Impact Assessment of Plantwise–Pakistan

Final Report

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Contributors

The evaluation of Plantwise–Pakistan was conducted by American Institutes for Research (AIR) for CABI. Juan Bonilla (AIR) is the principal investigator for the overall evaluation. The team leaders of this report are Juan Bonilla, Andi Coombes, and Adria Molotsky but many others made important contributions and are listed below in alphabetical order:

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List of Acronyms

AO	Agricultural officer
AIR	American Institutes for Research
FGD	Focus group discussion
GOP	Government of Pakistan
HH	Head of household
IPM	Integrated pest management
IPWRA	Inverse Probability Weight Regression-Adjustment
IRR	Internal Rate of Return
KII	Key informant interview
MDES	Minimum Detectable Effect Size
MOA	Ministry of Agriculture
PD	Plant doctor
PDV	Present Discounted Value
POMS	Plantwise Online Management System
PW	Plantwise
PW-P	Plantwise–Pakistan

Contents

Figures

Page

Tables

Page

1. Introduction

The American Institutes for Research (AIR) was contracted by CABI to design and implement a mixed-methods impact assessment of Plantwise in Pakistan and to conduct the necessary data collection, analysis, and reporting. This report presents the results for the evaluation of Plantwise–Pakistan (PW-P) as implemented in Punjab, the province where PW-P has been implemented for the longest period and that has the highest levels of plant clinic coverage in the country. We used qualitative and quantitative methods to answer four research questions. We used qualitative methods to assess the changes that PW-P brings to the plant health system, assess program sustainability, and evaluate the process of the PW implementation in the field. We used quantitative methods to identify farm-level impacts using a quasi-experimental approach in 8 districts of Punjab province. We collected one round of data at the end of 2018. A total of 1,805 farmers from 120 villages were interviewed to estimate the impacts of attending plant clinics. Lastly, we also used administrative quantitative data on program costs to conduct a cost-benefit analysis of the program.

The following section begins with a description of the agricultural sector in Pakistan and its system of agricultural advisory services; then, we describe how Plantwise responds to agricultural challenges in Pakistan and present the components of the program itself, followed by the evaluation methodology, analytical approach, results, and conclusion.

The Agricultural Sector in Pakistan

Pakistan has experienced a slow and steady economic transformation in the last decades. Nonetheless, the agricultural sector is still a key component of the national economy, as it accounts for 21% of the GDP and is the main sector of employment, making up approximately 47% of the country's labor force (Spielman, Malik, Dorosh, & Ahmad, 2016). The agriculture sector provides Pakistan's rapidly growing population with basic food staples and is a key input provider for many parts of the industrial and services sectors. Textile manufacturing, for example, which accounted for about 30% of the total industrial GDP in 2013–2014, is highly dependent on domestic cotton production. Overall, the agricultural sector accounts for 80% of the country's total export earnings.

Pakistan is one of the world's largest producers of raw cotton but also produces wheat, rice, sugarcane, fruits, and vegetables, in addition to milk, beef, mutton, and eggs. Pakistan depends on one of the world's largest irrigation systems to support production of these goods (Spielman et al, 2016). There are two principal agricultural seasons in Pakistan: kharif and rabi. During the kharif season, which lasts from April to October, the main crops produced are cotton, rice, and sugarcane. During the rabi season, which extends from November to April, wheat is the major crop. Punjab Province, the focus of our evaluation, grows 83% of Pakistan's cotton, 80% of wheat, 97% of fine aromatic rice, 63% of sugarcane, 95% of potato and 78% of maize. The agriculture sector contributes 27% to Punjab's GDP and employs 40% of its labor force (ADGP, 2015). The most important kharif crops in Punjab include rice, sugarcane, cotton and maize, whereas key rabi crops include wheat, gram, lentil and tobacco.

Agricultural Advisory Services

Smallholder farmers in developing countries rely on crops for income and food security. However, crop production is regularly threatened by output losses due to pest and disease outbreaks. While factors external to a farm may ultimately be the source of a pest or disease outbreak, the inability of farmers to avoid or respond to such external factors is partially due to a lack of available knowledge and access to information on how to maintain plant health.

From independence to 2004, agricultural extension services in Pakistan were provided to farmers as part of a top-down, centralised system with poor linkages to academic and research institutions (Baloch & Thapa, 2019; Shahbaz & Ata, 2014). Some flagship programmes included Village Cooperative Movement, Village Agriculture and Industrial Development Programme (Village-AID), Basic Democracy System (BDS), Integrated Rural Development Programme (IRDP) and Training and Visit (T&V) programme. These programs were abandoned over time (Malik, 2003; Bajwa et al., 2010) due to the lack of results. The extension system was reformed in 2004 to become more “decentralised” and to offer more innovative extension approaches. The current extension approach is a modified version of the T&V approach. The farmers’ training methodology being followed in the Punjab by the extension field staff in current decentralized system is called “Agricultural Hub Programme”. Under this program, a champion farmer is identified in a village to serve as a demonstration center for other farmers. The extension field staff visits this selected farmer at least once a week to introduce and disseminate approved agricultural practices (Shahbaz & Ata, 2014). The Farmer Field School (FFS) system is also being used by the extension departments. Despite making efforts to provide extension services in a more decentralized way, current services still focus on the main export crops, including sugar cane and cotton, and cereals like rice and wheat (Baloch & Thapa, 2019).

In Pakistan, the private sector is also actively engaged in providing agricultural extension services to farmers as well as agricultural inputs. The delivery of extension services has become a regular feature of private input-supplying agencies. The types of companies that provide extension services are pesticide, fertilizer, seed, and processing companies.

The Role for Plantwise

The information provided to farmers through advisory services should expand their knowledge and management skills and thereby increase agricultural productivity and returns. Farmers should have an incentive to increase their productivity and are expected to demand advisory services that allow them to do so if transaction costs are low. Farmers could potentially address their need for advisory services through the private sector. In considering the role of the private sector in extension, Umali and Schwartz (1994) conclude that the private sector provides extension services in areas where reasonable returns are possible. They note that private extension providers tend to focus on high-value crops, more favorable environments, and "big" individual farmers. This suggests that the best means of delivering agricultural services—whether private or public—depend on the nature of the information being provided and farmer circumstances (Anderson & Feder, 2004). Given the public-good nature of the assistance provided by agricultural extension services and the potential importance of this assistance for increasing agricultural productivity and agricultural incomes, governments need to play a significant role in extension activities. Many of the existing efforts, however, have proven to be controversial and have been found to have limited farm-level benefits. Thus, not surprisingly, governments have explored alternative ways in which advisory services could be provided to farmers. In an effort to contribute to addressing the global pest problem, CABI has initiated an innovative global program called PW to increase food security and improve rural livelihoods by reducing crop losses.

Plantwise–Pakistan Program

PW is a global initiative that provides smallholder farmers with vital information on the maintenance of crop health and on environmentally sustainable responses to adapt to pest problems including those resulting from climate change. PW activities were launched in Pakistan in 2011. Plant clinics are now running regularly in different parts of the country to provide local farmers with advice on how to prevent and manage crop damage from pests and diseases. PW is implemented through three interconnected activities. First, farmers can access trained plant doctors through a network of locally run plant clinics. Plant clinics provide farmers with low-cost access to plant health information, give diagnosis of plant health issues and provide a written recommendation on how to address the problem, while at the same time collecting data on reported pest and disease problems and the management advice given. Data is collected into the Plantwise Online Management System (POMS), which is intended to track trends in specific locations over time in order to better monitor and predict plant health problems. Second, PW engages key stakeholders, government extension staff, researchers, input suppliers, and regulators, to fortify plant health systems through encouraging collaboration. Third, PW uploads pest and disease content produced by in-country experts, which is peer reviewed, into an open-source, online database called the “Knowledge Bank,” which then serves as a repository for locally-relevant plant health information that can assist field staff with diagnosing, managing, and monitoring pests and diseases.

The design of PW includes a number of innovations that are of particular interest in addressing plant health issues. First, the delivery of agricultural extension assistance through plant clinics is distinct from dominant approaches to extension services (e.g., training and visitation, Farmer

Field Schools), in that farmers only attend if they have a problem they need to address (i.e., it is demand led). Second, through gathering data at plant clinics, PW is implementing a unique pest and disease monitoring system that could be incorporated into a nationwide system of pest management. These data are being used as a common thread for engaging with the relevant Plant health stakeholders providing an evidence-base for decision making.. The objective of this study is to conduct a thorough and rigorous assessment of how PW has been implemented in Pakistan and the effects that the program has had after 6 years of implementation.

The document is organized as follows: Section 2 presents the theory of change; Sections 3, 4, and 5 present the study design and approach to answering the research questions; Section 6 presents answers to the research questions using both qualitative and quantitative data collected as part of the evaluation; and Section 7 summarizes the key conclusions and discusses the implications of these conclusions for PW-P.

2. Evaluation Questions and Theory of Change

In this section, we present the specific evaluation questions and articulate a theory of change for the project.

A. Evaluation Questions

The evaluation is intended to answer the following four research questions, which were refined with the Plantwise–Pakistan (PW-P) team during the inception trip.

1. **Plant Health System Change.** Does PW-P lead to system change within the country's plant health system? Does PW-P lead to stronger institutions that expand knowledge availability, improve identification of new diseases and pests, and maintain numerous plant clinics? Does PW-P stimulate lasting changes in the behaviors of and relationships among those who work in the plant health system?
2. **Process.** How well does PW-P translate activities into support (outputs) for participants? How well does PW-P deliver technical quality, as judged by the program's participants (plant health system stakeholders, extension staff, and farmers)?
3. **Impact.** Does PW-P improve the well-being of farmers through improved pest and disease management and increased productivity?
4. **Cost Analysis.** Are the costs of implementing PW-P justified given the benefits the program provides?

To answer the research questions, we used a mixed-methods approach that includes qualitative and quantitative methods from multiple sources. On the quantitative side, we analyzed both primary data and PW-P administrative data. The primary data collection included a farm-level survey. We also used administrative cost data shared by CABI to conduct the cost-benefit analysis. On the qualitative side, we collected information at the national and local (district) level and used both key informant interviews and focus groups.

B. Theory of Change

This section presents the conceptual foundation for PW-P, previously introduced in the inception report. The theory of change presents PW-P's causal logic to map out the causal chain among inputs, activities, outputs, outcomes, and impacts as well as the underlying assumptions to bring about improved development outcomes (White, 2009).

Figure 2.1 provides a graphical representation of the theory of change for PW. Fundamentally, smallholder farmers rely on crop production for income and food security. However, their ability to generate income and maintain food security is threatened by the presence of pests and diseases, which reduces yields, and a general lack of knowledge and information to address pests and diseases. Farmers need to have various options for addressing pest and disease outbreaks that consider context-specific agricultural conditions and socioeconomic circumstances (Danielsen et al., 2013). However, maintaining and updating information on the types of pests and diseases and how to address them is difficult in an agricultural landscape that is changing quickly due to globalization and new market pressures as well as climate change. Given this context, PW has sought to find more effective and complimentary ways that fit in with the current extension services to manage crop protection to ultimately improve food security, alleviate poverty, and improve the livelihoods of farmers.

The activities of PW can be divided into three general categories: (a) institutional strengthening, (b) the Knowledge Bank, and (c) field activities. Institutional activities include various methods to provide support to and increase collaboration among participants in the plant health system, seeking to facilitate information flow between them and coordinate action. The key participants in the plant health system are organizations devoted to conducting crop research and providing agricultural extension assistance, regulators (e.g., state organizations responsible for ensuring the quality and safety of pesticides and fertiliser used), and departments of plant protection. Affiliated stakeholders include universities, input suppliers, and farm organizations. The improved coordination is intended to increase the availability of information to farmers. Additionally, it helps farmers benefit from coordinated responses and targeted messages that are immediate and delivered at scale.

The PW Knowledge Bank is the second component of the approach. The Knowledge Bank is a free and open-access online database of locally relevant plant health information. It is readily accessible to provide support to plant doctors who operate plant clinics, extension workers, and researchers. The Knowledge Bank provides diagnostic assistance, treatment support, and pest distribution data gathered from published literature, researchers, and international partners around the world. The investments from PW include establishing, hosting, and managing the database by keeping it up to date with relevant plant health information, along with providing ongoing advice to extension systems and national bodies. The Knowledge Bank is designed to increase the accountability and responsiveness of local organizations to farmers and guarantee the quality of information that farmers receive.

Figure 2.1. Plantwise Theory of Change

Initial Conditions

- Smallholder farmers rely on crops for income and food security
- Livelihood and food security threatened by:
  - Pests and diseases
  - Lack of knowledge and information to improve and maintain crop quality
- Changing pest/disease distribution due to climate change, globalization, trade, . .

Activities

INSTITUTIONAL ACTIVITIES

- Strengthening plant health system management and information collection

KNOWLEDGE BANK

- Creating a knowledge bank of plant health information for all stakeholders

FIELD ACTIVITIES

- Plant doctor training
- Plant clinics for expanding knowledge and improving crop health
- Technical support building on plant clinic knowledge (rallies, field days, . . .)

Assumptions

- Plant doctors have basic knowledge of crop management and diseases/pests
- Farmers have existing basic knowledge of farming and agriculture
- Stakeholders have internet access for knowledge bank
- Farmers have capacity to travel to plant clinics
- Markets for inputs and new outputs exist and function
- Farmers have the resources to adopt suggested practices
- Agriculture markets provide opportunities and are large enough to absorb new products

Intermediate Outcomes

Changes in system

- Increased stakeholder knowledge
- Improved advisory systems
- Improved regulatory systems for monitoring pests and diseases
- Expanded crop protection service access

Changes due to farmer behavior

- Expanded use of clinics and extension services
- Increased farmer knowledge
- Better investment in productive inputs (e.g., pesticides)
- Adoptions of new production practices
- Decreased crop losses
- Improved plant health and crop quality
- Crop and market diversification
- Increased product sales and higher prices

Impacts

Strengthened institutions

- Expanded knowledge availability
- Improved identification systems for new diseases/ pests
- Improved responses to disease/pest outbreak
- Sustainable plant clinics

Production

- Improved disease/ pest management
- Increased productivity and plant quality

The final component of PW is the establishment and maintenance of a network of plant clinics to act as a physical interface between farmers and crop protection experts known as plant doctors. The clinics are staffed by government extension agents who receive special training from PW to be plant doctors. Once trained, the plant doctors have increased capacity to diagnose pests and diseases and to offer recommendations related to, for example, cultural practices (methods that do not use chemicals) or the use of chemicals. In general, the plant doctors seek to promote the idea of integrated pest management (IPM), which uses multiple approaches to pest and disease management that minimize the hazard to people and the environment. While not excluding the use of chemicals, the plant doctors seek to ensure the rational use of these pesticides. Plant doctors are an alternative source of information to input suppliers, in that they provide an expert opinion without a sales agenda. In Pakistan, plant clinics are staffed by one agricultural officer and one field assistant and are set up often at agricultural markets, although occasionally at other locations where farmers congregate. The choice of location is generally based on making the clinics accessible to the largest number of farmers possible. The technical support aspect of the PW approach is intended to strengthen extension of crops and crop health. The clinics are held weekly or bi-weekly, free of charge, and they seek to increase farmers' knowledge over the long term and help farmers to shift their behavior toward better crop protection practices.

The plant clinics have a broader role beyond the immediate physical interface between farmers and crop protection experts. The broader effects are numerous. First, the plant doctors are part of the government staff, and they interact with farmers outside the plant clinics, with other extension agents, and with supervisors. Through these interactions, they transmit knowledge that reflects both their training as plant doctors and what they learn in the clinics where they are exposed to a wide diversity of problems to which they have to apply their diagnostic skills, which stimulates them to find out more about the problems and the management solutions either through resources such as the Plantwise KB or through peers, face-to-face or via social media networks associated to clinic activities. This transmission of information could influence the activities of local field agricultural extension offices. For example, the agricultural extension offices often hold field days for farmers to promote certain agricultural practices. The focus during these field days can change based on the information obtained by plant doctors. Second, the plant clinics are designed to systematically collect information on the crops and associated pests and diseases reported by farmers. These data are entered in the Plantwise Online Management System (POMS), where the information can be harmonised, validated and used for analysis. The data also provide information for additional investigation if new diseases or pests appear to be emerging. The database itself serves as a key source of information regarding the prevalence of pests and diseases and emerging vulnerabilities in plant health. Overall, the plant clinics play dual roles—addressing farmers' crop protection needs and stimulating broader institutional change that complements the other two components.

The three PW-P components are intended to lead to a set of initial effects (shown in Figure 2.1). These can be broadly categorized as (a) changes in the overall system for managing plant health and (b) changes that result from farmers altering their behavior as a result of the plant clinics and general system changes.

With respect to the overall system, the training of agricultural officers as plant doctors should increase knowledge about crop protection. The expectation is that advisory systems and regulatory systems for monitoring pests and diseases should improve with the shifts in the management system, expanded collaborative networks, and improved information gathering through the plant clinics and other information sources. Improvements in the overall management of crop protection services and the plant clinics should lead to greater quality in the provision of crop protection services if stakeholder behavior changes as a result of these investments.

With the improved overall service and availability of plant clinics, a behavioral response is expected from farmers as well. Farmers should respond by attending plant clinics and other related extension activities. The program should induce farmers to adopt new production practices if this occurs as planned and farmers internalize the information they obtain from participating in these activities. Proper diagnosis should then lead to appropriate recommendations, which should then lead to better use and investment in productive inputs (including cost-saving elements). Improved use of cultural practices or inputs should improve safety of production to the environment and farmers (e.g., PW has a focus on reducing the use of the most acutely toxic pesticides --the so called red list pesticides), decrease crop losses, and improve plant health, quality, and ultimately productivity.

The behavioural responses by stakeholders and farmers rest on a number of assumptions, some of which are noted in Figure 2.1. The theory of change assumes that both plant doctors and farmers have a sufficient base of knowledge on which to build. It also assumes that stakeholders have internet access and can obtain the information being continuously added to the Knowledge Bank, although offline access to content is facilitated both through a factsheet app and an offline version of the KB. With respect to farmers, the theory assumes that farmers can and do travel to clinics and that they are able to use the information—in other words, that markets exist for the required inputs and that farmers have the resources to obtain the necessary inputs. If farmers find the information sufficiently beneficial to explore new production opportunities, the theory also assumes that those opportunities exist and that the market can absorb expanded products.

Taken together, these behavioral changes on the part of stakeholders and farmers could lead to stronger institutions for managing crop protection; higher quantity and quality of production from farms; and improved safety for the environment, farmer and consumer. The institutions would be supported by a broad knowledge base that is continuously updated, improved systems for identifying pest and disease outbreaks, and improved responses to those outbreaks. The system would also have strong and sustainable plant clinics run by well-trained and well-informed plant doctors. The program could then increase agricultural productivity by improving overall pest and disease management strategies.

The theory of change shows the causal logic of PW-P and therefore helps to identify the evaluation questions that should be addressed. The research questions clearly emerge from the theory of change. The impacts of the program are ultimately a function of how it is implemented (Research Question 2). Understanding this implementation is therefore a critical aspect of evaluating the program. The plant clinic process can also lead to variation in the effectiveness of the program through contextual factors such as the population density of a region or the type of farming present. Research Question 2 is intimately related to Question 1, as it looks at the impact of the program on the overall plant health system, which is highly related to how the program is implemented in the field. Research Question 3, the impact at the farm level, is also clearly represented in the theory of change. Finally, another important consideration is the cost of PW-P (Research Question 4) and its relation to program's benefits.

3. Evaluation Methodology

In this section, we present our (a) approach to answering the research questions, (b) quantitative methods, (c) qualitative methods, and (d) measurement framework and instruments.

A. Approach to Answering the Research Questions

To answer **Research Question 1** (*assessing plant health system change*), we used qualitative methods to understand how PW-P fits within the current system. To do so, in collaboration with CABI, we identified the key stakeholders that play a role in the system and tried to understand how they work with PW-P. Further, we tried to understand the interactions between these stakeholders. We conducted in-depth interviews with key informants and focus group discussions (FGDs) with sets of stakeholders in the system. The final outcome of this exercise is an analysis of the stakeholders, as well as their roles and relationships in the system and to PW-P. To systematically consider how PW affects institutions for managing the plant health system, we organized the information into the following topics: institutional structure and coordination, data collection, outbreak identification and response, and finally, how plant clinics fit into the system.

To answer **Research Question 2** *(process)*, we adapted qualitative protocols from an earlier evaluation of Plantwise-Kenya to evaluate implementation in the field. We looked at how intervention components (inputs) did or did not translate into expected outputs. Through process tracing, we looked at whether implementers followed implementation procedures and the way the inputs then translated into a series of events resulting in expected and/or unexpected outputs. We conducted this analysis by asking informants about program materials (including training manuals, materials, and online/offline tools), data collection and data management, and activity guidelines as well as by considering implementers' and participants' accounts of program processes. We examined this through FGDs and key informant interviews (KIIs) with implementers as well as FGDs with program participants.

To answer **Research Question 3** (*program impacts at farmer level*), we compared outcomes for farmers who attended plant clinics in the last 12 months before the survey to outcomes for farmers who did not attend plant clinics by using a detailed questionnaire on agricultural conditions, agricultural knowledge, and production outcomes, among other things. In Section 4, we discuss the empirical strategy in detail and potential selection issues affecting plant clinic attendance.

To answer **Research Question 4**, we conducted a cost-benefit analysis and looked at two measures of program profitability: the benefit-cost ratio of the program as well as the internal rate of return. To assess whether the benefits of PW-P in Punjab justify its costs, we monetized estimated impacts of the program and compared them to the costs of implementing the program. Identifying costs associated with the project is not trivial, as costs include the resources provided by CABI and PW-P (including the costs of running the program by the government). To identify the costs, we used the ingredients method, in which every ingredient that could change an effect resulting from an intervention is considered. The information on the types of costs associated with the program was shared by CABI. After identifying these ingredients, we compared the actual costs from CABI and PW-P to the benefits (program impacts).

