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Demonstration plots, seed trial packs, bidirectional learning, and modern input sales: Evidence from a field experiment in Tanzania

By

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ABSTRACT

Greater integration of legumes in cropping systems, increased use of modern inputs, and more tailoring of extension recommendations to local contexts are essential for sustainable agricultural intensification. In addition, bidirectional learning (BDL) in which information providers and farmers iteratively refine extension recommendations is critical for improving extension recommendations. This study reports the main results from a randomized controlled trial conducted in the southern highlands of Tanzania that sought to determine if there is an appreciable difference in NGO lead farmer extension agents' improved bean input sales or bidirectional learning with other farmers if they set up a bean demonstration plot only vs. if they establish a demonstration plot and distribute to other farmers free trial packs of the inputs highlighted on the demonstration plot (seed for improved varieties and a new chemical seed treatment product, Apron Star). While no statistically significant differences were found between the two groups, endline survey results suggest that there may be unmet demand from farmers for the inputs promoted through the interventions but that the lead farmer extension agents are constrained in their ability to meet that demand by inadequate supply of the inputs or lack of financing. The endline survey results also indicate that many but far from all of the lead farmer extension agents consider farmers' feedback when making bean recommendations or believe that they can learn things from other farmers that could help them improve their recommendations. Explicit training in the importance of and strategies for BDL are likely needed if meaningful BDL is to occur.

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1 Introduction

Global food supply needs to increase by 60-70% by 2050 to keep pace with rising demand and population growth, and this increase will need to be even more substantial in sub-Saharan Africa (SSA) (Bruinsma, 2009; van Ittersum et al., 2016; Steensland, 2019). Many countries throughout the region, including our focus country of Tanzania, face soil degradation challenges, making increased agricultural production an even greater challenge (Bekunda et al., 1997; Muller et al., 2011; Tittonell and Giller, 2013). Sustainable agricultural intensification (SI), which strives to increase agricultural productivity while also conserving and protecting the environment, is widely viewed as a key way to close agricultural yield gaps and achieve food security (Pretty, 1997, 2008; Pretty, Toulmin and Williams, 2011; Garnett et al., 2013; Keating et al., 2013; Vanlauwe et al., 2014; Peterson and Snapp, 2015). Due to their nitrogen fixing capacities, legumes can have a positive impact on soil fertility, and legume intensification is an important mechanism for both SI and increased food security on smallholder farms (Tharanathan and Mahadevamma, 2013; Franke et al., 2018; Sauer et al., 2018; Chimonyo, Snapp and Chikowo, 2019; Kim et al., 2019a, 2019b; Vanlauwe et al., 2019).

Legume production requires extensive knowledge and, thus, effective extension systems. However, extension support that acknowledges the complexities of legume cropping systems is limited (Muoni et al., 2019). Additionally, resource constraints prevent government extension programs from reaching all farmers (Haug, 1999; Crawford et al., 2003; Friis-Hansen, 2004; Davis, 2008; Swanson and Rajalahti, 2010; Jensen et al., 2019). In Tanzania, for example, the ratio of extension officers to farm households is approximately 1:630, resulting in only about 10% of such households being adequately reached by extension services (Harris-Coble, 2016).

In this context, extension services provided by non-governmental organizations (NGOs) may be able to play an important role in promoting improved agricultural technologies and providing information to support SI (Rutatora and Mattee, 2001; Davis and Place, 2003). One such NGO is Farm Input Promotions Africa Ltd. (FIPS). FIPS aims to "assist farmers to gain access to advisory services and local access to the inputs and technologies they need to increase the productivity of their crops and livestock in a sustainable way," with an ultimate goal of helping farmers to become food secure (FIPS Africa, 2020a). FIPS' extension model involves the use of Village-Based Agricultural Advisors (VBAAs) – local farmers that are selected by their community to receive training from FIPS on good agricultural practices, entrepreneurship and small business development, and subsequently share this knowledge with other farmers in their community. FIPS also provides VBAAs with support to become registered agro-dealers and link them with wholesale inputs suppliers if they desire.

Two key activities lie at the heart of the FIPS approach: "mother demos" and "baby demos". Mother demos are demonstration plots set up by VBAAs (often with the assistance of other local farmers) that highlight improved crop varieties, inorganic fertilizers, crop protectants, and/or crop and soil management practices. VBAAs also distribute free small packs of select inputs highlighted in the mother demos to local farmers so that they can try out the inputs on their own land. FIPS refers to these free trial packs as "baby demos". In the past, most FIPS mother and baby demos in Tanzania were done for maize, and the mother and baby demos were always done jointly in a given community. As a result, little is known about the value-added by the baby demos. FIPS' theory of change hinges on the belief that these demos raise local farmers' demand for the inputs, which VBAAs can then sell

at market prices in future seasons – the goals being to improve local farmers' access to improved inputs as well as to provide an income-generating activity to VBAAs (i.e., operating as local agro-dealers) (FIPS Africa, 2020b). The baby demos allow recipients to supplement knowledge gained from the mother demo with experimenting with the new inputs on their own farms. We expect this additional, hands-on experience to increase farmer demand for the inputs and, in turn, VBAA sales of the inputs relative to those of VBAAs who conduct a mother demo but do not distribute baby demo input trial packs.

We test the VBAA sales part of this hypothesis in this study, which draws on the results of a randomized-controlled trial (RCT) conducted in the southern highlands of Tanzania in 2017. VBAAs were randomly assigned to the mother demo only control group or the mother and baby demos treatment group. These mother and baby demos highlighted improved varieties of common bean rather than maize to differentiate the demos from those previously conducted by most VBAAs. Common bean (henceforth, simply "beans") was also chosen because Tanzania accounts for almost a quarter of all beans produced in SSA, and because of the important role of legumes in SI (HarvestChoice, 2015). The study area, the southern highlands, is Tanzania's main bean-growing region. The demos also showcased Apron Star – a new seed treatment produced and commercialized by Syngenta – by including improved bean varieties and a local variety with and without Apron Star applied to the seed before planting. One main objective of the RCT was to understand if and to what extent the addition of baby demos affected VBAA commercial (unsubsidized) sales of Apron Star or seed for improved bean varieties. In addition to analyzing actual input sales, we explore the effects of including the baby demos on "unfilled orders" - i.e., requests from farmers for inputs that VBAAs were unable to fulfill but that indicate latent demand from farmers for the inputs.

To our knowledge, this is the first rigorous evaluation of whether and to what extent combining a demonstration plot (mother demo) with the distribution of free trial packs (baby demos) raises input sales (or unfilled orders) relative to doing only a demonstration plot. (Henceforth, we will use the terms demonstration plot and free trials packs instead of mother demo and baby demos.) In addition, we are aware of no other studies that compare the effects of these two sets of extension activities on other outcomes with the exception of Morgan et al. (in press), who conducted experimental auctions in a sub-set of the villages included in the same RCT that we report on here to elicit farmers' willingness-to-pay (WTP) for improved bean seed with and without Apron Star.[1] Morgan et al. find no statistically significant differences in WTP for these products between farmers in villages where the VBAA conducted only a demonstration plot compared to farmers in villages where the VBAA set up a demonstration plot and distributed free trial packs.

While we are aware of no other previous studies that analyze the effects of this particular combination of extension activities, previous studies have found that demonstration plots can raise farmers' awareness of improved agricultural technologies (Khan et al., 2009; Simtowe et al., 2011) and increase adoption (Maertens et al., 2018). Farmer field days – another extension activity – have also been effective in technology dissemination and adoption via improving farmer knowledge and awareness (Heiniger et al., 2002; Amudavi et al., 2009; Asmelah, 2014). The studies cited here largely focus on

[1] These auctions were conducted after the beans planted as part of the RCT were harvested.

effects on farmer awareness and/or adoption, and do not measure the effects of the extension activities on input sales.

Additional studies have looked at the impacts of either free seed packs or selling seed in small quantities on improved varieties technology dissemination, adoption, or farmer interest in buying the seed at market prices. Allowing farmers to try out a new variety and learn about it for themselves is considered key to promoting adoption (Fisher et al., 2015). Selling seed in small quantities has been effective in encouraging farmers to buy and try such inputs, especially those that may not be able to afford seed sold in larger package sizes (Sperling et al., 1996; David et al., 1997; Phiri et al., 2000, Sperling and Boettiger, 2013).[2] Selling these small packs at market prices or at subsidized rates via public-private partnerships is also cited as an important step in developing and scaling up seed markets (ICRISAT, 2014; Rubyogo et al., 2016; Rubyogo et al., 2019). Distributing free "tester" packs has also been found to increase farmer adoption in subsequent farming seasons. For example, Grisley and Shamambo (1993) documented the successful diffusion of a high-yielding variety of bean seed in Zambia following the distribution of free small seed packs.[3]

As evidenced above, a sizable amount of research has looked at the effects of *either* demonstration plots (and other extension activities like field days) *or* free/affordable small seed packs. To our knowledge, only one study has investigated the effects of an extension activity on subsequent input sales similar to our work. Audi et al. (2015) surveyed field day participants (farmers) to assess the amount of awareness the field day generated about new technologies and to record farmer preferences for specific seed varieties and sizes of packages to be sold. Agro-dealers were then selected to sell subsidized seed and fertilizer packs in accordance with the farmer-expressed preferences. The agro-dealers were also equipped with a semi-structured survey with which to collect feedback from farmers when they visited the agro-dealer to purchase small seed and/or fertilizer packs. A main objective of the paper was to establish if the preferences farmers expressed at the field days were correlated with their subsequent demand for the inputs (seed and fertilizer) via purchases from agro-dealers. Analysis of the survey data suggests a positive correlation. While the insights from Audi et al. (2015) are relevant to the current study, there are some major differences between their study and ours: (i) Audi et al. (2015) focus on field days with no distribution of free input packs, whereas our focus is on demonstration plots with and without free input packs; (ii) they focus on sorghum and finger millet in the north and central zones of Tanzania, whereas we focus on beans in the southern highlands; and (iii) Audi et al. (2015) is based on analysis of observational data, whereas this study is based on an RCT.

In addition to testing the hypothesis that the combination of a demonstration plot and free trial packs raises VBAA input sales/unfilled orders relative to a demonstration plot only, the second main objective of the RCT was to assess whether the addition of trials packs increases opportunities for "bidirectional learning" (BDL) between VBAAs and farmers. BDL is "an iterative process by which information providers (e.g., agro-dealers, extension services and NGOs) and farmers fine-tune

[2] In Kenya, small seed packs known as "Leldet Bouquets" include improved maize and legume varieties adapted to a farmer's location to encourage diversification and to enable farmers, especially women, to try out drought-tolerant varieties at a manageable cost before committing to larger quantities (Paul-Bossuet, 2011).

[3] There is also a large literature on the effects of government agricultural input subsidies on farmer demand for the inputs at market prices. See Jayne et al. (2018) for a comprehensive review of these studies.

recommendations" on inputs and management practices (Snapp et al., 2015, p. iii).[4] BDL is critical for the development of extension recommendations adapted to local context. In Tanzania and numerous other SSA countries, a large share of total agricultural production is undertaken by smallholder farmers under conditions that vary from farm to farm and by location within the country. A noted shortcoming of early government extension programs was that they provided "one size fits all" recommendations that were not tailored to local circumstances. Rather than viewing extension as a service or system, the emerging view is one that considers extension to be a "knowledge and information support function" for rural populations (Rivera and Qamar, 2003). Understanding local conditions and farmer needs in order to customize recommendations for inputs and management practices is therefore a necessity (Aune et al., 2017). Through their interactions with farmers, VBAAs can leverage farmers' specific knowledge about their land and farmers' feedback on what has worked well (or not) to provide more tailored advice. BDL therefore has the potential to enhance the quality, content, and relevance of extension recommendations in Tanzania and further encourage adoption of inputs and management practices in support of SI. We hypothesize that, by enabling farmer experimentation with the inputs on their own land, the combination of a demonstration plot and free trial packs increases the exchange of information and opportunities for BDL between farmers and VBAAs relative to if only a demonstration plot were done.

The results of this study are relevant not only to FIPS' efforts but also to ongoing and future efforts by government extension, other NGOs, and private companies seeking to promote modern inputs, improved agricultural management practices, and SI. The remainder of the paper is structured as follows. Section 2 provides details on the RCT and associated baseline and endline surveys. Section 4 describes the empirical strategy while Section 5 discusses results. Finally, Section 6 concludes and discusses relevant policy implications.

2 Experimental design, data, and interventions

2.1 Experimental design and baseline/endline surveys

The RCT was designed and implemented by FIPS and the International Center for Tropical Agriculture-Tanzania (CIAT-Tanzania) in collaboration with Michigan State University and the Tanzania Agricultural Research Institute-Uyole (TARI-Uyole), with funding from the Feed the Future Innovation Lab for Collaborative Research on Sustainable Intensification. The project intended to involve all 230 FIPS VBAAs in the southern highlands of Tanzania that were active during the

[4] Studies in many parts of the world have identified extension personnel as the primary source of information for farmers regarding new technologies and their merits, and both extension services and social learning among farmers have been found to be strong determinants of technology adoption and diffusion (see, for example, Foster and Rosenzweig, 1995; Rivera and Alex, 2003; World Bank, 2006; Conley and Udry, 2010; Pan et al., 2015; Wossen et al., 2017; BenYishay and Mobarak, 2018; Takahashi et al., 2019). Extension services and social learning are complementary in that the effectiveness of one is enhanced by the presence of the other (Genius et al., 2013). Several studies note that ineffective extension may be the result of insufficient knowledge transfer between extension agents and farmers (Lukuyu et al., 2012; Sekiya et al., 2015; Niu and Ragasa, 2018). For example, an evaluation of extension services in Tanzania found that only 5% of farmers considered the extension services they received to be "above average", but when farmers did receive high quality extension service there was a measurable increase in maize yield (Nijbroek and Andelman, 2015).

