	3796

Table 11. Effect of in-person training on food crops and women's control over income

	Change in non-coffee household income			Change in food crops grown		
	Pooled	HRNS	Techno Serve	Pooled	HRNS	Techno Serve
In-person training	0.01	-0.00	0.01	0.01	0.00	0.01
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
p-value	[0.709]	[0.893]	[0.631]	[0.466]	[0.917]	[0.587]
Control mean (endline)	-0.20	-0.19	-0.20	-0.24	-0.23	-0.25
Observations	7235	3437	3798	7235	3437	3798
	Change in women's non-coffee income			**Women's control over coffee income**		
	Pooled	HRNS	Techno Serve	Pooled	HRNS	Techno Serve
In-person training	-0.01	-0.01	-0.01	-0.00	0.00	-0.01
	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
p-value	[0.144]	[0.172]	[0.347]	[0.490]	[0.714]	[0.122]
Control mean (endline)	0.00	0.00	0.00	0.27	0.26	0.28
Observations	7235	3437	3798	7235	3437	3798

8.3 Impact of mobile phone interventions

The analysis presented in this sub-section is restricted to those farmers whose phone numbers were collected at baseline, as no impact is expected on farmers assigned to the phone-based interventions who were not able to receive messages.

Effects of the mobile reinforcement intervention are shown in Tables 12 and 13. The comparison group for these estimates consists of farmers who also resided in training villages, but who were not assigned to receive reinforcement messages. The assumption underlying these estimates is that spillover effects of reinforcement messages should be minimal, since these messages simply echo the recommendations already provided through in-person training.

The impact of the reinforcement intervention on the practice index is small and not near significant (Table 12, top panel). However, we estimate that famers in HRNS training villages who were additionally sent reinforcement messages improved their coffee practices relative to farmers who did not receive these messages to the extent that a 3% increase in yield would be expected (Table 12, middle panel). This effect, which is driven by effects on weeding and mulching practices, is close to statistically significant at the 90% confidence level (p = 0.105). The impact on mulching practices is most pronounced, though the estimated effect size is based on only 22% of the sample representing villages within which there was variation in this practice. Assuming no effect of the intervention in villages where all farmers either did, or did not, follow best practice for mulching implies a far more modest effect size of 0.13 x 0.22 = 0.03, which is roughly equal to mulching's contribution to the practice index. Weeding, pest and disease management, nutrition, and erosion control practices are also positively, though none statistically significantly, higher for farmers in the reinforcement group within in the HRNS region.

As shown in Table 13, the reinforcement intervention did not significantly affect agronomy knowledge in either the pooled sample or either of the regional sub-samples, and the magnitude of the estimated (non-significant) effect on the knowledge index is only 1 percentage point in the HRNS sub-sample. Moreover, knowledge about the specific practices which appear to have been improved are not, with the exception of weeding, qualitatively affected by reinforcement messaging. It is possible that the effect of the reinforcement intervention in the HRNS region came about primarily through the channel of reminding and encouraging farmers to adopt practices of which they were already aware. It is also possible, given that over a year passed between the end of the reinforcement intervention and the follow-up survey, that the additional effect of knowledge disseminated through phone calls had faded, while some impact on farm practices remained.

Table 12. Effect of mobile reinforcement intervention on coffee agronomy practices

	Practice Index	Weeding	IPDM	Rejuvenation	Pruning	Nutrition	Mulching	Erosion control	Shade	Inter-cropping
					Pooled Sample					
Reinforcement	0.01	0.01	0.02	0.00	-0.00	-0.02	0.01	0.01	0.01	-0.05**
	(0.01)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.04)	(0.02)	(0.02)	(0.02)
	[0.671]	[0.687]	[0.397]	[0.936]	[0.930]	[0.538]	[0.819]	[0.448]	[0.428]	[0.038]
Control mean (endline)	0.72	0.51	0.30	0.12	0.35	0.14	0.04	0.31	0.37	0.89
Observations	3739	3603	3471	2554	3640	2558	1239	3521	3704	2544
					HRNS					
	Practice Index	Weeding	IPDM	Rejuvenation	Pruning	Nutrition	Mulching	Erosion control	Shade	Inter-cropping
Reinforcement	0.03	0.04*	0.03	-0.01	0.01	0.05	0.14*	0.04	0.02	-0.07*
	(0.02)	(0.02)	(0.03)	(0.03)	(0.03)	(0.04)	(0.07)	(0.03)	(0.03)	(0.04)
	[0.136]	[0.079]	[0.205]	[0.763]	[0.704]	[0.217]	[0.054]	[0.195]	[0.482]	[0.060]
Control mean (endline)	0.62	0.37	0.25	0.15	0.30	0.08	0.02	0.22	0.39	0.89
Observations	1786	1733	1592	1299	1737	986	408	1603	1763	1202
					TechnoServe					
	Practice Index	Weeding	IPDM	Rejuvenation	Pruning	Nutrition	Mulching	Erosion control	Shade	Inter-cropping
Reinforcement	-0.02	-0.02	0.01	0.02	-0.01	-0.05	-0.05	-0.01	-0.00	-0.04
	(0.02)	(0.03)	(0.03)	(0.04)	(0.02)	(0.03)	(0.05)	(0.02)	(0.03)	(0.03)
	[0.421]	[0.522]	[0.635]	[0.675]	[0.682]	[0.115]	[0.272]	[0.738]	[0.947]	[0.228]
Control mean (endline)	0.82	0.63	0.34	0.09	0.40	0.19	0.06	0.39	0.35	0.89
Observations	1953	1870	1879	1255	1903	1572	831	1918	1941	1342

Table 13. Effect of mobile reinforcement intervention on coffee agronomy knowledge

	Knowledge index	Weeding	IPDM	Rejuvenation	Pruning	Nutrition	Mulching	Erosion control	Shade	Inter-cropping
Pooled Sample										
Reinforcement messages	0.02	0.01	-0.00	-0.00	0.01	0.00	0.00	0.01	-0.00	-0.00
	(0.03)	(0.01)	(0.00)	(0.00)	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)
	[0.473]	[0.384]	[0.676]	[0.345]	[0.388]	[0.314]	[0.590]	[0.471]	[0.659]	[0.778]
Control mean (endline)	0.00	0.90	0.26	0.60	0.49	0.93	0.73	0.74	0.96	0.59
Observations	3383	3383	3383	3383	3383	3383	3383	3383	3383	3383
HRNS										
	Knowledge index	Weeding	IPDM	Rejuvenation	Pruning	Nutrition	Mulching	Erosion control	Shade	Inter-cropping
Reinforcement messages	0.01	0.02	0.00	-0.01	-0.00	0.01	-0.00	0.00	-0.00	0.00
	(0.04)	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
	[0.773]	[0.143]	[0.807]	[0.295]	[0.965]	[0.274]	[0.808]	[0.867]	[0.740]	[0.992]
Control mean (endline)	0.00	0.81	0.23	0.49	0.47	0.90	0.70	0.73	0.97	0.61
Observations	1621	1621	1621	1621	1621	1621	1621	1621	1621	1621
TechnoServe										
	Knowledge index	Weeding	IPDM	Rejuvenation	Pruning	Nutrition	Mulching	Erosion control	Shade	Inter-cropping
Reinforcement messages	0.03	-0.00	-0.00	0.00	0.01	0.00	0.01	0.01	-0.01	-0.01
	(0.04)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)	(0.02)
	[0.432]	[0.222]	[0.601]	[0.597]	[0.266]	[0.391]	[0.220]	[0.290]	[0.682]	[0.673]
Control mean (endline)	0.00	0.98	0.28	0.70	0.51	0.96	0.76	0.75	0.95	0.57
Observations	1762	1762	1762	1762	1762	1762	1762	1762	1762	1762

To assess the impact of the standalone mobile phone-based intervention, we conduct two sets of analysis. First, we compare farmers who were assigned to receive the standalone coffee agronomy intervention with other farmers residing in the same village. This approach ignores potential spillovers of the intervention. Its advantage is the greater statistical precision enabled by comparing farmers within a single village, who tend to be similar in terms of their baseline knowledge and practices. We then compare farmers in PxD villages against those in pure control villages, where no intervention was implemented, to estimate spillover effects as well as a second, across-village version of the standalone intervention impact.

Results from the within-village comparison are shown in Tables 14 and 15. We estimate that famers assigned to the standalone intervention improved their coffee practices relative to farmers who did not receive these messages to the extent that a 3% increase in yield would be expected (first column, Table 15). This effect is not statistically significant; the randomization inference p-value, which accounts for the re-randomization conducted to achieve balance, is 0.29, meaning there is a 29% chance that the difference in the practice index between farmers who were sent messages and those who were not would have occurred under the null hypothesis that the mean value of the index is the same for these groups.[11]

Turning to individual practices (noting that results should be interpreted as only suggestive), we see impacts on the share of farmers who used recommended mulching and intercropping practices, and who had adequate shade on their coffee farms. There is also a qualitative positive impact on pest and disease management techniques. Much of sample dropped out of the model used to estimate the impact on mulching due to lack of within-village variation in this outcome. Scaling this effect based on the proportion of the sample included in the model (assuming no impact in villages where no farmers followed mulching best practice) results in a lower estimated overall impact of 10 percentage points.

We see no impact of the standalone intervention on farmers' knowledge of recommended practices as measured through the knowledge index (Table 15). The findings suggest that similar to the mobile reinforcement intervention, any impact of the standalone mobile intervention was achieved through a reminder or encouragement effect, rather than through new knowledge acquisition.

Next, we test whether the stand-alone mobile phone intervention led to spillover effects within the villages where it was implemented (Table 16). We do this by comparing outcomes among farmers in villages where *others* received the standalone intervention ("spillover farmers") against farmers in pure control villages, where no one received any intervention. While none of the effects on individual practices are close to statistically significant (the lowest p-value, for pruning, indicates a 47% chance that the difference between spillover and pure control village farmers occurred by chance), all of these effects are positive. As a result, the aggregated practice index shown in the first column of the table is also positive, and close to statistically significant at p = 0.13. Similar to the lack of impact on knowledge observed for farmers assigned to the standalone intervention, the spillover effect of this intervention on knowledge is near zero and not at all significant (p = 1.00) (first column, Table 17).

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[11] The effective sample size used to estimate treatment effects for this comparison is smaller than the sample size indicated in the tables, as pure control villages (where no farmers were sent stand-alone messages are included in the models to control for survey type effects. A total of 1030 farmers received standalone messages.

Table 14. Effect of standalone mobile intervention on coffee agronomy practices (within-village estimates)

	Practice Index	Weeding	IPDM	Rejuvenation	Pruning	Nutrition	Mulching	Erosion control	Shade	Inter-cropping
PxD standalone messages	0.03	0.01	0.05	-0.00	0.01	-0.02	0.25***	0.04	0.08**	0.09*
	(0.02)	(0.03)	(0.03)	(0.04)	(0.03)	(0.04)	(0.05)	(0.03)	(0.03)	(0.04)
RI p-value	[0.29]	[0.70]	[0.11]	[0.90]	[0.74]	[0.64]	[0.00]	[0.14]	[0.01]	[0.05]
Control mean (endline)	0.68	0.49	0.24	0.12	0.32	0.12	0.04	0.28	0.39	0.87
Observations in sample	4712	4660	4260	3576	4543	3436	1958	4396	4626	3663

Table 15. Effect of standalone mobile intervention on coffee agronomy knowledge (within-village estimates)

	Knowledge index	Weeding	IPDM	Rejuvenation	Pruning	Nutrition	Mulching	Erosion control	Shade	Inter-cropping
PxD standalone messages	-0.01	0.00	-0.01**	0.01*	-0.00	-0.01*	0.01	-0.02*	0.02	0.02
	(0.05)	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)
RI p-value	[0.81]	[0.64]	[0.04]	[0.05]	[0.93]	[0.08]	[0.62]	[0.09]	[0.27]	[0.19]
Control mean (endline)	0.00	0.89	0.25	0.56	0.47	0.92	0.74	0.74	0.93	0.57
Observations	4712	4712	4712	4712	4712	4712	4712	4712	4712	4712

Table 16. Spillover effect of standalone mobile intervention on coffee agronomy practices

	Practice Index	Weeding	IPDM	Rejuvenation	Pruning	Nutrition	Mulching	Erosion control	Shade	Inter-cropping
PxD spillover effect	0.07	0.00	0.06	0.07	0.08	0.05	0.00	0.02	0.02	0.06
	(0.02)	(0.14)	(0.18)	(0.23)	(0.12)	(0.10)	(0.21)	(0.14)	(0.13)	(0.14)
RI p-value	[0.13]	[0.99]	[0.89]	[0.65]	[0.47]	[0.62]	[0.99]	[0.93]	[0.84]	[0.68]
Control mean (endline)	0.68	0.49	0.24	0.14	0.31	0.11	0.05	0.27	0.38	0.88
Observations in sample	3898	3898	3684	3385	3890	3241	2039	3818	3884	3573

Table 17. Spillover effect of standalone mobile intervention on coffee agronomy knowledge

	Knowledge index	Weeding	IPDM	Rejuvenation	Pruning	Nutrition	Mulching	Erosion control	Shade	Inter-cropping
PxD spillover effect	0.01	-0.01	0.00	-0.01	-0.01	-0.01	0.00	0.01	0.02	0.04
	(0.05)	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)	(0.02)	(0.02)
RI p-value	[1.00]	[0.48]	[0.94]	[0.99]	[0.92]	[0.77]	[0.80]	[0.70]	[0.43]	[0.10]
Control mean (endline)	0.00	0.88	0.25	0.57	0.49	0.92	0.76	0.74	0.92	0.57
Observations	3898	3898	3898	3898	3898	3898	3898	3898	3898	3898

Finally, we compare farmers assigned to receive the standalone mobile phone intervention against pure control farmers. As this estimate is not affected by spillovers of the intervention to other farmers within the same village, it should provide a more accurate representation of the impact of this intervention if spillovers are present. The limitation of this estimate is the additional unrelated statistical variation introduced by the fact we are now comparing farmers in different villages. The relatively subtle impacts of a mobile phone-based intervention may be obscured by existing variation across villages.