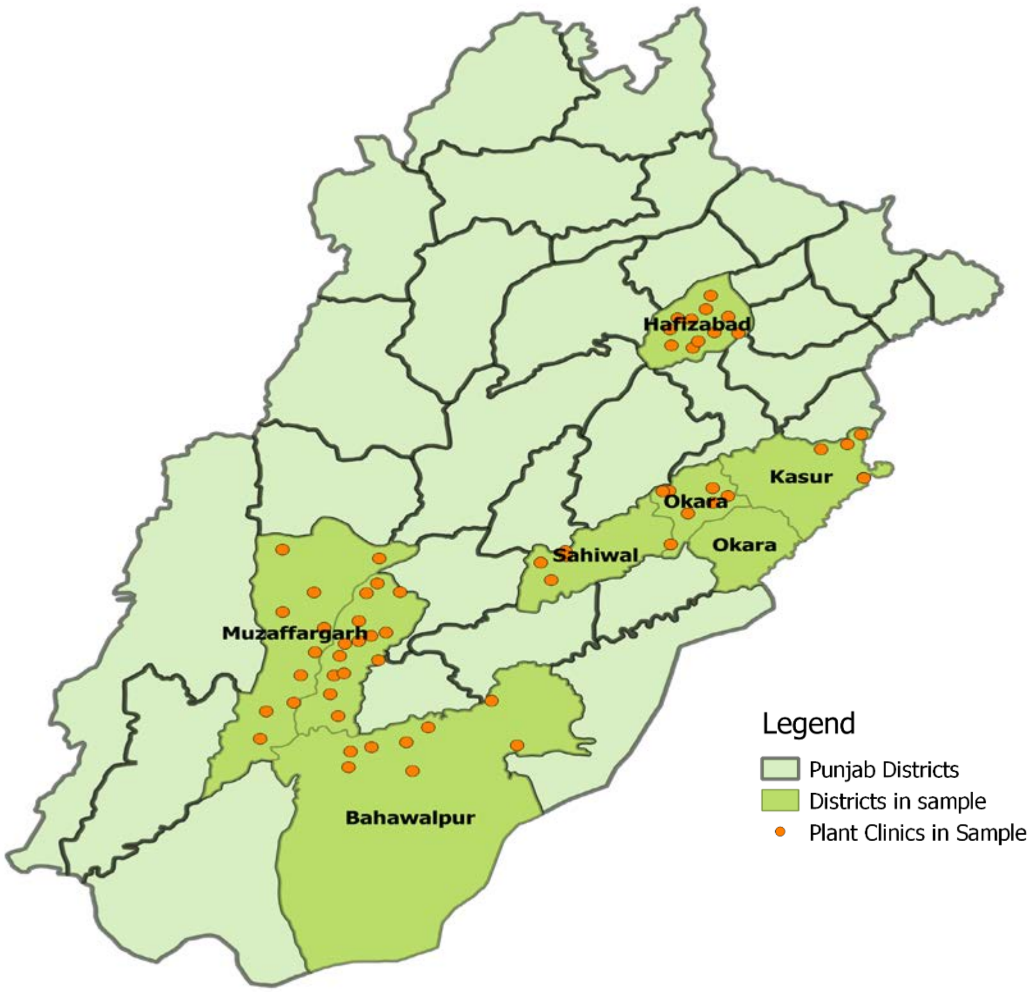
B. Quantitative Methods

We designed the impact evaluation based on rigorous methodological principles that enabled us to establish a clear counterfactual to address the following question: *What would have happened in the absence of the PW-P intervention?* Typically, these methodologies include both RCTs and quasi-experimental impact evaluations. The latter use background data to model selection into participation in a program. Given the ex-post nature of the evaluation, we relied on a quantitative quasi-experimental approach using a matching design to identify program impacts at the farm level. However, estimating program impacts by comparing a treatment group with a nonexperimental control group may be biased because participants self-select into the program or implementing partners specifically target those beneficiaries more likely to experience the largest program impacts. The main idea is to exploit the relevant information on program placement and targeting in order to identify control areas that are as similar as possible to program areas. In this section, we describe how we constructed a credible control group for PW-P beneficiaries to estimate program impacts.

Program Targeting. We used a series of steps to determine the sample for the evaluation of the program in Punjab. First, using information from the year clinics started and data from the 2010 agricultural census in each district, we identified seven districts in Punjab for the assessment: Hafizabad, Kasur, Okara, Sahiwal, Multan, Muzaffargarh, and Bahawalpur. These districts are located within the province and enabled us to capture the differences in crop production in Punjab.

To select these districts, we implemented an iterative elimination process of the districts in Punjab using district-level data from the agricultural census. In particular, there are 36 districts in Punjab, of which 24 started plant clinics in 2015 or earlier. This constitutes the first set of eligible districts, as this group ensures that the program has been implemented for a longer period. Of those 24 districts, we excluded a series of districts for reasons such as the following: (a) the district is very different from other districts in terms of irrigation access and crop distribution (e.g., in the districts of Bhakkar and Layyah, 50% of the farmers cultivate pulses and are less likely to cultivate the major crops in the province); (b) the district is highly urban, which makes it more difficult to identify areas where the program has an effect on farmers; and (c) the district has low levels of plant clinic utilization. Figure 3.1 is a map showing the Punjab districts and the location of all the plant clinics in the 8 districts selected for the evaluation.

Figure 3.1. Evaluation Districts in Punjab and Plant Clinic Locations



We present the variables used in the selection process in Table 3.1 and the source from where we obtained them.

Table 3.1. Data Used to Select Potential Districts for Assessment

Variable name	Description	Source
area_km2	Area in km^2	See Note 1
density_km2	Population density	See Note 1
n_presc_2016	No. of POMS records per district in 2016	POMS
n_presc_2017	No. of POMS records per district in 2017	POMS
n_farms	Number of farms	Table 1.1 (column 2)[2]
farm_area_ac	Farm area (acres)	Table 1.1 (column 4) [2]

Variable name	Description	Source
area_cultivated_ac	Area cultivated (acres)	Table 1.1 (column 6) [2]
p_area_cult	Cultivated area as % of farm area	Table 1.1 (column 8) [2]
m_farm_cul_area	Average size of cultivated area (acres)	Table 1.1 (column 10) [2]
n_farms_100irrigated	Number of farms with area cultivated being 100% irrigated	Table 4.1 (column 8) [2]
p_crop_area_wheat	% of cropped area on wheat	Table 6.7 (column 3) [2]
p_crop_area_rice	% of cropped area on rice	Table 6.7 (column 4) [2]
p_crop_area_cotton	% of cropped area on cotton	Table 6.7 (column 8) [2]
p_crop_area_sugarc	% of cropped area on sugar cane	Table 6.7 (column 9) [2]
p_crop_area_fodder	% of cropped area on fodder	Table 6.7 (column 13) [2]
p_crop_area_veg	% of cropped area on vegetables	Table 6.7 (column 14) [2]
p_crop_area_orch	% of cropped area on orchards	Table 6.7 (column 15) [2]
p_farms_fert	% farms reporting use of fertilizer	Table 7.1 (column 6) [2]
p_farms_pcide	% farms reporting use of pesticide	Table 7.1 (column 10) [2]
p_farms_hcide	% farms reporting use of herbicide	Table 7.1 (column 12) [2]
n_all_hh	Number of all households (HH)	Table 8.1 (column 1) [2]
n_agric_hh	Number of agricultural households	Table 8.1 (column 1) [2]
m_hh_size_all	Average household size (all households)	Table 8.1 (column 2) [2]
m_hh_size_ag	Average household size (agricultural households)	Table 8.1 (column 2) [2]
p_farms_tractors_use	Proportion of farms using tractors	Table 10.1 (column 5) [2]
hg_educ_bpri	% of HH where highest education level is "below primary"	Table 12.1 (column 3) [2]
hg_educ_pri	% of HH where highest education level is "primary"	Table 12.1 (column 3) [2]
hg_educ_matr	% of HH where highest education level is "matric"	Table 12.1 (column 3) [2]
hg_educ_int	% of HH where highest education level is "intermediate"	Table 12.1 (column 3) [2]
hg_educ_dg_plus	% of HH where highest education level is "degree and above"	Table 12.1 (column 3) [2]
hg_educ_none	% of HH where highest education level is "no education"	Table 12.1 (column 3) [2]

Note 1. The data on area and population density come from https://en.wikipedia.org/wiki/Districts_of_Punjab_(Pakistan)
Note 2. The variables from the 2010 agricultural census were obtained from http://www.pbs.gov.pk/sites/default/files/aco/publications/agricultural_census2010/Tabulation%20%28TABLES%29%20of%20Punjab%20Province.pdf

Second, in collaboration with CABI and our local partners, we identified 60 treatment villages using information from the POMS (year of establishment of plant clinics, information on catchment villages benefitting from the clinics, number of yearly visits) and the 2010

Agriculture Census. To do this we followed the following steps: First, using the POMS data, we identified all the existing plant clinics in the 7 selected districts. Then, we excluded plant clinics that had very low number of farmer visits per month relative to their population. We also excluded plant clinics for which we did not have valid GPS coordinates or were located in largely populated villages based on the population counts of the Census. Once we selected 60 plant clinics and the corresponding villages where those clinics were located, we selected a control village for each treatment village located nearby (approximately 5 kilometers or more from a treatment village). We selected control villages near the treatment villages to ensure that agricultural production, agroecological traits, and levels of community and farmer organization were as similar as possible between treatment and control farmers. While it may seem that farmers in control villages could still benefit from a program that is only 5 kilometers from those villages, the POMS data show that there are very few (if any) farmers from control villages who attended plant clinics in nearby treatment villages.

Sampling. Once we selected the treatment and control communities, we selected the actual farmers that we included in the evaluation sample. The final sample included three sets of farmer households: (a) plant clinic users (i.e., farmers who visited a plant clinic at least once in the last year); (b) clinic nonusers in treatment communities, that is, farmers who, despite living in a village where a plant clinic is located, did not visit a plant clinic (non-participants); and (c) clinic nonusers in the control communities (non-eligibles). We identified clinic users from the POMS data, which includes farmer names, location, crop brought to clinic, and phone number. For each plant clinic, we randomly selected 10 farmers who reported attending a plant clinic at least once in the last 12 months. We over-sampled for farmers bringing wheat to ensure there were sufficient observations for the most common crop brought to clinics. Non-participants were identified through a random walk in treatment villages and ensuring those farmers have never visited a plant clinic. Lastly, non-eligibles were identified through a random walk in control villages.

We included these three groups of farmers in order to understand the effects that PW-P has on non-participants as well as on non-eligibles. Using only non-participants in the treatment communities to construct the control group is potentially problematic for two reasons. First, participant and non-participants self-select into the program, which can bias impact estimates, as these may simply reflect fundamental differences between the two groups rather than the impact of the program. Secondly, since non-participants live near program beneficiaries, they may obtain indirect benefits from the program. Nevertheless, non-participants are a potentially useful group because their observable characteristics may be very similar to those of participants given that they live in the same communities where clinic users live. As shown in Section 6, it turns out that non-participants and non-eligibles are very similar in most aspects (i.e., demographics and farming characteristics) and as a result we combined these two groups to form a larger control group to estimate program impacts. Moreover, in Appendix B we re-estimate program impacts by considering only non-participants and non-eligible as a way to test for potential spillover effects of the program for non-participants. As shown, the fact that program estimates are similar for these two group suggests that spillovers are not important for our sample. Lastly, we also conducted heterogenous analysis of program impacts by looking at the subsample of farmers who report having a plant health issue in any of their main crops in the 12 months before the interview.

In Table 3.2, we present the power calculations that we used to guide the evaluation design. The final sample included a total of 1,800 households from 120 communities in Punjab.[1] Moreover, of the 120 communities in the study, half were treated and half were control. We collected data for 10 households in each of the control communities and for 20 households in each of the treatment communities. Within each treatment community, 10 households were clinic users and 10 were non-participants. Using standard assumptions on statistical power and the intracluster correlation of agricultural outcomes within a community, the proposed sample size allows us to identify an effect size of at least 0.21 standard deviations (*SD*) for any of the comparisons of interest. However, given that the design is a quasi-experimental evaluation, the actual minimum detectable effect size (MDES) should be slightly higher than 0.21 *SD*.[2]

Table 3.2. Power Calculations

Assumptions	Value	Comments
Alpha level (α)	0.05	Probability of a Type I error (Probability of a false positive: probability of rejecting that there is no program impact when the true program impact is zero)
Two-tailed or one-tailed test?	2	The null hypothesis is that there is no program impact and the alternative hypothesis is that program impact is different from zero (either greater or lower than zero – a two-tailed test)
Power (1 − β)	0.80	Statistical power (1 − probability of a Type II error): It is the same as the probability of rejecting a false null hypothesis.
Rho (ICC)	0.12	Proportion of variance in outcome that is between clusters
R_1^2	0.15	Proportion of variance in Level 1 outcomes explained by Level 1 covariates

[1] The power calculation determined the need to include 1800 observations. The actual sample size is 1805.
[2] Power calculations for matching methods depend crucially on common support coverage, which is the proportion of observations that have a propensity score that can be observed either in the treatment or in the control group. The more similar treatment and control observations are, the higher the common support coverage and the more similar the calculations of the MDES to those produced by an RCT (McKenzie, 2011). Nevertheless, the exact MDES is close to 0.21 SD given that our empirical strategy allows us to use all observations in sample, unlike other matching methods that only use observations within the common support.

Assumptions	Value	Comments
R_2^2	0.15	Proportion of variance in Level 2 outcomes explained by Level 2 covariates
g*	1	Number of Level 2 covariates
n (average cluster size)	10	Mean number of Level 1 units (farmers) per Level 2 cluster (village)
J (sample size [no. of clusters])	120	Number of Level 2 units (villages)
MDES	0.21	Minimum detectable effect size for each pair-wise comparison (i.e., treated vs. non-participants OR treated vs. non-eligibles). This is the minimum program impact that we are able to identify with our sample size.
Sample size for treated vs. non-participants (A)	1,200	Includes 20 households in each one of the 60 treated communities
Additional sample size for treated vs. non-eligibles (B)	600	Includes 10 households in each one of the 60 control communities
Total sample size (A + B)	**1,800**	

C. Qualitative Methods

We used qualitative methods to understand the program's implementation processes, the changes in the plant health system because of the program, and sustainability. To investigate research questions for each of these themes, we conducted KIIs with national and provincial officials, input suppliers, and local implementers. We also conducted FGDs with agricultural officers (AOs) working as plant doctors for the PW-P program as well as those that were not. Table 3.3 summarizes the design for qualitative research activities.

Table 3.3. Qualitative Research Design

Interview type	Respondent	Type	*N*
Key informant interview	Input suppliers	Control village	4
	Input suppliers	Treatment village	5
	National-level officials		3
	Provincial-level officials		11
	District-level officials	Treatment village	7
Focus group discussion	Agricultural officers (non-plant doctors)	Control village	4
	Agricultural officers (plant doctors)	Treatment village	6
	Farmers	Control village	6
	Farmers	Treatment village	6
Total			**52**

Key Informant Interviews

We conducted KIIs with a variety of informants at the national, provincial, and local levels to understand and compare their perspectives around the program processes, implementation, perceived impact, and sustainability. At the national level, we interviewed three members of the Pakistan Agricultural Research Council (PARC) on the efficiency of program implementation and the potential for sustainability of certain elements of the program, including the Plantwise National Coordinator. We also interviewed the Director of the Crop Disease Research Institute (CDRI) from the National Agricultural Research Centre (NARC). However, we conducted the majority of interviews at the provincial and local level since agriculture decisions primarily take place at the provincial level. In Punjab, we conducted 11 provincial-level interviews, including the Director General of Agriculture Extension, the Director of Agriculture Extension, the Director of Monitoring and Evaluation, and Deputy Directors of Agriculture Extension from 5 districts. In Sindh, we interviewed two deputy directors of extension (See Appendix C for an organigram with the positions of the officers interviewed). Lastly, we also conducted nine interviews with input suppliers working in program and control areas.

Focus Group Discussions

We conducted 10 FGDs with AOs and 12 FGDs with farmers. Focus groups with AOs included both control AOs and AOs implementing the role of plant doctor. AO interviews covered a broad range of themes because of AOs' crucial role in the program. Similarly, focus groups with farmers included both non-clinic users (non-participants and non-eligible) and clinic users and focused on perceptions of program processes and perceived program impacts.

4. Analytical Approach

In this section we present the main analytical frameworks that we used to estimate program impacts, including our plan to analyze the evaluation questions.

A. Quantitative Analysis Plan

To ensure a high degree of comparability between the treatment and control groups, it is important to collect a rich set of characteristics that are unlikely to be affected by the program over time. That helps us to statistically match treatment and control farmers to ensure they are as similar as possible in terms of their observable characteristics. To capture key time-invariant characteristics and retrospective information on farming, we included a short filter questionnaire at the beginning of the household survey to improve the matching between households in the control group to similar farm households in the treatment areas. That is, only farm households that were eligible as potential comparisons based on predetermined variables were part of the sample. The filter questionnaire ensured that survey participants satisfied the following criteria:

- Farmer cultivated wheat (the main crop cultivated in the province) on at least 5 Marla's (125 square meters or 1/32 of an acre) during one of the last two agricultural seasons.
- Farm has between 1 and 12.5 acres for agricultural production.
- Farmer was willing to participate in the interview/survey.

The identification strategy for estimating the causal effects of the program relies on the doubly robust estimator, also known as inverse-probability-weighted regression adjustment (IPWRA), developed by Robins and Rotnitzky (1995); Robins, Rotnitzky, and Lue Ping Zhao (1995); and van der Laan and Robins (2003). At the household level, the proposed approach combines regression and propensity score matching methods in a three-step approach to estimate treatment effects. In the first step, a treatment model is defined that explains the probability of attending a plant clinic. From this step, inverse-probability weights are derived from the estimated propensity score. Second, using the estimated inverse-probability weights, weighted regression models are fit for the outcome equation for each treatment level, and treatment-specific predicted outcomes for each subject are obtained. Lastly, means of the treatment-specific predicted outcomes are computed, and the difference of these averages provides the estimate of the average treatment effect of the program. Intuitively, weighting can be interpreted as removing the correlation between the treatment condition and other covariates that may be correlated with treatment, and regression can be interpreted as removing the direct effect of such variables on the outcomes of interest (Imbens & Wooldridge, 2009). The combination of regression and weighting—known as a double-robust estimator in the literature—leads to additional robustness to misspecifications of the parametric models or propensity score methods alone.

Formally, the estimation process described above is equivalent to estimating the following specification:

$$Y_i = \alpha_0 + \tau T_i + \alpha_1' Z_i + \alpha_2'(Z_i - \bar{Z})T_i + \varepsilon_i \qquad (1)$$

where Y_i is the outcome of interest for farmer *i*; T_i is a dummy variable that equals 1 if farmer *i* attended a plant clinic in the last 12 months before the survey and 0 otherwise; Z_i is a vector of observable characteristics (potentially a subsample of a bigger set X), with sample average $\bar{Z}$. The average treatment effect (ATE) of the program is given by τ. The regression is estimated using as weights the estimated propensity score $\hat{e}(x)$ of a logistic specification for the probability of being in the treatment group (*t* = 1, or having attended a plant clinic):

$$\widehat{\omega}(t,x) = \frac{t}{\hat{e}(x)} + \frac{1-t}{1-\hat{e}(x)} \qquad (2)$$

Note that the specification for the probability of attending a plant clinic may use a different set of explanatory variables than the ones used in the outcome equation (1). We provide more details below. Note that in our preferred specification, the control group is formed by all farmers who have not attended a plant clinic regardless of whether they are located in a treatment or a control village. In the results section, we also present some specifications where we compare differences in outcomes between non-participants and non-eligibles to determine if there is evidence of spillover effects. Finding positive impacts for non-participants relative to non-eligibles would imply that plant clinics generate an effect on those who live in villages with plant clinics even if they do not attend them.

The empirical approach proposed to estimate program impacts assumes that program participation is exogenous to potential outcomes conditional on observable characteristics—that is, that there is no selection bias due to unobserved characteristics and that the observable characteristics we capture determine program participation. Due to the unobservable nature of these potential additional characteristics, this assumption is untestable. Nevertheless, we employ a series of strategies to reduce the potential threat of the impact estimates being driven by unobserved characteristics of program participants. Specifically, in addition to selecting treatment and control areas that are similar in terms of their agroecological characteristics, we use a filter questionnaire to ensure the farmers are similar in terms of key production variables (e.g., crops produced and areas), and we collect numerous covariates as controls that are good predictors of program participation. Several authors have argued that social programs can be evaluated using matching methods as long as (a) there is access to a rich set of variables that determine program participation and (b) the nonexperimental control group is drawn from the same local region as participants (Heckman, Ichimura, Smith, & Todd, 1998; Heckman, Ichimura, & Todd, 1997). We are confident that our proposed empirical strategy allows us to estimate the causal effect of the program on smallholders.

Construction of Outcome Variables: Intermediate and Final Outcomes

Table 4.1 presents the most relevant intermediate and final outcomes used in the evaluation of the program. For each variable, the table indicates its type—whether it is a categorical or continuous variable and the units of measurement—as well as the level at which the variable can be constructed, namely at the crop (C) or household level (H). As shown in the table, almost all outcome variables can be analyzed at the crop level (C), including cultural practices, inputs used (e.g., seeds, fertilizers, pesticides, labor), and productivity (e.g., value of production per unit of area). The outcomes we analyze at the household level are those related to knowledge and practices of pesticide use and probability of receiving agricultural information (by type and source).