2015/16 agricultural year according to FIPS records and that FIPS expected to continue to operate as VBAAs during the 2016/17 agricultural year (when the interventions were implemented). FIPS had active VBAAs in seven districts in the southern highlands at the time of the project: Iringa Rural, Wanging'ombe, Songea Rural, Mufindi, Njombe Rural, Mbeya Rural, and Mbozi. Each district had 30 active VBAAs as of 2015/16 per FIPS' records with the exception of Njombe Rural, which is larger and had 50. There was no sampling per se because the project planned to engage all active VBAAs in the southern highlands. The main bean season for Mbeya Rural and Mbozi is from March to July, while the main bean growing season for the other five districts is January to May. We therefore refer to Mbeya Rural and Mbozi as the "late bean districts" and the other five districts as the "early bean districts" below.

The 230 individuals on FIPS' VBAA roster were randomly assigned to either the "demonstration plot only" (DP) control or the "demonstration plot plus free trial packs" (DPTP) treatment using Mahalanobis greedy pairwise matching (following Bruhn and McKenzie, 2009) based on 2015/16 administrative data on the VBAAs provided by FIPS.[5] This resulted in 115 VBAAs per treatment group.[6] (Details on the demonstration plots and free trial packs are provided in the next sub-section.) The matching was done separately for each district because VBAAs within a district were expected to be similar in observable and unobservable ways and because each district has a separate FIPS coordinator that oversees VBAAs' activities within the district. Note that VBAAs' villages were sufficiently distant from one another that there were not concerns about a given VBAA's activities affecting outcomes in other VBAAs' communities.

Several challenges were encountered during the implementation phase that resulted in fewer than 230 VBAAs ultimately participating in the project and a *de facto* uneven split between the two treatment groups. First, it was discovered that 16 of the individuals that were listed on FIPS' roster (all in Mufindi district) were, in fact, not VBAAs but rather government extension officers. These names were corrected during the baseline survey, which was conducted in January-February 2017. FIPS was unable to confirm if the administrative information for these 16 individuals that had been used for the pairwise matching was for the VBAAs or for the government extension officers.

Second, 36 of the VBAAs on the FIPS roster did not continue to serve as VBAAs in 2016/17 as anticipated.[7] Of these 36, 13 were replaced with a new VBAA that lived and served in the same community as the original VBAA that they replaced; in addition, FIPS added 14 new VBAAs in new communities. As a result, at the time of the baseline survey, 221 VBAAs were participating in the RCT (178 from the original roster used for pairwise matching, 16 VBAAs for which the local extension officer had been listed on the original roster, 13 replacement VBAAs in villages that had a VBAA on the original roster, plus 14 new recruits in new villages). In terms of treatment group, VBAAs in Mufindi where the extension agent-VBAA mix-ups occurred were assigned to the same treatment

[5] There was no pure control group (i.e., with neither activity implemented) because FIPS did not want to disadvantage any VBAAs.

[6] See Table A1 in the appendix for the characteristics on which VBAAs were matched and results of balance tests. Due to our use of pairwise matching, VBAAs are balanced on all characteristics available in the 2015/16 administrative data from FIPS. Moreover, we fail to reject that these characteristics are jointly orthogonal to VBAA treatment group ($p=0.704$) when we regress the treatment group dummy on all VBAA characteristics used for the matching plus matched pair fixed effects, with standard errors clustered at the matched pair level. See Table A2 in the appendix for these regression results.

[7] One died, one moved away, and the other 34 chose not to continue working as VBAAs.

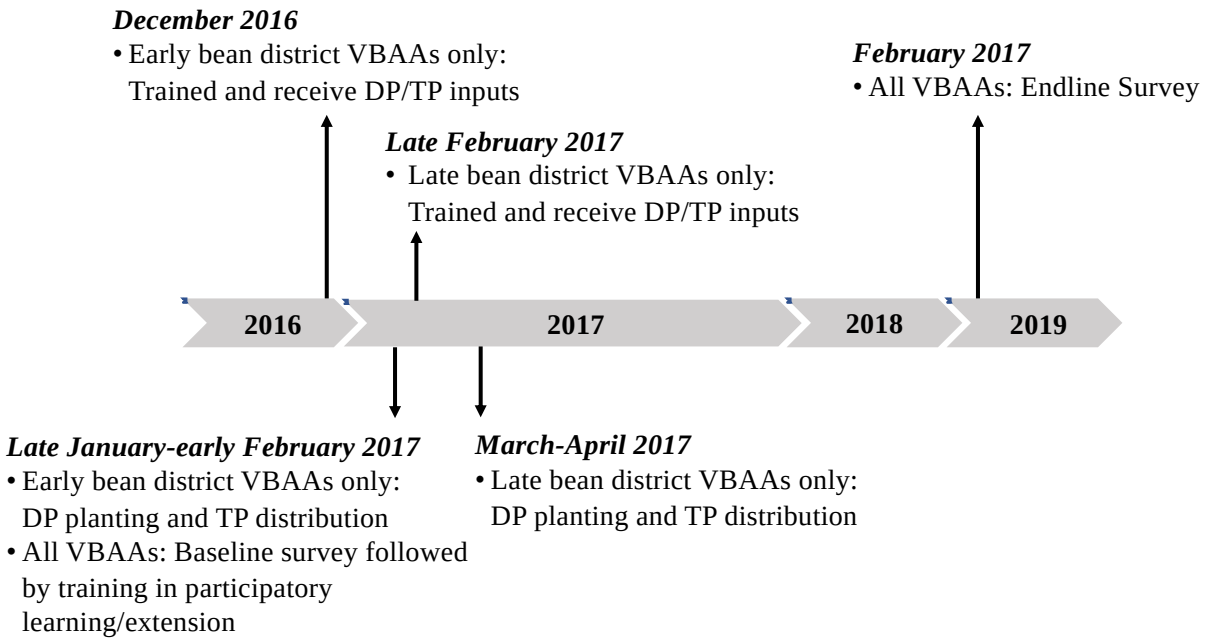
group that the extension agent had been randomly assigned to during the pairwise matching process. Similarly, new VBAAs that replaced in the same community VBAAs used in the original randomization were assigned to the same treatment to which the original VBAA had been assigned. New VBAA recruits in new villages were randomly assigned to the DP or DPTP treatment by FIPS.

Third, due to challenges with the timing of the baseline survey and the need to train and get inputs to the VBAAs for the DP and TP activities in time for planting during their respective main bean season, the baseline survey took place after early bean season VBAAs had been trained and given inputs for the interventions. This meant that there was not an opportunity to redo the randomization after problems were discovered at the time of the baseline survey. Of the 221 VBAAs known to be participating in the project as of the baseline survey, 216 were successfully interviewed. See Figure 1 for a timeline of project activities.

Fourth, although FIPS reported that the inputs for the DPs and TPs had been distributed to VBAAs per the assignments based on the randomization, follow-up phone calls to the VBAAs to confirm the inputs they had received revealed that this was not the case for many VBAAs. (We were able to reach by phone 204 of the 216 VBAAs that were interviewed at baseline.) It was not possible to definitively determine at what point in the process things went awry but insufficient sensitization of the FIPS district coordinators (who distributed the DP and TP inputs to VBAAs in their district) may have played a role, especially given the major variation across districts in terms of the share of VBAAs that ended up with the correct inputs per the original randomization (see Table 1).[8]

[8] Surprisingly, as shown in Table 1, seven VBAAs that were supposed to be participating in the project reported in the phone calls that they received no inputs whatsoever.

Figure 1. Project Timeline



Note: Training prior to the DP/TP inputs distribution to VBAAs was on bean variety characteristics and agronomic practices (Kato et al. 2016), use of Apron Star, and the protocols for the DP (and TPs for applicable VBAAs).

Table 1. VBAA treatment groups per the original random assignment (with corrections and replacement VBAAs) vs. follow-up calls, by district

District	(A) **Treatment group per random assignment** (N=202; excludes 14 new recruits for whom no original random assignment exists)		(B) **Treatment group based on inputs received per follow-up phone calls** (N=204, the number of VBAAs successfully reached by phone)			(C) **Percent of VBAAs for which follow-up phone call treatment group matches random assignment** (N=190, the number VBAAs included in both columns A and B)	
	DP	DPTP	DP	DPTP	Neither	Total N	% match
Iringa Rural	11	12	13	10	0	22	77.3%
Wanging'ombe	11	12	4	18	1	21	66.7%
Mbeya Rural	15	15	12	16	1	29	93.1%
Mbozi	15	14	15	14	0	29	100%
Mufindi	13	14	9	18	2	26	80.8%
Njombe Rural	22	23	4	39	2	41	56.1%
Songea Rural	11	14	10	15	1	22	18.2%
Total	98	104	67	130	7	190	71.1%[a]

Notes: These are of the 216 VBAAs successfully interviewed at baseline. [a]135 of 190 VBAAs.

The fact that nearly 30% of the VBAAs with an *ex ante* random treatment group assignment did not receive inputs consistent with that treatment group assignment per follow-up phone calls with them (Table 1, far right column) raises concerns about a lack of balance between the two treatment groups. Indeed, t-tests of VBAA characteristics as of the baseline survey and their input sales in the agricultural year before the DP and DPTP interventions indicate several statistically significant differences when we use the full sample of 197 VBAAs for which we could confirm their treatment group based on inputs received (Table 2).[9] Relative to VBAAs in the DPTP treatment group, those in the DP treatment group had, on average, 0.69 more years of experience as VBAAs and 0.50 more children in their household. In addition, we reject at the 5% level the null hypothesis of joint orthogonality to treatment status of the baseline VBAA characteristics and 2015/16 input sale variables in Table 2 (p=0.012, see Table A3 in the appendix for the full results).

Given this lack of balance in the full group of 197 VBAAs, we focus instead on the subset of VBAAs that received inputs consistent with their *ex ante* random treatment assignment. There are 135 such VBAAs and we fail to reject the null of joint orthogonality in this case (p=0.128, see Table A4 in the appendix for the full results). Table 3 shows the t-test-based balance test results for this set of VBAAs. The only variable that is statistically significantly different between the DP and DPTP groups is years worked as a VBAA, with VBAAs in the DP group having worked an average of 0.75 years longer as a VBAA. If experience as a VBAA is positively correlated with input sales and/or the proxies for BDL

[9] We exclude the seven VBAAs that reported receiving no inputs.

(described below) used as outcome variables, then this might upwardly bias our estimates of the value-added of the TP component on these outcomes. We discuss this further in the results section.

Of the 216 VBAAs interviewed at baseline, 189 (87.5%) were successfully re-interviewed during the endline survey conducted in February 2019 (two years after the baseline survey). A total of 179 of these 189 VBAAs were individuals for whom we were able to verify the inputs they received. Balance test results for this group of 179 VBAAs are similar to those for the group of 197 VBAAs reported earlier: we reject at the 5% level joint orthogonality of the VBAA characteristics and 2015/16 input sales variables to VBAA treatment status (see column 3 in Table A3 in the appendix) and find statistically significant differences in the mean levels of years of experience as a VBAA and number of children between VBAAs in the DP and DPTP groups (see Table A4 in the appendix).

Of the group of 135 VBAAs interviewed at baseline and for whom the inputs they received matched their *ex ante* randomly assigned treatment group, 120 (90.4%) were successfully interviewed on the endline survey. Balance test results for this group of 120 VBAAs are similar to those for the group of 135 VBAAs reported earlier: we fail to reject the null of joint orthogonality of the VBAA characteristics and 2015/16 input sales variables to VBAA treatment status (see column 4 in Table A3 in the appendix), and the only variable whose mean is statistically significantly different between the DP and DPTP VBAAs is years of VBAA experience, with those in the DPTP group having 0.69 more years of experience (see Table A5 in the appendix). In the analysis below, we mainly use this set of 120 VBAAs (those that participated in both surveys and whose treatment group based on inputs received matches their *ex ante* random assignment). As a robustness check, we use the set of 179 VBAAs that were interviewed on both surveys and for whom we could confirm their inputs received but whose *de facto* treatment status does not match their random assignment in some cases. The results are robust to using these two different sets of VBAAs (N=120 vs. N=179).

Both surveys were conducted centrally in each district capital, with VBAAs traveling there from their respective villages to be interviewed. The surveys were done in this way because each VBAA resides in a different village and the project resources were insufficient for enumerators to individually visit each VBAA at their home. The surveys were conducted in Swahili via computer-assisted personal interviewing (CAPI) using SurveyCTO software. The enumerators and survey supervisors were all employees of TARI-Uyole, located in Mbeya. After all VBAAs present for the baseline survey had been interviewed in a given district, the VBAAs were trained in participatory extension and learning methods. Both surveys captured information on, *inter alia*, the characteristics of the VBAAs and their households, their commercial sales of inputs, and information used to proxy for BDL. Details on the latter are discussed in the empirical strategy section for concision.

Table 2. Balance tests using observations on the 197 VBAAs that were interviewed on the baseline survey and whose treatment status based on inputs received could be confirmed

	Mean values					
		Treatment group based on inputs received per follow-up phone calls				
	All VBAAs (N=197)	DP (N=67)	DPTP (N=130)	Difference (B) – (C)	t-stat.	p-value (H0: diff=0, H1: diff≠0)
VBAA characteristics (as of the baseline survey)	**(A)**	**(B)**	(C)	**(D)**	**(E)**	**(F)**
Age (years)	44.90	44.40	45.15	-0.75	-0.57	0.572
Years worked as VBAA	3.38	3.84	3.15	0.69	3.21	0.002***
Gender: =1 if female	0.294	0.328	0.277	0.05	0.75	0.453
Education: =1 if completed above standard 7	0.147	0.179	0.131	0.048	0.91	0.364
Overall farming experience (years)	21.87	22.25	21.68	0.58	0.38	0.707
Bean farming experience (years)	17.07	16.54	17.34	-0.80	-0.44	0.657
Land area owned by household (acres)	9.39	9.93	9.11	0.82	0.51	0.614
Numbers of adult members in the household	3.01	3.31	2.85	0.46	1.51	0.133
Number of children in the household	2.75	3.07	2.58	0.50	1.97	0.050**
VBAA input sales in 2015/16						
Sold bean seed (=1)	0.036	0.060	0.023	0.037	1.32	0.188
Sold seed treatments or pesticides (=1)	0.036	0.045	0.031	0.014	0.50	0.615

Notes: N=197. ***, **, * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Binary variable used for education because standard 7 is the highest level of education completed by 83.3% of VBAAs.