As expected, the impact of the standalone mobile phone intervention on the practice index is larger when estimated based on a cross-village comparison than when estimated based on variation within-village, and also less statistically significant, with a p-value of 0.73 (first column, Table 18). Of the individual practice variables, shade is higher among the phone-based intervention group. Neither the knowledge index nor any of the practice-specific knowledge points differ significantly across groups (Table 19).

The months-long lag between the end of the standalone intervention, and follow-up data collection in the TNS region may have contributed to the absence of a statistically significant impact.

Table 18. Effect of standalone mobile intervention on coffee agronomy practices (across-village estimates)

	Pooled Sample: Practices (cross-village estimates)									
	Practice index	Weeding	IPDM	Rejuvenation	Pruning	Nutrition	Mulching	Erosion control	Shade	Inter-cropping
PxD standalone messages	0.04	0.01	0.09	-0.02	0.03	0.04	0.08	0.00	0.08**	-0.04
	(0.02)	(0.03)	(0.04)	(0.04)	(0.03)	(0.04)	(0.07)	(0.04)	(0.04)	(0.04)
RI p-value	[0.73]	[0.86]	[0.17]	[0.64]	[0.36]	[0.46]	[0.22]	[0.98]	[0.01]	[0.38]
Control mean (endline)	0.68	0.49	0.24	0.14	0.31	0.11	0.05	0.27	0.38	0.88
Observations	2605	2560	2483	2251	2512	1839	1274	2454	2600	2166

Table 19. Effect of standalone mobile intervention on coffee agronomy knowledge (across-village estimates)

	Pooled Sample - X-village estimates knowledge									
	Knowledge index	Weeding	IPDM	Rejuvenation	Pruning	Nutrition	Mulching	Erosion control	Shade	Inter-cropping
PxD standalone messages	-0.02	0.01	-0.01	0.00	-0.01	-0.01	-0.02	-0.03	0.03	0.02
	(0.05)	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)	(0.02)
RI p-value	[1.00]	[0.77]	[0.84]	[1.00]	[0.86]	[0.68]	[0.20]	[0.28]	[0.18]	[0.39]
Control mean (endline)	0.00	0.88	0.25	0.57	0.49	0.92	0.76	0.74	0.92	0.57
Observations	2605	2605	2605	2605	2605	2605	2605	2605	2605	2605

9. Cost-effectiveness

We translate the estimated effects of the interventions on coffee yield to a monetary return on investment (ROI). Inputs and results of this analysis are shown in Table 20. For the pooled sample, we multiply the control group mean of coffee revenue at endline ($369 US) by 7.3%, the overall percentage impact on yield, to obtain a mean annual estimated increase in coffee revenue due to training of $26.8. We subtract from this the estimated impact on farmers' total coffee production costs from the eighth column of Table 8 ($5.29).

The average training cost per farmer reached across the two implementers was $70.5.[12] Dividing the estimated increase in coffee gross profit (revenue minus production costs) due to training by this value, we calculate that the annual return on investment (ROI) for the overall UCAT program was 30% during the year beginning 14 to 16 months after training ended.

Coffee revenues were nearly three times higher in the region where TechnoServe operated relative to the region served by HRNS, and costs were over twice as high. To calculate ROI by implementer, we ignore these differences. We multiply the mean of revenue for the pooled control group by implementer-specific estimates of the percentage impact on yield, and subtract the estimated cost increase for the pooled sample. This results in estimated annual ROIs of 15% for HRNS and 44% for TechnoServe.

A major caveat to this analysis is that the data does not allow us to estimate the dynamic effects of training on yield – it is possible that the effect of training became either stronger or weaker over time. We apply findings from previous evaluation of TechnoServe's coffee training program in East Africa (Triple Line, 2017) to estimate the time path of impact. This allows us to approximate the total return on training over the total time during which farmers continued the practices on which they were trained.

The Triple Line evaluation concluded that 63% of the improvement in practices achieved by the end of the training period remained five years later (Triple Line, 2017). Assuming the decay in farmers' practices is linear implies an annual decay of 7.3% of the initial improvement. As we observed projected yield near the start of the second year after the end of training, we multiply the estimated impact, in dollar terms, by 1.073, to obtain the estimated impact immediately after training had finished. The difference between immediate post-training impact and impact approximately one year later is then subtracted to obtain the expected impact for each year going forward, until zero impact is reached 14 years post-training. This results in an overall average impact of the in-person training interventions of $170.4 US in additional net revenue per farmer. Subtracting the cost of the initial investment in training ($70.5), which has depreciated to a value of zero by this point, the total net return is $100 or 141% over 14 years. For farmers served by the HRNS and TechnoServe programs, the total benefits accrued to farmers are $78 and $266 US respectively, with associated total net returns on the investment in training of 19% and 251%.

[12] Both impacts and costs of in-person training are measured in terms of farmer reached (coffee farmers interested in training, in villages where trainings are held), rather than farmer trained, due to the difficulty of defining a "trained farmer", and conflicting evidence of training attendance from implementer records versus farmer recall as noted in Section 6. Scaling benefits and costs by the proportion of farmers who completed training would in any case yield the same ROI.

Table 20. Estimated annual return on investment of in-person coffee agronomy training

		Pooled	HRNS	TNS
(a)	Revenue (control mean, pooled sample)	369	369	369
(b)	Yield impact on farmers reached (%)	0.073	0.041	0.105
(c) = (a x b)	Annual value of yield increase (USD)	26.8	15.1	38.8
(d)	Estimated impact on coffee production cost (USD)	5.29	5.29	5.29
(e) = (c) - (d)	Annual net benefit per farmer	21.5	9.8	33.5
(f)	Cost per farmer reached	70.5	65.2	75.7
100 x (f) ÷ (e)	Annual % ROI 1 year post-training	30	15	44
(g)	Total return per farmer, assuming linear decay	170	78	266
(h) = (g - f) ÷ (f)	Total % ROI net of investment over 14 years	142	19	251

Cost-effectiveness analysis of the phone-based interventions proceeds as follows, based on figures reported in Table 21. We use the estimated impact of the interventions on the practice index to model their impact on coffee yield. By construction, the expected effect on yield according to coffee agronomists working in the study region, is equal to the change in the practice index.

This modeled effect on yield is then multiplied by the mean of coffee revenue in the pooled sample as before. Effects on costs are taken from the pooled sample and scaled down by the relative impact of each phone-based intervention on the practice index, relative to in-person training. For example, the stand-alone intervention is estimated to increase yields by 4 percent (based on the comparison of farmers who received standalone messages with those in pure control villages), so the estimated impact on costs is 4 percent divided by 7 percent (the effect of the in-person training intervention on practices in the pooled sample), multiplied by the estimated effect of in-person training on coffee production cost as shown in Table 20, row (d).

For the purposes of this evaluation, a total of 3,055 farmers were enrolled in the PxD interventions and sent messages over a period of 2 to 3 years at a total cost of 171,080 US. Since mobile phone based agricultural advisory services are only expected to be cost-effective at scale, we estimate the ROI of these interventions assuming a scale of one million farmers. This represents slightly more than half of Uganda's 1.8 million coffee-growing smallholders. Based on the fact that 90% of farmers in the study sample had mobile phones, it is reasonable to assume that a phone-based coffee intervention could be implemented at this scale in Uganda.

PxD estimates the personnel, technical support, and management costs to set up and run a three-year program serving one million farmers in Uganda would be $350,000. Phone service charges are available for bulk purchase from the same provider used during the UCAT intervention at $0.0185 per minute. We multiply this value by the average minutes used annually per farmer enrolled in the stand-alone and reinforcement UCAT interventions respectively. We include a $5 initial set-up cost to establish farmers' location and farm characteristics for the assumed scale-up scenario in which PxD only has access to farmer phone numbers; this cost is divided by the assumed three-year program duration to obtain an annualized cost of $1.67.

For the stand-alone PxD intervention, we present ROI calculations based on both the within-village estimate (assuming no spillovers) and the cross-village estimate comparing farmers who received messages against those in pure control villages. We make the conservative assumption that the value of this intervention fully depreciates each year, meaning that impacts on farmer behavior do not last beyond this time. Under these assumptions and at this level of scale, the annual return on investment of the standalone mobile intervention is estimated at between 225% and 335%. We note that this is a lower bound estimate, as the standalone intervention ended several months before follow-up data collection for most farmers.

For the reinforcement intervention, we present an ROI for the sub-sample of farmers in villages where HRNS provided in-person training, since the estimated effect of reinforcement messages in the region served by TechnoServe is negative. This is estimated at 269% annually, again assuming no lasting impact on farmers' behavior in subsequent seasons.

Table 21. Estimated annual return on investment of mobile interventions

		Stand alone (within-village)	Stand alone (across-village estimate)	Reinforce-ment (HRNS)
Modeled revenue of intervention on coffee revenue per farmer				
(a)	Revenue (control, pooled sample)	369	369	369
(b)	Practice index impact = modeled yield effect	0.03	0.04	0.03
(c) = (a x b)	Modeled value of annual yield impact (USD)	11.2	15.1	11.2
(d) = (d, Table20) x (b ÷ b, Table20)	Modeled impact on production cost (USD)	2.22	2.98	2.22
(e) = (c - d)	Annual net benefit per farmer	9.02	12.08	9.02
Modeled annual cost in USD per farmer of intervention at scale (1,000,000 farmers)				
(f)	Personnel, management, and technical support	0.35	0.35	0.35
(g)	Phone service charges	0.76	0.76	0.43
(h)	Farmer onboarding (annualized)	1.67	1.67	1.67
(i)	Total cost per farmer	2.78	2.78	2.44
100 x (e - i) ÷ (i)	Annual % ROI	225	335	269

10. Conclusions

The results presented in this report indicate that the income gains achieved by training smallholder coffee farmers in Uganda on agronomy practices are substantial. Yield gains ranged from 4.1% to 10.5%, depending on the training implementer and region, and were accompanied by changes in observed coffee agronomy practices consistent with a yield increase in this range. If we assume that all changes in yield arising through the intervention can be directly attributed to attendance of training sessions, as opposed to learning from other farmers who themselves were trained, the yield impact for trained farmers in the TechnoServe region reaches 18.1%, and for the HRNS region 8.2%.

At annual returns on investment of 15% to 44%, depending on the implementer and region, training is expected to more than pay for itself over a number of years, assuming based on a previous evaluation of TechnoServe training, that farmers continue to use promoted techniques.

We note that since each training implementer worked in a distinct region, it is not possible to separate the influence of trainer from that of regional characteristics. Coffee was a far less important crop in the region served by HRNS, and this may have influenced farmers' adoption of practices and yield impact.

There is suggestive evidence that mobile phone-based reinforcement messages can strengthen the impact of in-person agronomy training, but only when the training itself has a relatively modest impact – we find no effect of reinforcement in villages where TechnoServe trained. If we take seriously the nearly statistically significant 3 percentage-point impact of reinforcement on the yield-based index of practices in HRNS villages, this implies that the yield impact of HRNS training in the absence of reinforcement was 2.7%, and the combined impact of HRNS training and reinforcement messages was 5.5%.[13] Impacts of standalone phone messages delivered in the absence of in-person training are estimated with less statistical precision but are similar in magnitude to that of reinforcement messages. Taking the point estimates at face value, and based on assumed costs of taking these phone-based interventions to scale, our calculations indicate returns on investment of between 225% and 269%.