Table 4.1. Description of Selected Outcome Variables

Outcomes	Variable type	Variable level
Cultural practices		
Crop rotation, early planting, intercropping, removal of plant residue, use of improved planting material, planting resistant varieties, use of certified planting material, crop monitoring, appropriate use and knowledge of pesticide	Yes = 1, no = 0	C, H
Knowledge and practices of pesticide use	Yes = 1, no = 0	H
Probability of receiving agricultural information (by type and source)	Yes = 1, no = 0	H
Inputs		
Value of seed planted (imputed)	Rs and Rs/acre	C
Value of biological crop protection	Rs and Rs/acre	C
Organic fertilizer used	Yes = 1, no = 0	C
Inorganic fertilizer used	Yes = 1, no = 0	C
Value of inorganic fertilizer used	Rs and Rs/acre	C
Pesticide used	Yes = 1, no = 0	C
Pesticide used in red list	Yes = 1, no = 0	C
Value of pesticides used	Rs and Rs/acre	C
Total family labor days	No. of days	C
Total paid labor days	Rs and Rs/acre	C
Value of paid labor	Rs and Rs/acre	C
Final Outcomes: Productivity		
Yields (quantity per unit of area)	Weight units/acre	C
Value of production per unit of area	Rs and Rs/acre	C, H
Net Income per unit of area	Rs/acre	C, H

Intermediate Outcomes

PW-P's primary focus at the intermediate level is on crop protection, which allows households to avoid and reduce damage from pests and disease. In the short term, farmers who benefit from the program are expected to improve crop husbandry practices and reduce crop damage as a result of changing cultural practices and using inputs (e.g., fertilizers and pesticides) more efficiently. The most relevant intermediate outcome indicators are variables for cultural practice used, value of seed planted, use and value of organic and inorganic fertilizers, use and value of pesticides used, use and value of biological protection (if any), and quantity and value of labor used.

Final Outcomes

In order to measure the long-term effects of the program, we also collected detailed information on crops that are cultivated in an area larger than 125 square meters (or 1/32 of an acre). These long-term outcomes include crop production amounts and market values, which allow us to estimate program effects on yields (i.e., quantities per unit of area), the value of production per unit of area, and net income. Lastly, we also look at expenditures on seeds, fertilizers, pesticides, and labor to determine if the program had any impacts on input costs.

Note that the value of the inputs used were obtained directly from the farmer survey for each crop. In turn, the value of yields is estimated by multiplying the price per kilogram times the quantity produced in kilograms and divided by the area of production. Given there is a large dispersion of prices per kilogram reported, following common practices we used the median reported price for a given crop at the plant clinic area level to construct the value of yields. All area variables are converted to acres to express all monetary values per unit of area in order to facilitate the comparison of farm households with different land extensions.

B. Qualitative Analysis

To analyze the qualitative data, the research team coded transcripts in a qualitative analysis software package (NVivo 12) to identify and develop themes based on our research questions. Coding in NVivo is a manual process requiring careful reading of each piece of data (in this case, interview responses and other notes) and subsequent selection of appropriate codes to describe these data. To maintain consistency across researchers, we selected three transcripts to compare each researchers' coding. While coding, qualitative researchers wrote memos to identify themes from the data that help to answer the research questions. Memos are notes about the coding process and hypotheses researchers develop as they are reading and analyzing the transcripts in NVivo. Once we coded the transcripts, we analyzed the information coded to each theme and compared how the themes were linked using data queries to compare and contrast the data by important characteristics of interest. From this process, we developed written findings, which we support in this report with supporting quotes.

5. Data Collection

In this section, we outline our approach to data collection. All data collection activities flowed through our local partner, VTT Global. VTT is an international organization of strategy and management consultants with headquarters in Islamabad, Pakistan.

A. Training of Data Collectors

AIR worked with VTT to select and train data collectors for quantitative and qualitative data collection. After the finalization of the sample size and data collection locations, VTT recruited the field teams. For the qualitative data collection, a team led by a supervisor was hired and trained. For the quantitative data collection, given the large number of field team members and the vast spread throughout Punjab province, localized teams were hired. Three different clusters were formed for the quantitative teams: Cluster-I from Hafizabad district; Cluster-II from Kasur, Okara, and Sahiwal districts; and Cluster-III from Multan, Muzaffargarh, and Bahawalpur districts. Quantitative data collection was conducted by 20 enumerators distributed into the three clusters, with each cluster having a field supervisor.

The trainings were held in Hotel Pak Continental, Islamabad, over a span of 4 days, October 12–15, 2018 (including pretesting activity). To facilitate easy and relevant learning by the field staff making up the data collection teams, two different sessions were held simultaneously, one for the qualitative data collection teams and the other for the quantitative data collection teams.

The quantitative instrument was a household data collection tool. The training was imparted by AIR and Malik Waseem Awan, a trained agronomist, to the field supervisors and field enumerators. The training session lasted 4 days, 3 of which were devoted to the core training while the 4th day was allocated to pretesting activity in Taxila.

The training for the qualitative instrument was conducted by AIR and Irfan Jalil; the recipients were the field supervisor, moderators, and note-takers collectively. The training session spanned 3 days, 2 of which were devoted to the core training sessions while the 3rd day was allocated to pretesting activity in Taxila.

Prior to field work, the field supervisors were trained on interview techniques and how to select the best practices for obtaining the required information. Given that data collection coincided with the rice harvesting and wheat sowing season, enumerators informed potential farmers about the visit at least a day earlier than the planned area visit. Moreover, prior to undergoing the survey, each respondent was briefed about the purpose of the evaluation. The respondents were assured that the information provided would only be used for the study and that no outside entity would have access to it.

B. Data Collection

Plant doctors of clinics selected for the evaluation sample were contacted and informed a day before the visit to communicate about the data collection requirements and to request facilitation in the data collection. To contact plant clinic users, VTT used a list provided by AIR with information from the POMS. In addition to the year of visit, this list contained the names, contact numbers, addresses, and the crops for which the advice was taken. This list was used to identify and contact the farmers. In turn, non-participant farmers were contacted through the help of a local person of influence known as a Numberdar. The Numberdar assisted in arranging 10 interviews with farmers who fulfilled the criteria and were willing to have their responses recorded. Ultimately, field supervisors and the core staff were responsible for the selection of each farmer. The information collected was reaffirmed by the farmer as well as the Numberdar in order to avoid any errors in selection. Extension officers played a fundamental role in the selection of the control villages. Given the extension officers' knowledge of the area, the core team and the field supervisors selected the control village after discussing the proximity of the potential village. The farm-level survey was carried out using hand-held devices (tablets). The farm survey took between 40 and 60 minutes. The team completed 20 surveys on average per day.

To ensure the quality and integrity of the collected data, all field visits were by VTT's core staff. Field supervisors carried laptops to check that survey forms were completed and correct. Furthermore, VTT employed a three-layered check to ensure that the contact information provided by the farmers was correct. The information was reviewed by the field officers, the supervisors, and the regional coordinator to minimize the occurrence of mistakes and the risk of revisits, thus optimizing time and resource utilization.

Quantitative data were collected using password-protected tablets. All tablets had a SIM card and data connection to send the data to the server in real time. In remote areas, if the connection failed, the system sent the data as soon as the connection was re-established. In addition, the forms were programmed to (a) follow skip patterns present in the instruments, (b) block skipping of questions unless part of the planned skip patterns, and (c) review (with prompts) unusual answers that are likely caused by human error. We used the software Survey To Go to collect the quantitative data.

For the qualitative FGDs, teams comprising two researchers and one supervisor implemented the FGD protocols. One field researcher was responsible for interviewing and facilitating, while the second researcher assumed the primary responsibility for recording responses. During data collection, researchers noted responses in notebooks and recorded all interviews on portable digital recorders. Researchers then downloaded the recordings to a field laptop each day, renamed the recording files according to an anonymized code system, and then copied the files to an external hard drive for backup. These files were then transcribed, translated, and shared with the research team for analysis.

6. Results

Evidence from the impact assessment establishes that PW-P had a number of positive effects on the plant health system. PW-P appears to have added value to government extension systems and data collection. In addition, farmers value the advice they receive from plant doctors and believe it is of higher quality than plant health advice from non-plant doctors. In turn, AOs and other agricultural officers value the knowledge they gain from the plant doctor training. At the farm level, we find improvements in the use of cultural practices and inputs for farmers who use plant clinics. One key finding is that farmers in the treatment group who faced a plant health issue in the last 12 months experienced a positive and statistically significant increase in the value of production per acre relative to farmers in the control group. Lastly, the estimated profitability measures show that PW-P provides good value for money. The following sections, organized by the four primary research questions that guide the study, elaborate on these primary results.

A. Assessing Plant Health System Change

PW-P activities have led to system-level changes in the geographic areas of focus for the evaluation; however, given the size of the program compared to the number of farmers, existing systems, and other external agriculture programs in the country, PW-P lacks the reach, scale, and influence to change systemic approaches to pest and disease control. In addition, respondents indicated that PW-P had not changed how and with whom they interact on plant health, which seem to regularly involve the government as well as research institutions and university experts. In the provinces we studied, officials said that PW-P data align with priorities for farmer extension and supplement the data they collect on production, yields, and soil quality. In addition, all types of respondents valued the training plant doctors received and believe it has improved diagnosis in those cases. Our data do not, however, indicate that these improvements in diagnosis have the reach needed to influence the system or that data collected specifically from plant clinics are used in a systematic way to make provincial-level policy decisions on pest and disease outbreak and response. This section discusses these results related to system change.

GOP Agriculture System Structure

Qualitative data indicate that system structures for pest and disease identification and diagnosis have largely not changed as a result of PW-P, particularly because the government of Pakistan (GOP) already had an established system of interacting between administrative levels of employees within the Directorate of Agriculture, as well as with research institutions and universities. Provincial directors and deputy directors interact at the national level primarily through holding meetings with the Ministry of Food Security and Research and the Pakistan Agriculture Research Council; otherwise, the national level is not heavily involved in implementation or programming. Pest and disease control policies developed at the national level and programs such as PW-P are primarily implemented at the provincial level. According to numerous officials, the Director of Integrated Pest Management (IPM) works with the Director of Extension at the province level to make decisions on pests and diseases. Directors general (province-level), Deputy Directors (district-level) and research officers (national and province levels) said they primarily collaborate with companies, CABI, universities, and research organizations.

Deputy directors lead each of the nine divisions within the Directorate of Agriculture Extension and Adaptive Research in Punjab and Sindh provinces and oversee training and programming related to their division. Their responsibilities include coordinating with field units, collecting reports (including reports to be entered into the POMS), and district-level decision making about IPM and pest response. Assistant directors in each division supervise AOs, who work with field assistants and pest surveyors. Table 6.1 outlines the primary actors in Punjab and Sindh's systems of agriculture and the stakeholders with whom they interact at each level.

Table 6.1. Agricultural System Actor Mapping

Interaction	National	Provincial	District
National actors			
Ministry of Food Security and Research	PARC, CABI	Provincial staff	
Pakistan Agriculture Research Council (PARC)	CABI, NGOs, research organizations	Provincial staff	
Provincial actors			
Directors general	National officials, CABI, universities, research organizations	Companies, district officials	Field staff, plant clinics
Divisional directors		Companies, district officials	Field staff, plant clinics
District- and field-level actors			
Deputy Directors	CABI	Provincial officials	Field staff, plant clinics
Assistant Directors			Field staff, plant clinics

Interaction	National	Provincial	District
Input suppliers			Field staff (AOs), suppliers, famers
AOs		Research organizations	Input suppliers, farmers
Field assistants			Field staff, farmers
Government Pest surveyors		Provincial officials	Field staff, farmers

Collaboration among actors is frequent and strong, but not different as a result of clinics

Respondents indicated their impression that interactions between province-level officials and research organizations are relatively frequent, especially in dealing with pest diagnosis and response. One official described,

> If there is any sudden disease, pest attack on any crop, then plant protection officers, agronomists, pathologists and other scientists sit together and [prepare] an advisory framework for [a] solution, which [is] then further implemented through field teams. Sometimes we have to reframe our advisory. The whole panel of scientists works on it, and not just a single person.

In addition to interacting with research organizations, diagnostic facilities, as well as with CABI on various programs, respondents also mentioned that they collaborate with each other on various other external programs—including ones that focus on soil and water sampling, farmer loans, and mobile phone distribution—that provide information that complements PW-P pest and disease data.

Field-level AOs require more support to respond to farmer needs

Despite the overall strong level of interactions among actors on plant health at the province and district levels, interactions at the field level seemed to suffer from a lack of support for AOs, and as a result, a lack of consistent and sufficient support for farmers. Most AOs said they do not get support on pest and disease diagnosis apart from initial trainings, while some said they receive support from senior officers. Government officials said there is a shortage of field staff—a sentiment which was echoed by AOs and plant doctors. One plant doctor said, "We need staff's support. We are two people who are working, field staff and plant doctor." The shortage of field staff makes regular interactions with farmers less likely, and plant doctor FGDs indicate that plant clinics likely did not increase the frequency of interaction between AOs and farmers.

Plant Clinic Approach and Province-Level Priorities

Government officials said their priorities for agriculture were farmer extension services, farmer well-being, and helping farmers increase their income through value addition and ensuring high-quality pesticides; as such, the primary activities of PW-P both align with and support GOP priorities. When asked specifically about farmer extension services, most respondents said such services were a priority in the province, particularly insofar as they educate farmers about new technologies available in the market. However, one government official respondent pointed out that the shortage of extension staff relative to the number of farmers does not reflect that farmer extension assistance is a priority: "The problem is that [extension] positions are vacant, and every extension officer has 3 to 4 union council [areas], and one person [is] not able to reach to all these places." As indicated previously, plant clinics provided AOs a different mechanism for reaching farmers that would replace field visits on some days; therefore, clinics did not seem to increase interaction between AOs and farmers.

Field-level practices do not always reflect stated priorities

While province-level officials said IPM and environmentally friendly solutions to pests and diseases were a priority, local officials and plant doctors seem to rely heavily on pesticides and information from input suppliers, who get their information from pesticide companies. One plant doctor from Punjab described, "Over here we have different pesticide company representatives/area managers. We both keep a contact because of same interest; i.e., we both try to help farmers." A non-plant doctor extension agent also indicated that they maintain contact with pesticide companies, "The pesticide company's representative visits the field and they are aware of the new pest, crop issues, farmer problem, so they share the information with us. We also ask what pesticide you recommend for a particular crop disease."

Plant doctors also receive information in the form of fact sheets and Pest Management Decision Guides from PW-P. One official said that plant clinics "are playing a crucial role" in IPM-related initiatives on fruits and vegetables at the province level. Respondents mentioned that use of sanitation techniques and sex pheromones to attract male and female insects as approaches to pest control without pesticides. Quantitative data also indicate a reduction in the use of pesticides in cotton among treatment farmers. However, farmers said they primarily use pesticides to address pests and diseases, and plant doctors similarly said they lean toward recommending pesticides. Many farmers said pesticides were the only solution that is likely to work. When asked what happens when somebody discovers an unusual pest in the field, a provincial official said, "Definitely our recommendations go towards insecticides and pesticides." Another official judged that his province was "behind" because of their high use of pesticides and low use of natural pest remedies. Finally, farmers and plant doctors did not describe anything beyond pesticide use as a primary means of pest control. Note, however, farmers primarily using pesticides to address pests and diseases and plant doctors not describing anything beyond pesticides as a primary means of pest control is rather expected as, once you have a pest outbreak, some form of direct control is needed, and pesticides have an immediate effect on the problem.

External challenges affect staff ability to address priorities

In addition to the shortage of field staff and the high use of pesticides, respondents indicated that challenges resulting from forces beyond their control make it difficult to prioritize farmer extension assistance or other methods of addressing pests and diseases. External challenges to pest and disease control included agriculture sector underfunding by the government, frequent land division, and climate change-related issues, including water access. Respondents mentioned that access to enough water for irrigation is a common challenge, as is maintaining the quality of inputs. For example, one respondent said, “Too many companies are in micro nutrients, they are in thousands. The quality control becomes hard for such a large number.” The suppliers we interviewed said they sell quality goods but indicated that prices often prevent farmers from being able to afford supplier goods.

Finally, multiple stakeholders thought proper diagnosis and subsequent recommendation by AOs was a challenge, despite the fact that AOs are trained by the agriculture research institute before every crop season. For the most part, AOs and control farmers said they consult suppliers to understand new types of pesticides and seeds available on the market. Relying on suppliers and pesticide companies for information seems especially problematic given the impression among AOs that an increasing number of smallholder farmers have a limited education; less educated farmers would presumably be less equipped to access and consider information from additional sources that are not motivated by selling products.

Changes to Agricultural Data Collection and Use of Data for Decision-making at district/province level

Government officials and extension agents said they regularly collect and report on agricultural data indicators that complement the plant health-related data collected for PW-P, which seems to have been less systematic in GOP data collection. AOs said PW-P data helped identify and address disease outbreaks and forecast the presence of pests and diseases for other farmers; one AO said, “Yes, it provides us a lot of help. Through this we know that what is the actual problem whether it is a disease or any pest attack and then we give relevant advisory solutions to the farmers.” This section discusses how PW-P data collection has added value to agricultural data collection in the areas where PW-P is implemented.

PW-P data collection complements GoP field-level indicators

Respondents said GoP data collection at district level involves compiling general information on employee activity compliance (such as farmer visits and seminar attendance) and project reporting on land and agriculture indicators (such as pest count, soil and water reports, total land area, and how much area in a village is cultivated for crops). AOs said they compile weekly reports on those indicators, hold weekly farmer meetings, and send daily emergency reports. One respondent described collecting data during pest scouting activities:

> Yes, we use numeric data. We keep the record of the data like [the location of] the pest attack, what type of pest it was, what was the pressure, and what was our recommendation. We keep the record of farmer registration cards. We keep the record of the distributed seeds and seeds kits which had been given to farmers. We keep E credit and soil sampling record.

Many officials spoke of data collection as combining government indicators and PW-P indicators (collected through clinics, as described in section B), indicating that data collection at the district and tehsil levels[3] is perceived as a single activity rather than separate program and government activities. One AO said, “Sometimes we gather the data from our stakeholders, i.e., pesticide companies, CABI and other related farming organization.” Specifically referring to data collection on pests and diseases through plant clinics, another official said,

> We survey our [teams’] work in their jurisdictions. When this whole formation conducts their surveillance then we generate/compile weekly reports. And if there is a serious issue then we take decision on the spot at a daily basis; prescription slips are given to farmer at the spot depending on problem.

Finally, multiple respondents said integrating digital technologies to support data collection is a priority. One respondent provided an example: “We have another project of CABI, in which the farmers send the sample picture through WhatsApp and in response we give them advice for solution. I am bound and responsible to give a feedback to [a farmer’s] question within 48 hours.” However, uptake of technology among farmers and AOs—including for use in e-clinics—can be slow in areas where internet is a challenge and where AOs and farmers prefer to use paper to track data.

One consistent element of data collection and use was that news and knowledge of outbreaks most commonly comes from the farmers and AOs at the field level, though some respondents said they can find out about outbreaks through social media as well. One provincial official

[3] Sub-unit of District supervised by Assistant Director.

described his impression of the process for identifying a pest or disease through plant clinics and other AO activities and taking subsequent action to address the problem:

> The plant doctors access the sample brought by the farmer and [based] on his diagnosis further action is taken. The plant doctors tell the farmers about location and timing of plant clinic. He also tells the farmer to bring the specimen of plant for examination. Initially the field staff diagnose the problem or any pests attack on crop by checking the specimen or plant for their recommendation. This [provincial] office receives two reports—one relating to pests count and other from the plant clinics. We assess both reports and based on these reports we generate [an] advisory on [a] weekly basis. Then this advisory is shared with directors and deputy directors of the area just to let them know what problem can arise in coming days and advise farmers accordingly.

The same respondent said, “The reports gathered from the plant clinics and pest scouting reports helps us in decision making,” but did not indicate the types of decisions made in which cases.

Data reported to provincial level is used to inform farmers of outbreak and response
Officials at the provincial level explained that both clinic and non-clinic data are collected to help the GOP understand a pest or disease, the area that is affected, and how the pest is traveling. Provincial officials said the data are used for general monitoring through the crop-reporting department, and officials regularly collaborate with research organizations to understand new pest and disease outbreaks. AOs generally understand that the data they collect are passed on to their deputy directors, directors, and higher-ups at the provincial level. One AO described generating weekly reports, which are ultimately delivered to the director of integrated pest management and the Pest Warning Department:

> We—our department—generate the data reports by our own. For the major crops such as wheat, cotton etc., we have weekly reports and for minor orchard crops we generate [fortnightly] reports. The main source of getting data are the farmers and our field staff. Our field assistants and agriculture officers visit the farms and meet the farmers and ask their plant disease. Thus, by this way we get the data from farmers, the data which we gather from field, we generate our weekly reports from field data.

For PW-P, the provincial-level director general reported using information from PD forms to understand the plant health situation and to coordinate the supply of farming inputs in the locations they manage:

> This is the information coming from plant doctors; then there’s information coming from our field assistants—that information also comes to me. Then it’s easy for me to see what

> is going on in Punjab, what is going in Lahore, what is going in DG Khan and different localities. Then I can plan. If there's shortage of insecticide, then I have to work with the federal government and input suppliers to say "please, arrange the required inputs for farmers."

Plant clinic data seems to have been recorded and consolidated, though data (from PD forms, specifically) was not linked to a larger data system used to identify and track outbreaks on a national level. One provincial official stated, "I don't know, I haven't gone to the whole system; I am [uncertain] as to whether this is linked with an early pest warning system or not." Part of the lack of knowledge on data consolidation could have to do with staffing transfers, but also more broadly indicates a lack of communication about the ultimate purpose of data collection among officials.

District- and local-level collect and use data to refer to specific cases

Plant clinic data were mostly used by local implementers for use in maintaining individual records and contacts, though there was some use at the district level. Plant doctors used the official diagnosis and prescription forms from CABI to find farmers' contact numbers to be able to follow up with them on their reported issues. A plant doctor explained, "We keep a record of farmers with their contact number. So, when we need to contact farmers, we can get number from record and information about crops too." Data were also used by local implementers to increase the capacity of plant doctors. A local implementer said, "We get the data from the prescription [form] and we give recommendations based on the prescription form. We regularly check the prescription form, if any deficiency then we arrange cluster meetings and workshops for their capacity building. These capacity building trainings helps them in any upcoming adverse situation."