Table 3. Balance tests using observations on the 135 VBAAs that were interviewed on the baseline survey and whose treatment status based on inputs received could be confirmed and is consistent with their ex ante random assignment

	Mean values					
		Treatment group (inputs received consistent with *ex ante* random assignment)				
	All VBAAs (N=135)	DP (N=52)	DPTP (N=83)	Difference (B) – (C)	t-stat.	p-value (H0: diff=0, H1: diff≠0)
VBAA characteristics (as of the baseline survey)	**(A)**	**(B)**	(C)	**(D)**	**(E)**	**(F)**
Age (years)	44.34	44.33	44.35	-0.02	-0.01	0.989
Years worked as VBAA	3.42	3.88	3.13	0.75	3.04	0.003***
Gender: =1 if female	0.296	0.269	0.313	-0.044	-0.55	0.586
Education: =1 if completed above standard 7	0.163	0.192	0.145	0.048	0.73	0.465
Overall farming experience (years)	21.96	22.56	21.58	0.98	0.55	0.585
Bean farming experience (years)	17.16	17.02	17.25	-0.23	-0.11	0.912
Land area owned by household (acres)	9.44	9.30	9.53	-0.24	-0.11	0.911
Numbers of adult members in the household	3.16	3.48	2.95	0.53	1.49	0.138
Number of children in the household	2.80	3.08	2.63	0.45	1.42	0.159
VBAA input sales in 2015/16						
Sold bean seed (=1)	0.037	0.058	0.024	0.034	1.01	0.315
Sold seed treatments or pesticides (=1)	0.037	0.058	0.024	0.034	1.01	0.315

Notes: N=135. ***, **, * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Binary variable used for education because standard 7 is the highest level of education completed by 80.7% of VBAAs.

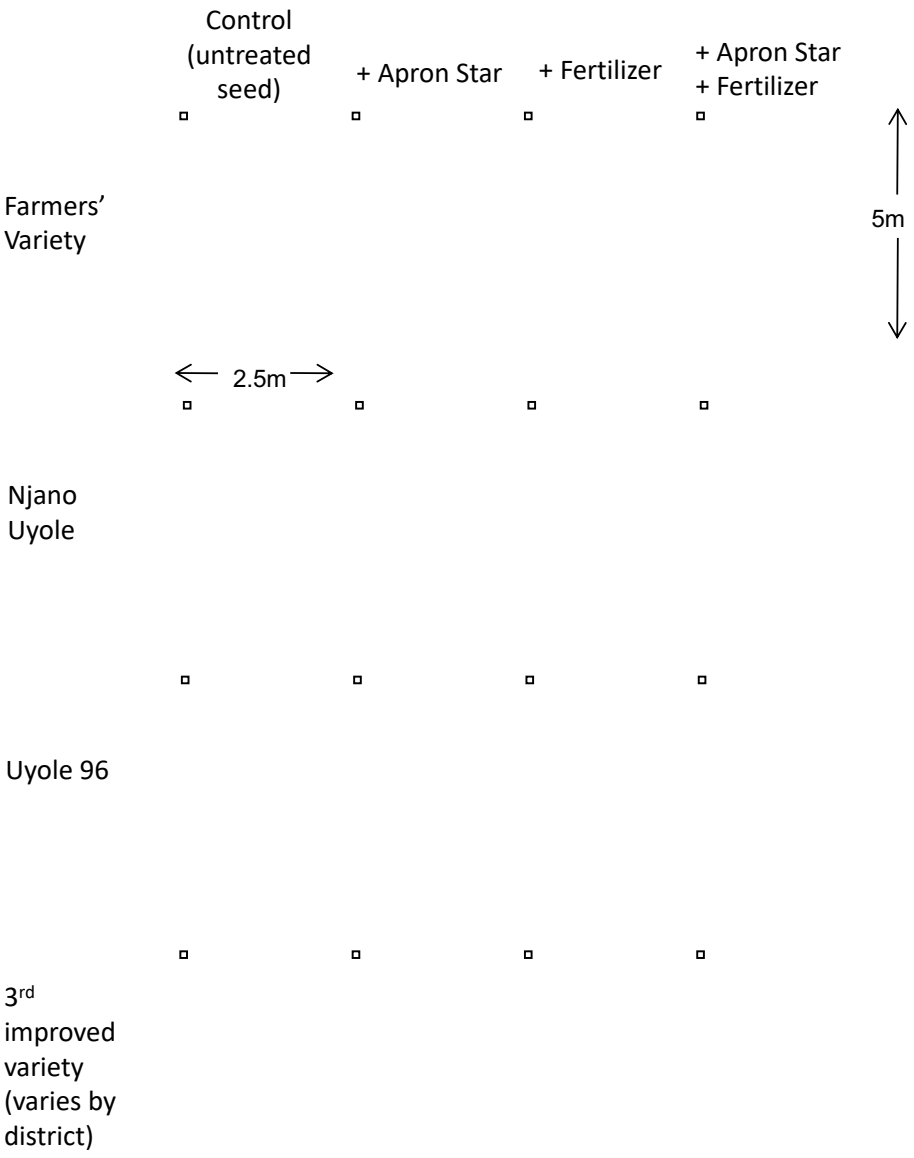
2.2 Intervention

Each VBAA was to set up a DP with sub-plots as shown in Figure 2. The DP featured three improved varieties: Njano Uyole and Uyole 96 in all districts, and a third improved variety that varied by district to reflect differences in preferences/demand and agro-ecological conditions across districts.[10] (See Table A6 in the appendix for descriptions of the bean varieties.) The preferred local variety in each VBAA's village (referred to as "farmers' variety" in Figure 2) was also included in the DP. Each variety was planted with no inputs applied, with Apron Star applied to the seed prior to planting, with inorganic fertilizer applied, and with both Apron Star and inorganic fertilizer. Apron Star was brand new in the southern highlands and was not commercially available at the time of the interventions. It is a fungicide/insecticide seed treatment used to control early season pests and diseases (Syngenta n.d.), and a product that was viewed by the FIPS and CIAT-Tanzania staff involved in the project as a potential "game-changer" for bean productivity in the study region. VBAAs were to invite community members to attend and participate in the DP planting, and to encourage them to visit the DP throughout the growing season.

Each VBAA in the DPTP treatment group was to receive trial packs for 150 farmers. Each trial pack consisted of four 100 g packets of seed: the preferred local variety with and without Apron Star applied, and one of the three improved varieties included in the DP with and without Apron Star applied (such that 50 trial pack recipients got Uyole 96, 50 got Njano Uyole, and 50 got the third, district-specific improved variety). VBAAs were encouraged to distribute the TPs to farmers that attended the DP planting, with any remaining TPs distributed to other bean-growing households in the community in a manner consistent with the VBAA's usual practice for maize TPs. (This was done so that the project would mimic as closely as possible the ways in which VBAAs usually distribute maize TPs.) Bean TP recipients were encouraged to set up their "baby demo" as shown in Figure 3.

[10] The third improved variety was Calima Uyole in Wanging'ombe, Songea Rural, and Njombe Rural, because its appearance is similar to a local variety (Rosekoko) that is popular in those districts; Uyole 03 in Mbeya Rural and Mbozi due to high demand there from an exporter; and Wanja in Iringa Rural and Mufindi due to market demand and its being well-suited to the drier, shorter rainfall seasons in those districts.

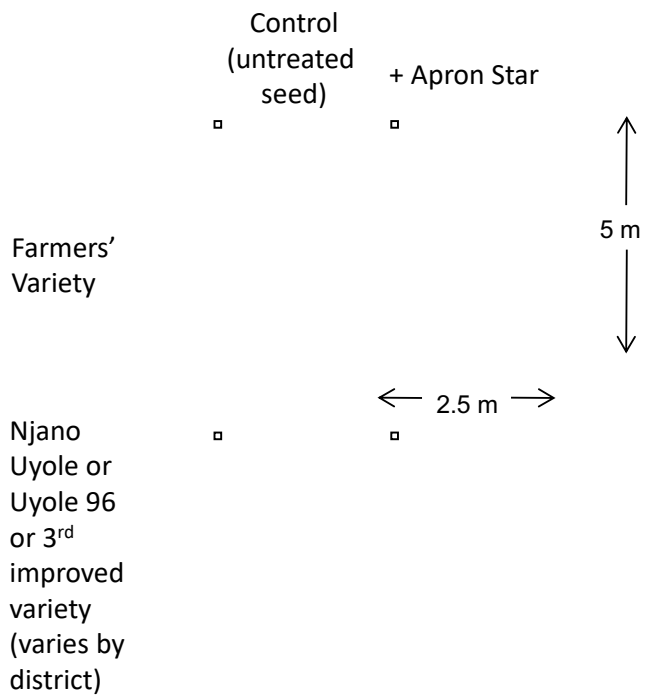
Figure 2. Bean demonstration plot (DP) setup



Source: CIAT-Tanzania (2017)

Notes: 1 m spacing between plots. Seeding rate = 100 g seed per 12.5 m^2 plot. Apron Star application rate = 0.25 g per 100 g of seed. Fertilizer application rate = 0.3 kg per 12.5 m^2 plot of YaraMila CEREAL (NPK 23:10:5 +2 MgO + 3 S + 0.3 Zn), which is appropriate for use on beans and maize.

Figure 3. Bean "baby demo" setup recommended to TP recipients



Source: CIAT-Tanzania (2017)

Notes: 1 m spacing between plots. Seeding rate = 100 g seed per 12.5 m^2 plot. Apron Star application rate = 0.25 g per 100 g of seed.

3 Empirical strategy

The econometric estimator(s) used varies from outcome variable to outcome variable, so we describe the method(s) used for each outcome variable (or set of outcome variables) in turn. In each case, the goal is to test the null hypothesis that the effect of being in the DP treatment group is equal to that of being in the DPTP treatment group (against a two-sided alternative hypothesis).

3.1 Input sales and unfilled orders

We consider several potential commercial (unsubsidized) input sales-related outcome variables for the regressions, all of which are specified as binary variables:

- =1 if sold bean seed (any variety), =0 otherwise (o.w.)
- =1 if sold bean seed for one of the three improved varieties promoted through the DPs/TPs in the VBAA's district, =0 o.w. (Recall that Njano Uyole and Uyole 96 were promoted in all districts, and that the third variety varied by district.)
- =1 if sold Njano Uyole bean seed, =0 o.w.

- =1 if sold Uyole 96 bean seed, =0 o.w.
- = if sold any seed treatments or pesticides, =0 o.w. (Recall that Apron Star is a fungicide/insecticide seed treatment product.)
- =1 if sold Apron Star, =0 o.w.

In addition, we analyze variables similar to those listed above but framed in terms of: (i) if the VBAA received any orders/requests for the product(s) that s/he could not fill ("unfilled orders"); and (ii) if the VBAA sold *and/or* had unfilled orders for the product(s). See Table 4 for summary statistics for these variables for the main analytical sample of 120 VBAAs by year (2015/16 – prior to the intervention; 2016/17 – the intervention year; 2017/18 – one year after the intervention; and 2018/19 – two years after the intervention but only covering through January so considered a partial year of sales/unfilled orders). Summary statistics for the robustness check sample of 179 VBAAs are available in Table A7 in the appendix. Note that the unfilled orders question was not asked on the baseline survey, so no 2015/16 values are available.

As shown in Table 4, very few VBAAs sold bean seed. (The percentage selling ranges from 2.5-5.8%.) The percentage selling any of the promoted varieties is nearly identical to the overall percentage selling any variety, so separate regressions are not run for this aggregate of promoted varieties. Moreover, too few VBAAs sell Njano Uyole or Uyole 96 seed to warrant regression analysis. Apron Star was not yet available in Tanzania in 2015/16, so it is not surprising that no VBAAs sold the product that year. But fewer than 2% sold the product in the intervention and post-intervention years, so here again, regression analysis is not warranted given the lack of variation in the data. All of the other outcome variables listed in Table 4 vary sufficiently to enable regression analysis.

We use two regression approaches. First, using the endline data only, we estimate the following simple linear model via ordinary least squares (OLS) for all outcome variables:

$$y_i = \beta_0 + \beta_1 DPTP_i + \varepsilon_i \quad (1)$$

where *i* indexes the VBAA; y_i is the outcome variable; $DPTP_i$ equals one if the VBAA was in the DPTP treatment group and zero if s/he was in the DP treatment group; and ε_i is the idiosyncratic error term. The main parameter of interest is β_1. This equation is estimated separately for each of the years captured on the endline survey (2016/17, 2017/18, and 2018/19). The main year in which we might expect to see an effect is in 2017/18 (the agricultural year after the interventions), but there could be effects in the intervention year itself and/or two years later.

Second, for the input sales outcome variables only, which were measured at both baseline and endline, we also estimate the following difference-in-differences (DD) model via OLS:

$$y_{it} = \alpha_0 + \alpha_1 DPTP_i + \alpha_2 S_t + \gamma DPTP_i \times S_t + u_{it} \quad (2)$$

where *t* indexes the agricultural year; *i*, *y* and $DPTP$ are as defined in equation 1 (but note that *y* is time-varying in equation 2); S_t is a time fixed effect equal to one if the observation is from the endline survey and equal to zero if it from the baseline survey; and u_{it} is the idiosyncratic error term. The parameter of interest here is γ – the regression DD effect of being in the DPTP group relative to the DP group. Here, we compare outcomes in 2015/16 to those in either 2016/17 or 2017/18. We do

not use the 2018/19 outcomes in the DD regressions because those are partial year outcomes only and so not directly comparable to 2015/16 (which reflects a full year).