A weakness of previous evaluations of similar programs is their reliance on farmer-reported coffee yields. As coffee is harvested over several months, and most farmers do not keep records of their sales, such data on yields is notoriously unreliable. Moreover, farmers who have been given free training may consciously or unconsciously overstate yields. This could arise due to higher salience of coffee production or a desire to show they have made good use of the training.

While measured yield gains are not dramatic, we observe that these persist for at least a year after the end of training. Assuming a level of persistence similar to that observed for practices in previous evaluations, we show that agronomy training more than pays for itself over time, and can be a cost-effective approach to improving the incomes of smallholder coffee farmers.

COVID-related disruptions negatively impacted the delivery of the in-person training programs evaluated in this report. The timing of data collection was also affected by pandemic-related restrictions on travel, so that farmer practices were measured as much as 16 months after the end of the mobile phone-based interventions. The impacts described here should therefore be considered a lower-bound estimate of what is feasible under typical circumstances.

[13] These estimates ae based on the facts that 50% of farmers in training villages were assigned to be sent reinforcement messages, and 90% of farmers provided valid phone numbers to which these messages were sent. Since the training and reinforcement impacts were randomized at different levels and thus require a different set of stratification controls, we are not able to estimate the joint impact of training and reinforcement directly.

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Appendix 1: Additional Tables

Table A1. Reasons for survey attrition

	Freq.	Percent
Respondent unavailable	275	28.0
Relocated	185	18.9
Refused	105	10.7
Unknown	93	9.5
No coffee plot	76	7.7
Could not locate	72	7.3
Deceased	70	7.1
Already surveyed	58	5.9
Respondent incapacitated	34	3.5
No valid respondent	12	1.2
Equipment error	1	0.1
Total	981	100

Table A2. Reasons for missing yield data (yield sample, non-attriters)

	N	Percent
Sold pre-harvest	244	30.5
Refused	173	21.6
Already harvested	113	14.1
Not specified	107	13.4
Only harvests ripe coffee	74	9.3
Price too low	40	5
Could not locate	30	3.8
Respondent unavailable	19	2.4
Total	800	100

Table A3. Survey attrition by treatment group

	In-person Training			PxD Reinforcement			PxD Standalone	PxD Spillover	PxD Standalone
	HRNS	TNS	Pooled	HRNS	TNS	Pooled	Pooled	Pooled	Pooled
	(1)	(2)	(3)	(1)	(2)	(3)	(3)	(3)	(3)
Treatment	0.00	-0.03	-0.02	-0.05	-0.04	-0.05*	0.04	-0.06*	0.02
	(0.03)	(0.02)	(0.02)	(0.04)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
	[0.977]	[0.192]	[0.424]	[0.140]	[0.243]	[0.099]	[0.260]	[0.064]	[0.552]
N	3754	4116	7870	1226	1420	2646	4677	4186	2738
Singletons dropped	35	95	130	745	732	1477	1158	336	526
Control group attrition	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10

Notes: Marginal effects from FE logit model, bootstrap standard errors in parentheses, p-values in square brackets. *,**,*** indicate significance at the 10%, 5% & 1% levels respectively.

Table A4. Yield measurement attrition by treatment group

	In-person Training		
	HRNS	TNS	Pooled
	(1)	(2)	(3)
Treatment	-0.00	0.02	0.01
	(0.02)	(0.02)	(0.01)
	[0.857]	[0.377]	[0.571]
Fixed Effects		Cluster	
N	3789	4164	7953
Singletons dropped	0	47	47
Control group attrition	0.15	0.22	0.19

Notes: Marginal effects from FE logit model, bootstrap standard errors in parentheses, p-values in square brackets. *,**,*** indicate significance at the 10%, 5% & 1% levels respectively.

Table A5. Baseline descriptive statistics and balance, in-person training vs. control and mobile reinforcement vs training only, pooled sample (part 1)

	In-person training				PxD Mobile Reinforcement			
	Control	Treatment	Adjusted difference (T-C)	p-value	Training only	Training & reinforcement	Adjusted difference (T-C)	p-value
Primary coffee farmer is male	0.83	0.82	-0.01	0.466	0.82	0.84	0.02	0.173
	(0.37)	(0.38)	(0.01)		(0.38)	(0.37)	(0.01)	
	3496	3739			1694	1689		
Female-headed household	0.10	0.09	-0.01	0.169	0.09	0.08	-0.02	0.067
	(0.30)	(0.29)	(0.01)		(0.29)	(0.26)	(0.01)	
	3496	3739			1694	1689		
Household size	6.66	6.58	-0.05	0.470	6.54	6.88	0.31**	0.005
	(2.81)	(2.84)	(0.07)		(2.77)	(2.87)	(0.11)	
	3496	3739			1694	1689		
Children ≤ 12 yrs	2.80	2.85	0.05	0.285	2.80	2.98	0.16*	0.014
	(1.75)	(1.75)	(0.04)		(1.71)	(1.76)	(0.07)	
	3275	3492			1591	1596		
Children 13-18 yrs	1.11	1.07	-0.03	0.213	1.07	1.12	0.03	0.440
	(1.16)	(1.14)	(0.03)		(1.16)	(1.14)	(0.04)	
	3496	3739			1694	1689		
Number of adults	2.94	2.86	-0.05	0.121	2.85	2.95	0.08	0.146
	(1.48)	(1.46)	(0.03)		(1.42)	(1.53)	(0.06)	
	3496	3739			1694	1689		
Age of the primary farmer	46.36	46.67	0.13	0.709	46.16	46.11	-0.19	0.716
	(14.17)	(14.23)	(0.34)		(14.26)	(13.61)	(0.52)	
	3072	3706			1682	1676		
Female head literate	0.70	0.71	0.00	0.780	0.73	0.72	-0.01	0.514
	(0.46)	(0.46)	(0.01)		(0.44)	(0.45)	(0.02)	
	3327	3572			1623	1625		
Male head literate	0.85	0.86	0.01	0.544	0.88	0.87	-0.01	0.210
	(0.36)	(0.35)	(0.01)		(0.32)	(0.34)	(0.01)	
	2786	3392			1538	1562		

Table A5. Baseline descriptive statistics and balance, in-person training vs. control and mobile reinforcement vs training only, pooled sample (part 2)

	In-person training				PxD Mobile Reinforcement			
	Control	Treatment	Adjusted difference (T-C)	p-value	Training only	Training & reinforcement	Adjusted difference (T-C)	p-value
Male head less than primary	0.51	0.52	0.01	0.320	0.49	0.50	-0.00	0.987
	(0.50)	(0.50)	(0.01)		(0.50)	(0.50)	(0.02)	
	2745	3337			1512	1538		
Male head completed primary	0.38	0.38	-0.00	0.808	0.39	0.40	0.02	0.351
	(0.49)	(0.49)	(0.01)		(0.49)	(0.49)	(0.02)	
	2745	3337			1512	1538		
Male head completed secondary	0.02	0.02	-0.00	0.475	0.02	0.02	-0.00	0.437
	(0.14)	(0.13)	(0.00)		(0.14)	(0.13)	(0.01)	
	2745	3337			1512	1538		
Male head vocational training	0.07	0.06	-0.01	0.143	0.07	0.06	-0.01	0.323
	(0.25)	(0.24)	(0.01)		(0.26)	(0.24)	(0.01)	
	2745	3337			1512	1538		
Male head university degree	0.02	0.02	0.00	0.692	0.03	0.02	-0.00	0.409
	(0.14)	(0.14)	(0.00)		(0.16)	(0.14)	(0.01)	
	2745	3337			1512	1538		
Female head less than primary	0.65	0.65	0.01	0.659	0.63	0.63	0.00	0.963
	(0.48)	(0.48)	(0.01)		(0.48)	(0.48)	(0.02)	
	2873	3486			1583	1586		
Female head completed primary	0.31	0.31	-0.00	0.822	0.34	0.32	-0.01	0.469
	(0.46)	(0.46)	(0.01)		(0.47)	(0.47)	(0.02)	
	2873	3486			1583	1586		
Female head completed secondary	0.01	0.00	-0.00	0.723	0.00	0.01	0.01*	0.041
	(0.07)	(0.07)	(0.00)		(0.05)	(0.09)	(0.00)	
	2873	3486			1583	1586		
Female head vocational training	0.03	0.03	0.00	0.968	0.02	0.03	0.01	0.209
	(0.16)	(0.16)	(0.00)		(0.16)	(0.18)	(0.01)	
	2873	3486			1583	1586		
Female head university degree	0.01	0.01	-0.00	0.282	0.01	0.01	-0.00	0.661
	(0.09)	(0.08)	(0.00)		(0.09)	(0.09)	(0.00)	
	2873	3486			1583	1586		

Table A5. Baseline descriptive statistics and balance, in-person training vs. control and mobile reinforcement vs training only, pooled sample (part 3)

	In-person training				PxD Mobile Reinforcement			
	Control	Treatment	Adjusted difference (T-C)	p-value	Training only	Training & reinforcement	Adjusted difference (T-C)	p-value
Household asset index	0.02	-0.01	-0.04	0.095	0.09	0.10	0.01	0.729
	(0.94)	(1.00)	(0.03)		(0.90)	(0.95)	(0.03)	
	3496	3739			1694	1689		
Owns radio	0.80	0.80	-0.01	0.440	0.82	0.81	-0.00	0.815
	(0.40)	(0.40)	(0.01)		(0.39)	(0.39)	(0.01)	
	3496	3739			1694	1689		
Owns mobile phone	0.90	0.89	0.00	0.854	0.96	0.96	-0.00	0.988
	(0.30)	(0.31)	(0.01)		(0.19)	(0.19)	(0.01)	
	3496	3739			1694	1689		
Number of phones	1.67	1.64	-0.01	0.856	1.77	1.78	0.00	0.902
	(1.18)	(1.14)	(0.03)		(1.13)	(1.06)	(0.04)	
	3496	3739			1694	1689		
Every member owns closed shoes	0.68	0.68	0.00	0.919	0.68	0.71	0.03	0.054
	(0.47)	(0.47)	(0.01)		(0.47)	(0.46)	(0.02)	
	3496	3739			1694	1689		
Housing index	0.01	-0.03	-0.05*	0.032	0.02	0.01	-0.01	0.802
	(0.94)	(1.00)	(0.02)		(0.96)	(1.02)	(0.03)	
	3496	3739			1694	1689		
Total land (acres)	5.20	4.97	-0.21	0.172	4.97	5.22	0.20	0.343
	(5.71)	(5.53)	(0.15)		(5.38)	(5.77)	(0.21)	
	3126	3313			1501	1510		
Land under coffee (acres)	1.38	1.27	-0.09*	0.014	1.27	1.31	0.03	0.542
	(1.39)	(1.25)	(0.04)		(1.25)	(1.27)	(0.04)	
	3160	3362			1543	1524		
Number of coffee plots	1.80	1.75	-0.02	0.322	1.75	1.79	0.03	0.341
	(1.01)	(0.96)	(0.02)		(0.97)	(0.98)	(0.03)	
	3496	3737			1694	1688		
Livestock holdings (TLU)	1.47	1.44	-0.02	0.811	1.47	1.53	0.03	0.765
	(4.08)	(3.03)	(0.09)		(3.08)	(3.19)	(0.12)	
	3094	3739			1694	1689		

Table A5. Baseline descriptive statistics and balance, in-person training vs. control and mobile reinforcement vs training only, pooled sample (part 4)

	In-person training				PxD Mobile Reinforcement			
	Control	Treatment	Adjusted difference (T-C)	p-value	Training only	Training & reinforcement	Adjusted difference (T-C)	p-value
Practice index	0.62	0.63	0.01	0.217	0.64	0.64	-0.01	0.633
	(0.37)	(0.38)	(0.01)		(0.38)	(0.38)	(0.01)	
	(3496)	(3739)			(1694)	(1689)		
Weeding best practice	0.77	0.76	-0.00	0.784	0.77	0.77	0.00	0.854
	(0.42)	(0.43)	(0.01)		(0.42)	(0.42)	(0.02)	
	3496	3739			1694	1689		
IPDM best practice	0.08	0.08	-0.00	0.922	0.08	0.08	-0.01	0.468
	(0.28)	(0.27)	(0.01)		(0.28)	(0.27)	(0.01)	
	3496	3739			1694	1689		
Rejuvenation best practice	0.29	0.31	0.01	0.371	0.33	0.32	-0.01	0.619
	(0.45)	(0.46)	(0.01)		(0.47)	(0.47)	(0.02)	
	3496	3739			1694	1689		
Nutrition best practice	0.21	0.23	0.02	0.056	0.23	0.23	-0.00	0.769
	(0.41)	(0.42)	(0.01)		(0.42)	(0.42)	(0.01)	
	3496	3739			1694	1689		
Mulching best practice	0.33	0.33	0.01	0.396	0.33	0.34	0.01	0.714
	(0.47)	(0.47)	(0.01)		(0.47)	(0.47)	(0.02)	
	3496	3739			1694	1689		
Intercropping best practice	0.65	0.64	0.00	0.955	0.64	0.65	0.01	0.628
	(0.48)	(0.48)	(0.01)		(0.48)	(0.48)	(0.02)	
	3496	3739			1694	1689		
Correctly defines rejuvenation	0.77	0.77	-0.01	0.552	0.78	0.79	0.01	0.378
	(0.42)	(0.42)	(0.01)		(0.42)	(0.41)	(0.01)	
	3496	3739			1694	1689		
# Coffee farmers known nearby villages	1.35	1.39	0.02	0.848	1.41	1.36	-0.04	0.764
	(3.68)	(3.84)	(0.11)		(3.78)	(3.84)	(0.13)	
	3496	3739			1694	1689		
Average age of coffee trees (years)	10.29	11.04	0.44	0.120	10.72	10.65	-0.17	0.665
	(11.18)	(11.43)	(0.28)		(11.19)	(10.65)	(0.39)	
	2879	3438			1582	1549		