However, none of the responses from the plant doctor level or even the district official level indicated a clear understanding of what the data are specifically used to accomplish. One respondent said generally, "The data which we collect from the field is used for policymaking at central level." Another respondent was slightly more specific, indicating particular departments that utilize data from the field: "Patwaris,[4] [the] revenue department, and [the] statistics department use the data. The food department takes a very packed report from us, [and] from that they prepare/develop the procurement strategy."

Data contributes to pest response, but direct link to decision making is unclear

The government data-reporting structure enables the identification of a pest or disease to move up through the agriculture system and help determine the proper response given the

[4] Patwaris maintain land use data and serve as accountants.

nature and severity of the problem. Officials said that, depending on the issue, they decide which level should handle the follow-up and develop an action plan, in conjunction with the pest warning departments, extension departments, adaptive research departments and international organizations where necessary. A respondent from the national level described the process of identifying and subsequently communicating the follow-up actions to address *Tuta absoluta*:

> First, we identify [pests] to see the localized problem and then when we see it unresolved, we raise the level from the county level to the district. If the situation is alarming, we usually create an emergency …
>
> …likewise we have been receiving the threats of Tomato Leaf miner "*Tuta absoluta*." We talked to [a representative from CABI's Action on Invasive Project] and told him that we are receiving threats from Afghanistan, as we have tomatoes all around the [country]; therefore, they provide us traps. That's why they have given us the Pheromone traps. [We] installed traps in the tribal areas … and then [went] to support the extension agents of the tribal areas to learn about the pests.

After developing a strategy, officials will recruit staff from the areas to investigate the invasion and create a team to control the outbreak. Control measures include reaching out to farmers and suppliers, updating district offices on progress, and continuously identifying hotspots.

Many respondents indicated that it is challenging to ensure that information reaches farmers after an outbreak. One official said,

> The information sharing—like white fly and other insects—such information doesn't reach the lower level quickly. This information is shared with Secretary, DG, then director and then district tier. Since the flow is slow, the damages/losses increase and we don't know [about it]. If the flow is quick and information reaches grass root earlier, the system could be better.

Respondents said they currently focus on communicating information to farmers via demonstration plots and field visits, which are available only to a fraction of the farmers in each area given the low ratio of field staff to farmers. Other respondents said farmers are made aware of challenges through social media (where accessible)[5] and through announcements over the loudspeaker at local mosques. We elaborate more on the specific use of PW-P data for disseminating information on pests and diseases throughout the data management discussion in the following section.

[5] 95% of farmers in our sample own a mobile phone

B. Assessing the Implementation of PW-P

Our analysis found that overall the plant clinics were implemented as intended. The training successfully prepared AOs to act as plant doctors in the plant clinics and provide relevant advice to farmers. Initially participation in clinics was low, but it increased over time, possibly because of targeted initiatives to increase uptake, including establishing quotas for farmer attendance (five people per session). While plant clinics provided a different way for farmers who are most in need to connect with AOs/plant doctors in an environment that was more accessible, consistent, and approachable, plant clinics most likely did not increase the number of farmers that AOs were able to connect with on a weekly basis. The plant clinics continue to be challenged by the workload placed on AOs to run the plant clinics, the physical setup of the clinic, providing recommendations that are affordable for farmers, and connecting PW-P services to women farmers. We describe each of these findings in greater detail below.

Clinic Implementation

All plant doctors implemented plant clinics on a weekly basis, but there was variation in when the clinics were open. Plant doctors said they held plant clinics at various times of day. One plant doctor explained the variation as follows: "[The] clinic starts at 10 o'clock and ends at 2 p.m. having 4 chairs and forms for writing data under one umbrella where 5 to 10 farmers come normally, and this could be extended up to 3 o'clock." There are limited data on the duration of individual sessions with farmers,6 but one plant doctor said their session lasted 15–20 minutes.

The main strengths of the weekly clinic logistics were that the location and time were consistent and that the format provided farmers with direct access to AOs in a more neutral space. Areas for improvement included the workload given to AOs to participate in the program and the physical setup of the plant clinics.

Location and timing create direct connection to plant health support

By locating plant clinics in the markets, the plant clinics also increased AOs' direct contact with farmers, strengthening the relationship between AOs and farmers. The plant clinics offer the only time in which an AO is available for consultation in a public space. This provides a unique opportunity for farmers to approach plant doctors in a space that farmers find more approachable. A provincial official explained,

> Sometimes our farming community [hesitates] to visit the extension officer`s office. But when the same extension officer visits the plant clinic, then even small farmers visit and ask for the [services]. The farmer can easily visit, and he can discuss his issues with the plant doctor in a friendly environment.

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[6] Data on individual farmer session start and end times should be available on prescription forms.

Holding the plant clinics at a regular time also allowed farmers consistent access to plant health advice. Prior to the program, farmers did not have direct access to field staff from the agriculture department. Plant doctors held plant clinics on the same day of the week to help provide regular access to support. A local implementer explained,

> Establishing plant clinics was really a good step, the clinic is running once a week and the day and time of the clinic is fixed. Table, chair and green umbrella is available at clinic. It's quite easy for farmers to find the plant doctors at the clinic on that defined day. They bring the diseased plant specimen to the clinic and get advisory solutions from the doctor.

Farmers confirmed that regularity was helpful for knowing when and how to access plant health services. One farmer said, "The farmers know that the clinic is set up on Thursday at a particular place and they are aware about that, those who are not aware of the plant clinics also visit. The farmer believes that we the plant doctor[s] will be available at plant clinic that's why they visit."

This increased opportunity for exposure seemed to create a more established and open relationship between farmers and plant doctors. One plant doctor described the plant doctors' satisfaction with how the program improved their relationship with farmers:

> It has been a great experience to get closer to the farmers and to know about the on-the-ground realities and problems farmers [have] in their daily routines. There has been an improvement in coordination with those farmers who for some reasons were unable to visit us in our offices. The visibility has improved direct contact with farmers.

AOs find it challenging to manage regular work and plant doctor responsibilities

AOs struggled to implement their responsibilities as plant doctors on top of their existing work without additional incentives. PW-P relied on AOs to perform plant doctor responsibilities in addition to existing AO responsibilities. AOs said it was too much work to perform both duties without incentives or support provided by additional project staff. One plant doctor said, "Our 70% concentration is on our weekly internal reports and our 30% time is for plant clinics. We are [overburdened]. We are unable to run the program efficiently." In a small minority of cases, plant doctors reported that they were not able to staff the clinics because of their conflicting responsibilities. In these instances, plant doctors relied on field assistants to run the plant clinics. A plant doctor who was not always able to attend the clinic said,

> Our plant clinic working hours are from 8AM to 3PM. I try my level best to be at the plant clinic all the time to give advice to farmers. Although we have a field assistant at the clinic, the assistant doesn't have the capacity to diagnose pests. If I am on a field

> visit or go somewhere else for meeting etc., then he contacts me through the phone and he discusses the farmers issue with me and I give him recommendations.

One provincial official noted that when field staff run plant clinics, it is more likely that the advice is lower quality:

> In plant clinics the agriculture officers working as plant doctors are much better [than] those being run by field assistants. In the absence of an agriculture officer, the field assistant runs the plant clinic. The results are that plant clinics run by agriculture officers are much better than [those run by] field assistants. My suggestion is that only agriculture officers should be plant doctors.

Government officials and plant doctors suggested that the government hire non-AO staff to manage plant clinics, as the high responsibility placed on AOs could reduce the quality of their work as AOs and for PW-P.

Farmers and PDs suggest improving the physical setup of clinics

The physical setup and the location of the plant clinic could also be a challenge, according to several informants who reported that the logistics did not always meet the needs of plant doctors and attending farmers. Many plant doctors said the physical setup of the plant clinic did not meet their expectations, including the number of chairs and the quality of the umbrellas. The number of chairs was also described as a barrier to uptake because there were not enough places for more than four farmers to sit. One farmer explained that if there were not enough available chairs, farmers would not participate: "The sitting space at the plant clinic is not sufficient. They have 2–3 chairs and 1–2 benches which [are usually] occupied. And we have no space to sit and wait for our turn. Due to this, we don't take advice from the plant doctors."

Another plant doctor described how the umbrella was not helpful in providing shade to plant doctors and farmers: "The umbrella is just a symbol; it does not provide proper shadow because its size is small. We feel unsecure at the plant clinic. Do you know how high the temperature gets in Multan? Only a mad person can sit in such a heat in Multan and run a clinic." Other plant doctors also reported challenges with the plant clinic location. One plant doctor said, "The sitting place is not conducive for working. We have to sit roadside in a dusty environment," while others said some locations did not provide access to a washroom.

Uptake of Plant Clinics

The plant clinics were intended to increase farmers' access to plant health services. We found that while AOs indicated that plant clinics were regularly attended, the clinics did not necessarily increase the total number of farmers that AOs worked with on a weekly basis. Control group AOs reported working daily with 6–7, 10–15, and 20–25 farmers. AOs working as plant doctors saw a similar number of farmers at the plant clinics; they reported working with 5–6, 6–10, 10–12, 15, and 10–15 farmers per day at the clinics. One plant doctor stated that the majority of interactions with farmers actually take place outside of plant clinics: "On average we advise around 160 farmers per week but in [the] plant clinic we interact and [advise] around 5 to 6 farmers a week." While plant clinics provided farmers a different type of access to AOs, clinics do not appear to have increased how many farmers AOs support in total. This section presents perceived strengths and challenges with clinic uptake.

Accessible location increases likelihood of uptake

Locating the plant clinics in the market made the plant clinics easy for farmers to access. The market is a common location that is generally easy for farmers to access, particularly because they often visit the market to purchase goods. One farmer said, "The plant clinic is accessible. We have to visit the market in any case, [so] the placement of [the] plant clinic in the market is a useful technique." This sentiment was echoed by a plant doctor who noted that plant clinics are also close to where farmers live: "The plant clinics save time of the farmer as he is sitting in an area near to farmer, so the plant doctor is easily approachable." Locating plant clinics in the market also made it easier for plant doctors, since they did not have to conduct field visits to support farmers.

Uptake increased over time as farmers became familiar with the new concept

Plant clinics initially struggled to have high farmer participation but managed to increase uptake over time. Most officials said clinic uptake was initially low because farmers were hesitant to approach the plant clinics or thought doing so would be a time-consuming process. An input supplier confirmed that uptake was slow initially, explaining that it took time for people to understand and access the clinics. The supplier said, "The plant clinic was a new concept. Initially the farmer was not aware what is plant doctor. Even we the dealer was not aware what is plant doctor. It been 4 years when I met the first time with plant doctor." Government officials responded to these uptake challenges by providing some farmers with cell phones as well as instituting participation quotas at clinics. One official explained how participation quotas were set up to increase farmers' participation:

> P[7]: Earlier the farmer visit frequency was very low, so we fixed that five farmers must visit a single plant clinic per week.
>
> I: How did you decide that it had to be five farmers?
>
> P: It is the minimum criteria; the number can increase but this is the minimum standard. If the agriculture [officer] is placed in the field … and no farmer visits, then it is considered as

[7] "P" in transcript text signifies the participant or the person being interviewed while "I" signifies the interviewer.

> an economic loss. So, we decided to follow these criteria of five farmers per clinic. The field staff was instructed to create awareness [of] the plant clinics among [the] community. This strategy has worked and since then the number of visits has increased.

Over time, plant clinic attendance increased. One official explained,

> In the beginning people were reluctant to visit the plant clinics but slowly the trends have changed; now more farmers visit and seek help from plant clinics. The response of farmers in the cotton area is better in comparison with areas where other crops are grown. Through our farmer training program, we are spreading the information; that these plant clinics are for the benefit of farmers.

Most treatment farmers reported that they did access plant clinics during the program for plant doctors' advice. The only group of informants that reportedly did not use the plant clinics frequently were older farmers. One farmer stated, "The older are not visiting." Several farmers stated that older farmers are more likely to rely on their own experience and use traditional methods.

Awareness of plant clinics is still not widespread among farmers

The plant clinic media campaign was not large enough to generate significant awareness of the plant clinics. Information about plant clinics was delivered by plant doctors through loudspeakers, Facebook, and print media. The communications included the time the plant clinic would be held and the fixed location. Plant doctors stated that several farmers in the area near the market remained unaware of the plant clinic or did not know where to find an AO on the day of the plant clinic:

> When some people see the umbrella then they ask what is this place for. Some of the farmers are already aware about the plant clinics, but some say, "What are you doing here? We went to your office but you were not there. What are you doing under umbrella?" When I told them that we are here to help you out—come, and we will let you know about the pests and disease which can affect your crops, they said, "You can tell this to us in our village. Why we should come here?"

Plant doctors and government officials thought the awareness efforts were insufficient and suggested pursuing broader efforts to inform farmers: "Awareness campaigns must be launched to spread more awareness so that more and more farmers come to the clinics."

Low uptake by women because of distance and lack of female plant doctors

Plant clinics did not affect women farmers' access to plant health services. Women farmers did not access the plant clinics. One plant doctor stated, "In this area it's mostly small-scale male farmers [who] visit us. Females don't visit us" and suggested "if we have mobile van, we can access many females." Respondents cited two obstacles to women's attendance: (a) the distances women must travel to get to the plant clinic and (b) the fact that nearly all plant doctors are men. Expanding on the challenge of traveling as a woman without additional support, one of the few woman plant doctors explained, "I have one genuine problem we are females we have transportation problem. Government don't provide us conveyance. It's quite difficult for me to come to this village as a female without proper conveyance. Government should facilitate us on this regard."

Plant Doctor Training

Implementers stated that the logistics of the plant doctor training were implemented as intended. PW-P used a cascading training model to prepare AOs: CABI supported a master trainer to train several individuals who then led trainings with AOs. Provincial officials confirmed that the program training lasted 1 week and covered multiple modules. Provincial and district officials also confirmed the trainings included a large number of AOs.

The trainings also prepared AOs to act as plant doctors and provide high-quality advice, including proper diagnosis and prescriptions. Local program implementers believed that plant clinics ran smoothly after the training. One trainer said, "I trained almost 350 people in different districts of Punjab. Now all of them [plant doctors] are smoothly operating their plant clinics and generating data on a daily basis." One provincial official said that plant doctors were well prepared because after the training they were able to "solve plant problems." The official continued by saying that the plant doctors "have the practical knowledge regarding the pests, their mode of attack, conditions, favorable things to increase their population, biological control." Another provincial official also said that plant doctors "do not make confused decisions and they provide proper description" and are able to make effective diagnoses as a result of the training.

Plant Health Advice

The main plant health issues farmers discussed in plant clinics included how to deal with pests and how to select and use farming inputs such as pesticides, seeds, and fertilizers—often farmers sought advice on both. A farmer described the experience of receiving advice at a plant clinic in this way: "There is a plant clinic where they sit. I go there and take advice. We tell them that my crop is destroyed or there is a pest attack. We ask them what we need to do and ask them to come with us." Most farmer consultations had to do with insects and weeds. A smaller number of farmers sampled for FGDs said they reached out to plant doctors for advice on water-related issues. Control farmers were also asked how they would use clinics if they could access them. Similar to clinic users, most control farmers reported that they would seek advice on crop problems, disease outbreaks, which inputs to use, and how to cultivate plants.

Most farmers were able to consult plant clinics for advice on any topic. One farmer stated, "I always consult plant doctors." Other farmers described two additional circumstances when they might not bring a problem to a plant doctor: when they are too busy to attend a plant clinic and when the problem is minor. One farmer explained that farmers rely on their own expertise to deal with minor issues: "Now we have enough of understanding and experience, so for minor issues we are not consulting the plant doctors, we know the solutions we resolved it by our self."

While most farmers used plant doctors' recommendations, they experienced mix results implementing the recommendations. There were farmers who reported using the recommended pesticides, fertilizers, and practices (irrigation and cultivation) successfully. For example, one farmer stated, "I asked them about a disease they prescribed a spray (pesticide). I bought it from the dealer, applied it and it worked and showed good results." But other farmers had experiences where plant doctors' advice did not work. One farmer said, "I told them about a pest which hasn't been controlled since now. Their advice did not work." Farmers generally evaluated the credibility of plant doctors' advice by how well their recommendations solved plant health problems. When the recommendations did not work, farmers said they might be less likely to go back for advice: "I usually go there for recommendations, but if the pesticide does not work then I do not go back again with the same problem."

Plant doctors focus on providing proper prescriptions

The main strength of plant doctor recommendations was their increased focus on providing relevant, more specific plant health advice to farmers. Plant doctors provided farmers advice with a greater focus on providing proper prescriptions. Plant doctors and government officials said farmers received quality advice on plant health issues and proper use of inputs from plant clinics. Plant doctors said their advice was of high quality because they provided improved prescriptions to farmers. For example, one plant doctor explained why the advice provided at plant clinics is better than the advice provided by pesticide dealers:

> Earlier dealers used to give long prescriptions to farmers, and if one spray didn't work so they prescribed another spray. If still pesticides were not effective so they used to get another pesticide their expense increases through this, but whenever we recommend some pesticide, we recommend it with proper tool and chemical composition which is effective in killing pesticide and we have guidelines provided by plant-wise so we recommend accordingly.

Government officials also reported that advice from plant doctors was "more specific" and "relevant." Plant doctors were able to address farmers' needs in plant clinics by providing good advice based on their education and experience. One farmer said, "They have the experience as well as the educational background required to solve our problems," while another farmer stated, "Yes, they are meeting my needs based on my personal experience. I have always received good advice."

Farmers in many cases are unable to purchase recommended inputs

Many farmers were unable to purchase the inputs plant doctors recommended because of their socioeconomic status, limiting the impact of the plant clinic recommendations. Some farmers said the inputs recommended were too expensive, particularly for farmers with small plots of land. One farmer said, "They recommended fertilizer amounting to Rs. 7000 for just 4 kanals[8] of land, and this costs us too much." Plant doctors also thought the plant clinics may not benefit farmers unable to afford pesticides. One plant doctor said, "The local farmers are poor, and they are not in a position to buy any pesticides, chemical etc. I haven`t noticed any positive change after the establishment of plant clinics." Another farmer said that because the inputs were expensive, farmers did not adopt the advice the plant doctors gave them: "I did not get much help as solutions recommended to us were expensive and unaffordable. They diagnose the disease that's affecting the crops."

Use and Uptake of PW-P-Specific Online Tools

Plant doctors consistently filled out paper prescription forms (PD forms) during plant clinics that were digitized and entered into the POMS system. The forms were useful for plant doctors, local implementers, and provincial officials, but—as indicated in the systems-level section on data collection—were not used at the national level or integrated into national systems. There is also low reported use of the Knowledge Bank and the data compiled in POMS according to familiarity with and reported use in the qualitative data, though participants noted the potential utility of the systems. This section reports results on the management and use of data gathered specifically using PW-P tools through clinics – by the field staff directly involved in clinic operations.

Use of the Knowledge Bank is low at the local level

While plant doctors and government officials largely agreed that the Knowledge Bank is useful, very few accessed or used it. Of the different types of participants, local implementers most frequently reported using the Knowledge Bank. Agricultural officers noted that the colorful visuals helped with diagnosis: "Yes, it is very helpful especially when we see the colorful picture of the pests then we can easily understand and identify the pests and diseases."

Many plant doctors said they knew what the Knowledge Bank was, but very few accessed it. One plant doctor said, "I am not using Knowledge Bank, but I heard its name." A local

[8] Approximately 2,023 square meters.

implementer agreed that there should be greater support for wider uptake of the Knowledge Bank and suggested promoting the website link more broadly:

> My advice is to create a publicity of it. People should be made aware of its importance and they should be given access to the benefits that it provides. It should be provided to them through internet and the link of its website should be promoted and they must know of it has a source of information. Its awareness [is] crucial and they should know that it is just like google but it has local data that can help them a lot.

The Knowledge Bank was helpful for officials and plant doctors because it combined all relevant knowledge into one location that was easy to access. The two plant doctors who reported using the Knowledge Bank accessed it to support their diagnosis of plant health problems. A plant doctor explained, “In a case, if there is a new disease and I don’t have much knowledge then I use Plantwise website to get knowledge about disease and if we can cure the disease through cultural methods then I look for it.” Government officials also said they were able to access easy solutions through the Knowledge Bank. One official stated, “Yes, immediate and quick solution. It works as a consultant. You never need to go to anyone. You just have to open the website and visit the page with the required information.”

Prescription forms are useful and understandable

Farmers, plant doctors, and government officials in our sample confirmed that plant doctors provided farmers with PD forms during the plant clinic. Farmers described that PD forms included the name of the pest or disease, the recommended product, how to use the product, and precautionary information about the product. Farmers then used the forms to get recommended inputs. One farmer said, “Yes, as prescription is about medicine and how it is to be used. The application is recommended on the basis of the direction of the wind.” One farmer also said they take the form to input suppliers to provide the product.

Nearly all provincial officials found the PD forms to be comprehensive and useful. For interviewed officials, the most useful sections were those containing information on the type of disease and the recommendation the plant doctor provided to the farmer. By looking at these sections, officials could see if “recommendations are in line with the problem.” Officials also stated the forms were helpful because they were relatively short and did not require much time to fill out. One official explained, “No, I think it’s ok, forms have to be short. People are short of time. If forms are long then they won’t come, because farmers are short of time. In a short duration, you have to guide them and collect information.”

Data indicated only minor initial issues filling out the PD forms. One local implementer said, “Initially they had some issues, but now they are used to the prescription form and they fill it correctly. It is started in 2014 and they are trained now.” There were no other reported issues with PD forms, besides one comment from a provincial official who underlined how the quality of the PD forms depends on the capabilities of the person filling it out: “Although, their performance is not at an equal level. We have 665 plant clinics—we trained them in the same system, but every person has different capacities, then delivering is also different.”

Use of the Plantwise Online Management System (POMS) is low and inconsistent
Overall, there was limited use of the POMS data by national and provincial officials[9]. The majority of participants reported that they did not access the POMS for their plant health work. One provincial official stated, “I have never used this system, because I have a lot of work and I am busy.” Participants state that it is mainly used for data entry and is not used broadly across government divisions. When asked whether the POMS was used, one official said, “Not at the moment. Right now, it is just limited to data feeding.”