In the regressions associated with both equations 1 and 2 (and all other regressions described below) we do not control for matched pair fixed effects or cluster standard errors at the matched pair level due to the implementation problems outlined in section 2.1. We also do not cluster the standard errors at the district level because there are only seven districts – too few for clustering, even if we were to apply wild cluster bootstrapping.

Table 4. Summary statistics – input sales- and unfilled order-related outcome and related variables (N=120 VBAAs interviewed on both surveys and whose treatment status based on inputs received could be confirmed and is consistent with their ex ante random assignment)

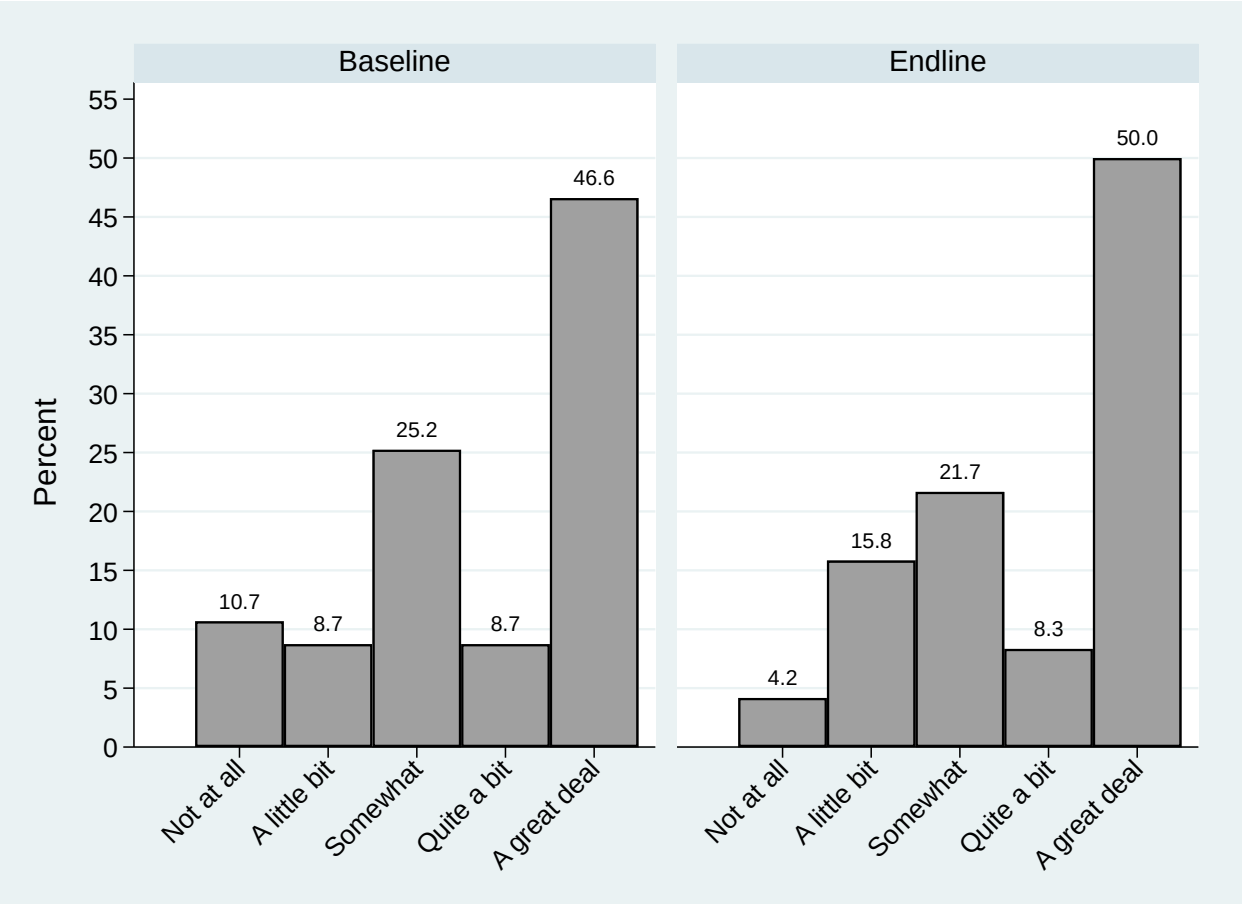
	Year			
	2015/16	2016/17 (intervention year)	2017/18	2018/19 (partial year)
Bean seed sales				
=1 if sold bean seed (any variety)	0.033	0.058	0.050	0.025
=1 if sold any of the promoted varieties of bean seed*	0.033	0.058	0.042	0.025
=1 if sold Njano Uyole seed*	0.017	0.042	0.025	0.017
=1 if sold Uyole 96 seed*	0.033	0.025	0.017	0.008
Bean seed unfilled orders				
=1 if had any unfilled orders for bean seed (any variety)	N/A	0.250	0.300	0.217
=1 if had any unfilled orders for any promoted variety of bean seed	N/A	0.233	0.258	0.183
=1 if had any unfilled orders for Njano Uyole	N/A	0.117	0.125	0.125
=1 if had any unfilled orders for Uyole 96	N/A	0.108	0.108	0.083
Bean seed sales or unfilled orders				
=1 if sold or had any unfilled orders for bean seed (any variety)	N/A	0.300	0.333	0.233
=1 if sold or had any unfilled orders for any promoted variety of bean seed	N/A	0.292	0.300	0.208
=1 if sold or had any unfilled orders for Njano Uyole	N/A	0.158	0.150	0.142
=1 if sold or had any unfilled orders for Uyole 96	N/A	0.133	0.125	0.092
Seed treatment/pesticide sales				
=1 if sold any seed treatments or pesticides	0.033	0.125	0.133	0.142
=1 if sold Apron Star*	0	0.008	0.017	0.008
Seed treatment/pesticide unfilled orders				
=1 if had any unfilled orders for seed treatments or pesticides	N/A	0.158	0.175	0.175
=1 if had any unfilled orders for Apron Star	N/A	0.067	0.100	0.083
Seed treatment/pesticide sales or unfilled orders				
=1 if sold or had any unfilled orders for seed treatments or pesticides	N/A	0.250	0.275	0.283
=1 if sold or had any unfilled orders for Apron Star	N/A	0.075	0.117	0.092

Notes: N=120. N/A = not included on baseline survey. *No regression analyses for these variables due to insufficient variation.

3.2 Bidirectional learning

A necessary (but not sufficient) condition for BDL as defined in the Introduction is that information providers take into consideration feedback from farmers when formulating and making recommendations for inputs and management practices. To that end, both the baseline and endline surveys included the following question: "How much do you consider feedback from farmers when you make recommendations on bean inputs or crop management practices?", with a 5-point Likert scale of responses available: 1=not at all, 2=very little, 3=somewhat, 4=quite a bit, and 5=a great deal. See Figure 4 for histograms of the responses to this question on the baseline and endline surveys.

Figure 4. Histograms of responses to "How much do you consider feedback from farmers when you make recommendations on bean inputs or crop management practices?"



Note: N=120 VBAAs interviewed on both surveys and whose treatment status based on inputs received could be confirmed and is consistent with their *ex ante* random assignment.

Three approaches are taken to analyze these data: regressions analogous to equations (1) and (2), as well as an ordered probit regression using the endline survey data only. This latter approach explicitly

takes into account the fact that Likert scale responses are not a continuous variable; there is a natural ordering to them but going from 1 to 2, for example, is not necessarily the same as going from 4 to 5, even though both are one unit changes in the scale. Ordered probit models (Aitchison and Silvey, 1957; Long and Freese, 2014) preserve the ordering of response options but make no assumptions about the interval distances between options.

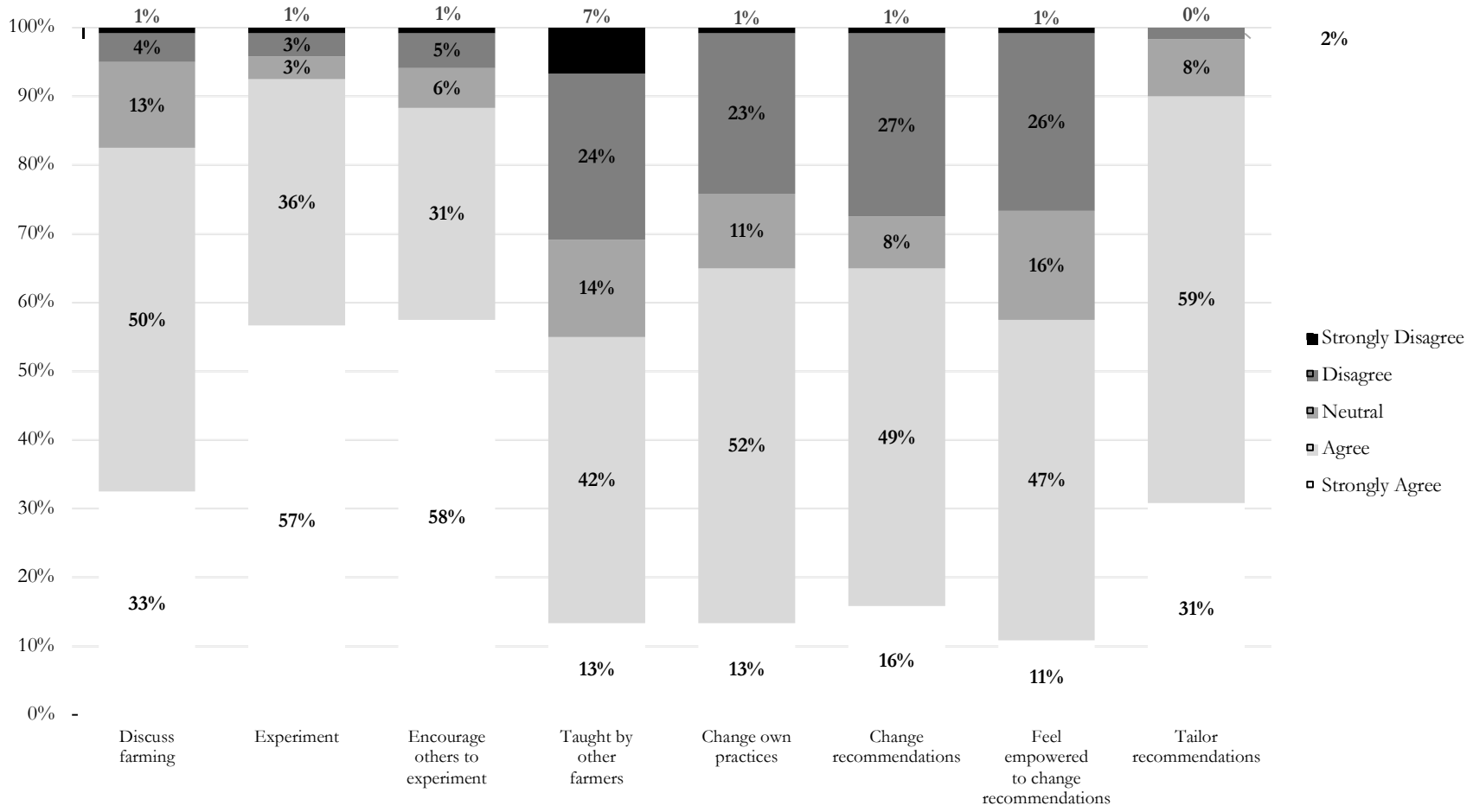
To further capture VBAA interactions with farmers and attitudes about experimentation and learning from others that might facilitate or contribute to BDL, the eight statements in Table 5 were included on the endline survey. After being read each statement, the respondent was asked to choose the response from the following five-point Likert scale that best captured the degree to which they agreed or disagreed with the statement: 1=strongly disagree, 2=disagree, 3=neutral, 4=agree, or 5=strongly agree. The statements were adapted from a learning scale developed by Leykum et al. (2011) to capture what they refer to as "reciprocal learning" and define "as a shared, back-and-forth [learning] process" (p. 3) – a concept that is very similar to what we refer to as BDL.[11] Figure 5 summarizes VBAAs' responses to these statements. Given the ordinal nature of the responses, OLS and ordered probit models are used to analyze these data. A DD model is not feasible as these statements were not included on the baseline survey.

Table 5. VBAA-farmer learning interactions and attitudes statements

You often get together with other farmers to **discuss farming** practices or inputs.
You like to **experiment** with new farming practices or inputs.
You **encourage others to experiment** with new farming practices or inputs.
You are frequently **taught new things by other farmers** about farming practices or inputs.
You often consider **changing your own farming practices** or the inputs you use because of things you have learned from other farmers.
You often consider **changing the recommendations you make** to others on farming practices or inputs because of things you have learned from other farmers.
You **feel empowered** to alter the recommendations you make to other farmers on farming practices or inputs based on things you learn from other farmers.
You try to **tailor the recommendations** you make to other farmers on farming practices or inputs based on the needs of each farmer.

[11] Leykum et al. (2011) studied reciprocal learning among clinicians at primary care clinics, particularly as it relates to improving care for patients with chronic illnesses.

Figure 5. Summary of responses to VBAA-farmer learning interactions and attitudes statements



Note: N=120.