Table A5. Baseline statistics & balance, in-person training vs. control; reinforcement vs training only, pooled (part 5)

	In-person training				PxD Mobile Reinforcement			
	Control	Treatment	Adjusted difference (T-C)	p-value	Training only	Training & reinforcement	Adjusted difference (T-C)	p-value
Income sources (proportion of total)								
Coffee	0.28	0.30	0.01**	0.008	0.30	0.30	-0.01	0.319
	(0.23)	(0.24)	(0.01)		(0.24)	(0.24)	(0.01)	
	3085	3734			1692	1687		
Maize	0.07	0.07	0.00	0.717	0.07	0.07	-0.00	0.624
	(0.17)	(0.17)	(0.00)		(0.17)	(0.17)	(0.01)	
	3085	3734			1692	1687		
Banana	0.12	0.14	0.00	0.415	0.14	0.14	-0.00	0.850
	(0.21)	(0.21)	(0.01)		(0.21)	(0.21)	(0.01)	
	3085	3734			1692	1687		
Cassava	0.01	0.01	0.00	0.765	0.01	0.01	0.00	0.918
	(0.07)	(0.07)	(0.00)		(0.07)	(0.07)	(0.00)	
	3085	3734			1692	1687		
Legumes/beans	0.09	0.09	-0.00	0.892	0.09	0.09	-0.01	0.189
	(0.17)	(0.17)	(0.00)		(0.17)	(0.17)	(0.01)	
	3085	3734			1692	1687		
Groundnut	0.02	0.02	-0.00	0.635	0.02	0.02	-0.00	0.606
	(0.08)	(0.07)	(0.00)		(0.07)	(0.07)	(0.00)	
	3085	3734			1692	1687		
Root crops	0.02	0.01	-0.01*	0.016	0.01	0.01	-0.00	0.393
	(0.09)	(0.07)	(0.00)		(0.07)	(0.06)	(0.00)	
	3085	3734			1692	1687		
Other cash crops	0.03	0.03	-0.00	0.502	0.03	0.03	0.00	0.646
	(0.13)	(0.11)	(0.00)		(0.11)	(0.11)	(0.00)	
	3085	3734			1692	1687		
Livestock	0.06	0.06	0.00	0.874	0.06	0.07	0.01	0.224
	(0.13)	(0.13)	(0.00)		(0.13)	(0.13)	(0.00)	
	3085	3734			1692	1687		
Casual labor	0.03	0.03	0.00	0.890	0.03	0.04	0.01*	0.015
	(0.12)	(0.12)	(0.00)		(0.10)	(0.13)	(0.00)	
	3085	3734			1692	1687		
Salaries	0.02	0.02	-0.00	0.136	0.02	0.02	0.00	0.485
	(0.10)	(0.09)	(0.00)		(0.09)	(0.09)	(0.00)	
	3085	3734			1692	1687		
Non-farm business	0.08	0.08	-0.00	0.586	0.08	0.08	-0.00	0.843
	(0.17)	(0.16)	(0.00)		(0.16)	(0.16)	(0.01)	
	3085	3734			1692	1687		

Table A5. Baseline statistics & balance, in-person training vs. control; reinforcement vs training only, pooled (part 6)

	In-person training				PxD Mobile Reinforcement			
	Control	Treatment	Adjusted difference (T-C)	p-value	Training only	Training & reinforcement	Adjusted difference (T-C)	p-value
Coffee expenses:								
Any labor expense	0.39	0.40	0.00	0.808	0.41	0.42	0.01	0.715
	(0.49)	(0.49)	(0.01)		(0.49)	(0.49)	(0.02)	
	3094	3739			1694	1689		
Any fertilizer expense	0.12	0.11	-0.01	0.475	0.12	0.12	-0.00	0.988
	(0.32)	(0.32)	(0.01)		(0.32)	(0.32)	(0.01)	
	3094	3739			1694	1689		
Any pesticide expense	0.24	0.23	-0.01	0.619	0.23	0.26	0.03*	0.027
	(0.43)	(0.42)	(0.01)		(0.42)	(0.44)	(0.01)	
	3094	3739			1694	1689		
Any inorganic fertilizer expense	0.04	0.03	-0.01*	0.027	0.03	0.04	0.01	0.070
	(0.20)	(0.17)	(0.00)		(0.16)	(0.19)	(0.01)	
	3094	3739			1694	1689		
Any manure expense	0.08	0.08	-0.00	0.820	0.09	0.08	-0.02	0.157
	(0.27)	(0.27)	(0.01)		(0.29)	(0.27)	(0.01)	
	3094	3739			1694	1689		
Any compost expense	0.01	0.02	0.00	0.172	0.02	0.01	-0.00	0.706
	(0.11)	(0.13)	(0.00)		(0.13)	(0.12)	(0.00)	
	3094	3739			1694	1689		
Any equipment expense	0.24	0.28	0.03*	0.013	0.29	0.28	-0.01	0.529
	(0.43)	(0.45)	(0.01)		(0.45)	(0.45)	(0.02)	
	3094	3739			1694	1689		
Any transportation expense	0.26	0.27	0.00	0.849	0.27	0.29	0.01	0.450
	(0.44)	(0.44)	(0.01)		(0.44)	(0.45)	(0.02)	
	3094	3739			1694	1689		
Any processing expense	0.13	0.13	-0.00	0.640	0.14	0.14	0.00	0.695
	(0.34)	(0.34)	(0.01)		(0.34)	(0.35)	(0.01)	
	3094	3739			1694	1689		
Any seedling expense	0.05	0.05	0.00	0.660	0.05	0.06	0.00	0.602
	(0.23)	(0.22)	(0.01)		(0.22)	(0.23)	(0.01)	
	3094	3739			1694	1689		
Any mulch expense	0.11	0.12	0.01	0.458	0.13	0.12	-0.01	0.353
	(0.31)	(0.32)	(0.01)		(0.33)	(0.32)	(0.01)	
	3094	3739			1694	1689		
Any other coffee expense	0.00	0.01	0.00*	0.046	0.01	0.00	-0.00	0.575
	(0.05)	(0.07)	(0.00)		(0.08)	(0.07)	(0.00)	
	3094	3739			1694	1689		

Table A5. Baseline statistics & balance, in-person training vs. control; reinforcement vs training only, pooled (part 7)

	In-person training				PxD Mobile Reinforcement			
	Control	Treatment	Adjusted difference (T-C)	p-value	Training only	Training & reinforcement	Adjusted difference (T-C)	p-value
Took coffee payment prior to harvest	0.21	0.24	0.02*	0.030	0.24	0.25	0.01	0.624
	(0.41)	(0.43)	(0.01)		(0.42)	(0.43)	(0.01)	
	3094	3739			1694	1689		
Total sales revenue (USD)	165.37	160.85	-13.34	0.215	178.38	162.67	-10.02	0.523
	(427.85)	(412.36)	(10.76)		(497.22)	(349.21)	(15.69)	
	2657	3161			1430	1434		
Total sales revenue (USD/acre)	116.93	121.27	-2.16	0.646	121.90	128.99	5.57	0.533
	(187.92)	(186.83)	(4.69)		(180.82)	(201.35)	(8.93)	
	2405	2876			1319	1310		
Plan to increase coffee area	0.39	0.40	0.00	0.808	0.41	0.42	0.01	0.715
	(0.49)	(0.49)	(0.01)		(0.49)	(0.49)	(0.02)	
	3094	3739			1694	1689		
Plan to reduce coffee area	0.12	0.11	-0.01	0.475	0.12	0.12	-0.00	0.988
	(0.32)	(0.32)	(0.01)		(0.32)	(0.32)	(0.01)	
	3094	3739			1694	1689		

Table A6. Baseline descriptive statistics and balance, in-person training vs. control and mobile reinforcement vs training only, HRNS sample (part 1)

	In-person training				PxD Mobile Reinforcement			
	Control	Treatment	Adjusted difference (T-C)	p-value	Training only	Training & reinforcement	Adjusted difference (T-C)	p-value
Primary coffee farmer is male	0.86	0.86	-0.00	0.831	0.86	0.87	0.01	0.415
	(0.35)	(0.35)	(0.01)		(0.35)	(0.34)	(0.02)	
	1651	1786			818	803		
Female-headed household	0.08	0.07	-0.01	0.348	0.07	0.06	-0.01	0.403
	(0.27)	(0.26)	(0.01)		(0.26)	(0.24)	(0.01)	
	1651	1786			818	803		
Household size	6.81	6.85	0.05	0.626	6.72	7.20	0.40*	0.025
	(3.05)	(3.09)	(0.11)		(3.03)	(3.10)	(0.18)	
	1651	1786			818	803		
Children ≤ 12 yrs	3.23	3.26	0.02	0.741	3.17	3.42	0.21*	0.046
	(1.86)	(1.86)	(0.07)		(1.83)	(1.88)	(0.11)	
	1541	1669			763	767		
Children 13-18 yrs	1.05	1.08	0.03	0.408	1.06	1.16	0.08	0.212
	(1.17)	(1.20)	(0.04)		(1.24)	(1.19)	(0.07)	
	1651	1786			818	803		
Number of adults	2.75	2.73	0.00	0.998	2.73	2.77	0.02	0.814
	(1.36)	(1.38)	(0.04)		(1.35)	(1.41)	(0.08)	
	1651	1786			818	803		
Age of the primary farmer	44.73	44.80	0.19	0.697	44.02	44.90	0.73	0.328
	(13.94)	(14.06)	(0.49)		(14.34)	(13.33)	(0.75)	
	1651	1786			818	803		
Female head literate	0.66	0.65	-0.01	0.445	0.68	0.65	-0.03	0.318
	(0.47)	(0.48)	(0.02)		(0.47)	(0.48)	(0.03)	
	1564	1692			777	769		
Male head literate	0.84	0.84	0.01	0.668	0.87	0.86	-0.01	0.646
	(0.37)	(0.36)	(0.01)		(0.34)	(0.35)	(0.02)	
	1521	1660			760	754		

Table A6. Baseline descriptive statistics and balance, in-person training vs. control and mobile reinforcement vs training only, HRNS sample (part 2)

	In-person training				PxD Mobile Reinforcement			
	Control	Treatment	Adjusted difference (T-C)	p-value	Training only	Training & reinforcement	Adjusted difference (T-C)	p-value
Primary coffee farmer is male	0.86	0.86	-0.00	0.831	0.86	0.87	0.01	0.415
	(0.35)	(0.35)	(0.01)		(0.35)	(0.34)	(0.02)	
	1651	1786			818	803		
Female-headed household	0.08	0.07	-0.01	0.348	0.07	0.06	-0.01	0.403
	(0.27)	(0.26)	(0.01)		(0.26)	(0.24)	(0.01)	
	1651	1786			818	803		
Household size	6.81	6.85	0.05	0.626	6.72	7.20	0.40*	0.025
	(3.05)	(3.09)	(0.11)		(3.03)	(3.10)	(0.18)	
	1651	1786			818	803		
Children ≤ 12 yrs	3.23	3.26	0.02	0.741	3.17	3.42	0.21*	0.046
	(1.86)	(1.86)	(0.07)		(1.83)	(1.88)	(0.11)	
	1541	1669			763	767		
Children 13-18 yrs	1.05	1.08	0.03	0.408	1.06	1.16	0.08	0.212
	(1.17)	(1.20)	(0.04)		(1.24)	(1.19)	(0.07)	
	1651	1786			818	803		
Number of adults	2.75	2.73	0.00	0.998	2.73	2.77	0.02	0.814
	(1.36)	(1.38)	(0.04)		(1.35)	(1.41)	(0.08)	
	1651	1786			818	803		
Age of the primary farmer	44.73	44.80	0.19	0.697	44.02	44.90	0.73	0.328
	(13.94)	(14.06)	(0.49)		(14.34)	(13.33)	(0.75)	
	1651	1786			818	803		
Female head literate	0.66	0.65	-0.01	0.445	0.68	0.65	-0.03	0.318
	(0.47)	(0.48)	(0.02)		(0.47)	(0.48)	(0.03)	
	1564	1692			777	769		
Male head literate	0.84	0.84	0.01	0.668	0.87	0.86	-0.01	0.646
	(0.37)	(0.36)	(0.01)		(0.34)	(0.35)	(0.02)	
	1521	1660			760	754		