A minority of local implementers and provincial officials working in data management did report using the POMS to support plant doctors’ knowledge, to understand pest prevalence, and to connect to the large plant health system. One provincial official acknowledged using the POMS to crosscheck data and track pest prevalence: “Yes, I use it with the help of my assistant. We utilize the POMS, for validation of data, and for field preparation for example, we build our understanding about the abundance of pests on crop and plan accordingly.” Participants reported that the POMS approach is strong because it connects stakeholders in the plant health system and is easy to use. A local implementer said, “I have no problem and challenges while using the POMS. It is very simple and every extension officer can easily use this system.”

Characterizing Plant Clinic Users

We end this section on the implementation of PW-P with a characterization of the type of farmers that use plant clinics. We used data from the farm-level survey to characterize plant clinic users and two groups of nonusers (non-participants and non-eligibles). That is, we compare the observable characteristics of those who attended a plant clinic at least once in the 12 months before the survey (clinic users) to the observable characteristics of those who did not attend a clinic but live in a village with a plant clinic (non-participants) and of those in villages without plant clinics (non-eligibles). Table 6.2 shows the mean of key observable characteristics for these three groups of farmers. We also regressed each characteristic on a dummy for clinic users, a dummy for non-participants, and the district fixed effects. The standard errors are clustered at the village level. In column 2, in addition to reporting the average of each variable for non-participants, we report whether the difference between non-

[9] Since the time of data collection, PW-P has created the POMS accounts at all levels and the Plantwise Factsheet app is available to every plant doctor.

participants and non-eligibles is statistically significant. Similarly, in column 3, we report whether the difference between plant clinic users and non-eligibles is statistically significant.

Overall, it appears those who attend plant clinics in treatment areas are better off than farmers in either of the other two groups. Compared to farmers in control villages (non-eligible) (see column 3), those who use plant clinics:

- Have larger farms
- Have more household members
- Have a larger proportion of members in their prime age (15 to 64 years old)
- Have more years of education
- Are more likely to state that their most fertile parcel is very fertile
- Are more likely to own agricultural equipment, including a planter, thresher, and tractor
- Have a higher asset index
- Have a more rooms in dwelling
- Are less likely to use firewood as a source of energy
- Are more likely to have their own flush toilet in house

By design, those who attend plant clinics are closer to plant clinics than those in control villages (non-eligible). Moreover, there is no difference in the average distance between those who attend plant clinics (users) and those who do not attend but live in plant clinic villages (non-participants).

Interestingly, there are very few differences between non-participants and non-eligibles. Specifically, compared to the group of non-eligibles, non-participants have slightly larger farms, have more years of education, and live in dwellings more likely to be made of more durable materials. For all other variables, there are no differences between the two groups. Thus, for our main estimation results below in Section 6C, we combine the two groups of nonusers of plant clinics into a larger control group and compare the results against those who attend plant clinics.

Table 6.2. Descriptive Statistics (Means) for Farmers by Treatment Condition

	Non-eligible (1)	Non-participants (2)	Plant Clinic Users (3)
Area of production (acres)	4.42	4.79*	5.37***
How many people live in the household	7.77	7.92	8.22*
% household members aged between 15 and 64	0.64	0.63	0.66

	Non-eligible (1)	Non-participants (2)	Plant Clinic Users (3)
Years of farming experience	22.61	21.41	21.43
Head married	0.93	0.92	0.95
Highest grade HH: primary	0.24	0.17**	0.16***
Highest grade HH: 6th to 8th	0.18	0.17	0.16
Highest grade HH: 9th to 10th	0.19	0.24**	0.32***
Highest grade HH: 11th or more	0.13	0.14	0.19***
Main occupation—ag and livestock	0.96	0.96	0.97
Irrigation any parcel	0.90	0.90	0.89
Most fertile parcel—very fertile soil	0.78	0.79	0.83*
Steepest parcel is flat	0.97	0.95	0.96
No erosion on most eroded parcel	0.87	0.87	0.87
HH owns a planter	0.06	0.05	0.10**
HH owns a thresher	0.08	0.08	0.12*
HH owns a tractor	0.25	0.28	0.40***
Asset index	-0.10	-0.04	0.17**
Roof made of: brick tiles	0.73	0.70	0.71
Number of rooms	3.63	3.68	4.14***
Walls made of: burnt brick	0.50	0.56**	0.53
Floor made of: concrete only	0.29	0.27	0.32
Floor made of: bricks	0.11	0.15**	0.16**
Main source of drinking water: own tap	0.35	0.34	0.31
Energy used for cooking: collected firewood	0.58	0.56	0.50**
Main type of toilet facility: own flush in house	0.85	0.86	0.88**
Distance to plant clinic (km)	5.59	4.01**	3.8**
N	599	600	606

Note. Table shows descriptive statistics for three groups of farmers: those in control villages (non-eligible), those in treatment villages who have not attended a plant clinic (non-participants), and farmers in treatment villages who have attended a plant clinic at least once (clinic users). Stars next to means in the "Non-participants" and "clinic users" columns indicate a statistically significant difference between that group and the non-eligible group estimated through a regression that controls for district fixed effects. $^*p < .10$. $^{**}p < .05$. $^{***}p < .01$.

C. Identifying Farm-Level Impacts

The process through which PW-P is implemented improves knowledge at multiple levels through accessible diagnosis for farmers, improved training for extension officers, and data collection to help understand where diagnosis could be improved in the short term and where the system should address problems in the long term. In this section, we investigate to what extent PW-P is able to translate the institutional changes in the plant health system and the process through which the program is implemented into measurable impacts at the farm level. We find that PW-P has some positive impacts on agricultural practices, on knowledge and practices for pesticide use, and the yields and value of yields for farmers with plant health issues. Before presenting program impacts, we assess the quality of the counterfactual we use in this evaluation to estimate program impacts.

Quality of the Counterfactual Group

We begin this section by first assessing the quality of the combined control group that is used to estimate program impacts. We provide a clear description of the steps that were taken to ensure that the treatment and control groups were as similar as possible in their observable characteristics. We conclude that the data collected allowed us to construct a good counterfactual for plant clinic users as long as we used all nonusers as part of the control group (non-participants and non-eligibles).

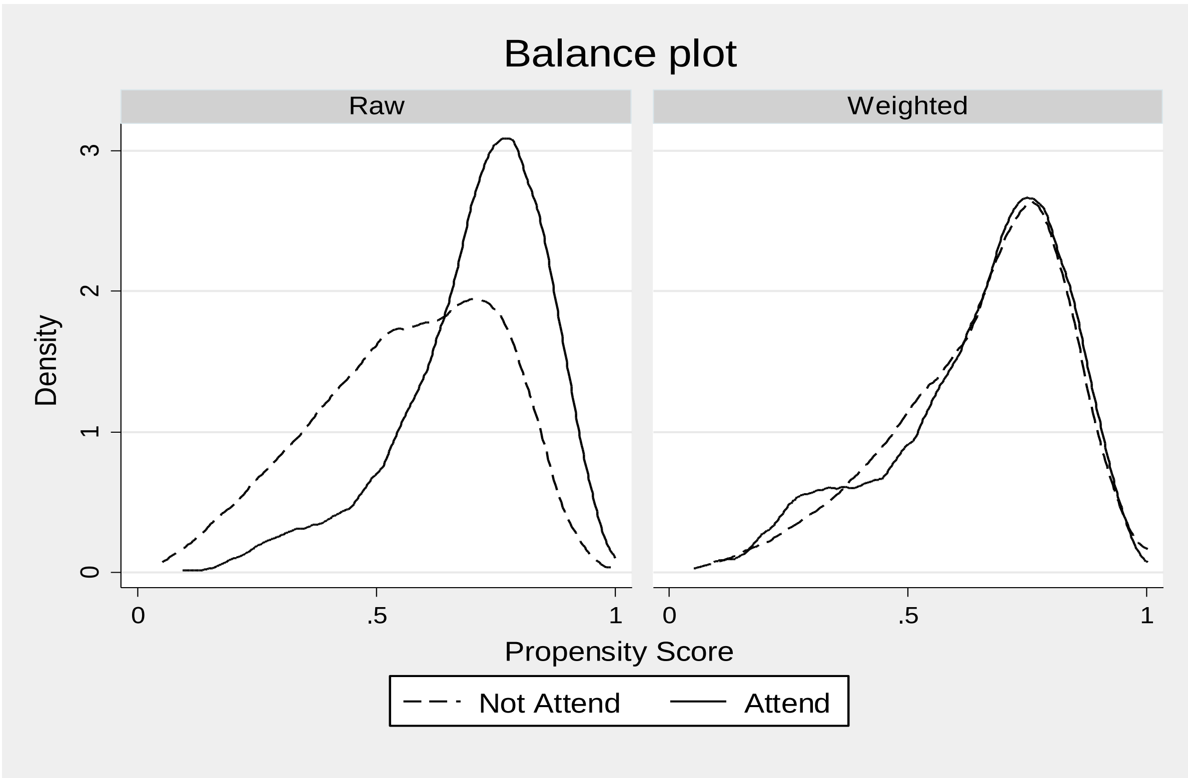
The construction of the treatment group started by pairing each of the 60 selected treatment villages to a nearby village that was not served by a plant clinic and could be used as a pure control village. This matching process was a first step to ensuring that the agroecological conditions of the treatment and control villages were as similar as possible. Nevertheless, matching villages does not guarantee that the individual farmers within these villages are similar. Thus, to increase comparability beyond the study site selection, we included a short filter questionnaire at the beginning of the farm survey to capture key time-invariant characteristics and retrospective information on farming to improve the matching of households in the treatment group and households in the control areas.

The overall results presented in Section 6B show that farmers who attend plant clinics are better off socioeconomically than farmers who do not attend regardless of where they live. The reported differences in observable characteristics could be an indication that there are differences in unobservable characteristics between those who attend and those who don’t that may ultimately bias estimates of program impacts. In Figure 6.1, we plot the predicted probability of attending a plant clinic obtained by running a logistic regression of the dummy of plant clinic attendance on the variables presented in Table 6.3. The balance plot below shows that, as expected, the predicted probability of those who attend a plant clinic are to the right of the probability of those who do not attend.[10] This difference in the distributions of the predicted probabilities of clinic attendance motivates the use of the IPWRA empirical strategy discussed in Section 4. It is reassuring for the identification strategy that the weights that will be

[10] As discussed above, the control group is formed by farmers who have not attended a plant clinic; that is, those from control villages (non-eligible) and those from treatment villages who have not attended (non-participants). Unless noted otherwise, we refer to the control group as the one formed by farmers in these two categories.

used in program estimation also produce very similar densities of the propensity score, as shown in the right-hand side of Figure 6.1.

Figure 6.1. Balance Plot



Note. The Attend group corresponds to clinic users. The Not Attend group is the one formed by non-participants and non-eligible.

Although the weighted propensity score looks balanced, which means that the propensity of attending a plant clinic between the treatment and control group is very similar after reweighting, that does not necessarily imply that the individual variables used to estimate the probability of attending a plant clinic are balanced. Thus, to further assess the comparability of the treatment and control groups, we assess the balance of each one of the variables with and without weights. The results in Table 6.3 show that the weights derived from the treatment equation of the IPWRA strategy do a good job of making the standardized differences of the observable characteristics close to 0 and the variance ratios close to 1, which is just another way of saying that the weights constructed balance the covariates from the treatment and control groups.

Table 6.3. Standardized Differences in Observable Characteristics with and without Weights

	Standardized differences		Variance ratio	
	Raw	**Weighted**	**Raw**	**Weighted**
Area of production (acres)	0.25	-0.01	1.20	1.03
How many people live in the household	0.10	0.00	1.24	1.06
% household members aged between 15 and 64	0.09	0.00	1.05	1.09
Years of farming experience	-0.05	0.00	0.88	0.89
Head married	0.11	0.01	0.66	0.97
Highest grade HH: primary	-0.13	-0.01	0.81	0.98
Highest grade HH: 6th to 8th	-0.02	-0.01	0.97	0.99
Highest grade HH: 9th to 10th	0.24	0.01	1.30	1.01
Highest grade HH: 11th or more	0.13	0.00	1.28	1.01
Main occupation—ag and livestock	0.06	0.00	0.73	0.99
Irrigation any parcel	-0.03	0.01	1.08	0.97
Most fertile parcel—very fertile soil	0.12	0.01	0.83	0.99
Steepest parcel is flat	0.02	0.01	0.93	0.96
No erosion on most eroded parcel	0.02	0.00	0.95	1.00
Has HH changed crops produced	0.04	0.00	1.09	0.99
HH owns a planter	0.16	0.02	1.69	1.08
HH owns a knapsack sprayer	0.09	-0.02	1.04	0.99
HH owns a motorized sprayer	0.09	0.02	1.15	1.03
HH owns a thresher	0.12	0.02	1.38	1.06
HH owns a tractor	0.30	0.00	1.24	1.00
HH owns a chaff cutter	0.10	-0.01	1.31	0.98
HH owns a greenhouse	0.12	0.01	1.54	1.02
HH owns irrigation equipment	0.04	0.00	1.01	1.00
HH owns a water tank	0.07	0.01	1.03	1.00
Farm asset index[11]	0.12	0.01	1.00	0.93
Roof made of: brick tiles	-0.02	-0.03	1.02	1.02
Roof made of: concrete	0.05	0.02	1.08	1.02
Number of rooms	0.27	-0.01	1.47	1.06
Walls made of: burnt brick	0.01	-0.02	1.00	1.00
Floor made of: concrete only	0.08	0.02	1.08	1.02
Floor made of: bricks	0.08	0.00	1.18	1.01
Main source of drinking water: own tap	-0.07	-0.02	0.95	0.98
Energy used for cooking: collected firewood	-0.14	-0.01	1.02	1.00
Energy used for cooking: purchased firewood	-0.10	0.00	0.86	1.00
Toilet facility: own flush in house	0.08	0.02	0.85	0.96
N	**1,805**			

[11] The farm asset index is constructed using principal components analysis based on ownership of farms assets. It includes the assets presented in Table 6.3 and other less common assets. We include the index as a way to summarize the differences in all farm assets.

Lastly, we formally test for balance by viewing the restrictions imposed by balance as overidentifying conditions (Imai & Ratkovic, 2014). Under the null hypothesis of covariate balance, the test has chi-squared distribution with J degrees of freedom, where J corresponds to the number of variables included in the test. We conducted the test, and the value of the chi-squared statistic equals 33.4, which for 43 degrees of freedom implies a *p*-value equal to 0.85. The results from this test imply that we cannot reject the null hypothesis that the IPWRA model balanced all the 43 covariates. In other words, our estimation model is well balanced, which means that at least on the rich set of observable characteristics we use, the treatment and control groups are very similar.

Production Descriptive Statistics

Before discussing the estimated program impacts on intermediate and final outcomes, we describe some key features related to crop production in our sample. In Table 6.4, we present the distribution of crop production by district. The table includes the most common crops that are produced by at least 4% of farmers in our sample. Wheat is the most common crop across all counties. There is also a large degree of regional variation in terms of crops cultivated. In Hafizabad, for example, rice production is very important, and rice is also a common crop in Kazur and Okara; cotton is widely produced in Bahawalpur, Multan, and Muzaffargarh; and maize is produced in Kasur, Okara, and Sahiwal. Overall, the table shows that wheat, cotton, and rice represent 75% of the number of crops reported in our sample. We thus focus on these three crops in the impact analysis below. Note that there are not significant differences in crop distribution between clinic users and nonusers.

Table 6.4. Percentage of Households Producing Crops, by District

	Most common crops					
County	**Wheat**	**Cotton**	**Rice**	**Maize**	**Millet**	**Berseem**
Bahawalpur	39.3	37.6	0.6	0.3	8.1	7.5
Hafizabad	41.9	0.0	38.3	0.1	7.0	2.8
Kasur	33.3	0.0	15.6	11.3	6.9	11.1
Multan	56.7	32.5	7.3	1.2	0.4	0.0
Muzaffargarh	53.5	31.0	8.7	2.0	0.2	0.2
Okara	34.7	3.3	16.8	15.3	7.1	9.5
Sahiwal	41.5	17.3	7.0	10.6	2.2	2.8
Total (Clinic users)	43.3	18.1	13.9	5.1	4.3	3.7
Total (nonusers)	43.6	17.8	14.8	4.8	4.9	5.1
Total	43.5	17.9	14.5	4.9	4.7	4.6

Note. This table presents the percentage of households by district that produce at least one kilogram of the crop. Only crops produced by more than 4% of the farms are included.

The information provided in Table 6.4 does not consider the size of the area where the crops are produced. In Table 6.5, we present the average area used in the production of some selected crops and the number farms that produce the crop in areas larger than the specified threshold of 1/32 of an acre (125 square meters). The results show that the average area used to produce wheat in our sample is 4. 8 acres, which is similar to the area used for rice production. Cotton is usually produced on 3.7 acres, maize on 2.7 acres, millet on 1.4 acres, and berseem on 1.1 acres. In terms of the number of farms for which we collected production data, we see that we have relatively good sample sizes for wheat (*n* = 1799), cotton (*n* = 738), and rice (*n* = 600) to estimate program impacts. However, for the other crops reported in the table, the number of observations is rather low for detecting program impacts. Thus, when estimating program impacts, we focus our attention on the three main crops.[12]

Table 6.5. Average Area of Most Common Crops (Acres)

	Control	Clinic Users	Total
Wheat	4.6	5.4	4.8
	[1,197]	[602]	[1,799]
Cotton	3.5	4.2	3.7
	[487]	[251]	[738]
Rice	4.7	4.9	4.8
	[407]	[193]	[600]
Maize	2.7	2.8	2.7
	[136]	[67]	[203]
Millet	1.3	1.5	1.4
	[136]	[60]	[196]
Berseem	1.2	1.0	1.1
	[139]	[52]	[191]

Note. The first row for each crop gives the average area of land used for production, and the second row gives the number of farms with an area larger than 1/32 of an acre that produce the crop.

Impacts on Cultural Practices

We explore the impact of PW-P on intermediate outcomes related to farmers' use of cultural practices and inputs. All quantitative tables in this and the following sections follow a format that provides information about program impacts as well as statistics for both the treatment and the control groups. Column 1 in each of these tables shows the average treatment effect

[12] The most common crops brought to plant clinics in Punjab are: wheat (26%), cotton (23%), rice (10%), sugarcane (8%), maize (4%), and berseem (3%).

(ATE) impact of PW-P. Columns 2 and 3 show the mean values for the control and treatment groups. These are important in assessing the magnitude of the estimated impacts reported in column 1. Column 4 shows the number of observations used in the estimation for each outcome. We denote statistically significance using stars next to impact estimates.

First, we present the impact estimates for all the crops produced on an area of land greater than 1/32 of an acre (125 square meters). Note that all crops considered are annual crops, as there were very few observations in our sample that produced perennial crops in areas larger than the specified threshold.

Table 6.6 presents impact estimates on agricultural practices used by farmers for all crops. We find few significant effects of plant clinic attendance on agricultural practices. However, we do find that farmers that attended plant clinics are 4 percentage points more likely to plant crops early and 3 percentage points more likely to weed in a timely manner. We also created an indicator for the number of good practices a farmer used and find a marginally significant effect: Plant clinic attendance increased the number of good practices implemented by 0.11 (about 1/10 of a practice). The results by individual crop resemble the results for all crops and are presented in Appendix A.

Table 6.6. Impacts on Agricultural Practices (All Crops)

Outcome of interest	Impact estimate	Mean control	Mean clinic users	*N*
Rotated crop	-0.01	0.74	0.72	4,130
Used improved planting material or variety	-0.01	0.74	0.73	4,130
Planted with certified planting material	0.00	0.64	0.65	4,130
Removed all plant residue prior to planting	0.01	0.92	0.92	4,130
Planted early	0.04***	0.54	0.59	4,130
Implemented intercropping	-0.00	0.04	0.04	4,130
Times checked for pests/diseases	0.25	50.83	51.08	4,130
Log of times checked for pests/diseases	0.06	3.09	3.15	4,072
Weeded in a timely manner	0.03**	0.74	0.78	4,130
Removed volunteer crops	0.01	0.56	0.56	4,130
Removed infested or damaged material	0.02	0.82	0.84	4,130
Used trap crops to protect crop	0.01	0.07	0.08	4,130
Burnt crop residue to control pests/diseases	0.01	0.62	0.63	4,130
Number of good practices implemented	0.11*	6.48	6.59	4,131

Note. Impacts are estimated using the inverse-probability-weighted regression adjustment (Doubly-robust estimator). Robust standard errors are in parentheses. *** p<0.01; ** p<0.05; * p<0.1.

Impacts on Inputs Use

Before presenting the results on inputs, it is worth discussing some technical decisions we made to conduct the estimation. First, for some of the input variables, we present the estimates based on natural logarithm transformed outcome variables, in which the transformed outcome variable equals the natural log of the original outcome variable.[13] While we controlled for outliers[14] during our analysis, the natural log transformation helped further account for any outliers present with these variables. With this transformation, the interpretation of the impact of PW-P was that the outcome changed by approximately 100%* (impact estimate), all else being equal.[15]

In Table 6.7 we present program impacts on the natural log of seed costs. We construct this variable by adding the cost of seeds bought plus the market value of the seeds used from the farmers' own sources. It is important to monetize the value of seeds to get the actual opportunity cost of the seeds used. We estimate that farmers who attend plant clinics spend 6% more on seeds than farmers who don't. The impact is driven by cotton farmers. We also observe a positive impact of the program on the cost of purchased seeds per acre, although we do not observe an impact for the individual crops. Lastly, there is evidence that clinic users are less likely to use seeds from previous harvests relative to the control group. Overall, plant clinic users are 4 percentage points less likely to use seeds from their own sources. This impact is driven by wheat and rice growers.