4 Results

4.1 Input sales and unfilled orders

The OLS estimates of the effect of the DPTP treatment relative to the DP treatment on the various input sales and unfilled orders outcome variables using the endline survey data only are reported in Table 6. (Only the main parameter estimate of interest is reported – the estimate of β_1 in equation 1.) In no case do we find evidence of a statistically significant effect of adding TPs on these outcomes relative to only doing a DP. These results hold when we use the set of 179 VBAAs instead of the set of 120 VBAAs reported in Table 6. (See Table A8 in the appendix for details.) The DD regressions for both sets of VBAAs also generally suggest no statistically significant differential effects between the treatments on bean seed or seed treatment/pesticide sales (see Table 7 and Table A9 in the appendix). The only exception is a very weakly significant (p=0.095) positive effect of the DPTP treatment relative to the DP treatment on bean seed sales in the intervention year itself (2016/17) when we use the set of 179 VBAAs (Table A9 in the appendix). However, in addition to being only very weakly significant, this result is not robust to using instead the set of 120 VBAAs (Table 7). Potential reasons for the general lack of statistically significant DP vs. DPTP effects on input sales and unfilled orders are discussed in section 5.3.[12]

Although we find no evidence that adding TPs increased VBAAs input sales of bean seed or seed treatments/pesticides, there are three other important findings to note. First, regressions of each sale dummy on a survey dummy (i.e., a regression like equation 2 but excluding the $DPTP_i$ and $DPTP_i \times S_t$ terms) suggest that VBAAs were 9.2 (10.0) percentage points more likely in 2016/17 (2017/18) to sell seed treatments or pesticides relative to 2015/16 (Table 8). An increase in the share of VBAAs selling seed treatments or pesticides is also evident in the summary statistics in Table 4. There is no statistically significant time effect for selling bean seed (Table 8), and per Table 4, only marginal changes in the share of VBAAs selling bean seed over time.[13] We cannot attribute the increase in the share of VBAAs selling seed treatments or pesticides to the DP or TP interventions due to the lack of a pure (no DP or TPs) control group. However, it is possible that these interventions may have played a role and that the increase in sales over time may be reflective of an increase over time in farmer demand for the inputs. Future studies with a pure control group and that directly evaluate the effects of the interventions on farmer demand would be helpful.

A second notable finding is the non-negligible share of VBAAs that received orders or requests for inputs that they were unable to fulfill in the intervention year and beyond. Per Table 4, for bean seed, roughly 22-30% of VBAAs had unfilled orders overall; 18-26% had unfilled orders for one of the varieties promoted through the DPs and TPs; and 12-13% (8-11%) had unfilled orders for Njano Uyole (Uyole 96). For seed treatments and pesticides in general, 16-18% of VBAAs had unfilled orders, while 7-10% had unfilled orders for Apron Star specifically. These unfilled orders may be

[12] All results reported in this paper are robust to controlling for the baseline covariates on which the VBAAs are unbalanced (years worked as a VBAA and number of children in the case of the set of 179 VBAAs, and years worked as a VBAA for the set of 120 VBAAs). These results are available upon request and suggest that our main results are unlikely to be biased by differences in years of VBAA experience between DP and DPTP VBAAs.

[13] The results described in this section are robust to using the set of 179 VBAAs instead of the set of 120 VBAAs. See Tables A7 and A10 in the appendix.

indicative of unmet demand for the improved varieties and for Apron Star and other seed treatments and pesticides. Again, we cannot attribute these unfilled orders or apparent latent demand to the DPs or TPs, but these findings that would benefit from further study.

Table 6. Input sales and unfilled orders endline only regressions: OLS estimates of the effect of the DPTP treatment relative to the DP treatment, by dependent variable (N=120)

	Year		
Dependent variable	2016/17 (intervention year)	2017/18	2018/19 (partial year)
Bean seed sales			
=1 if sold bean seed (any variety)	0.055	-0.031	0.003
	(0.045)	(0.042)	(0.030)
Bean seed unfilled orders			
=1 if had any unfilled orders for bean seed (any variety)	-0.009	-0.004	-0.025
	(0.083)	(0.088)	(0.080)
=1 if had any unfilled orders for any promoted variety of bean seed	0.037	0.040	0.032
	(0.081)	(0.084)	(0.074)
=1 if had any unfilled orders for Njano Uyole	0.073	0.014	0.014
	(0.061)	(0.063)	(0.063)
=1 if had any unfilled orders for Uyole 96	-0.012	-0.012	0.021
	(0.060)	(0.060)	(0.053)
Bean seed sales or unfilled orders			
=1 if sold or had any unfilled orders for bean seed (any variety)	0.069	0.012	0.001
	(0.088)	(0.090)	(0.081)
=1 if sold or had any unfilled orders for any promoted variety of bean seed	0.092	-0.004	0.035
	(0.087)	(0.088)	(0.078)
=1 if sold or had any unfilled orders for Njano Uyole	0.102	-0.020	0.040
	(0.069)	(0.069)	(0.067)
=1 if sold or had any unfilled orders for Uyole 96	0.027	-0.023	0.034
	(0.065)	(0.063)	(0.055)
Seed treatment/pesticide sales			
=1 if sold any seed treatments or pesticides	-0.095	-0.046	-0.033
	(0.063)	(0.065)	(0.067)
Seed treatment/pesticide unfilled orders			
=1 if had any unfilled orders for seed treatments or pesticides	-0.007	-0.017	0.019
	(0.070)	(0.073)	(0.073)
=1 if had any unfilled orders for Apron Star	-0.005	0.011	0.057
	(0.048)	(0.058)	(0.053)
Seed treatment/pesticide sales or unfilled orders			
=1 if sold or had any unfilled orders for seed treatments or pesticides	-0.045	-0.006	0.007
	(0.083)	(0.086)	(0.087)
=1 if sold or had any unfilled orders for Apron Star	0.008	0.037	0.070
	(0.051)	(0.062)	(0.055)

Notes: N=120. ***, **, * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Values reported are the OLS estimates of β_1 in equation (1) for each dependent variable. Standard errors in parentheses.

Table 7. Input sales and unfilled orders endline only regressions: OLS estimates of the effect of the DPTP treatment relative to the DP treatment, by dependent variable (N=120)

Dependent variable:	=1 if sold bean seed (any variety)		=1 if sold any seed treatments or pesticides	
Comparison year:	2016/17 (intervention year)	2017/18	2016/17 (intervention year)	2017/18
Explanatory variables:				
=1 if DPTP, =0 if DP	-0.021	-0.021	-0.021	-0.021
	(0.040)	(0.038)	(0.051)	(0.052)
=1 if comparison year, =0 if 2015/16 (pre-intervention)	-0.023	0.023	0.140**	0.116**
	(0.045)	(0.043)	(0.057)	(0.059)
=1 if DPTP × =1 if comparison year	0.075	-0.010	-0.075	-0.025
	(0.056)	(0.054)	(0.072)	(0.074)
Constant	0.047	0.047	0.047	0.047
	(0.032)	(0.031)	(0.041)	(0.042)
R-squared	0.013	0.006	0.044	0.037

Notes: N=240 (120*2). ***, **, * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors in parentheses.

Table 8. Input sales: Regressions on a year dummy (2015/16 vs. 2016/17 or 2017/18), by dependent variable (N=240=120*2)

Dependent variable:	=1 if sold bean seed (any variety)		=1 if sold any seed treatments or pesticides	
Comparison year:	2016/17 (intervention year)	2017/18	2016/17 (intervention year)	2017/18
Explanatory variables:				
=1 if comparison year, =0 if 2015/16 (pre-intervention)	0.025	0.017	0.092***	0.100***
	(0.027)	(0.026)	(0.034)	(0.035)
Constant	0.033*	0.033*	0.033	0.033
	(0.019)	(0.018)	(0.024)	(0.025)
R-squared	0.004	0.002	0.029	0.033

Notes: N=240 (120*2). ***, **, * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors in parentheses.

The third notable finding is the insights from the endline surveys on the reasons for these unfilled orders. As shown in Figure 6, the most frequently cited reason for unfilled bean seed and seed treatment/pesticide orders was inadequate financing. The product being unavailable (meaning the VBAA could not source the product for resale to farmers) was also frequently cited, but much less often than inadequate financing.[14] We discuss the potential policy implications these findings in the final section.

4.2 Bidirectional learning

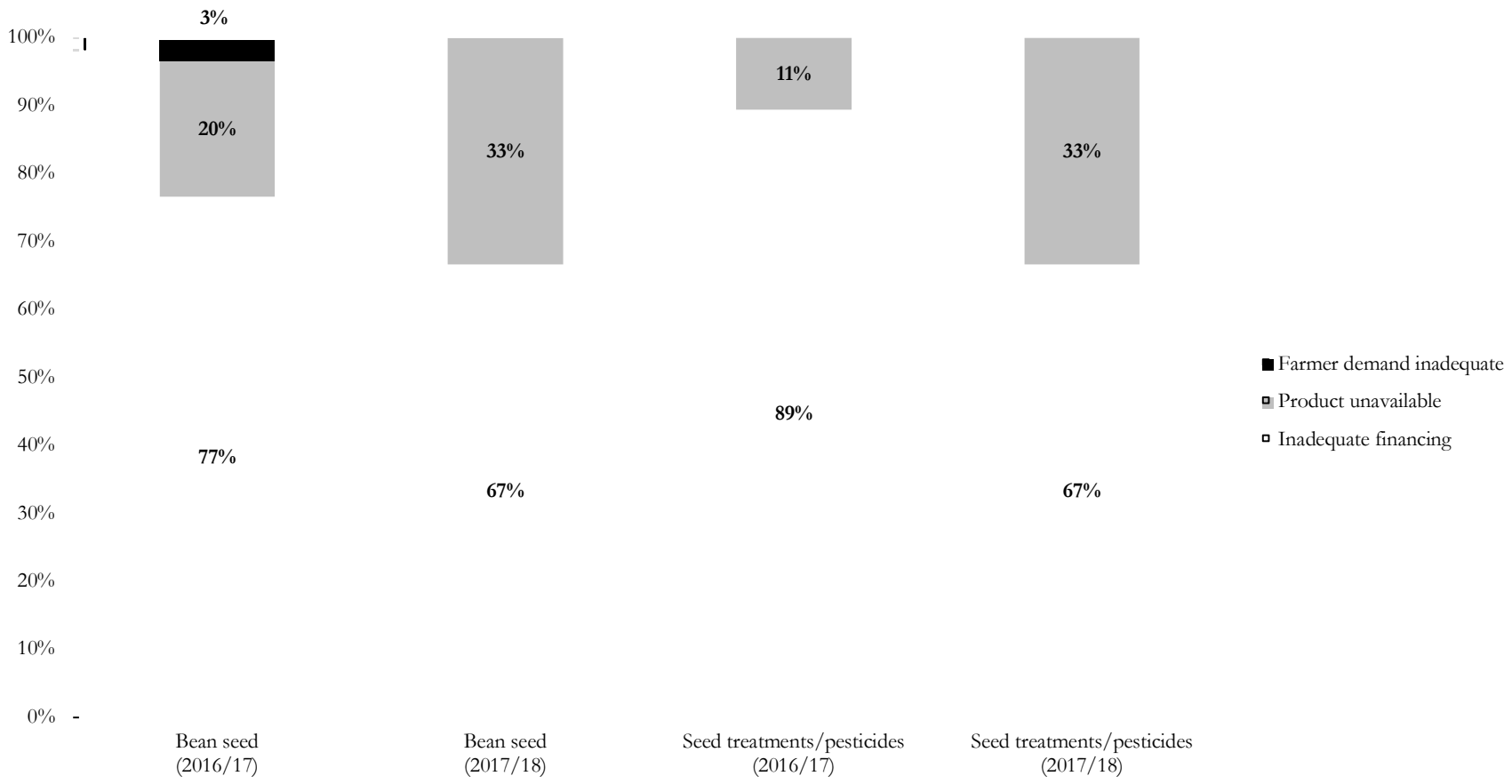
The regression results for the BDL-related outcome variables are reported in Tables 9 (endline survey only OLS regressions), 10 (DD regressions for the "how much do you consider farmer feedback" question that was on both surveys), and 11 and 12 (endline survey only ordered probits). See also the robustness checks with the alternative set of VBAAs in Tables A11 and A12 in the appendix. As was the case for the input sales and unfilled orders outcome variables, we find no robust evidence of statistically significant effects of the DPTP treatment relative to the DP treatment on the BDL-related outcome variables. Potential reasons for this are discussed in section 5.3. The only outcome variable with any statistically significant effects is "You try to tailor the recommendations you make to other farmers on farming practices or inputs based on the needs of each farmer" (Table 9 model 9 and Table 12 model 8); however, this result is not robust to using the set of 179 VBAAs instead of the set of 120 (appendix Table A11 model 9 and Table A12 model 8).

There are two other notable findings from the BDL-related variables. The potential policy implications of these additional findings are discussed in the final section of the paper. First, the histograms in Figure 4 suggest that more than 55% of VBAAs consider farmers' feedback at least "quite a bit" when making recommendations on bean inputs or crop management practices. Another 22-25% consider farmers' feedback "somewhat", with the rest (19-20%) considering it only a little bit or not at all. So although farmer feedback is an important consideration for the majority of VBAAs, this is not the case for all VBAAs.

Second, based on the reactions to the eight statements on VBAA-farmer learning interactions and attitudes (see Figure 5 for a summary and Table 5 for the full statements) the vast majority (83-93%) of VBAAs agreed or strongly agreed with the statements related to discussing farming practices or inputs with other farmers, experimenting with farming practices or inputs, and tailoring recommendations to the needs of each farmer, far fewer (55-65%) agreed or strongly agreed with the statements related to: (i) learning from other farmers; (ii) considering changing their own practices or the recommendations they make (including feeling empowered to do so) based on things learned from other farmers.[15] Without the belief that there are things to be learned from other farmers, it makes sense that those VBAAs would then not feel compelled to change their own practices or the recommendations they make to other farmers based on such learnings.

[14] Similar findings hold when we use the alternative set of 179 VBAAs. See Figure A1 in the appendix.
[15] Similar patterns hold when we use the alternative set of 179 VBAAs. See Figure A2 in the appendix.

Figure 6. Reasons for unfilled orders – 2016/17 and 2017/2018



Note: Drawing on the N=120 set of VBAAs.