Table A6. Baseline descriptive statistics and balance, in-person training vs. control and mobile reinforcement vs training only, HRNS sample (part 3)

	In-person training				PxD Mobile Reinforcement			
	Control	Treatment	Adjusted difference (T-C)	p-value	Training only	Training & reinforcement	Adjusted difference (T-C)	p-value
Household asset index	-0.05	-0.12	-0.06	0.102	-0.02	0.01	0.01	0.850
	(1.03)	(1.12)	(0.04)		(0.99)	(1.09)	(0.05)	
	1651	1786			818	803		
Owns radio	0.79	0.78	-0.01	0.582	0.80	0.78	-0.02	0.509
	(0.41)	(0.42)	(0.01)		(0.40)	(0.41)	(0.02)	
	1651	1786			818	803		
Owns mobile phone	0.87	0.87	0.00	0.733	0.94	0.94	-0.00	0.843
	(0.33)	(0.33)	(0.01)		(0.24)	(0.24)	(0.01)	
	1651	1786			818	803		
Number of phones	1.51	1.50	-0.00	0.993	1.61	1.64	0.02	0.754
	(1.09)	(1.09)	(0.04)		(1.06)	(1.04)	(0.05)	
	1651	1786			818	803		
Every member owns closed shoes	0.63	0.63	0.00	0.999	0.64	0.65	0.01	0.625
	(0.48)	(0.48)	(0.02)		(0.48)	(0.48)	(0.02)	
	1651	1786			818	803		
Housing index	-0.00	-0.09	-0.08*	0.030	-0.05	-0.03	0.01	0.923
	(1.04)	(1.15)	(0.04)		(1.06)	(1.17)	(0.05)	
	1651	1786			818	803		
Total land (acres)	5.52	5.20	-0.29	0.193	5.12	5.52	0.36	0.273
	(6.25)	(5.83)	(0.22)		(5.65)	(6.15)	(0.32)	
	1541	1656			757	745		
Land under coffee (acres)	1.04	1.01	-0.00	0.953	0.99	1.07	0.07	0.163
	(1.18)	(1.07)	(0.04)		(1.06)	(1.06)	(0.05)	
	1585	1702			785	764		
Number of coffee plots	1.55	1.54	-0.01	0.690	1.49	1.60	0.11**	0.008
	(0.80)	(0.77)	(0.03)		(0.72)	(0.83)	(0.04)	
	1651	1784			818	802		
Livestock holdings (TLU)	1.34	1.38	0.07	0.512	1.36	1.52	0.14	0.363
	(2.97)	(2.68)	(0.10)		(2.37)	(3.13)	(0.16)	
	1651	1786			818	803		

Table A6. Baseline descriptive statistics and balance, in-person training vs. control and mobile reinforcement vs training only, HRNS sample (part 4)

	In-person training				PxD Mobile Reinforcement			
	Control	Treatment	Adjusted difference (T-C)	p-value	Training only	Training & reinforcement	Adjusted difference (T-C)	p-value
Practice index	0.51	0.53	0.02	0.099	0.53	0.54	0.00	0.782
	(0.34)	(0.35)	(0.01)		(0.35)	(0.35)	(0.02)	
	(1651)	(1786)			(818)	(803)		
Weeding best practice	0.68	0.67	-0.01	0.629	0.67	0.69	0.02	0.572
	(0.47)	(0.47)	(0.02)		(0.47)	(0.46)	(0.03)	
	1651	1786			818	803		
IPDM best practice	0.03	0.03	0.00	0.738	0.03	0.04	0.01	0.278
	(0.18)	(0.18)	(0.01)		(0.17)	(0.19)	(0.01)	
	1651	1786			818	803		
Rejuvenation best practice	0.28	0.28	0.00	0.925	0.29	0.28	-0.01	0.689
	(0.45)	(0.45)	(0.02)		(0.45)	(0.45)	(0.03)	
	1651	1786			818	803		
Nutrition best practice	0.13	0.16	0.04**	0.004	0.17	0.16	-0.01	0.687
	(0.34)	(0.37)	(0.01)		(0.37)	(0.37)	(0.02)	
	1651	1786			818	803		
Mulching best practice	0.23	0.24	0.01	0.343	0.24	0.25	0.01	0.522
	(0.42)	(0.43)	(0.01)		(0.43)	(0.43)	(0.02)	
	1651	1786			818	803		
Intercropping best practice	0.56	0.59	0.02	0.165	0.59	0.60	0.01	0.777
	(0.50)	(0.49)	(0.02)		(0.49)	(0.49)	(0.03)	
	1651	1786			818	803		
Correctly defines rejuvenation	0.79	0.78	0.00	0.885	0.78	0.80	0.02	0.330
	(0.41)	(0.41)	(0.01)		(0.41)	(0.40)	(0.02)	
	1651	1786			818	803		
# Coffee farmers known nearby villages	0.93	1.00	0.02	0.897	1.10	0.89	-0.20	0.217
	(3.17)	(3.30)	(0.12)		(3.51)	(3.15)	(0.16)	
	1651	1786			818	803		
Average age of coffee trees (years)	7.57	7.84	0.24	0.505	7.65	7.42	-0.43	0.386
	(10.01)	(9.74)	(0.36)		(9.55)	(8.71)	(0.49)	
	1651	1786			818	803		

Table A6. Baseline statistics and balance, training vs. control and reinforcement vs training only, HRNS sample (part 5)

	In-person training				PxD Mobile Reinforcement			
	Control	Treatment	Adjusted difference (T-C)	p-value	Training only	Training & reinforcement	Adjusted difference (T-C)	p-value
Income sources (proportion of total)								
Coffee	0.19	0.20	0.01	0.092	0.20	0.20	-0.00	0.795
	(0.21)	(0.21)	(0.01)		(0.21)	(0.20)	(0.01)	
	1647	1784			817	802		
Maize	0.13	0.13	0.01	0.427	0.13	0.13	-0.00	0.688
	(0.22)	(0.23)	(0.01)		(0.23)	(0.22)	(0.01)	
	1647	1784			817	802		
Banana	0.03	0.04	0.01	0.224	0.04	0.03	-0.01	0.316
	(0.12)	(0.13)	(0.00)		(0.14)	(0.13)	(0.01)	
	1647	1784			817	802		
Cassava	0.02	0.02	0.00	0.523	0.02	0.02	0.00	0.898
	(0.09)	(0.10)	(0.00)		(0.10)	(0.10)	(0.01)	
	1647	1784			817	802		
Legumes/beans	0.07	0.07	0.00	0.956	0.07	0.07	-0.00	0.545
	(0.18)	(0.18)	(0.01)		(0.18)	(0.18)	(0.01)	
	1647	1784			817	802		
Groundnut	0.02	0.02	-0.01	0.094	0.02	0.01	-0.00	0.678
	(0.10)	(0.08)	(0.00)		(0.08)	(0.08)	(0.00)	
	1647	1784			817	802		
Root crops	0.03	0.02	-0.01*	0.018	0.02	0.01	-0.00	0.747
	(0.12)	(0.08)	(0.00)		(0.08)	(0.08)	(0.00)	
	1647	1784			817	802		
Other cash crops	0.05	0.05	-0.00	0.455	0.05	0.05	0.00	0.597
	(0.16)	(0.15)	(0.01)		(0.15)	(0.15)	(0.01)	
	1647	1784			817	802		
Livestock	0.07	0.08	0.00	0.320	0.07	0.08	0.01	0.355
	(0.13)	(0.14)	(0.00)		(0.14)	(0.14)	(0.01)	
	1647	1784			817	802		
Casual labor	0.03	0.03	-0.00	0.993	0.02	0.03	0.01	0.271
	(0.11)	(0.11)	(0.00)		(0.08)	(0.11)	(0.00)	
	1647	1784			817	802		
Salaries	0.02	0.02	-0.00	0.670	0.02	0.02	0.00	0.754
	(0.09)	(0.09)	(0.00)		(0.09)	(0.10)	(0.00)	
	1647	1784			817	802		
Non-farm business	0.09	0.08	-0.01	0.324	0.08	0.08	-0.00	0.986
	(0.18)	(0.17)	(0.01)		(0.17)	(0.17)	(0.01)	
	1647	1784			817	802		

Table A6. Baseline statistics and balance, training vs. control and reinforcement vs training only, HRNS sample (part 6)

	In-person training				PxD Mobile Reinforcement			
	Control	Treatment	Adjusted difference (T-C)	p-value	Training only	Training & reinforcement	Adjusted difference (T-C)	p-value
Coffee expenses								
Any labor expense	0.32	0.35	0.03	0.089	0.36	0.37	0.01	0.717
	(0.47)	(0.48)	(0.02)		(0.48)	(0.48)	(0.03)	
	1651	1786			818	803		
Any fertilizer expense	0.08	0.08	0.00	0.770	0.08	0.10	0.02	0.157
	(0.27)	(0.27)	(0.01)		(0.27)	(0.29)	(0.01)	
	1651	1786			818	803		
Any pesticide expense	0.26	0.26	0.00	0.869	0.25	0.31	0.05*	0.027
	(0.44)	(0.44)	(0.02)		(0.43)	(0.46)	(0.02)	
	1651	1786			818	803		
Any inorganic fertilizer expense	0.04	0.03	-0.01	0.098	0.03	0.04	0.02	0.058
	(0.20)	(0.18)	(0.01)		(0.16)	(0.20)	(0.01)	
	1651	1786			818	803		
Any manure expense	0.04	0.04	0.00	0.594	0.05	0.04	-0.00	0.750
	(0.19)	(0.20)	(0.01)		(0.21)	(0.20)	(0.01)	
	1651	1786			818	803		
Any compost expense	0.01	0.02	0.01	0.054	0.02	0.02	0.01	0.519
	(0.11)	(0.15)	(0.00)		(0.14)	(0.16)	(0.01)	
	1651	1786			818	803		
Any equipment expense	0.24	0.25	0.01	0.469	0.25	0.28	0.03	0.164
	(0.43)	(0.43)	(0.02)		(0.43)	(0.45)	(0.02)	
	1651	1786			818	803		
Any transportation expense	0.21	0.20	-0.01	0.605	0.20	0.23	0.02	0.242
	(0.41)	(0.40)	(0.02)		(0.40)	(0.42)	(0.02)	
	1651	1786			818	803		
Any processing expense	0.02	0.02	0.00	0.664	0.02	0.02	-0.00	0.765
	(0.14)	(0.14)	(0.00)		(0.15)	(0.14)	(0.01)	
	1651	1786			818	803		
Any seedling expense	0.07	0.07	0.01	0.587	0.07	0.08	0.01	0.398
	(0.25)	(0.25)	(0.01)		(0.25)	(0.27)	(0.01)	
	1651	1786			818	803		
Any mulch expense	0.05	0.06	0.01	0.179	0.06	0.06	-0.00	0.876
	(0.21)	(0.24)	(0.01)		(0.24)	(0.24)	(0.01)	
	1651	1786			818	803		
Any other coffee expense	0.00	0.00	0.00	0.836	0.00	0.00	-0.00	0.713
	(0.06)	(0.07)	(0.00)		(0.07)	(0.06)	(0.00)	
	1651	1786			818	803		

Table A6. Baseline statistics and balance, training vs. control and reinforcement vs training only, HRNS sample (part 7)

	In-person training				PxD Mobile Reinforcement			
	Control	Treatment	Adjusted difference (T-C)	p-value	Training only	Training & reinforcement	Adjusted difference (T-C)	p-value
Coffee revenues, costs, and plans								
Took coffee payment prior to harvest	0.15	0.17	0.02	0.223	0.16	0.19	0.03	0.129
	(0.36)	(0.38)	(0.01)		(0.37)	(0.39)	(0.02)	
	1651	1786			818	803		
Total sales revenue (USD)	82.45	80.64	-0.97	0.910	83.65	84.13	-1.03	0.939
	(251.94)	(252.08)	(8.56)		(306.93)	(203.10)	(13.45)	
	1510	1605			729	727		
Total sales revenue (USD/acre)	78.45	77.34	-2.25	0.641	75.70	82.72	3.34	0.687
	(135.96)	(131.27)	(4.81)		(126.03)	(141.63)	(8.29)	
	1448	1532			698	697		
Plan to increase coffee area	0.32	0.35	0.03	0.089	0.36	0.37	0.01	0.717
	(0.47)	(0.48)	(0.02)		(0.48)	(0.48)	(0.03)	
	1651	1786			818	803		
Plan to reduce coffee area	0.08	0.08	0.00	0.770	0.08	0.10	0.02	0.157
	(0.27)	(0.27)	(0.01)		(0.27)	(0.29)	(0.01)	
	1651	1786			818	803		