Table 6.7. Impacts on Use of Seeds

Outcome of interest	Impact estimate	Mean control	Mean clinic users	*N*
Imputed Cost of Seed per Acre				
All crops	0.06***	7.78	7.84	4,027
Wheat	-0.01	7.78	7.77	1,799
Cotton	0.06*	8.19	8.25	738
Rice	0.00	6.69	6.69	600
Cost of Purchased Seed per Acre				
All crops	0.12***	7.63	7.75	2,163
Wheat	-0.01	7.63	7.62	484

[13] Agricultural outcomes are commonly highly skewed to the right (i.e., the mean is much larger than the median) due to the presence of outliers. It is common practice to log those variables to reduce the influence of outliers.

[14] For numeric variables, we also set as missing those values above the 99th percentile and those below the 1st percentile to further control for outliers.

[15] For example, suppose you have a model of the form $Log(y) = \alpha + \beta * treat + \varepsilon$, where y is production of a crop in kilograms and treat is a dummy variable equal to 1 if part of the treatment group and 0 otherwise. If the estimated value of $\hat{\beta} = 0.05$, we say that treatment increases the production of the crop by approximately 5% (=100*$\hat{\beta}$).

Outcome of interest	Impact estimate	Mean control	Mean clinic users	*N*
Cotton	0.05	7.98	8.03	591
Rice	0.03	6.48	6.51	409
% of Seed Used from Own Stores				
All crops	-0.04***	0.52	0.48	4,027
Wheat	-0.06***	0.77	0.71	1799
Cotton	-0.03	0.29	0.26	738
Rice	-0.08**	0.44	0.36	600

Note. Impacts are estimated using the inverse-probability-weighted regression adjustment (Doubly-robust estimator). The seed costs are in natural logs. Robust standard errors are in parentheses. *** p<0.01; ** p<0.05; * p<0.1.

In Table 6.8 we present the results for the use of organic and inorganic fertilizer. We report impacts on the use of inputs and the log of quantities used per acre or cost per acre. For organic fertilizer, we report quantities used per acre as opposed to actual cost because most organic fertilizers are produced on the farm and are not bought in the market. In turn, for inorganic fertilizers, it is more appropriate to present results for cost per acre. We find no significant effects of plant clinic attendance on organic fertilizer use for all crops or among the most prevalent crops in the region (wheat, cotton, and rice). Likewise, we find no significant effects of plant clinic attendance on inorganic fertilizer use. However, we find a slight marginally significant 2 percentage point reduction in the use of inorganic fertilizer for rice (significant at the 10% level).[16] Note, however, close to 99% of farmers, regardless of the crop or treatment status, use some type of inorganic fertilizer. It is less common that farmers use organic fertilizers, which is expected given the high rates of inorganic fertilizer use.

Table 6.8. Impacts on Organic and Inorganic Fertilizer Use

Outcome of interest	Impact estimate	Mean control	Mean clinic users	*N*
All Crops				
Organic fertilizer used = 1	-0.00	0.27	0.26	4,131
Log of organic fertilizer in kg/acre	0.04	1.93	1.97	4,131
Inorganic fertilizer used = 1	-0.00	0.98	0.98	4,131
Log of cost of inorganic fertilizer per acre	0.03	8.73	8.76	4,057

[16] Linear probability models, which we used to estimate program impacts, do not behave well for outcomes with means very close to 0 or 1, as is the case of rice farmers using inorganic fertilizer, which has a mean for the control group of .99.

Outcome of interest	Impact estimate	Mean control	Mean clinic users	*N*
Wheat				
Organic fertilizer used = 1	-0.01	0.30	0.29	1,799
Log of organic fertilizer in kg/acre	0.04	2.03	2.07	1,799
Inorganic fertilizer used = 1	0.00	0.99	0.99	1,799
Log of cost of inorganic fertilizer per acre	-0.03	8.70	8.67	1,780
Cotton				
Organic fertilizer used = 1	0.00	0.08	0.08	738
Log of organic fertilizer in kg/acre	0.11	0.42	0.53	738
Inorganic fertilizer used = 1	-0.00	0.99	0.99	738
Log of cost of inorganic fertilizer per acre	0.04	9.23	9.27	729
Rice				
Organic fertilizer used = 1	-0.01	0.29	0.28	600
Log of organic fertilizer in kg/acre	0.01	2.07	2.08	600
Inorganic fertilizer used = 1	-0.02*	0.99	0.98	600
Log of cost of inorganic fertilizer per acre	0.03	8.66	8.69	592

Note. Impacts are estimated using the inverse-probability-weighted regression adjustment (Doubly-robust estimator). Robust standard errors are in parentheses. *** p<0.01; ** p<0.05; * p<0.1.

We also investigate the use of pesticides by treatment and control groups in Table 6.9. We look at the indicator variable of any pesticide use as well as the number of applications, the number of days used in pesticide application, and the log of total pesticide costs. Note that it is not feasible to estimate total quantities of pesticides used because some farmers report quantities in kilograms and others in liters, depending on the type of pesticide, and, as a result, quantities cannot be aggregated. The descriptive statistics show that a large proportion of farmers use pesticides, although the usage rates vary importantly by crop. While around 80% of wheat and rice producers use pesticides, almost all cotton farmers use them. Cotton farmers also exhibit a higher number of pesticide applications, higher pesticide costs, and more days used in pesticide application as expected given that cotton is a pesticide-intensive crop.

Overall, we find no significant impacts on pesticide use for those who attended plant clinics for all crops, wheat, or rice. However, we do find a reduction in pesticide use for cotton of 5 percentage points. Not using pesticides on cotton may improve the price farmers can sell it for. However, we do not find a significant reduction in the number of applications or cost, likely due to noise contained within these variables. We do find some small effects of the program on the probability of not using pesticides that are banned or restricted by international agreements (i.e., pesticide red list) for wheat and rice farmers. While very few farmers use pesticides that are included in the red list (3% of farmers in the control group), wheat and rice clinic users are 1 and 2 percentage points less likely to use them, respectively.

Table 6.9. Impacts on Pesticide Use

Outcome of interest	Impact estimate	Mean control	Mean clinic users	*N*
All Crops				
Pesticide use = 1	0.00	0.72	0.72	4,131
Number of applications	0.12	1.72	1.85	4,131
Log of cost per acre	0.04	7.22	7.26	2,995
Days used in pesticide application	0.12	2.51	2.62	4,131
Use pesticide in red list	-0.01	0.03	0.02	2995
Wheat				
Pesticide use = 1	0.00	0.78	0.78	1,799
Number of applications	0.10	1.12	1.22	1,799
Log of cost per acre	0.03	6.67	6.70	1,406
Days used in pesticide application	0.17	1.97	2.14	1,799
Use pesticide in red list	-0.01*	0.01	0.00	1406
Cotton				
Pesticide use = 1	-0.05***	0.97	0.92	738
Number of applications	-0.17	4.72	4.56	738
Log of cost per acre	-0.06	8.45	8.39	705
Days used in pesticide application	-0.01	4.87	4.85	738
Use pesticide in red list	0.01	0.06	0.07	705
Rice				
Pesticide use = 1	-0.01	0.84	0.82	600
Number of applications	-0.04	1.40	1.36	600
Log of cost per acre	0.00	7.04	7.05	505
Days used in pesticide application	0.07	2.24	2.31	600
Use pesticide in red list	-0.02*	0.03	0.01	505

Note. Impacts are estimated using the inverse-probability-weighted regression adjustment (Doubly-robust estimator). Robust standard errors are in parentheses. *** p<0.01; ** p<0.05; * p<0.1.

Despite not observing differences in the overall decision to use pesticides except in the case of cotton where fewer farmers (p<0.01) used pesticide, there is evidence that farmers who attend plant clinics are less likely to use red-list chemicals and more likely to use safety equipment when applying pesticide. The results in Table 6.10 show that attending a plant clinic increases the chance of checking for plant health problems more regularly and responding to the problems. We find that plant clinic attendance resulted in a 3 percentage point increase in checking for plant health problems on a regular basis and a 6 percentage point decrease in doing nothing after finding a plant health problem. Specifically, on pesticide practices, we find a 5 percentage point increase in wearing gloves and wearing a mask and a 4 percentage point increase in wearing goggles when spraying pesticides. We also estimate that those who attend plant clinics are 4 percentage points less likely to store chemicals in living areas. We also found a counterintuitive result, which is that those who attend plant clinics are 2 percentage points less likely to use pesticide containers only for pesticide use.[17]

Table 6.10. Impacts on Knowledge and Practices of Pesticide Use (Data at Farm Level)

Outcome of interest	Impact estimate	Mean control	Mean clinic users	*N*
Check for plant health problems regularly	0.03*	0.82	0.85	1,798
Do nothing after finding a plant health problem	-0.06***	0.08	0.02	1,798
Gloves used when spraying pesticides	0.05**	0.39	0.44	1,798
Mask used when spraying pesticides	0.05**	0.44	0.49	1,798
Goggles used when spraying pesticides	0.04**	0.13	0.16	1,798
Spraying pesticides in the morning	0.04*	0.41	0.45	1,798
Avoid chemical drift	-0.01	0.02	0.02	1,798
Washing self after spraying pesticides	0.00	0.06	0.06	1,798
Washing equipment after spraying	0.02	0.07	0.09	1,798
Using container after spraying pesticides	-0.02***	0.03	0.01	1,798
Store chemicals in living areas	-0.04***	0.16	0.12	1,798

Note. Impacts are estimated using the inverse-probability-weighted regression adjustment (Doubly-robust estimator). Robust standard errors are in parentheses. *** p<0.01; ** p<0.05; * p<0.1.

[17] Linear probability models, which we used to estimate program impacts, do not behave well for outcomes with means very close to 0 or 1, as is the case with using the same container, which has a mean for the treatment group of .01.

Plant Health Challenges and Access to Agricultural Information

We also investigate if farmers who attend clinics are more (or less) likely to experience any damage due to a plant health issue and the level of severity. Overall, 23% of all crops experienced problems with a pest or disease in the last 12 months before the survey, with no significant difference in this rate between treatment and control farmers. Regarding the level of severity, we observe that farmers who had a plant health issue reported that 22% of their crops were affected. Again, we do not observe a difference in the level of severity between treatment and control. The data by crop show that 42% of cotton farmers and 32% of rice farmers reported having a plant health issue, rates that are higher than the overall incidence of plant health issues for all crops. Also, cotton farmers who experienced damages due to a pest or disease also reported larger proportions of their crops being affected (27%) relative to the average proportion for other crops (23%).

Table 6.11. Impacts on Challenges Due to Pests or Diseases

Outcome of interest	Impact estimate	Mean control	Mean clinic users	*N*
All Crops				
Had damage due to pest or disease = 1	-0.01	0.23	0.23	4,130
% of crop affected by damage	-0.01	0.23	0.22	900
Wheat				
Had damage due to pest or disease = 1	-0.02	0.21	0.20	1,798
% of crop affected by damage	-0.01	0.19	0.18	336
Cotton				
Had damage due to pest or disease = 1	0.04	0.42	0.46	738
% of crop affected by damage	0.03	0.27	0.29	325
Rice				
Had damage due to pest or disease = 1	0.01	0.32	0.32	600
% of crop affected by damage	-0.04	0.24	0.21	168

Note. Impacts are estimated using the inverse-probability-weighted regression adjustment (Doubly-robust estimator). Robust standard errors are in parentheses. *** p<0.01; ** p<0.05; * p<0.1.

The results from Table 6.12 can be interpreted as evidence that farmers who attend plant clinics are looking for general agricultural extension services and not just seeking aid when facing a plant health issue. In fact, when farmers were asked about the type of information they received in the last 12 months before the survey, those who attended plant clinics were significantly more likely to report having received information on all production activities. Farmers who attended plant clinics were more than 30 percentage points more likely to report that they received information on seed varieties, pest control, fertilizer use, and agronomic practices, which are the key topics discussed by plant doctors.[18] When asked about the usefulness of the advice received, we find statistically significant differences between users and nonusers in terms of primary areas of plant clinic advice such as seed varieties, pest control, and fertilizer use. Furthermore, regarding pest control, plant clinic users are 23 percentage points more likely to report receiving improved pest information. Only 34% of individuals in the control group (those who did not attend plant clinics in either treatment areas or control areas) reported receiving improved pest information over this same period, compared with 57% of plant clinic attendees. Overall, the results presented provide evidence that plant clinic users are receiving more information on agricultural topics and that they, more than nonusers, regard the information they received as useful.

Table 6.12. Impacts on Probability of Receiving Information (Data at Farm Level)

Outcome of interest	Impact estimate	Mean control	Mean clinic users	*N*
Pest information improved	0.23***	0.34	0.57	1,798
Received information on …				
New seed varieties	0.31***	0.54	0.85	1,798
Pest control	0.34***	0.47	0.82	1,798
Fertilizer use	0.34***	0.46	0.80	1,798
Agronomic practices	0.33***	0.22	0.55	1,798
Irrigation	0.25***	0.27	0.52	1,798
Composting	0.19***	0.12	0.31	1,798
Marketing or crop sales	0.17***	0.22	0.39	1,798
Postharvest technologies	0.16***	0.12	0.28	1,798
Value addition/agro-processing	0.14***	0.07	0.22	1,798
Found Information received on … useful				

[18] While plant clinic users are more likely to receive advice on a large variety of topics that at first glance do not seem to be related to plant health issues, it is still possible that some of the advice-categories considered are linked to pest management and preventative measures. For instance, advice on new seed varieties can be linked to using varieties that are more resistant to diseases; agronomic practices can be aimed at pest reduction or prevention; also, post-harvest technologies could be aimed at pest and disease control.

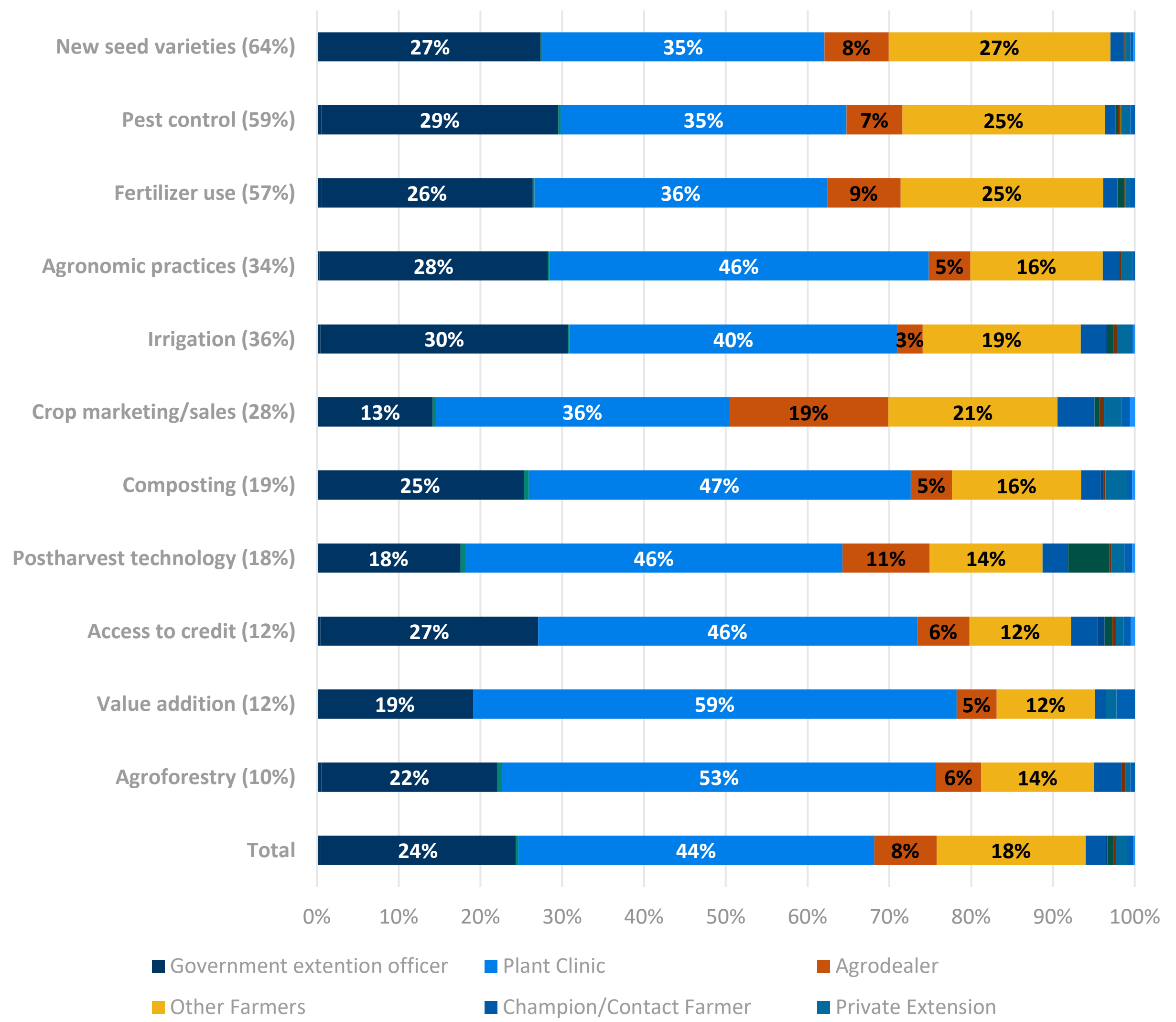
Outcome of interest	Impact estimate	Mean control	Mean clinic users	*N*
New seed variety	0.02**	0.97	0.99	1,150
Pest control	0.03**	0.95	0.98	1,062
Fertilizer use	0.03***	0.96	0.99	1,023
Agronomic practices	0.01	0.97	0.98	607
Irrigation	0.03**	0.94	0.98	645
Composting	0.02	0.97	0.99	334
Marketing or crop sales	-0.00	0.99	0.98	506
Postharvest technologies	0.01	0.99	1.00	315
Value addition/agro-processing information	0.01	0.98	0.99	224

Note. Impacts are estimated using the inverse-probability-weighted regression adjustment (Doubly-robust estimator). Robust standard errors are in parentheses. *** p<0.01; ** p<0.05; * p<0.1.

It is worth discussing the sources of information and agricultural advice received by farmers, which we present in Figures 6.2, 6.3, 6.4 and 6.5. Data from all respondents (figure 6.2) show that farmers received information from multiple sources in addition to plant clinics and on a variety of topics. Most farmers received their information from plant clinics and government extension officers. The next most important source of information consisted of agrodealers and other farmers.

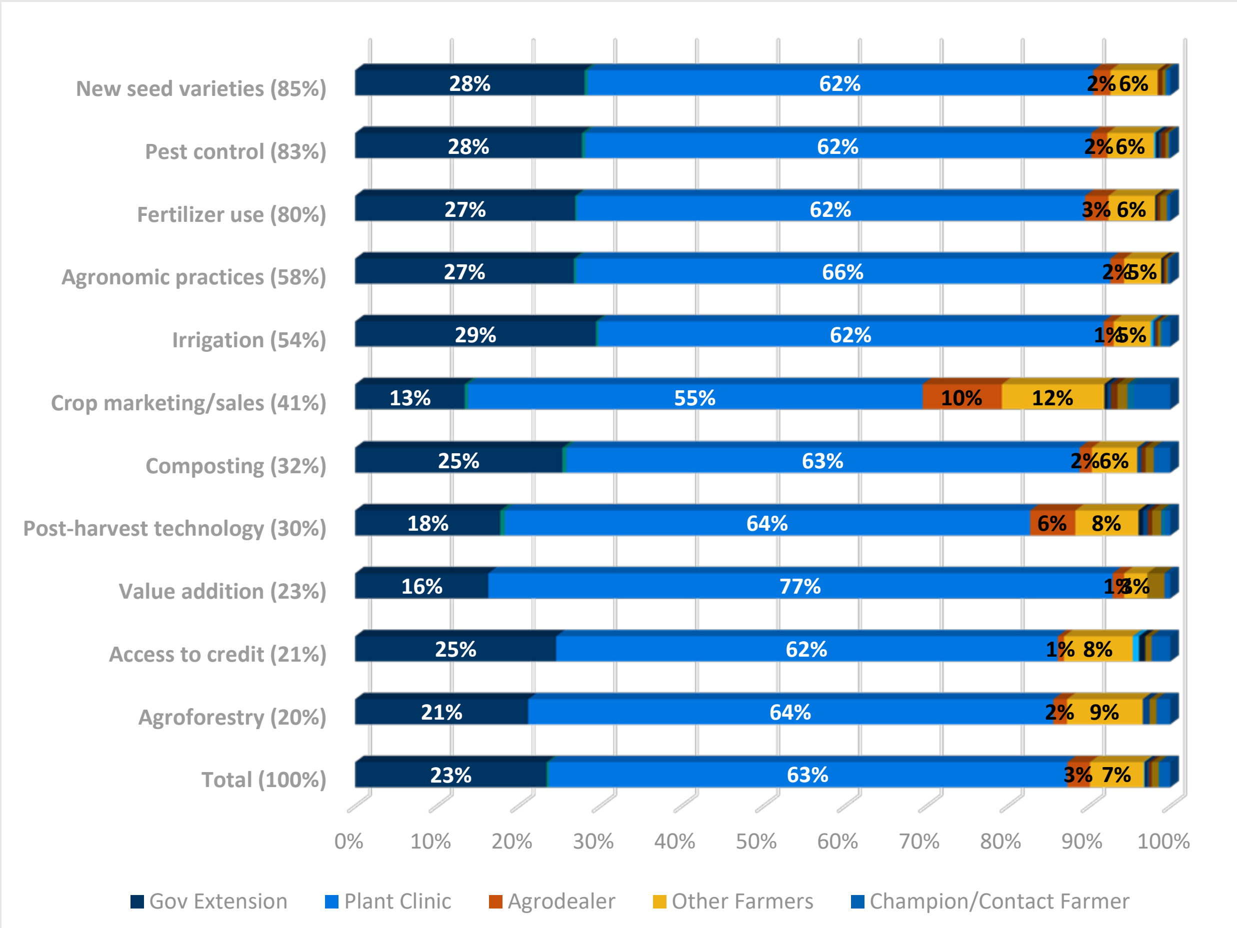
In general, farmers use the same type of sources regardless of the type of advice they request. However, in some cases we observe that there are some specific sources that are more relevant for a given topic. The most relevant information source for all types of topics are plant clinics. Government extension officers and other farmers are also common sources for those seeking information specifically on new seed varieties, pest control, fertilizer use, irrigation, composting, agronomic practices, and access to credit. Next in importance are agrodealers that provide relevant information on crop sales and postharvest technologies. Lastly, the data show that farmers get limited advice from electronic media, specifically TV, private extension officers, champion farmers and agricultural coops.