Table 9. Bidirectional learning-related outcomes: OLS estimates of the effect of the DPTP treatment relative to the DP treatment, by dependent variable (N=120)

	(1)	(2)	(3)	(4)	(5)
Explanatory variables	How much do you consider feedback from farmers when you make recommendations on bean inputs or crop management practices?	You often get together with other farmers to discuss farming practices or inputs.	You like to experiment with new farming practices or inputs.	You encourage others to experiment with new farming practices or inputs.	You are frequently taught new things by other farmers about farming practices or inputs.
=1 if DPTP, =0 if DP	0.043	-0.038	0.108	0.139	-0.136
	(0.250)	(0.159)	(0.150)	(0.166)	(0.224)
Constant	3.814***	4.116***	4.372***	4.302***	3.395***
	(0.200)	(0.127)	(0.120)	(0.133)	(0.179)
R-squared	0.000	0.000	0.004	0.006	0.003

	(6)	(7)	(8)	(9)
Explanatory variables	You often consider changing your own farming practices or the inputs you use because of things you have learned from other farmers.	You often consider changing the recommendations you make to others on farming practices or inputs because of things you have learned from other farmers.	You feel empowered to alter the recommendations you make to other farmers on farming practices or inputs based on things you learn from other farmers.	You try to tailor the recommendations you make to other farmers on farming practices or inputs based on the needs of each farmer.
=1 if DPTP, =0 if DP	-0.256	-0.124	0.201	-0.245**
	(0.194)	(0.206)	(0.193)	(0.123)
Constant	3.698***	3.605***	3.279***	4.349***
	(0.155)	(0.165)	(0.155)	(0.098)
R-squared	0.015	0.003	0.009	0.033

Notes: N=120. ***, **, * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors in parentheses. Outcome variables are 5-point Likert scales. For model (1), the scale is: 1=not at all, 2=very little, 3=somewhat, 4=quite a bit, and 5=a great deal. For models (2) through (9), the scale is: 1=strongly disagree, 2=disagree, 3=neutral, 4=agree, and 5=strongly agree.

Table 10. How much do you consider farmer feedback: Difference-in-differences estimates of the effect of the DPTP treatment relative to the DP treatment

Analytical sample (see note):	N=179 VBAAs	N=120 VBAAs
Explanatory variables:		
=1 if DPTP, =0 if DP	-0.152	-0.174
	(0.230)	(0.275)
=1 if endline survey, =0 if baseline survey	0.288	0.050
	(0.263)	(0.304)
=1 if DPTP × =1 if endline survey	0.085	0.331
	(0.325)	(0.389)
Constant	3.788***	3.825***
	(0.186)	(0.215)
APE of =1 if endline survey	0.344**	0.252
	(0.154)	(0.190)
R-squared	0.018	0.012
Observations	302	206

Notes: Sample sizes less than 179*2 and 120*2 because some VBAAs did not make bean recommendations as of the baseline survey. Regressions utilize observations from VBAAs that answered this question on both the baseline and endline surveys. ***, **, * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors in parentheses. Outcome variable is 5-point Likert scale with: 1=not at all, 2=very little, 3=somewhat, 4=quite a bit, and 5=a great deal.

Table 11. How much do you consider farmer feedback: Ordered probit average partial effects (APEs) of the effect of the DPTP treatment relative to the DP treatment

	Average partial effect of DPTP relative to DP on the probability of each response at left	
Analytical sample:	N=179 VBAAs	N=120 VBAAs
Response		
1=not at all	0.011	-0.003
	(0.014)	(0.019)
2=very little	0.025	-0.006
	(0.032)	(0.041)
3=somewhat	0.016	-0.003
	(0.022)	(0.023)
4=quite a bit	0.003	-0.000
	(0.005)	(0.002)
5=a great deal	-0.055	0.012
	(0.072)	(0.085)

Note: Responses are to the question, "How much do you consider feedback from farmers when you make recommendations on bean inputs or crop management practices?". ***, **, * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors in parentheses.

Table 12. VBAA-farmer learning interactions and attitudes statements: Ordered probit average partial effects (APEs) of the effect of the DPTP treatment relative to the DP treatment (N=120)

	Average partial effect of DPTP relative to DP on the probability of each response at left			
	(1)	(2)	(3)	(4)
Response	You often get together with other farmers to discuss farming practices or inputs.	You like to experiment with new farming practices or inputs.	You encourage others to experiment with new farming practices or inputs.	You are frequently taught new things by other farmers about farming practices or inputs.
1=strongly disagree	0.000	-0.004	-0.005	0.018
	(0.005)	(0.006)	(0.007)	(0.025)
2=disagree	0.001	-0.011	-0.021	0.032
	(0.017)	(0.016)	(0.024)	(0.046)
3=neutral	0.002	-0.008	-0.017	0.007
	(0.032)	(0.013)	(0.019)	(0.010)
4=agree	0.002	-0.039	-0.040	-0.025
	(0.022)	(0.055)	(0.041)	(0.034)
5=strongly agree	-0.005	0.061	0.083	-0.031
	(0.075)	(0.088)	(0.087)	(0.046)
	(5)	(6)	(7)	(8)
Response	You often consider changing your own farming practices or the inputs you use because of things you have learned from other farmers.	You often consider changing the recommendations you make to others on farming practices or inputs because of things you have learned from other farmers.	You feel empowered to alter the recommendations you make to other farmers on farming practices or inputs based on things you learn from other farmers.	You try to tailor the recommendations you make to other farmers on farming practices or inputs based on the needs of each farmer.
1=strongly disagree	0.005	0.003	-0.005	Not estimable
	(0.006)	(0.005)	(0.007)	(no observations)
2=disagree	0.078	0.045	-0.060	0.015
	(0.058)	(0.063)	(0.064)	(0.011)
3=neutral	0.017	0.006	-0.012	0.054*
	(0.014)	(0.008)	(0.012)	(0.029)
4=agree	-0.039	-0.018	0.042	0.088*
	(0.029)	(0.024)	(0.046)	(0.053)
5=strongly agree	-0.062	-0.036	0.035	-0.156*
	(0.049)	(0.052)	(0.036)	(0.081)

Notes: N=120. ***, **, * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors in parentheses.

4.3 Why no differential effects of DPTP vs. DP?

A consistent finding across all the input sales/unfilled orders and BDL-related questions is that we find no statistically significant difference in these outcomes between VBAAs in the DP vs. DPTP treatment groups in the intervention year or up to two years thereafter. Why might this be the case? There are at least eight potential reasons.

First, and as described in detail above, there were major challenges during the project in terms of lack of consistency between the randomly assigned treatment groups and VBAAs' *de facto* treatment groups based on inputs received.

Second, even beyond these treatment group issues, visits to VBAAs' demonstration plots by CIAT-Tanzania staff in April 2017 indicated numerous challenges with the set up and maintenance of the demonstration plots. Although not all VBAAs could be visited due to resource constraints, among the 170 VBAAs that were visited, approximately two thirds (111/170) had not set up the DP according to the DP protocol in Figure 2 and as was described during the training in which they partook prior to receiving the DP inputs (Kato, 2017).

Third, many VBAAs in the DPTP treatment group did not distribute the TPs as intended/trained (see section 2.2) and thus failed to reach 150 farmers with the TPs and give them an opportunity to compare an improved variety to a local variety on their own farms, and both with and without Apron Star.

Given these challenges with the DP setup and TP distribution, the estimates here should be interpreted as the effects of providing DP or DPTP inputs to VBAAs, and not the effects of the VBAAs establishing DPs vs. establishing DP and distributing TPs per the project protocols. These challenges may also contribute to the lack of statistically significant differences between the DP and DPTP treatments on VBAA input sales/unfilled orders and BDL.

A fourth potential reason for this lack of effect is that one year of interventions might not be enough to significantly move the needle on input sales/unfilled orders or BDL. The results may have differed if the interventions had been implemented during several consecutive main bean growing seasons.

Fifth, it may take more than one to two years for the effects of the interventions to materialize. We measure the effects during the intervention year itself and one and two years later (with the two years later data being for a partial main bean growing season due to the timing of the endline survey). The effects of the interventions may manifest in the longer run but not after just one or two years.

Sixth, even if the 150 TPs per DPTP VBAA had been distributed per the established protocol, that number still would have only reached a minority (roughly a quarter) of bean growing households in the VBAA's community. This coverage may have been insufficient to have an appreciable impact on the outcomes considered here.

Seventh, the lack of effects on bean seed sales or unfilled orders could be related to the interventions having been done for beans and farmers using saved seed in subsequent years (obviating the need to purchase seed). If the interventions had been for hybrid maize seed, for example, the results may have differed. However, this explanation for the lack of an effect is not applicable to Apron Star and other

seed treatments/pesticides sales/unfilled orders. The limited availability and supply of certified bean seed might have also contributed to the lack of impacts of bean seed sales by VBAAs. Indeed, evidence from Lwehabura and Rubyogo (2019) suggests that Beula Seed Company sold 9 MT of certified Njano Uyole seed dressed with Apron Star through agro-dealers in Mbeya and Mbozi without fully satisfying seed demand in the area.

And eighth, the findings of no statistically significant difference between the DP and DPTP treatments on the outcomes considered here could be indicative of there truly being no difference. Further evaluations are needed to determine if this is indeed the case.

Similar to our findings, Morgan et al. (in press) find no differential effect of being in a DP vs. DPTP VBAA's village on other farmers' WTP for Uyole 96 or Njano Uyole seed, without Apron Star, with a sachet of Apron Star, or pre-treated with Apron Star. They focus on farmers in the villages of matched pairs of VBAAs in Mbeya Rural and Mbozi that received inputs per their original random treatment assignment and who set up the DP and distributed the TPs following the established protocols. So in their case, the explanations above related to implementation challenges do not explain the lack of statistically significant effects. However, Morgan et al. (in press) find that farmers do have a positive WTP for the two varieties studied and Apron Star, which is consistent with our findings of a non-negligible share of VBAAs selling or having unfilled orders for these inputs.

5 Conclusions and policy implications

Greater integration of legumes in cropping systems, increased use of improved varieties and crop protectants, and more tailoring of extension recommendations to local contexts via bidirectional learning are critical for sustainable agricultural intensification. This paper reports the main results from an RCT that sought to determine if there is an appreciable difference in NGO lead farmer extension agents' (VBAAs') improved bean inputs sales or unfilled orders or bidirectional learning with other farmers if they set up a demonstration plot only vs. if they establish a demonstration plot and distribute to other farmers free input trial packs of the inputs highlighted on the demonstration plot. Numerous challenges were encountered during the RCT, and the main conclusion that can be drawn is that there is no statistically significant difference in the aforementioned outcomes between VBAAs that receive inputs to establish a bean demonstration plot only and those that receive such inputs plus free input trial packs to distribute to 150 other farmers in their community. The previous section discussed numerous potential reasons for the lack of significant differences in the outcomes studied.

In addition to this main result, three other key findings emerge from this study. First, non-negligible shares of VBAAs received requests/orders for bean seed (22-30%) or seed treatments/pesticides (16-18%) but were unable to fill these orders, largely due to a lack of financing or the inputs not being available for them to purchase for onward sale to other farmers. This may signal an unmet demand for these inputs by farmers, and that improving access to credit for VBAAs (e.g., through providing the inputs to the VBAAs on credit or through greater availability of cash loans) or increasing the supply of these inputs (either at the district center or more locally) may enable VBAAs to more effectively function as local agro-dealers in their communities. To the extent that other local agro-dealers also operate in VBAAs' communities, these findings may also point to business opportunities for them.

Second, while the majority (55%+) of VBAAs consider farmers' feedback quite a bit or a great deal when making recommendations on bean inputs or management practices, about 20% consider such feedback only a little bit, if at all (with the remaining roughly 25% somewhat considering such feedback). There is growing evidence of the value of enhanced communication between agricultural advisors and farmers regarding local practices and priorities, which is consistent with the need to facilitate bidirectional learning (Nord and Snapp, 2020). Information-intensive knowledge systems are particularly important for sustainable intensification, which suggests the need for explicit training of VBAAs and other agricultural advisors in bidirectional learning. That is, provide educational opportunities to explore how VBAAs can consider farmers' feedback and how to incorporate it into agricultural recommendations. New information and communications technologies (ICTs) such as LandPKS are now available that support bidirectional learning; these tools are being tried out in Tanzania and deserve broader consideration (Nord and Snapp, 2020).

And third, although the vast majority (83-93%) of VBAAs discuss farming with other farmers, try to tailor their recommendations based on each farmer's needs, and experiment or encourage others to experiment with new inputs or management practices, far fewer (55-65%) felt that they could learn about inputs or management practices from other farmers, or would consider changing their own behavior or the recommendations they make in response to learnings from other farmers. This, too, may signal that additional training in the importance of and strategies for eliciting farmer feedback and incorporating it into extension recommendations may be needed to effectively support bidirectional learning between information providers like VBAAs and other farmers.

Finally, given the challenges encountered during the implementation of this RCT, further studies and randomized evaluations are needed to determine the value addition (if any) of providing free input trial packs in addition to doing a demonstration plot. If the main finding of this study is upheld for the outcomes considered here as well as other relevant outcomes, then NGOs like FIPS may find it a better use of their resources to focus on demonstration plots only.

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Appendix A.

Table A-1. Balance tests using administrative data provided by FIPS for the original list of VBAAs and random treatment group assignment (2015/16 VBAA characteristics)

VBAA characteristic	Mean value			Differ-ence (B-C)	p-value from t-test	p-value from regression-based balance test
		Treatment group				
	All (N=230)	DP (N=115)	DPTP (N=115)			
	(A)	(B)	(C)	(D)	(E)	(F)
Education (years)	7.90	7.93	7.87	0.06	0.818	0.739
Age (years)	42.3	42.2	42.3	-0.1	0.945	0.936
Years since started as VBAA	1.88	1.89	1.88	0.01	0.957	0.936
Number of maize trial pack allocated by FIPS	328.9	331.7	326.1	5.7	0.555	0.434
Number of farmers involved in maize mother demos*	60.9	61.1	60.8	0.4	0.942	0.795
=1 if VBAA is female, =0 if male	0.287	0.278	0.296	-0.02	0.771	0.620
=1 if VBAA did maize and bean demos, =0 if VBAA did maize demos only	0.217	0.226	0.209	0.017	0.749	0.566

Note: Regression-based test is the VBAA characteristic regressed on a treatment group dummy (1=DPTP, 0=DP) and matched pair fixed effects with standard errors clustered at the matched pair level. *N=228 for this variable due to missing data for two Iringa Rural-based VBAAs. Variable not used in matching algorithm for Iringa Rural.)