Table A7. Baseline descriptive statistics and balance, in-person training vs. control and mobile reinforcement vs training only, TechnoServe sample (part 1)

	In-person training				PxD Mobile Reinforcement			
	Control	Treatment	Adjusted difference (T-C)	p-value	Training only	Training & reinforcement	Adjusted difference (T-C)	p-value
Primary coffee farmer is male	0.81	0.79	-0.01	0.428	0.79	0.81	0.02	0.275
	(0.39)	(0.41)	(0.01)		(0.41)	(0.39)	(0.02)	
	1845	1953			876	886		
Female-headed household	0.12	0.11	-0.01	0.313	0.11	0.09	-0.03	0.097
	(0.32)	(0.32)	(0.01)		(0.32)	(0.28)	(0.02)	
	1845	1953			876	886		
Household size	6.53	6.34	-0.15	0.082	6.37	6.60	0.22	0.093
	(2.57)	(2.57)	(0.09)		(2.49)	(2.63)	(0.13)	
	1845	1953			876	886		
Children ≤ 12 yrs	2.41	2.47	0.07	0.180	2.47	2.59	0.11	0.147
	(1.55)	(1.54)	(0.05)		(1.52)	(1.54)	(0.08)	
	1734	1823			828	829		
Children 13-18 yrs	1.17	1.06	-0.10**	0.005	1.08	1.08	-0.01	0.849
	(1.15)	(1.09)	(0.03)		(1.09)	(1.10)	(0.06)	
	1845	1953			876	886		
Number of adults	3.11	2.97	-0.11*	0.041	2.96	3.10	0.15	0.088
	(1.57)	(1.52)	(0.05)		(1.47)	(1.62)	(0.09)	
	1845	1953			876	886		
Age of the primary farmer	48.25	48.40	0.06	0.893	48.18	47.22	-1.05	0.147
	(14.21)	(14.17)	(0.48)		(13.89)	(13.77)	(0.72)	
	1421	1920			864	873		
Female head literate	0.74	0.76	0.02	0.212	0.79	0.78	0.00	0.911
	(0.44)	(0.43)	(0.02)		(0.41)	(0.41)	(0.02)	
	1763	1880			846	856		
Male head literate	0.86	0.87	0.01	0.665	0.90	0.88	-0.02	0.203
	(0.34)	(0.34)	(0.01)		(0.30)	(0.33)	(0.02)	
	1265	1732			778	808		

Table A7. Baseline descriptive statistics and balance, in-person training vs. control and mobile reinforcement vs training only, TechnoServe sample (part 2)

	In-person training				PxD Mobile Reinforcement			
	Control	Treatment	Adjusted difference (T-C)	p-value	Training only	Training & reinforcement	Adjusted difference (T-C)	p-value
Educational attainment								
Male head less than primary	0.44	0.46	0.02	0.167	0.44	0.43	-0.02	0.481
	(0.50)	(0.50)	(0.02)		(0.50)	(0.50)	(0.03)	
	1245	1703			767	794		
Male head completed primary	0.42	0.41	-0.01	0.622	0.40	0.44	0.05	0.078
	(0.49)	(0.49)	(0.02)		(0.49)	(0.50)	(0.03)	
	1245	1703			767	794		
Male head completed secondary	0.02	0.02	-0.00	0.883	0.03	0.02	-0.01	0.084
	(0.15)	(0.14)	(0.00)		(0.17)	(0.13)	(0.01)	
	1245	1703			767	794		
Male head vocational training	0.10	0.09	-0.02*	0.050	0.10	0.09	-0.01	0.389
	(0.30)	(0.28)	(0.01)		(0.30)	(0.28)	(0.01)	
	1245	1703			767	794		
Male head university degree	0.02	0.02	0.00	0.398	0.03	0.02	-0.00	0.616
	(0.14)	(0.15)	(0.01)		(0.17)	(0.15)	(0.01)	
	1245	1703			767	794		
Female head less than primary	0.59	0.57	-0.02	0.260	0.55	0.53	-0.02	0.338
	(0.49)	(0.49)	(0.02)		(0.50)	(0.50)	(0.02)	
	1355	1845			832	840		
Female head completed primary	0.35	0.37	0.02	0.124	0.40	0.39	0.00	0.948
	(0.48)	(0.48)	(0.02)		(0.49)	(0.49)	(0.02)	
	1355	1845			832	840		
Female head completed secondary	0.01	0.01	0.00	0.969	0.00	0.01	0.01	0.093
	(0.09)	(0.08)	(0.00)		(0.06)	(0.11)	(0.00)	
	1355	1845			832	840		
Female head vocational training	0.04	0.04	0.00	0.967	0.04	0.05	0.01	0.266
	(0.20)	(0.19)	(0.01)		(0.19)	(0.22)	(0.01)	
	1355	1845			832	840		
Female head university degree	0.01	0.01	-0.01*	0.030	0.01	0.01	0.00	0.579
	(0.12)	(0.09)	(0.00)		(0.08)	(0.10)	(0.00)	
	1355	1845			832	840		

Table A7. Baseline descriptive statistics and balance, in-person training vs. control and mobile reinforcement vs training only, TechnoServe sample (part 3)

	In-person training				PxD Mobile Reinforcement			
	Control	Treatment	Adjusted difference (T-C)	p-value	Training only	Training & reinforcement	Adjusted difference (T-C)	p-value
Household asset index	0.09	0.08	-0.02	0.520	0.19	0.19	0.01	0.759
	(0.84)	(0.86)	(0.03)		(0.80)	(0.79)	(0.04)	
	1845	1953			876	886		
Owns radio	0.82	0.82	-0.01	0.588	0.83	0.84	0.01	0.670
	(0.38)	(0.38)	(0.01)		(0.37)	(0.37)	(0.02)	
	1845	1953			876	886		
Owns mobile phone	0.92	0.92	-0.00	0.925	0.98	0.98	0.00	0.784
	(0.27)	(0.28)	(0.01)		(0.13)	(0.12)	(0.01)	
	1845	1953			876	886		
Number of phones	1.82	1.77	-0.01	0.815	1.92	1.91	-0.01	0.926
	(1.23)	(1.17)	(0.04)		(1.17)	(1.06)	(0.06)	
	1845	1953			876	886		
Every member owns closed shoes	0.72	0.72	0.00	0.880	0.71	0.76	0.05*	0.025
	(0.45)	(0.45)	(0.02)		(0.45)	(0.43)	(0.02)	
	1845	1953			876	886		
Housing index	0.02	0.03	-0.02	0.461	0.08	0.05	-0.02	0.618
	(0.84)	(0.84)	(0.03)		(0.86)	(0.85)	(0.04)	
	1845	1953			876	886		
Total land (acres)	4.88	4.75	-0.11	0.574	4.81	4.92	0.05	0.858
	(5.12)	(5.20)	(0.20)		(5.09)	(5.35)	(0.28)	
	1585	1657			744	765		
Land under coffee (acres)	1.72	1.53	-0.20**	0.002	1.56	1.56	-0.02	0.798
	(1.50)	(1.37)	(0.06)		(1.36)	(1.41)	(0.07)	
	1575	1660			758	760		
Number of coffee plots	2.03	1.93	-0.04	0.351	1.99	1.96	-0.04	0.472
	(1.12)	(1.07)	(0.04)		(1.10)	(1.07)	(0.05)	
	1845	1953			876	886		
Livestock holdings (TLU)	1.61	1.49	-0.11	0.479	1.58	1.54	-0.07	0.693
	(5.06)	(3.31)	(0.16)		(3.62)	(3.25)	(0.17)	
	1443	1953			876	886		

Table A7. Baseline descriptive statistics and balance, in-person training vs. control and mobile reinforcement vs training only, TechnoServe sample (part 4)

	In-person training				PxD Mobile Reinforcement			
	Control	Treatment	Adjusted difference (T-C)	p-value	Training only	Training & reinforcement	Adjusted difference (T-C)	p-value
Practice index	0.72	0.72	0.00	0.821	0.74	0.73	-0.02	0.354
	(0.38)	(0.38)	(0.01)		(0.38)	(0.38)	(0.02)	
	(1845)	(1953)			(876)	(886)		
Weeding best practice	0.85	0.85	0.00	0.869	0.86	0.85	-0.01	0.641
	(0.36)	(0.36)	(0.01)		(0.35)	(0.36)	(0.02)	
	1845	1953			876	886		
IPDM best practice	0.13	0.12	-0.00	0.778	0.14	0.11	-0.02	0.144
	(0.33)	(0.33)	(0.01)		(0.34)	(0.32)	(0.02)	
	1845	1953			876	886		
Rejuvenation best practice	0.30	0.34	0.02	0.252	0.36	0.35	-0.01	0.768
	(0.46)	(0.48)	(0.02)		(0.48)	(0.48)	(0.02)	
	1845	1953			876	886		
Nutrition best practice	0.29	0.29	0.00	0.804	0.29	0.29	-0.00	0.946
	(0.45)	(0.45)	(0.02)		(0.46)	(0.45)	(0.02)	
	1845	1953			876	886		
Mulching best practice	0.42	0.41	0.01	0.761	0.42	0.42	-0.00	0.957
	(0.49)	(0.49)	(0.02)		(0.49)	(0.49)	(0.02)	
	1845	1953			876	886		
Intercropping best practice	0.72	0.69	-0.02	0.145	0.69	0.69	0.01	0.691
	(0.45)	(0.46)	(0.02)		(0.46)	(0.46)	(0.03)	
	1845	1953			876	886		
Correctly defines rejuvenation	0.75	0.76	-0.02	0.362	0.77	0.77	0.00	0.802
	(0.43)	(0.43)	(0.02)		(0.42)	(0.42)	(0.02)	
	1845	1953			876	886		
# Coffee farmers known nearby villages	1.72	1.74	0.03	0.886	1.69	1.79	0.11	0.565
	(4.04)	(4.24)	(0.18)		(4.00)	(4.33)	(0.19)	
	1845	1953			876	886		
Average age of coffee trees (years)	13.93	14.49	0.67	0.127	14.01	14.12	0.11	0.858
	(11.63)	(12.09)	(0.44)		(11.87)	(11.43)	(0.62)	
	1228	1652			764	746		

Table A7. Baseline descriptive statistics and balance, in-person training vs. control and mobile reinforcement vs training only, TechnoServe sample (part 5)

	In-person training				PxD Mobile Reinforcement			
	Control	Treatment	Adjusted difference (T-C)	p-value	Training only	Training & reinforcement	Adjusted difference (T-C)	p-value
Income sources (proportion of total)								
Coffee	0.38	0.39	0.02*	0.042	0.39	0.38	-0.01	0.261
	(0.22)	(0.23)	(0.01)		(0.22)	(0.23)	(0.01)	
	1438	1950			875	885		
Maize	0.01	0.01	-0.00*	0.012	0.01	0.01	-0.00	0.590
	(0.05)	(0.04)	(0.00)		(0.03)	(0.03)	(0.00)	
	1438	1950			875	885		
Banana	0.22	0.23	0.00	0.799	0.23	0.23	0.00	0.696
	(0.24)	(0.23)	(0.01)		(0.23)	(0.23)	(0.01)	
	1438	1950			875	885		
Cassava	0.00	0.00	-0.00	0.234	0.00	0.00	-0.00	0.926
	(0.03)	(0.02)	(0.00)		(0.02)	(0.03)	(0.00)	
	1438	1950			875	885		
Legumes/beans	0.11	0.11	-0.00	0.805	0.11	0.10	-0.01	0.226
	(0.17)	(0.17)	(0.01)		(0.16)	(0.16)	(0.01)	
	1438	1950			875	885		
Groundnut	0.01	0.02	0.00	0.056	0.02	0.02	-0.00	0.760
	(0.06)	(0.07)	(0.00)		(0.07)	(0.06)	(0.00)	
	1438	1950			875	885		
Root crops	0.01	0.01	-0.00	0.501	0.01	0.01	-0.00	0.330
	(0.05)	(0.05)	(0.00)		(0.06)	(0.04)	(0.00)	
	1438	1950			875	885		
Other cash crops	0.01	0.01	0.00	0.855	0.01	0.01	-0.00	0.928
	(0.05)	(0.05)	(0.00)		(0.05)	(0.05)	(0.00)	
	1438	1950			875	885		
Livestock	0.05	0.05	-0.00	0.330	0.05	0.05	0.00	0.431
	(0.12)	(0.11)	(0.00)		(0.11)	(0.11)	(0.01)	
	1438	1950			875	885		
Casual labor	0.04	0.04	0.00	0.855	0.03	0.05	0.01*	0.028
	(0.14)	(0.13)	(0.00)		(0.11)	(0.14)	(0.01)	
	1438	1950			875	885		
Salaries	0.02	0.02	-0.01	0.084	0.02	0.02	0.00	0.510
	(0.10)	(0.09)	(0.00)		(0.09)	(0.09)	(0.00)	
	1438	1950			875	885		
Non-farm business	0.07	0.07	0.00	0.796	0.08	0.07	-0.00	0.799
	(0.16)	(0.16)	(0.01)		(0.16)	(0.16)	(0.01)	
	1438	1950			875	885		