Figure 6.2. Distribution of Crop Information Sources by Topic of Advice Received



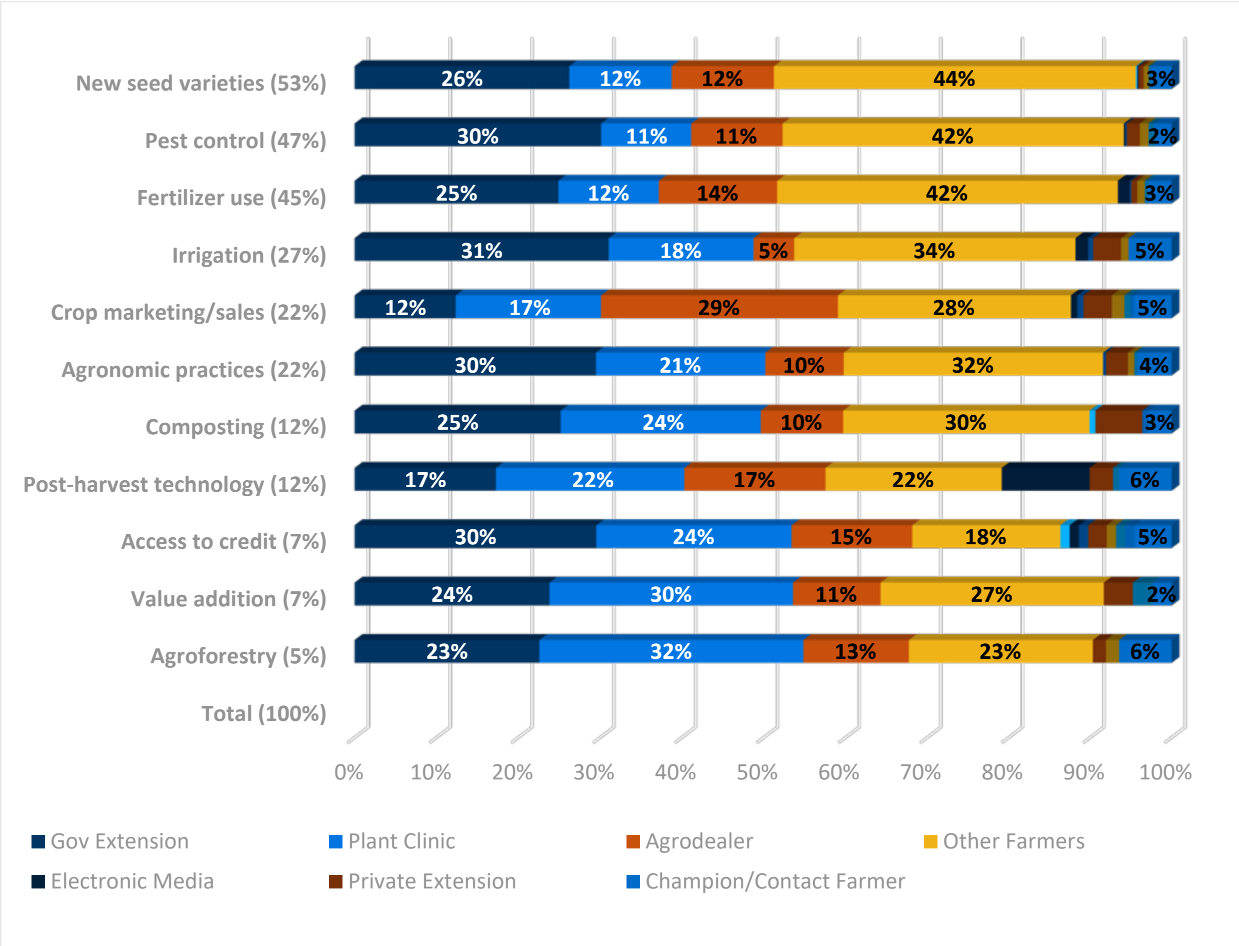
We further explored the distribution of sources of information for those farmers who attended clinics and for those who did not (see Figures 6.3 and 6.4, respectively). Clinic users report the most important source of information for almost all topics is the plant clinics with government extension officers cited as the second most common source, and very little information being obtained from other sources such as agrodealers and fellow farmers. The fact that clinic users do not rely much on agrodealers is a positive sign given that there are often concerns about agrodealers partiality when making recommendations on input use. Only for crop marketing/sales and post-harvest technology were levels of consultation of agrodealers the same for control and clinic user groups. These results provide evidence that plant clinics are seen as an important source of information and provide information to farmers beyond plant health issues.

Figure 6.3. Distribution of Crop Information Sources by Topic of Advice Received for Clinic Users



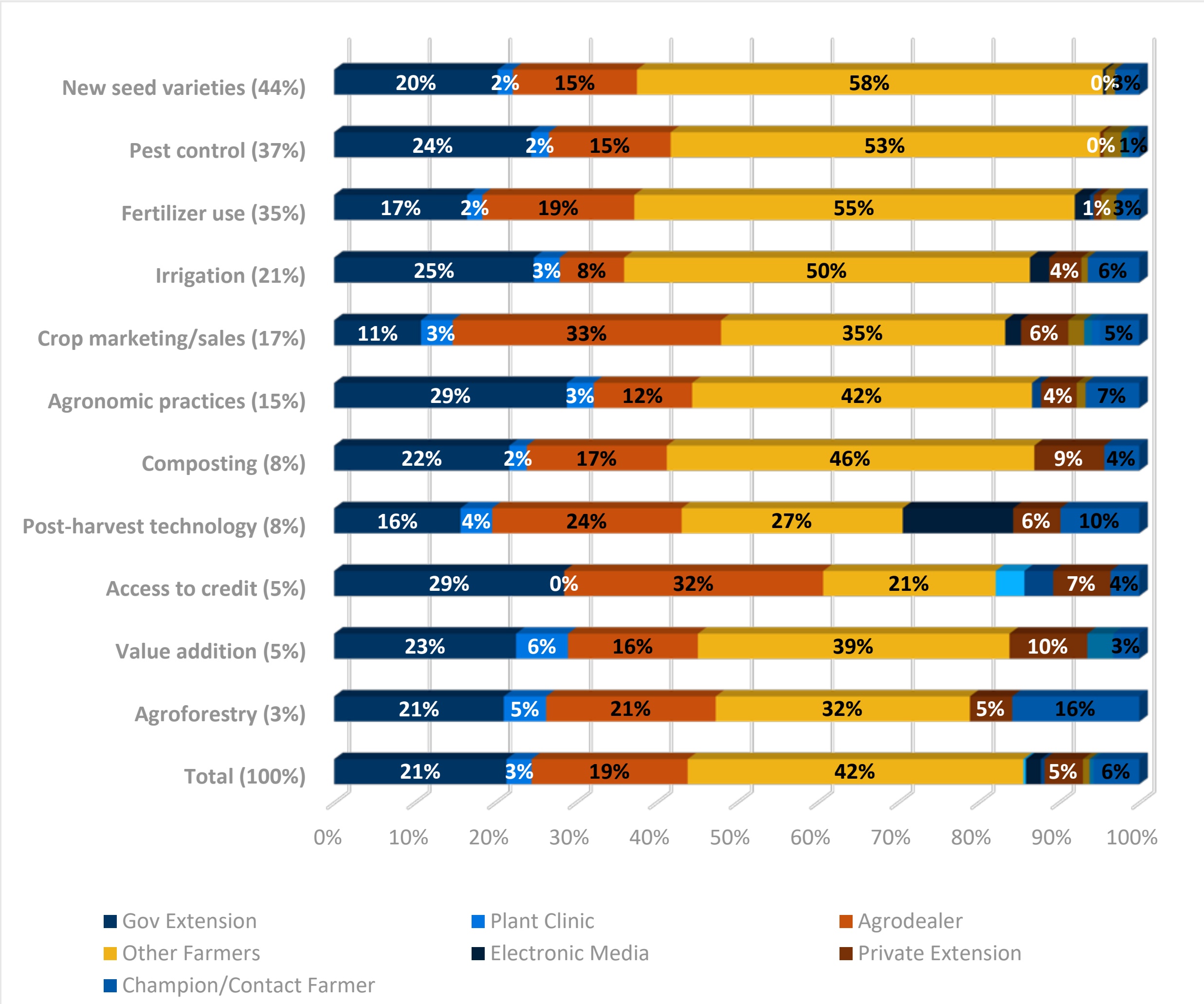
The most common source of information for farmers who did not use plant clinics is fellow farmers with plant clinics, government extension officers and agrodealers serving as supplemental sources of information.

Figure 6.4. Distribution of Crop Information Sources by Topic of Advice Received for Clinic Nonusers



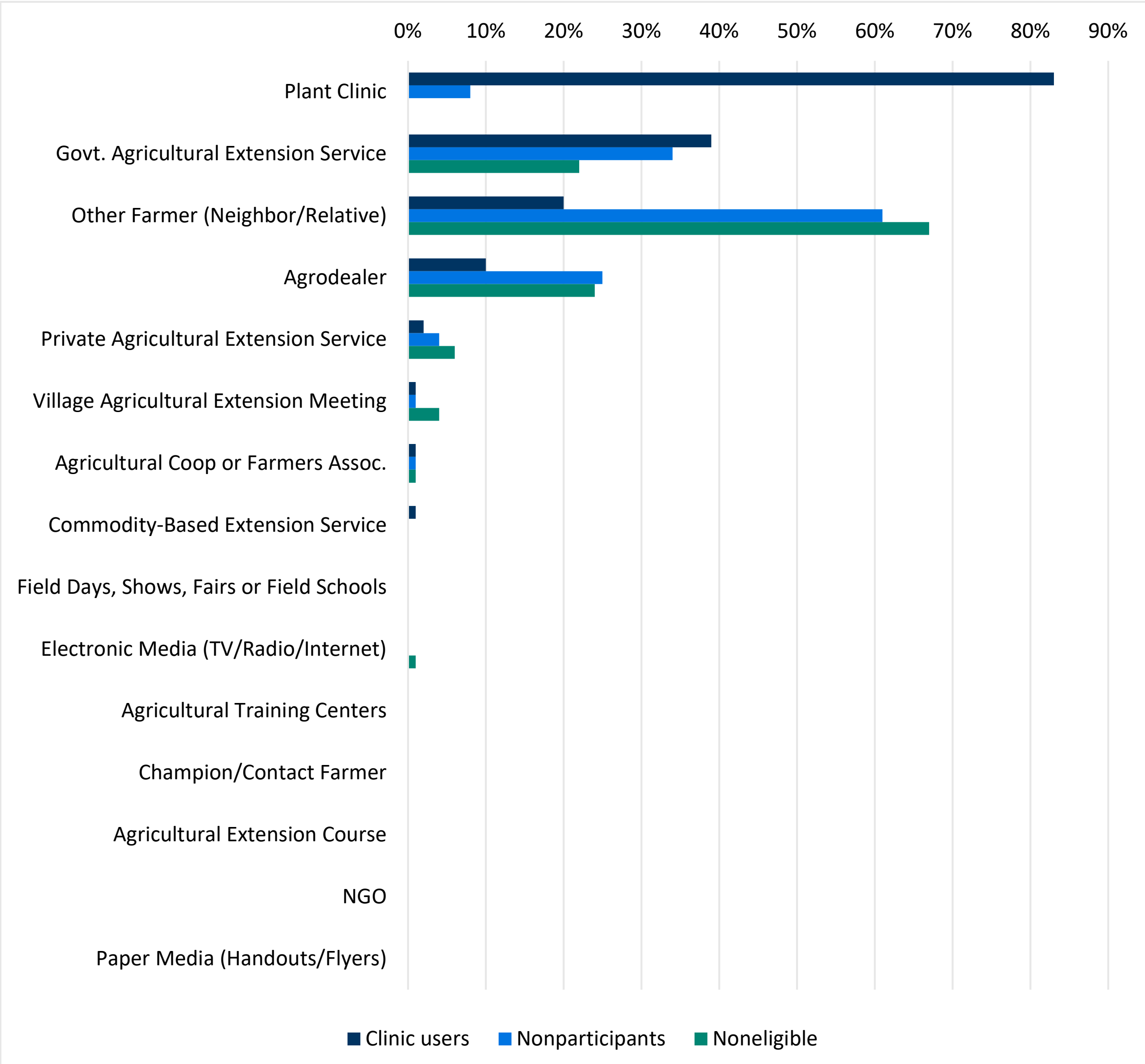
When only looking at farmers in the pure control group, we see that plant clinics become a far less important source of information, and that fellow farmers provide the most common means of obtaining information. Although any mention of plant clinics may seem questionable in the control group – this may be as a result of misunderstanding of the question by a few farmers. Such errors are common in this type of survey. Agrodealers and government extension officers are also relevant sources of advice for a range of issues; most importantly, crop sales, access to credit and agronomic practices.

Figure 6.5. Distribution of Crop Information Sources by Topic of Advice Received for Pure Control Group



We also explored the distribution of sources of useful information for farmers regardless of topic. Figure 6.6 shows that plant clinic users reported plant clinics as being the main source of useful information. Government extension officers were reported as the next most useful source of information for this group of farmers. Conversely, non-participant farmers and non-eligible farmers reported other farmers as being the main source of useful information.

Figure 6.6. Most Important Sources of Information by Type of Farmer



Final Outcomes: Productivity and Costs

We use data on crop production amounts, production area, and market values to estimate program effects on crop productivity. Before presenting the results, it is worth recalling some technical decisions we made to conduct the estimation. First, we collected detailed production data for crops cultivated in an area larger than 125 square meters (or 1/32 of an acre). All production estimates are for the sample of observations that reported harvesting at least 1 kilogram in the last 12 months before the survey. Second, we calculated yields as kilograms divided by production area in acres. Also, we calculated the value of yields (i.e., the value of production in Pakistani rupees [PKR] per acre) by multiplying the quantity in kilograms of each crop produced per acre by the market price of the production, where the price was calculated as the median selling value for each crop at each one of the plant clinics. We calculate the total value of production regardless of whether production was sold to the market or consumed at the farm. Third, we focus our productivity analysis on the value of yield per unit of area and costs per unit of area following common practice in the evaluation of extension programs (Ragasa & Mazunda, 2018). Fourth, as discussed above, in order to deal with extreme values of all quantities and values, we transformed all variables to natural logs and trimmed values above the 99th percentile to reduce the effect of possibly spurious outliers.

Panel A of Table 6.13 presents the impact estimates on productivity for all crops together and for the three major crops. The results indicate that for all crops combined, there is no impact of the program on yields, value of yields, or net income as impact estimates are very close to 0. We observe, however, an 8 percent increase in net income for cotton producers, which seems to be driven by a reduction in production costs. Panel B presents the impacts on production costs, including seed, inorganic fertilizer, pesticide, and labor costs. We do not find cost increases for most of the cost categories and crops. These results are expected given that we do not observe changes in productivity. The only significant impacts on costs per area we observe are an increase in seed costs for all crops, which seems to be driven by cotton producers, and a reduction in paid labor costs for cotton. This was apparently driven by a reduction in paid labor for harvest, but the result should be treated with caution as responses (n) for other categories of paid labor (planting, fertilizer application, pesticide application, cultural practices) were too small for separate analysis.

Table 6.13. Impacts on Yields and Value of Yields, by Crop

Outcome of interest	Impact estimate	Mean control	Mean clinic users	*N*
PANEL A. PRODUCTIVITY OUTCOMES				
All crops				
Log of value of production per acre (PKR/acre)	-0.03	11.26	11.23	3,854
Log of net income	-0.03	10.95	10.93	3711
Wheat				
Log yields (kg/acre)	-0.01	11.18	11.17	1,780
Log of value of production per acre (PKR/acre)	-0.01	10.86	10.85	1,780
Log of net income	-0.01	10.56	10.54	1776
Cotton				
Log yields (kg/acre)	-0.00	10.54	10.54	717
Log of value of production per acre (PKR/acre)	0.00	11.36	11.36	717
Log of net income	0.08**	10.87	10.95	636

Outcome of interest	Impact estimate	Mean control	Mean clinic users	*N*
Rice				
Log yields (kg/acre)	-0.00	11.35	11.34	568
Log of value of production per acre (PKR/acre)	-0.00	11.48	11.48	568
Log of net income	-0.00	11.29	11.28	558
PANEL B. COST OUTCOMES				
All crops				
Log of total cost per acre	0.02	9.56	9.58	3,918
Log of seed cost per acre	0.04*	7.80	7.85	3,918
Log of inorganic fertilizer cost per acre	0.02	8.74	8.75	3,882
Log of pesticide cost per acre	0.02	7.22	7.24	2,894
Log of paid labor cost per acre	-0.03	8.49	8.46	2,695
Wheat				
Log of total cost per acre	-0.00	9.38	9.38	1,780
Log of seed cost per acre	-0.01	7.78	7.77	1,780
Log of inorganic fertilizer cost per acre	-0.03	8.70	8.66	1,762
Log of pesticide cost per acre	0.02	6.66	6.68	1,398
Log of paid labor cost per acre	-0.05	8.18	8.12	1,196
Cotton				
Log of total cost per acre	-0.03	10.25	10.22	717
Log of seed cost per acre	0.05*	8.19	8.24	717
Log of inorganic fertilizer cost per acre	-0.01	9.26	9.25	709
Log of pesticide cost per acre	-0.07	8.46	8.40	690
Log of paid labor cost per acre	-0.15**	9.23	9.07	545
Rice				
Log of total cost per acre	0.04	9.54	9.58	568
Log of seed cost per acre	-0.01	6.71	6.70	568
Log of inorganic fertilizer cost per acre	0.04	8.67	8.70	560
Log of pesticide cost per acre	0.02	7.05	7.06	480
Log of paid labor cost per acre	-0.01	8.74	8.72	490

Note. Impacts are estimated using the inverse-probability-weighted regression adjustment (Doubly-robust estimator). Robust standard errors are in parentheses. *** p<0.01; ** p<0.05; * p<0.1.

We also investigate program impacts on the subsample of farmers who reported having a plant health issue in the last 12 months before the survey in any of their larger crops (i.e., those with a production area larger than 125 square meters).[19] It is worth noting that according to POMS, about one third of plant clinic visits in Punjab for all crops are related to nutrient deficiency and weeds. Farmers in this sub-sample were those reporting that they had had damage due to insects, fungus, diseases or other pests. This means that farmers with concerns on weeds and nutrient deficiencies are unlikely to be included in this sub-sample. The main difference between the sample of crops that report any damage relative to the overall sample is that the former includes a larger proportion of cotton and rice observations.[20]

The results in Table 6.14 show that, relative to the control group, farmers who attended plant clinics and reported having a plant health issue are 8 percentage points more likely to plant early, 5 percentage points more likely to weed in a timely manner, 5 percentage points more likely to control pest and diseases by burning crop residue, and 3 percentage points more likely to use traps. Once we combine all practices into a single index, we find that plant clinic users implement 0.26 more practices than the control group. In terms of inputs use, except for the use of organic fertilizer per acre, we do not observe statistically significant differences relative to the control group. Overall, the results show that plant clinic users with plant health issues exhibit larger impacts on agricultural practices relative to the sample that includes all farmers (i.e., those with and without plant health issues).

Table 6.14. Impacts on Intermediate Outcomes for farmers with Plant Health Issues

Outcome of interest	Impact estimate	Mean control	Mean clinic users	*N*
Agricultural Practices				
Rotated crop	-0.03	0.80	0.77	966
Planted improved planting material or variety	0.00	0.74	0.74	966
Planted with certified planting material	0.03	0.65	0.68	966
Removed all plant residue prior to planting	0.01	0.97	0.98	966
Planted early	0.08***	0.50	0.58	966
Implemented intercropping	0.00	0.02	0.02	966
Times checked for pests/diseases	3.35	58.15	61.50	966

[19] The subsample is defined as those responding yes to the following question: "During production [in the last 12 months], did your [CROP] experience any damage due to insects, fungus, disease or other pests?"
[20] As shown in Table 6.4, in the full sample, the distribution of crops is 43% for wheat, 18% for cotton, and 15% for rice. In turn, for the sample of crops experiencing a plant health issue, 39% are wheat, 34% cotton, and 20% rice.

Outcome of interest	Impact estimate	Mean control	Mean clinic users	*N*
Log of times checked for pests/diseases	0.04	3.33	3.37	963
Weeded in a timely manner	0.05**	0.83	0.88	966
Removed volunteer crops	0.00	0.70	0.70	966
Removed infested or damaged material	0.01	0.94	0.95	966
Used trap crops to protect crop	0.01	0.05	0.06	966
Burnt crop residue to control pests/diseases	0.05*	0.58	0.64	966
Use traps	0.03*	0.04	0.07	966
Number of good practices implemented	0.26***	6.81	7.07	967
Fertilizer Use				
Organic fertilizer used = 1	-0.03	0.29	0.26	967
Log of organic fertilizer in kg/acre	-0.38*	2.18	1.79	967
Inorganic fertilizer used = 1	-0.00	0.99	0.98	967
Log of cost of inorganic fertilizer per acre	0.04	9.05	9.10	952
Pesticide Use				
Pesticide use = 1	-0.00	0.94	0.94	967
Number of pesticide applications	0.16	2.54	2.70	967
Log of pesticide cost per acre	0.09	7.42	7.50	907
Days used pesticide application	0.12	3.52	3.64	967
Use pesticide in red list	-0.00	0.04	0.04	907

Notes: Impacts are estimated using the inverse-probability-weighted regression adjustment (Doubly-robust estimator). Robust standard errors are in parentheses. *** p<0.01; ** p<0.05; * p<0.1.