Table A-2. Regressions results for joint orthogonality test – original list of VBAAs from FIPS and based on FIPS administrative data from 2015/16

VBAA characteristics	Dependent variable: =1 if DPTP, =0 if DP
Education (years)	-0.010
	(0.108)
Age (years)	-0.003
	(0.019)
Years since started as a VBAA	-0.006
	(0.195)
Number of maize trial packs allocated by FIPS	-0.003*
	(0.002)
Number of farmers involved in maize mother demos	-0.005
	(0.012)
=1 if VBAA is female, =0 if male	0.513
	(0.554)
=1 if VBAA did maize and bean demos, =0 if VBAA did maize demos only	-0.614
	(0.538)
Constant	1.373
	(1.559)
Matched pair fixed effects?	Yes
R-squared	0.050
Joint significance (F-test) p-value	0.704

N=228 (due to missing data on number of farmers involved in maize mother demos for two Iringa Rural-based VBAAs. Variable not used in matching algorithm for that district.) ***, **, * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors clustered at the match pair level in parentheses.

Table A-3. Regression results for joint orthogonality test – various sets of VBAAs that were interviewed on at least the baseline survey and drawing on the baseline survey data

	Dependent variable: =1 if DPTP, =0 if DP			
	Set of VBAAs (see note for details)			
	(1)	(2)	(3)	(4)
VBAA characteristics	N=197	N=135	N=179	N=120
Age (years)	0.010*	0.009	0.010*	0.009
	(0.006)	(0.008)	(0.006)	(0.008)
Years worked as VBAA	-0.077***	-0.087***	-0.073***	-0.082**
	(0.024)	(0.031)	(0.025)	(0.033)
Gender: =1 if female	-0.076	0.038	-0.063	0.096
	(0.078)	(0.103)	(0.084)	(0.113)
Education: =1 if completed above standard 7	-0.113	-0.101	-0.122	-0.118
	(0.095)	(0.116)	(0.096)	(0.117)
Overall farming experience (years)	-0.008	-0.005	-0.008	-0.005
	(0.006)	(0.007)	(0.006)	(0.008)
Bean farming experience (years)	0.005	0.004	0.007	0.006
	(0.004)	(0.005)	(0.004)	(0.005)
Land area owned by household (acres)	-0.001	0.002	-0.000	0.003
	(0.003)	(0.004)	(0.003)	(0.004)
Numbers of adult members in the household	-0.034**	-0.041*	-0.028	-0.038
	(0.017)	(0.022)	(0.018)	(0.023)
Number of children in the household	-0.033	-0.016	-0.029	-0.008
	(0.020)	(0.024)	(0.021)	(0.025)
Sold bean seed in 2015/16 (=1)	-0.207	-0.220	-0.140	-0.184
	(0.179)	(0.227)	(0.192)	(0.247)
Sold seed treatments or pesticides in 2015/16 (=1)	-0.071	-0.187	-0.002	-0.156
	(0.181)	(0.232)	(0.195)	(0.255)
Constant	0.795***	0.739***	0.722***	0.631**
	(0.213)	(0.280)	(0.229)	(0.301)
Observations	197	135	179	120
R-squared	0.120	0.120	0.109	0.119
Joint significance (F-test) p-value	0.012**	0.128	0.049**	0.222

Note: ***, **, * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors in parentheses. The sets of VBAAs are as follows: N=197 is the VBAAs that were interviewed on the baseline survey and whose treatment status based on inputs received could be confirmed. N=135 is the VBAAs that were interviewed on the baseline survey and whose treatment status based on inputs received could be confirmed and is consistent with their *ex ante* random assignment. N=179 is the VBAAs that were interviewed on both surveys and whose treatment status based on inputs received could be confirmed. N=120 is the VBAAs that were interviewed on both surveys and whose

treatment status based on inputs received could be confirmed and is consistent with their *ex ante* random assignment

Table A-4. Balance tests using observations on the 179 VBAAs that were interviewed on both surveys and whose treatment status based on inputs received could be confirmed

	Mean values					
		Treatment group based on inputs received per follow-up phone calls				
	All VBAAs (N=197)	DP (N=67)	DPTP (N=130)	Difference (B) – (C)	t-stat.	p-value (H0: diff=0, H1: diff≠0)
VBAA characteristics (as of the baseline survey)	**(A)**	**(B)**	(C)	**(D)**	**(E)**	**(F)**
Age (years)	45.11	43.97	45.65	-1.69	-1.22	0.226
Years worked as VBAA	3.41	3.83	3.21	0.61	2.67	0.008***
Gender: =1 if female	0.279	0.310	0.264	0.046	0.64	0.522
Education: =1 if completed above standard 7	0.162	0.207	0.140	0.066	1.13	0.259
Overall farming experience (years)	21.71	21.17	21.97	-0.79	-0.50	0.621
Bean farming experience (years)	17.18	15.64	17.93	-2.29	-1.21	0.228
Land area owned by household (acres)	9.56	9.89	9.41	0.48	0.27	0.787
Numbers of adult members in the household	2.97	3.19	2.87	0.32	0.99	0.323
Number of children in the household	2.81	3.12	2.66	0.46	1.68	0.094*
VBAA input sales in 2015/16						
Sold bean seed (=1)	0.034	0.052	0.025	0.027	0.94	0.349
Sold seed treatments or pesticides (=1)	0.034	0.034	0.033	0.001	0.05	0.961

Notes: N=179. ***, **, * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Binary variable used for education because standard 7 is the highest level of education completed by 81.6% of VBAAs.

Table A-5. Balance tests using observations on the 120 VBAAs that were interviewed on both surveys and whose treatment status based on inputs received could be confirmed and is consistent with their ex ante random assignment

	Mean values					
		Treatment group based on inputs received per follow-up phone calls				
	All VBAAs (N=197)	DP (N=67)	DPTP (N=130)	Difference (B) – (C)	t-stat.	p-value (H0: diff=0, H1: diff≠0)
VBAA characteristics (as of the baseline survey)	**(A)**	**(B)**	(C)	**(D)**	**(E)**	**(F)**
Age (years)	44.33	43.72	44.68	-0.95	-0.54	0.591
Years worked as VBAA	3.44	3.88	3.19	0.69	2.56	0.011**
Gender: =1 if female	0.275	0.233	0.299	-.066	-0.77	0.437
Education: =1 if completed above standard 7	0.183	0.233	0.156	0.077	1.04	0.298
Overall farming experience (years)	21.45	21.16	21.61	-0.45	-0.23	0.815
Bean farming experience (years)	16.99	15.91	17.60	-1.69	-0.75	0.455
Land area owned by household (acres)	9.60	9.10	9.87	-0.77	-0.33	0.744
Numbers of adult members in the household	3.06	3.35	2.90	0.45	-0.31	0.243
Number of children in the household	2.88	3.14	2.73	0.41	1.17	0.243
VBAA input sales in 2015/16						
Sold bean seed (=1)	0.033	0.047	0.026	0.021	0.60	0.548
Sold seed treatments or pesticides (=1)	0.033	0.047	0.026	0.021	0.60	0.548

Notes: N=120. ***, **, * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Binary variable used for education because standard 7 is the highest level of education completed by 78.3% of VBAAs.

Table A-6. Descriptions of the improved bean varieties included in the interventions

Variety	Release date	Characteristics (bean type, bean color, disease/drought tolerance, days to maturity)	Yield potential (kg/acre)	Seed size and recommended seeding rate
Uyole 96	1996	• Bush type • Dark red • Tolerant to ALS and bean rust • 84 days to maturity	480-1,000	• Large • 36 - 40 kg/acre
Njano Uyole	2008	• Bush type • Yellow • Tolerant to CBB, ALS, bean rust, halo blight, and root rots • 88 days to maturity	600-1,200	• Medium • 26-28 kg/acre
Uyole 03	2003	• Sugar type • Cream with red speckles • Tolerant to CBB, ALS, and halo blight • 97 days to maturity	600-1,200	• Medium • 26-28 kg/acre
Calima Uyole	2011	• Bush type • Red mottled • Tolerant to CBB, ALS, and bean rust • 85 days to maturity	600-1,200	• Large • 36 - 40 kg/acre
Wanja	2002	• Bush type • Khaki • Adapted to dry areas • 78 days to maturity	400-1,000	• Large • 36 - 40 kg/acre

Source: CIAT-Tanzania (2016).
Notes: ALS = angular leaf spot. CBB = common bacterial blight.

Table A-7. Summary statistics – input sales- and unfilled order-related outcome and related variables (N=179 VBAAs interviewed on both surveys and whose treatment status based on inputs received could be confirmed)

	Year			
	2015/16	2016/17 (intervention year)	2017/18	2018/19 (partial year)
Bean seed sales				
=1 if sold bean seed (any variety)	0.034	0.050	0.034	0.017
=1 if sold any of the promoted varieties of bean seed*	0.028	0.045	0.028	0.017
=1 if sold Njano Uyole seed*	0.017	0.028	0.017	0.011
=1 if sold Uyole 96 seed*	0.022	0.017	0.011	0.006
Bean seed unfilled orders				
=1 if had any unfilled orders for bean seed (any variety)	N/A	0.318	0.346	0.251
=1 if had any unfilled orders for any promoted variety of bean seed	N/A	0.307	0.313	0.229
=1 if had any unfilled orders for Njano Uyole	N/A	0.140	0.156	0.140
=1 if had any unfilled orders for Uyole 96	N/A	0.168	0.168	0.112
Bean seed sales or unfilled orders				
=1 if sold or had any unfilled orders for bean seed (any variety)	N/A	0.352	0.369	0.263
=1 if sold or had any unfilled orders for any promoted variety of bean seed	N/A	0.346	0.341	0.246
=1 if sold or had any unfilled orders for Njano Uyole	N/A	0.168	0.173	0.151
=1 if sold or had any unfilled orders for Uyole 96	N/A	0.184	0.179	0.117
Seed treatment/pesticide sales				
=1 if sold any seed treatments or pesticides	0.034	0.112	0.117	0.117
=1 if sold Apron Star*	0	0.017	0.011	0.006
Seed treatment/pesticide unfilled orders				
=1 if had any unfilled orders for seed treatments or pesticides	N/A	0.190	0.179	0.179
=1 if had any unfilled orders for Apron Star	N/A	0.084	0.095	0.073
Seed treatment/pesticide sales or unfilled orders				
=1 if sold or had any unfilled orders for seed treatments or pesticides	N/A	0.268	0.263	0.268
=1 if sold or had any unfilled orders for Apron Star	N/A	0.101	0.106	0.078

Notes: N=179. N/A = not included on baseline survey. *No regression analyses for these variables due to insufficient variation.

Table A-8. Input sales and unfilled orders endline only regressions: OLS estimates of the effect of the DPTP treatment relative to the DP treatment, by dependent variable (N=179)

	Year		
Dependent variable	2016/17 (intervention year)	2017/18	2018/19 (partial year)
Bean seed sales			
=1 if sold bean seed (any variety)	0.049	-0.027	-0.001
	(0.035)	(0.029)	(0.021)
Bean seed unfilled orders			
=1 if had any unfilled orders for bean seed (any variety)	0.012	-0.023	-0.036
	(0.075)	(0.076)	(0.070)
=1 if had any unfilled orders for any promoted variety of bean seed	0.046	0.029	0.007
	(0.074)	(0.074)	(0.067)
=1 if had any unfilled orders for Njano Uyole	-0.023	-0.049	-0.049
	(0.056)	(0.058)	(0.058)
=1 if had any unfilled orders for Uyole 96	0.069	0.044	0.063
	(0.060)	(0.060)	(0 .050)
Bean seed sales or unfilled orders			
=1 if sold or had any unfilled orders for bean seed (any variety)	0.062	-0.016	-0.020
	(0.077)	(0.077)	(0.071)
=1 if sold or had any unfilled orders for any promoted variety of bean seed	0.079	-0.006	0.007
	(0.076)	(0.076)	(0.069)
=1 if sold or had any unfilled orders for Njano Uyole	-0.007	-0.075	-0.032
	(0.060)	(0.061)	(0.057)
=1 if sold or had any unfilled orders for Uyole 96	0.094	0.035	0.072
	(0.062)	(0.061)	(0.051)
Seed treatment/pesticide sales			
=1 if sold any seed treatments or pesticides	-0.039	-0.005	-0.005
	(0.051)	(0.052)	(0.052)
Seed treatment/pesticide unfilled orders			
=1 if had any unfilled orders for seed treatments or pesticides	0.051	0.009	0.035
	(0.063)	(0.062)	(0.061)
=1 if had any unfilled orders for Apron Star	0.022	0.013	0.031
	(0.044)	(0.047)	(0.042)
Seed treatment/pesticide sales or unfilled orders			
=1 if sold or had any unfilled orders for seed treatments or pesticides	0.040	0.031	0.040
	(0.071)	(0.071)	(0.071)
=1 if sold or had any unfilled orders for Apron Star	0.047	0.029	0.039
	(0.048)	(0.049)	(0.043)

Notes: N=179. ***, **, * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Values reported are the OLS estimates of β_1 in equation (1) for each dependent variable. Standard errors in parentheses.