Table A7. Baseline descriptive statistics and balance, in-person training vs. control and mobile reinforcement vs training only, TechnoServe sample (part 6)

	In-person training				PxD Mobile Reinforcement			
	Control	Treatment	Adjusted difference (T-C)	p-value	Training only	Training & reinforcement	Adjusted difference (T-C)	p-value
Coffee expenses:								
Any labor expense	0.47	0.44	-0.02	0.179	0.46	0.46	0.00	0.875
	(0.50)	(0.50)	(0.02)		(0.50)	(0.50)	(0.02)	
	1443	1953			876	886		
Any fertilizer expense	0.16	0.14	-0.01	0.236	0.16	0.14	-0.02	0.370
	(0.36)	(0.35)	(0.01)		(0.37)	(0.35)	(0.02)	
	1443	1953			876	886		
Any pesticide expense	0.21	0.20	-0.01	0.356	0.20	0.21	0.02	0.376
	(0.41)	(0.40)	(0.02)		(0.40)	(0.41)	(0.02)	
	1443	1953			876	886		
Any inorganic fertilizer expense	0.04	0.03	-0.01	0.143	0.03	0.03	0.01	0.536
	(0.19)	(0.17)	(0.01)		(0.17)	(0.18)	(0.01)	
	1443	1953			876	886		
Any manure expense	0.12	0.11	-0.01	0.524	0.14	0.11	-0.03	0.150
	(0.33)	(0.32)	(0.01)		(0.34)	(0.31)	(0.02)	
	1443	1953			876	886		
Any compost expense	0.01	0.01	-0.00	0.738	0.01	0.01	-0.01	0.091
	(0.10)	(0.10)	(0.00)		(0.12)	(0.07)	(0.00)	
	1443	1953			876	886		
Any equipment expense	0.25	0.30	0.05**	0.007	0.33	0.28	-0.05*	0.046
	(0.43)	(0.46)	(0.02)		(0.47)	(0.45)	(0.02)	
	1443	1953			876	886		
Any transportation expense	0.32	0.32	0.01	0.462	0.34	0.34	0.00	0.969
	(0.47)	(0.47)	(0.02)		(0.47)	(0.48)	(0.02)	
	1443	1953			876	886		
Any processing expense	0.26	0.24	-0.01	0.546	0.24	0.25	0.01	0.618
	(0.44)	(0.43)	(0.02)		(0.43)	(0.44)	(0.02)	
	1443	1953			876	886		
Any seedling expense	0.04	0.04	-0.00	0.991	0.04	0.04	-0.00	0.804
	(0.19)	(0.19)	(0.01)		(0.20)	(0.19)	(0.01)	
	1443	1953			876	886		
Any mulch expense	0.17	0.17	0.00	0.947	0.19	0.17	-0.02	0.325
	(0.38)	(0.38)	(0.01)		(0.39)	(0.38)	(0.02)	
	1443	1953			876	886		
Any other coffee expense	0.00	0.01	0.00**	0.006	0.01	0.01	-0.00	0.670
	(0.04)	(0.08)	(0.00)		(0.08)	(0.07)	(0.00)	

Table A7. Baseline descriptive statistics and balance, in-person training vs. control and mobile reinforcement vs training only, TechnoServe sample (part 7)

	In-person training				PxD Mobile Reinforcement			
	Control	Treatment	Adjusted difference (T-C)	p-value	Training only	Training & reinforcement	Adjusted difference (T-C)	p-value
Took coffee payment prior to harvest	0.28	0.30	0.03	0.070	0.31	0.30	-0.01	0.575
	(0.45)	(0.46)	(0.02)		(0.46)	(0.46)	(0.02)	
	1443	1953			876	886		
Total sales revenue (USD)	274.54	243.59	-27.64	0.189	276.88	243.43	-19.38	0.502
	(565.40)	(516.25)	(21.00)		(622.62)	(438.43)	(28.84)	
	1147	1556			701	707		
Total sales revenue (USD/acre)	175.14	171.35	-2.04	0.818	173.83	181.60	8.12	0.628
	(234.92)	(224.42)	(8.88)		(215.74)	(242.27)	(16.75)	
	957	1344			621	613		
Plan to increase coffee area	0.47	0.44	-0.02	0.179	0.46	0.46	0.00	0.875
	(0.50)	(0.50)	(0.02)		(0.50)	(0.50)	(0.02)	
	1443	1953			876	886		
Plan to reduce coffee area	0.16	0.14	-0.01	0.236	0.16	0.14	-0.02	0.370
	(0.36)	(0.35)	(0.01)		(0.37)	(0.35)	(0.02)	
	1443	1953			876	886		

Table A8. Baseline descriptive statistics and balance, PxD standalone messages, within-village controls (spillover), and pure controls, pooled sample (part 1)

	PxD Messages vs Within-Village Controls				Spillover vs Pure Control Villages				Treatment vs Pure Control Villages			
	Control	PxD Standalone	Adjusted difference	p-value	Control	PxD Spillover	Adjusted difference	p-value	Control	PxD Standalone	Adjusted difference	p-value
Primary coffee farmer male	0.84	0.84	-0.00	0.514	0.83	0.84	0.02	0.176	0.83	0.84	-0.00	0.446
	(0.37)	(0.36)	(0.02)		(0.38)	(0.37)	(0.02)		(0.38)	(0.36)	(0.04)	
	3682	1030			1576	2322			1575	1030		
Female-headed household	0.09	0.09	-0.01	0.595	0.09	0.10	-0.02	0.068	0.09	0.09	-0.03	0.622
	(0.29)	(0.28)	(0.01)		(0.29)	(0.29)	(0.02)		(0.29)	(0.28)	(0.03)	
	3682	1030			1576	2322			1575	1030		
Household size	6.85	6.76	-0.19	0.527	6.87	6.71	-0.02	0.581	6.87	6.76	-0.05	0.865
	(2.82)	(2.82)	(0.13)		(2.73)	(2.88)	(0.16)		(2.74)	(2.82)	(0.23)	
	3682	1030			1576	2322			1575	1030		
Children below 12 yrs	2.86	2.87	-0.01	0.365	2.85	2.83	-0.36	0.122	2.85	2.87	0.19	0.338
	(1.77)	(1.74)	(0.08)		(1.75)	(1.77)	(0.09)		(1.75)	(1.74)	(0.16)	
	3483	967			1492	2177			1491	967		
Children 13 to 18 yrs	1.17	1.16	-0.03	0.878	1.20	1.11	0.05	0.554	1.20	1.16	-0.16	0.216
	(1.18)	(1.17)	(0.05)		(1.16)	(1.18)	(0.06)		(1.16)	(1.17)	(0.09)	
	3682	1030			1576	2322			1575	1030		
Number of adults	2.99	2.91	-0.12	0.851	2.97	2.96	0.20	0.108	2.97	2.91	-0.03	0.581
	(1.51)	(1.43)	(0.07)		(1.48)	(1.52)	(0.08)		(1.48)	(1.43)	(0.13)	
	3682	1030			1576	2322			1575	1030		
Age of the primary farmer	45.65	46.39	0.85	0.230	45.61	46.25	1.11	0.838	45.62	46.39	-0.27	0.432
	(13.78)	(14.15)	(0.72)		(13.14)	(14.56)	(1.00)		(13.15)	(14.15)	(1.17)	
	3017	828			1283	1910			1282	828		
Female head literate	0.72	0.73	0.02	0.230	0.72	0.70	-0.05	0.500	0.72	0.73	0.10	0.176
	(0.45)	(0.45)	(0.02)		(0.45)	(0.46)	(0.03)		(0.45)	(0.45)	(0.04)	
	3515	979			1515	2200			1514	979		

Table A8. Baseline descriptive statistics and balance, PxD standalone messages, within-village controls (spillover), and pure controls, pooled sample (part 2)

	PxD Messages vs Within-Village Controls				Spillover vs Pure Control Villages				Treatment vs Pure Control Villages			
	Control	PxD Standalone	Adjusted difference	p-value	Control	PxD Spillover	Adjusted difference	p-value	Control	PxD Standalone	Adjusted difference	p-value
Household asset index	0.13	0.14	-0.02	0.432	0.11	0.04	0.02	0.946	0.11	0.14	0.03	0.608
	(0.88)	(0.91)	(0.04)		(0.89)	(0.95)	(0.06)		(0.89)	(0.91)	(0.09)	
	3682	1030			1576	2322			1575	1030		
Owns radio	0.81	0.78	-0.01	0.946	0.80	0.81	0.02	0.203	0.80	0.78	0.08	0.068
	(0.39)	(0.41)	(0.02)		(0.40)	(0.40)	(0.02)		(0.40)	(0.41)	(0.04)	
	3682	1030			1576	2322			1575	1030		
Owns mobile phone	0.97	0.97	-0.01	0.149	0.97	0.90	-0.03	0.176	0.97	0.97	-0.02*	0.027
	(0.17)	(0.18)	(0.01)		(0.18)	(0.30)	(0.02)		(0.18)	(0.18)	(0.02)	
	3682	1030			1576	2322			1575	1030		
Number of phones	1.84	1.80	-0.10	0.176	1.83	1.70	0.09	0.797	1.83	1.80	0.01	0.068
	(1.15)	(1.14)	(0.06)		(1.15)	(1.20)	(0.07)		(1.15)	(1.14)	(0.10)	
	3682	1030			1576	2322			1575	1030		
Every member owns shoes	0.69	0.73	0.03**	0.000	0.69	0.68	0.02	0.270	0.69	0.73	0.06	0.500
	(0.46)	(0.44)	(0.02)		(0.46)	(0.47)	(0.03)		(0.46)	(0.44)	(0.04)	
	3682	1030			1576	2322			1575	1030		
Housing index	0.04	0.02	-0.03	0.716	0.02	0.02	0.02	0.554	0.02	0.02	0.01	0.932
	(0.96)	(1.00)	(0.04)		(0.95)	(0.96)	(0.06)		(0.95)	(1.00)	(0.09)	
	3682	1030			1576	2322			1575	1030		
Total land (acres)	5.38	5.19	-0.27	0.514	5.39	5.21	0.29	0.189	5.38	5.19	0.44	0.338
	(5.92)	(5.44)	(0.28)		(6.03)	(5.69)	(0.35)		(6.03)	(5.44)	(0.51)	
	3344	937			1427	2092			1426	937		
Land under coffee (acres)	1.41	1.31	-0.11	0.851	1.39	1.38	0.10	0.514	1.38	1.31	0.14	0.284
	(1.40)	(1.32)	(0.07)		(1.41)	(1.37)	(0.11)		(1.41)	(1.32)	(0.13)	
	3374	967			1446	2106			1445	967		
Number of coffee plots	1.85	2.01	0.10*	0.014	1.87	1.81	0.02	0.541	1.87	2.01	0.18	0.689
	(1.04)	(1.07)	(0.05)		(1.04)	(1.02)	(0.06)		(1.04)	(1.07)	(0.10)	
	3682	1029			1576	2322			1575	1029		

Table A8. Baseline descriptive statistics and balance, PxD standalone messages, within-village controls (spillover), and pure controls, pooled sample (part 3)

	PxD Messages vs Within-Village Controls				Spillover vs Pure Control Villages				Treatment vs Pure Control Villages			
	Control	PxD Standalone	Adjusted difference	p-value	Control	PxD Spillover	Adjusted difference	p-value	Control	PxD Standalone	Adjusted difference	p-value
Practice index	0.63	0.62	-0.01	0.581	0.64	0.62	-0.01	0.649	0.64	0.62	0.02	0.635
	(0.37)	(0.37)	(0.02)		(0.37)	(0.37)	(0.02)		(0.37)	(0.37)	(0.03)	
	3682	1030			1576	2322			1575	1030		
Weeding best practice	0.03	0.00	-0.02	0.581	0.06	-0.01	-0.02	0.649	0.06	0.00	0.06	0.635
	(1.00)	(0.99)	(0.05)		(1.00)	(1.00)	(0.06)		(1.00)	(0.99)	(0.09)	
	3682	1030			1576	2322			1575	1030		
IPDM best practice	0.75	0.72	-0.04	0.230	0.75	0.75	-0.03	0.811	0.75	0.72	0.05	0.811
	(0.43)	(0.45)	(0.02)		(0.43)	(0.44)	(0.02)		(0.44)	(0.45)	(0.04)	
	3682	1030			1576	2322			1575	1030		
Rejuvenation best practice	0.09	0.07	-0.01	0.068	0.10	0.08	-0.04	0.446	0.10	0.07	-0.06	0.297
	(0.28)	(0.25)	(0.01)		(0.30)	(0.27)	(0.02)		(0.30)	(0.25)	(0.03)	
	3682	1030			1576	2322			1575	1030		
Nutrition best practice	0.32	0.31	0.02	0.932	0.33	0.31	-0.03	0.405	0.33	0.31	0.01	0.932
	(0.47)	(0.46)	(0.02)		(0.47)	(0.46)	(0.03)		(0.47)	(0.46)	(0.04)	
	3682	1030			1576	2322			1575	1030		
Mulching best practice	0.26	0.46	0.16	0.824	0.27	0.25	-0.15	0.446	0.27	0.46	0.22**	0.000
	(0.44)	(0.50)	(0.19)		(0.45)	(0.43)	(0.08)		(0.45)	(0.50)	(0.39)	
	468	59			172	334			172	59		
Intercropping best practice	0.22	0.20	-0.02	0.851	0.22	0.21	0.05	0.149	0.22	0.20	0.03	0.419
	(0.41)	(0.40)	(0.02)		(0.41)	(0.41)	(0.03)		(0.41)	(0.40)	(0.04)	
	3682	1030			1576	2322			1575	1030		
Correctly defines rejuvenation	0.57	0.64	-0.01	0.622	0.52	0.57	-0.04	1.000	0.52	0.64	0.28	0.230
	(0.50)	(0.48)	(0.16)		(0.50)	(0.50)	(0.09)		(0.50)	(0.48)	(0.34)	
	468	59			172	334			172	59		
# Coffee farmers known nearby villages	0.76	0.74	-0.00	0.878	0.76	0.76	-0.01	0.959	0.76	0.74	-0.03	0.514
	(0.42)	(0.44)	(0.02)		(0.43)	(0.43)	(0.03)		(0.43)	(0.44)	(0.04)	
	3682	1030			1576	2322			1575	1030		

Appendix 2: Coffee agronomy knowledge questions and scoring

A. Endline knowledge questions

Scoring shown in red font

Nutrition

1. What type of materials can be composted? (multiple select)
   NOTE: MULTIPLE answers can be selected. Select all that the farmer mentions.
   1 knowledge point: 1 for any correct answer, as indicated below

   a. Any plant materials (1 point)
   b. Any materials that can decompose (1 point)
   c. Organic kitchen waste, for example vegetable peelings (1 if combined with d, e, or f, 0 otherwise)
   d. Crop residues, for example banana leaves, maize husks (1 if combined with c, e, or f, 0 otherwise)
   e. Animal dung / manure (1)
   f. Ash (1 if combined with c, d, or e, 0 otherwise)
   g. Plastic waste (0 points for question if selected)
   h. Other (specify)
   i. Don't know

2. What can you do to ensure a compost pile or pit remains moist? (multiple select)
   2 knowledge points: one point if one of (a) through (d) is mentioned, two points if two are mentioned.

   Note: probe until the respondent can't think of any more responses

   a. Add water to the pit/pile
   b. Cover, for example with banana leaves, soil, polythene, or other material
   c. Locate the pit/pile in a shady spot
   d. Turn the pile regularly
   e. Other (specify)

3. How often should a compost pile or pit be turned or mixed? (select one)
   1 knowledge point: responses (c) and (d) are both correct

a. Every day (0 points)
b. At least once per week (0 points)
c. Every 3-4 weeks
d. At least once per month
e. About every 2 months
f. Less often than every 2 months

4. Please describe where and how in the coffee garden NPK fertilizer should be applied. (enumerator: probe as needed to understand whether fertilizer is dug deep into the soil, spread on top, or applied into a shallow trench) (select one)
   1 knowledge point: responses (a) and (c) are both correct

   a. Spread under the tree canopy, without digging
   b. Dug into the soil under the canopy
   c. In a shallow trench dug around the tree
   d. Broadcast all over the field

5. What should the soil conditions be when applying chemical fertilizer? (select one)
   1 knowledge point: response (a) is correct.

   a. Soil should be moist/wet
   b. Soil should be dry
   c. Other (specify)

6. What is the best time of year to apply fertilizer to mature coffee trees? (select one)
   1 knowledge point: responses (a) and (b) are both correct.

   a. When the crop is flowering
   b. During the rainy season
   c. Other (specify)
   d. Don't know

Weeding

1. What is the best way to control weeds **under** the coffee canopy in a mature coffee garden? (select one)

1 knowledge point: responses (a), (b) and (e) are all correct

   a. Pull weeds by hand

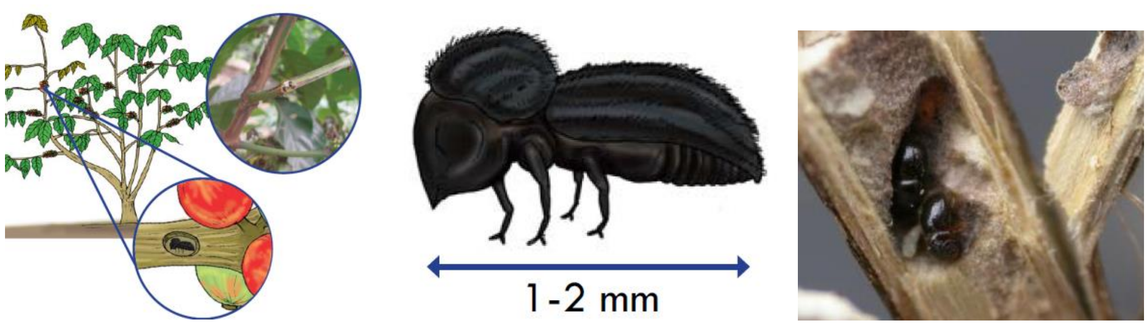
b. Apply mulch
c. Dig using a hoe
d. Cut weeds with a slasher
e. Remove weeds with a machete/panga
f. Apply herbicide
g. Other (describe)

2. Is it a good practice to weed by digging up the soil under the coffee tree with a hoe?
1 knowledge point: (b) is correct

a. Yes (0 point)
b. No

Integrated Pest and Disease Management

1. What is the name of the pest shown these photos and illustrations? (single select)
1 knowledge point: (c) is correct



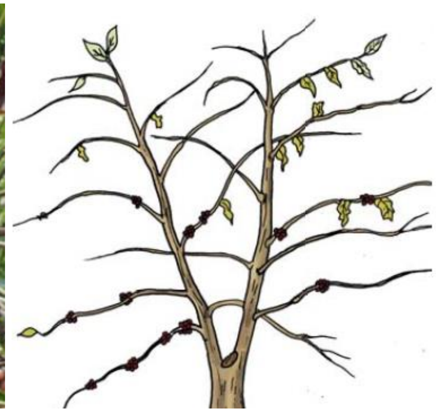
a. Coffee wilt disease
b. Coffee leaf miner
c. Coffee twig borer
d. Coffee mealybug
e. Other (specify)

2. What methods do you know for controlling or eliminating this pest?
Note: Select all method the farmer mentions. Probe until the respondent can't think of any more responses

3 knowledge points: one point if one of (a) through (e) is mentioned, two points if two are mentioned, 3 points if 3 are mentioned.

a. Remove infested twigs
b. Burn infested twigs
c. Prune / remove unwanted suckers
d. Spray pesticides containing imidachloprid (e.g. Bravo, Imax, Confidol)
e. Reduce excessive shade
f. Don’t know
g. None of the above

3. What problem is affecting the coffee in these pictures? (single select)
1 knowledge point: (c) is correct

a. Coffee berry borer
b. Coffee twig borer
c. Coffee wilt disease
d. Lack of fertilizer
e. Other (specify)

4. What methods do you know for controlling this problem? (multiple select)
Note: do not read answers; select all method the farmer mentions. Probe until the respondent can’t think of any more responses
2 knowledge points: one point if one of (a) through (d) is mentioned, two points if two are mentioned

a. Use varieties resistant to coffee wilt disease (e.g. CWDR)
b. Uproot and burn infested trees

c. Do not replant at site of tree for 2 years
d. Disinfect tools used to remove infested trees
e. None of the above

Rejuvenation

1. What is the **best** tool to use when rejuvenating coffee? (select one)
   1 knowledge point: (a) is correct

   a. Pruning saw
   b. Panga / Machete
   c. Secateurs
   d. Other (specify)
   e. Don't know

2. After how many years should you rejuvenate a coffee tree? (select one)
   1 knowledge point: (b) and (c) are both correct

   a. Don't know
   b. 6 or 7 years after the first time the tree is harvested
   c. 8 or 9 years after the tree was planted or last rejuvenated
   d. Other (specify)

3. At what angle should the stems be cut when rejuvenating?
   1 knowledge point: (c) is correct

   a. Flat
   b. Vertical
   c. 45 degree (1 point)
   d. Don't know

4. How many main stems should you leave when rejuvenating a coffee tree? (integer)
   1 knowledge point: either 0 or 1 is correct

5. When you rejuvenate your coffee, new shoots (suckers) will grow. What is the maximum number of suckers should you keep on each coffee tree?
   ________ (integer)
   1 knowledge point: either 3 or 4 is correct

Pruning

1. Could you please describe what should be done when pruning a coffee tree? (multiple select)
   4 knowledge points: 1 for each of (a) through (d)

    1. Remove branches at the centre of the tree / open centres
    2. Remove unwanted suckers
    3. Remove dead and broken branches
    4. Remove branches touching the ground
    5. None of the above mentioned

Mulching

1. What are the benefits of applying mulch to the coffee farm? (multiple select)
   2 knowledge points, 1 point if only one of (a) through (e) is mentioned; 2 if more than 1 of these are mentioned.

    a. Conserves soil moisture
    b. Controls weeds
    c. Prevents erosion / runoff
    d. Improves soil quality (nutrients and/or texture)
    e. Adds organic matter
    f. Other (specify)

2. Where on the coffee farm is the most important place to apply mulch, **if you have a limited amount**? (enumerator should probe to distinguish a, b, and c)
   1 knowledge point: (a) is correct.

    a. Under the tree canopy
    b. Only outside the coffee canopy
    c. All over the field, both under the canopy and between the trees
    d. Other (specify)

Erosion control

1. What are all the methods you know of to prevent erosion of soil on a coffee farm? (multiple select)

Note: Do not read answers, but probe until the respondent can't think of any more responses
2 knowledge points, 1 point if only one of (a) through (f) is mentioned; 2 if more than 1 of these are mentioned.

a. Plant stabilizing grasses at the edges and along ridges/terraces/contour bands
b. Plant cover crops
c. Apply mulch
d. Dig water traps / pits / trenches / troughs
e. Use physical barriers (e.g. rocks)
f. Terracing
g. Other (specify)
h. Don't know

Shade

1. Is it a good practice to grow your coffee in the full sun, with no shade?
   1 knowledge point; (b) is correct.

   a. Yes
   b. No

Intercropping

1. What are the best crops for planting together with coffee? (multiple select)
   2 knowledge points: one for either (a) or (b); two for both; zero points if (c), (d) or (e) is mentioned.

   a. Banana
   b. Legumes (or mentions any of beans, groundnuts, cowpeas or soybeans)
   c. Cassava (0 points for question if mentioned)
   d. Maize (0 points for question if mentioned)
   e. Potato (0 points for question if mentioned)
   f. Other (specify)

B. Baseline knowledge questions

Coffee knowledge questions at baseline were limited to the following:

1. What methods do you know for controlling or reducing Coffee Wilt Disease (CWD)?

4 knowledge points: responses (a) through (d) are correct.

   a. Use varieties resistant to coffee wilt disease (e.g. CWDR)
   b. Uproot and burn infested trees
   c. Do not replant at site of tree for 2 years
   d. Disinfect tools used to remove infested trees
   e. None of the above

2. What methods do you know for controlling or reducing Coffee Twig Borer (CTB)?

5 knowledge points; responses (a) through (d) and (e) are correct.

   a. Remove infested twigs
   b. Burn infested twigs
   c. Remove of unwanted suckers
   d. Spray pesticides containing imidachloprid as an active ingredient (e.g. using imax, confidol)
   e. Spray other pesticides
   f. Reduce shade

3. What can you do to make your coffee trees more productive when they have become old and are not yielding as many cherries as they were before?

   HRNS region response options

   One knowledge point; (b) is considered correct.

      a. Do not know any methods
      b. Remove one or more main stems
      c. Other

   TNS region response options

   One knowledge point; (b) is correct.

      a. Do not know any methods
      b. Remove all but 1 or 2 of the main stems, then allow the stems to grow back
      c. Remove some of the stems, but leave 3 or more on the tree
      d. Other