Table A-9. Input sales: Difference-in-differences estimates of the effect of the DPTP treatment relative to the DP treatment, by dependent variable (N=358=179*2)

Dependent variable:	=1 if sold bean seed (any variety)		=1 if sold any seed treatments or pesticides	
Comparison year:	2016/17 (intervention year)	2017/18	2016/17 (intervention year)	2017/18
Explanatory variables:				
=1 if DPTP, =0 if DP	-0.027	-0.027	-0.001	-0.001
	(0.032)	(0.029)	(0.041)	(0.042)
=1 if comparison year, =0 if 2015/16 (pre-intervention)	-0.034	0.000	0.103**	0.086*
	(0.037)	(0.034)	(0.048)	(0.049)
=1 if DPTP × =1 if comparison year	0.076*	-0.000	-0.037	-0.004
	(0.045)	(0.041)	(0.058)	(0.059)
Constant	0.052*	0.052**	0.034	0.034
	(0.026)	(0.024)	(0.034)	(0.034)
R-squared	0.010	0.005	0.025	0.025

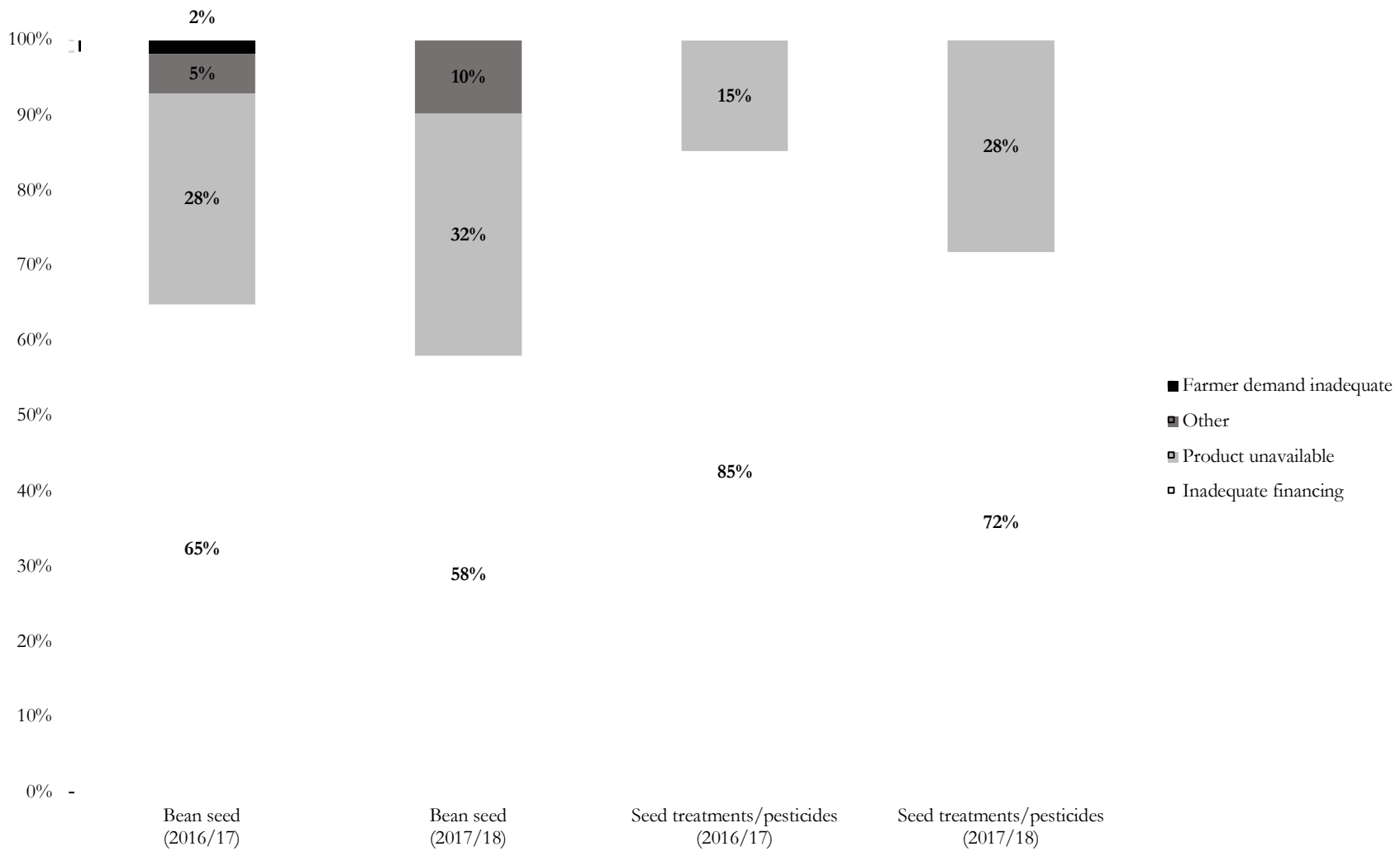
Notes: N=358 (179*2). ***, **, * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors in parentheses.

Table A-10. Input sales: Regressions on a year dummy (2015/16 vs. 2016/17 or 2017/18), by dependent variable (N=358=179*2)

Dependent variable:	=1 if sold bean seed (any variety)		=1 if sold any seed treatments or pesticides	
Comparison year:	2016/17 (intervention year)	2017/18	2016/17 (intervention year)	2017/18
Explanatory variables:				
=1 if comparison year, =0 if 2015/16 (pre-intervention)	0.011	-0.005	0.085***	0.085***
	(0.021)	(0.019)	(0.027)	(0.027)
Constant	0.037**	0.037***	0.032*	0.032*
	(0.015)	(0.013)	(0.019)	(0.019)
R-squared	0.001	0.000	0.001	0.000

Notes: N=358 (179*2). ***, **, * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors in parentheses.

Figure A-1. Reasons for unfilled orders – 2016/17 and 2017/2018 (alternative set of VBAAs)



Notes: Drawing on the N=179 set of VBAAs. "Other" reasons were "I was not given the seeds to sell", "Social issues", and "Poor communication with FIPS" for 2016/17, and "I was not given the seeds to sell", "I was sick", "Social issues", and "Poor communication with FIPS" for 2017/18.

Table A-11. Bidirectional learning-related outcomes: OLS estimates of the effect of the DPTP treatment relative to the DP treatment, by dependent variable (N=179)

	(1)	(2)	(3)	(4)	(5)
Explanatory variables	How much do you consider feedback from farmers when you make recommendations on bean inputs or crop management practices?	You often get together with other farmers to discuss farming practices or inputs.	You like to experiment with new farming practices or inputs.	You encourage others to experiment with new farming practices or inputs.	You are frequently taught new things by other farmers about farming practices or inputs.
=1 if DPTP, =0 if DP	-0.149	0.029	0.157	0.167	0.063
	(0.204)	(0.138)	(0.123)	(0.132)	(0.198)
Constant	4.000***	4.086***	4.397***	4.362***	3.276***
	(0.168)	(0.114)	(0.102)	(0.109)	(0.163)
R-squared	0.003	0.000	0.009	0.009	0.001

	(6)	(7)	(8)	(9)
Explanatory variables	You often consider changing your own farming practices or the inputs you use because of things you have learned from other farmers.	You often consider changing the recommendations you make to others on farming practices or inputs because of things you have learned from other farmers.	You feel empowered to alter the recommendations you make to other farmers on farming practices or inputs based on things you learn from other farmers.	You try to tailor the recommendations you make to other farmers on farming practices or inputs based on the needs of each farmer.
=1 if DPTP, =0 if DP	-0.144	-0.075	0.152	-0.163
	(0.172)	(0.178)	(0.174)	(0.108)
Constant	3.690***	3.603***	3.310***	4.345***
	(0.141)	(0.146)	(0.143)	(0.089)
R-squared	0.004	0.001	0.004	0.013

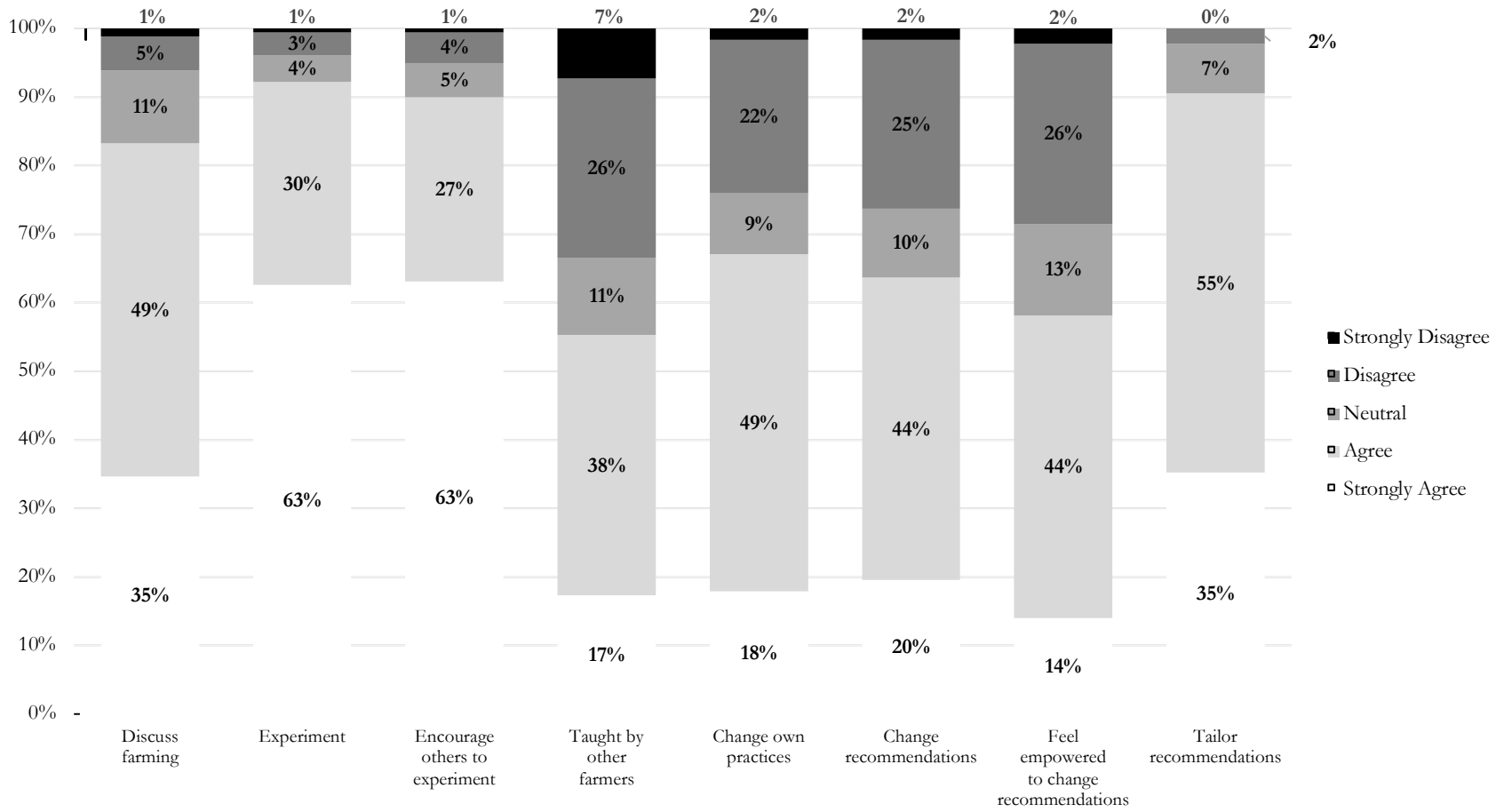
Notes: N=179. ***, **, * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors in parentheses. Outcome variables are 5-point Likert scales. For model (1), the scale is: 1=not at all, 2=very little, 3=somewhat, 4=quite a bit, and 5=a great deal. For models (2) through (9), the scale is: 1=strongly disagree, 2=disagree, 3=neutral, 4=agree, and 5=strongly agree.

Table A-12. VBAA-farmer learning interactions and attitudes statements: Ordered probit average partial effects (APEs) of the effect of the DPTP treatment relative to the DP treatment (N=179)

	Average partial effect of DPTP relative to DP on the probability of each response at left			
	(1)	(2)	(3)	(4)
Response	You often get together with other farmers to discuss farming practices or inputs.	You like to experiment with new farming practices or inputs.	You encourage others to experiment with new farming practices or inputs.	You are frequently taught new things by other farmers about farming practices or inputs.
1=strongly disagree	-0.002	-0.003	-0.004	-0.006
	(0.006)	(0.004)	(0.005)	(0.024)
2=disagree	-0.007	-0.015	-0.020	-0.010
	(0.017)	(0.015)	(0.019)	(0.038)
3=neutral	-0.010	-0.013	-0.016	-0.001
	(0.023)	(0.013)	(0.015)	(0.005)
4=agree	-0.009	-0.047	-0.043	0.006
	(0.019)	(0.043)	(0.037)	(0.024)
5=strongly agree	0.028	0.079	0.083	0.011
	(0.064)	(0.073)	(0.073)	(0.042)
	(5)	(6)	(7)	(8)
Response	You often consider changing your own farming practices or the inputs you use because of things you have learned from other farmers.	You often consider changing the recommendations you make to others on farming practices or inputs because of things you have learned from other farmers.	You feel empowered to alter the recommendations you make to other farmers on farming practices or inputs based on things you learn from other farmers.	You try to tailor the recommendations you make to other farmers on farming practices or inputs based on the needs of each farmer.
1=strongly disagree	0.006	0.005	-0.007	Not estimable
	(0.007)	(0.007)	(0.010)	(no observations)
2=disagree	0.044	0.034	-0.036	0.014
	(0.045)	(0.048)	(0.049)	(0.010)
3=neutral	0.009	0.006	-0.006	0.031
	(0.010)	(0.009)	(0.008)	(0.020)
4=agree	-0.015	-0.011	0.022	0.063
	(0.015)	(0.015)	(0.031)	(0.044)
5=strongly agree	-0.044	-0.033	0.027	-0.108
	(0.048)	(0.049)	(0.036)	(0.070)

Notes: N=179. ***, **, * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors in parentheses.

Figure A-2. Summary of responses to VBAA-farmer learning interactions and attitudes statements (alternative set of VBAAs)



Note: N=179.