We also investigate the impacts on final outcomes for the subsample of farmers who reported having a plant health issue. The results in Table 6.15 show that plant clinic users who experienced a plant health issue exhibit an 8% increase in the value of yields and in net income relative to nonusers who also experienced plant health issues. At the same time, these productivity increases did not result from higher overall production costs per unit of area. To check whether these positive impacts are driven by the extent of the plant health issue experienced, in Panel B we control for a 10-point scale variable that farmers used to rate the extent of the damage suffered by the crop. That the results are unaffected by controlling for this variable suggests that the results presented in Panel A are not driven by differences in the extent of the plant health issues. Moreover, as discussed earlier in Table 6.11, there are no differential rates in the probability of reporting a plant health issue between clinic users and nonusers. This point is relevant because it suggests that clinic users and nonusers are also very similar in terms of their propensity to be affected by a pest or disease and of the damage levels when they are so affected. Combined with the higher observed impacts on agricultural practices, these results provide evidence that while plant clinics may not generate productivity impacts on the full sample, they positively impact the productivity of those farmers facing plant health issues, a key objective of the Plantwise theory of change. Note that we are unable to present the results in Table 6.14 and 6.15 by crop, as the sample sizes for each individual crop are too small to enable reliable impact estimates.

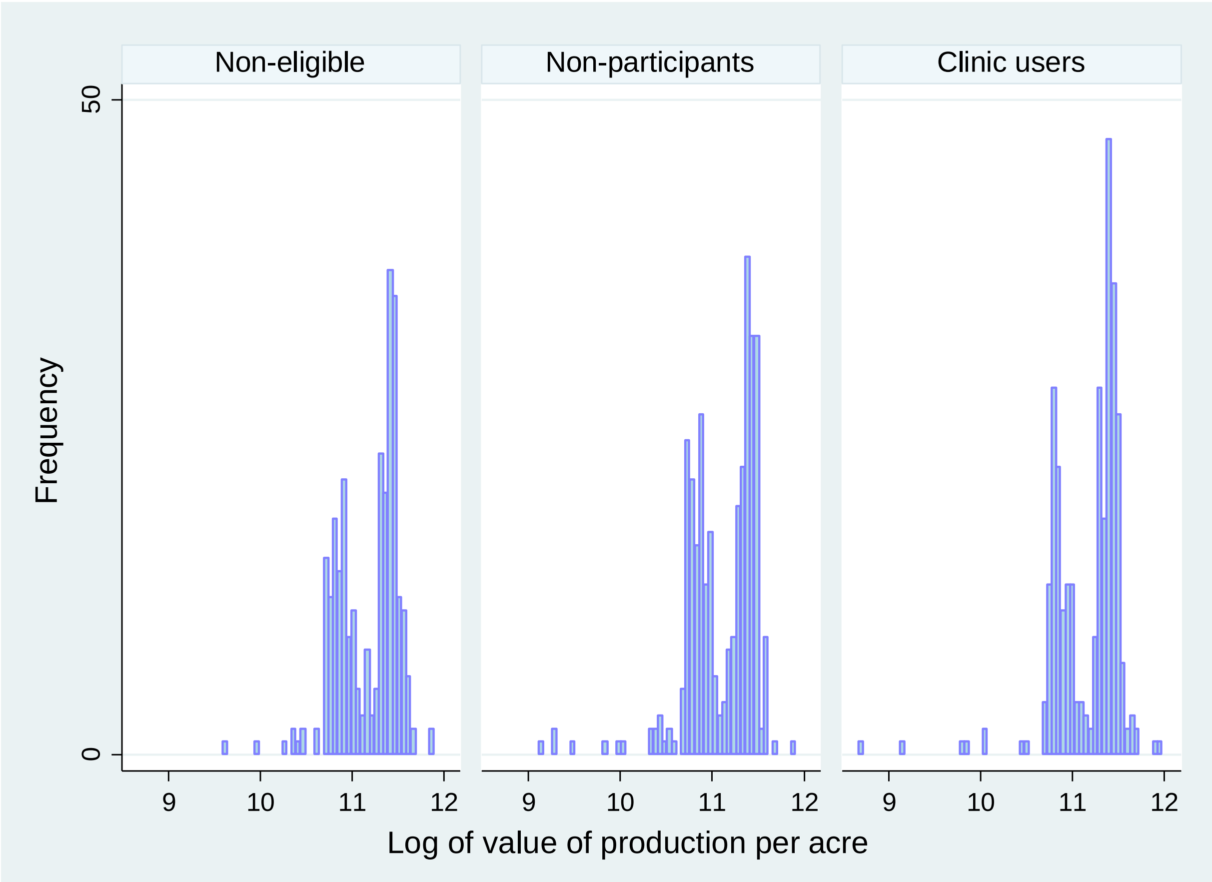
Table 6.15. Impacts on Value of Yields, and Costs for Farmers with Plant Health Issues

Outcome of interest	Impact estimate	Mean control	Mean clinic users	*N*
Panel A. All crops				
Log of value of production per acre (PKR/acre)	0.08**	11.16	11.25	934
Log of total cost per acre (PKR/acre)	0.05	9.92	9.98	926
Log of net income	0.08*	10.70	10.78	839
Panel B. All crops—controlling for severity of plant health Issue				
Log of value of production per acre (PKR/acre)	0.09**	11.16	11.25	934
Log of total cost per acre (PKR/acre)	0.06	9.92	9.98	926
Log of net income	0.09**	10.70	10.79	839

Notes: Impacts are estimated using the inverse-probability-weighted regression adjustment (Doubly-robust estimator). Robust standard errors are in parentheses. *** p<0.01; ** p<0.05; * p<0.1.

The results shown in Table 6.15 are the average effects of the program on the value of yields. Given that average effects may be driven by few data points (outliers), we conduct a robustness check in Figure 6.7 where we present the discrete distributions of the value of production for each one of the three groups of farmers. The distributions for farmers in the pure control group as well as the one for farmers in treatment villages who did not attend a plant clinic session are very similar. In turn, the distribution for plant clinic users provides evidence that the estimated positive impacts on the value of production per acre are driven by a slight shift to the right in the distribution and not due to data anomalies like outliers.

Figure 6.7. Histograms of Value of Production per Acre by Group



Note. The figure shows histograms for the three groups of farmers considered in the evaluation: those in the control communities (non-eligible), those in treatment communities who have not attended plant clinics (non-participants) and those who have attended a plant clinic session at least once in the 12 months before the survey. The outcome analyzed is the natural logarithm of the value of yields for all crops produced in areas larger than 1/32 acres (125 square meters).

Spillover Effects

One potential concern with aggregating non-participant and non-eligible farmers into a single control group when estimating program impacts is that the estimates may be attenuated due to spillover effects of plant clinics on non-participants. To investigate this issue, we compared differences in outcomes between non-participants and non-eligible. Finding positive impacts for non-participants relative to non-eligible would imply that plant clinics generate an effect on those who live in villages with plant clinics even if they do not attend them. The results for intermediate and final outcomes are presented in Appendix B. As shown, with the exception of few statistically significant effect on intermediate outcomes, there is no evidence that living in a village that holds plant clinic sessions affects non-participant farmers in a significant way.

D. Cost-Benefit Analysis and Sustainability

A key question in assessing program impact is whether the monetary gains resulting from the intervention outweigh the program running costs. To compare projects with different time lengths, we need to aggregate the projects' benefits and costs over time. However, aggregating the annual flows of benefits and costs over time needs to account for the fact that a dollar today is worth more than a dollar tomorrow or in 10 years' time. To aggregate monetary values for different years, we need to express all past and future flows of benefits and costs in present value terms by using a discount rate. A common discount rate is the market interest rate.

We used two common measures to assess whether the benefits of PW-P justify the costs. The first measure was the benefit-cost ratio, which is given by the share of the present value of benefits to the present value of costs:

$$BC = B/C = \frac{\sum_{j=0}^{T} B_j/(1+i)^j}{\sum_{j=0}^{T} C_j/(1+i)^j}$$

where B is the present discounted value (PDV) of the program benefits from the initial year of the program (i.e., when $j = 0$) up to a future year T. The PDV of the benefits is calculated by adding the yearly benefits of the program after discounting each year's flow using the interest rate (i). The PDV of the costs is calculated in a similar way. According to the benefit-cost ratio, an investment is profitable if the ratio is greater than 1—in other words, if benefits are larger than costs for the duration of the project.

The second measure we used to assess the program's profitability is the internal rate of return (IRR). This is defined as the discount rate that yields the PDV of the net benefits (i.e., benefits minus costs) equal to zero. That is:

$$0 = \sum_{j=0}^{T} (B_j - C_j)/(1+IRR)^j$$

According to the IRR criterion, an investment is profitable if the computed IRR is greater than the market interest rate of return.

To calculate these two measures of program profitability, we first needed to calculate the program costs and benefits for a determined period.[21,22] In order to calculate PW-P program costs, we used the ingredients approach. This approach is a well-tested systematic procedure for identifying all comprehensive costs for implementing program services, including costs that are routinely not adequately identified in budget or expenditure data, such as contributed (in-kind) resources, opportunity costs, or costs that are shared between the program and other operational activities.

The costs associated with PW-P fall into three main categories: (a) CABI coordination and advocacy, (b) plant clinic operations, and (b) the Knowledge Bank and the POMS operations (see Table 6.16). For each of these sets of activities, the additional costs of PW-P (beyond the normal operating costs of the agricultural extension system) include the costs of investing in each of these activities—both to initiate the activities and to maintain them—as well as the opportunity costs of government employees' time.

Table 6.16. PW-P Cost Analysis 2012–2017

Cost analysis 2012–2017							
Coordination, advocacy, and M&E	**Source**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Advocacy activities	CABI	0	5	63	117	0	0
CABI coordination	CABI	9,232	13,013	16,440	94,181	22,865	15,901
Salary of key Plantwise staff	GOP	81	242	968	1,937	18,303	21,208
Plantwise key staff additional funding	CABI	24,721	21,010	18,408	22,027	28,646	27,876
Subtotal (GBP)		**34,034**	**34,271**	**35,879**	**118,261**	**69,813**	**64,985**
Plant clinics	**Source**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Clinic operations	CABI	0	800	11,895	12,957	11,393	6,848
Local coordination	CABI	2,733	4,640	10,412	16,959	2,057	6,534
Plant doctor trainings	CABI	0	11,516	11,355	15,335	14,301	16,556
Salary of plant doctors	GOP	3,357	10,355	63,243	142,587	337,855	408,394

[21] For the analysis, we define time 0 as 2012, the initial year of Plantwise in Punjab, and time *T*, the final year of the analysis, as 2024. We chose 2024 as the final year in order to have a 10-year period from the moment PW started producing benefits for farmers (we assume that occurred early on).

[22] While the choice of the final year in the estimation is arbitrary, the profitability estimates are highly insensitive to changes in the final year. This is because we are discounting benefits and costs over time to express all magnitudes in terms of 2012 values. Thus, the contribution of a given year to the estimation of the profitability measures decreases as time goes by. For example, the contribution of the magnitudes in 2024 to the analysis is lower than the contribution of the magnitudes in 2023, and so on. This means that the results do not vary importantly if for the estimation we assume a different final year close to 2024.

Cost analysis 2012–2017							
Clinic coordinator and plant doctor additional funding	CABI	0	8,110	18,844	6,540	2,178	1,389
Subtotal (GBP)		**6,090**	**35,422**	**115,750**	**194,378**	**367,784**	**439,721**
POMS and Knowledge Bank	**Source**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Data entry, validation, and harmonization	CABI	3,545	3,500	9,869	10,411	20,010	13,260
Knowledge Bank costs	CABI	101,911	72,729	132,688	173,703	173,697	176,271
Subtotal (GBP)		**105,456**	**76,229**	**142,557**	**184,114**	**193,707**	**189,530**
Total (GBP)		145,580	145,923	294,186	496,753	631,304	694,237
CABI Total *(Proportion of Total)*		142,142 *(97.6%)*	135,325 *(92.7%)*	229,975 *(78.2%)*	352,229 *(75.0%)*	275,146 *(43.6%)*	264,635 *(38.1%)*
GOP Total *(Proportion of Total)*		3,438 *(2.4%)*	10,598 *(7.3%)*	64,211 *(12.9%)*	144,524 *(25.0%)*	356,158 *(56.4%)*	429,602 *(61.9%)*

Note. We assume that the proportion of the global Knowledge Bank costs that are assigned to Pakistan are 6.3%, 3.6%, 4.7%, 5%, 4.5%, 5.3%, and 5.9% for the years from 2012 to 2017, respectively.

Several costs are associated with getting PW started in Pakistan and maintaining its organization. First, we included CABI coordination costs associated with organizing and participating in the agricultural expos and steering committee meetings. Additionally, this category includes costs for other advocacy activities, including marketing PW-P. These costs vary by year, depending on the extent of activities. To ensure effective operation of PW-P, the Ministry of Agriculture (MOA) employs one Deputy Director of Agriculture per district whose time is completely devoted to PW-P (working closely with CABI) and multiple Assistant Directors of Agriculture per district who dedicate a significant portion of their time to PW-P activities. Salaries of Deputy and Assistant Directors are calculated as the estimated time costs for these employees during attendance at meetings and trainings. These are based on government salary rates provided by CABI. Estimating these costs required making assumptions about the number of days for each meeting or training and the job level of the attendees. Both positions receive salary top-ups from CABI to cover the additional costs of activities associated with PW-P.

The next category of costs is associated with plant clinic operations. Costs within this category include those related to initiating plant clinics: the costs of training plant doctors, the costs of materials required to set up and operate the clinics, and the costs of local coordination. As plant doctors and clinic coordinators are employed as extension officers with the MOA, they are provided their regular salaries through the Pakistan government according to the salary rates mentioned above. They, too, receive additional funding through CABI to support their work with PW-P: Clinic coordinators receive monthly salary top-ups, while plant doctors receive money for airtime and travel costs for relevant PW-P activities.

Once the plant clinics are established and operational, data from the clinics are collected, validated, and organized within the POMS. Accordingly, costs in this final category include those associated with updating and maintaining the data management system and the costs of equipment necessary for data collection. Lastly, this category encompasses funding to support Knowledge Bank activities in Pakistan as a percentage of worldwide Knowledge Bank support expenditures.

Costs for all three categories were totaled by year and funder, as seen in Table 6.17. All cost information used in this analysis was provided by CABI for the period 2012–2017.

Table 6.17. Total PW-P Costs by Funder, 2012–2017

Total costs by year (GBP)							
	2012	2013	2014	2015	2016	2017	2018
Total	145,580	145,923	294,186	496,753	631,304	694,237	723,968
Total CABI	142,142	135,325	229,975	352,229	275,146	264,635	262,474
Total GOP	3,438	10,598	64,211	144,524	356,158	429,602	461,494

We calculated program benefits from the estimated results of the impact assessment (Figure 6.15). The calculation of program benefits focused exclusively on outcomes for farmers reporting a pest or crop disease in the past year, as this is the subpopulation for which the evaluation found an economically and statistically significant impact on the value of total production. While it is possible that PW-P is generating positive impacts for other farmers, the results were not statistically significant. We estimated program benefits by multiplying the 9% increase in the annual value of production for farmers reporting pests or crop disease by the median value of production for the control group (GBP 933). We then multiplied that by the number of farmers who benefit (i.e., the proportion of farmers who reported having a pest or disease issue (23%) multiplied by the number of farmers attending plant clinics each year).

Figure 6.8. Benefit Calculation

Benefits = *(A x B)* *x* *(C x D)*

A = % increase in annual value of production for farmers with pests or crop disease due to PW **= 9%**

B= Median value of production for control group
= PKR 173,150
= GBP 933

C = Proportion of farmers reporting pests or crop disease = **23%**

D = No. of farmers in PC catchment area who attended plant clinics (varies by year)

Total program costs in 2017 were estimated to be GBP 694,236, and total program benefits in 2017 were estimated to be GBP 827,894. This gives a benefit-cost ratio for 2017 of 827,894/694,236, or approximately 1.19:1, showing that the benefits outweighed the costs of running the program in 2017. Assuming that the costs and benefits remain stable after 2017, the benefit-cost ratio for the 2012–2024 period is 1.07:1.

We also calculated the associated IRR of PW-P to be 28%, using the methodology introduced above. As discussed, the higher a project's IRR, the more desirable it is to undertake the project. For the evaluation of PW-P, the IRR was estimated using the following assumptions: (a) The number of plant clinics will remain stable for the period 2018–2024, (b) a plant clinic starts generating the observed full monetary benefits we estimated immediately, and (c) program benefits and costs will remain stable in real terms for the period 2018–2024.

At present, CABI funds about one-third of the investment in PW-P through direct payments and the time of their staff. The opportunity costs of MOA staff time are covered by the Pakistan government. However, in the future many of the coordination and advocacy costs are likely to disappear as systems become more developed; if the program is sustainable and the government absorbs the running costs of PW-P, many costs would be unnecessary. We therefore conducted an additional benefit-cost analysis factoring in only those costs and activities that would be undertaken by the government should CABI transition out of ownership. If costs related to CABI coordination, advocacy, and salary top-ups are excluded, the total annual costs would become approximately 97% of current program costs, and the benefit-cost ratio for 2017 would increase to 1.28:1.

Program Sustainability

Our data indicate that PW-P has been successful in establishing a system of well-functioning plant clinics because of the continuous funding and in providing training that enables higher quality diagnosis. However, the ability to sustain the clinics will require that PW-P provide guidance on how to fund the program and maintain high-quality, adaptable training that responds to the evolving needs in the sector. Program sustainability is more likely with a plan, ideally developed at the beginning of a program, that encompasses (a) the elements of the program that would determine sustainability, (b) the elements of the program that should be sustained, and (c) ways of incorporating activities that encourage sustainability throughout the life of the program, preferably with relevant milestones. Though PW-P could still benefit from defining explicit steps to achieve sustainability, we used our data from the cost and qualitative analyses to assess the likelihood that some elements of the program could be sustained.

The estimated measures used to assess the profitability of PW-P show that the program provides good value for money. Compared to cost-benefit analyses conducted on other agricultural extension programs, the estimated IRR for PW-P is above average. A systematic review by the International Food Policy Research Institute in 2018 (Nin-Pratt and Magalhaes, 2018) found the average rate of return for similar research and extension programs to be 6%. As is common in other development programs, benefits may increase relative to costs over time, as knowledge learned by farmers and other stakeholders is reused without further need for direct advice on recurrent problems.

Aside from funding, qualitative data show that program sustainability will be largely dependent on the ability of PW-P to institutionalize high-quality, ongoing plant doctor training, along with refreshers, to equip the largest number of AOs with the knowledge they need to accurately diagnose pests and diseases. Respondents' suggestions that clinics should go to farmers instead of holding clinics in the marketplace indicate that, in addition to diagnosing and prescribing solutions for problems, PW-P should work to broaden its reach to more farmers. As with the training and diagnosis activities, sustaining the process of data collection and increasing data utilization will require PW-P (a) to collaborate with GOP officials to incorporate PW data into larger systems of data collection and (b) to demonstrate the advantages of doing so.

7. Conclusions, Implications for PW-P, and Recommendations

In this section we discuss the key findings of the evaluation and provide recommendations based on the data and our analysis. The conclusions and recommendations are presented using the four research questions that motivated the evaluation.

A. Plant Health Systems Change

Overall, plant clinics seem to be well received in the system, complementary to other extension activities and agriculture programs, and implemented as intended. We also found that the data collection through plant clinics complements the data collected by all AOs for the GOP. The data seem to be reported up to the provincial level, though the extent of the use of the data to track and identify outbreaks and take appropriate action was unclear. Officers were not familiar with the POMS and did not use the POMS to conduct analyses on the data at an aggregate level. In addition, although some of the impacts suggest that IPM practices are being promoted through clinics (e.g., diversifying the number of practices used, reducing the use of hazardous pesticides that harm people or the environment, or monitoring for the problem and not acting unless a notional threshold has been crossed), there is room to expand the use of IPM practices and to explicitly tie IPM as a concept to the clinics. We recommend the following to further integrate PW-P and encourage systems change.

1. Align data use and reporting with government systems

Though the type of data collected through PW-P is complementary to the indicators the GOP collects, PW-P could further enhance the use of the data by helping refine systems to provide timely information from the clinics to key actors in the plant health system and thereby encourage rapid action and response. This may entail ongoing mentorship and commitment from partners on entering, cleaning, navigating, and analyzing data in ways that could yield changes in actions or policies. We recommend a template of standard, tailored questions that analysts at the provincial level could answer on a regular basis using the data—such as accuracy in prescriptions—in addition to some exploratory questions that will encourage analysis based on the context.

In addition, we recommend slight changes to the way pest and disease data are collected, including shortening prescription forms to require only the most important information and reinforcing training on how to send recommendations to farmers directly through the portal on the tablets. Plant doctors also indicated the need for more frequent updates on the Knowledge Bank (primarily fact sheets) would increase its usefulness, as well as guidance on how to recommend solutions to poorer farmers who cannot afford pesticides.

2. Intrinsically tie IPM to activities and programming

We recommend that PW-P further integrate IPM methods into its plant doctor training in a way that intrinsically ties IPM to the program. Currently, many officers discuss IPM as a priority, but data do not indicate that field-level participants are consistently using IPM to prevent and respond to pest and disease problems. In addition, farmers seem to trust pesticides more than biological methods of preventing or addressing pests and diseases, which they do not believe work well for them. PW-P could further integrate IPM recommendations into plant doctor training and provide specific IPM methods (including rational and appropriate use of pesticides) and biological alternatives to pesticides for common problems, thus explicitly encouraging use of IPM and providing ways to do so.

B. Implementation of PW-P

Plant doctors and clinic farmers both had the impression that information from training and plant clinics was more reliable and useful than information from non-plant-doctor AOs. However, respondents indicated that plant doctors thought that clinics gave them more work than regular AOs, despite the fact that the presence of clinics did not seem to increase the number of farmers interacted with. Farmers and AOs also stated that more mobility and frequency may increase farmer attendance. Finally, PW-P should incorporate efforts to include women plant doctors and accommodate their needs if the program expects to increase women's participation. The following changes may have the potential to improve implementation.

1. Improve clinic accessibility and setup

We recommend that PW-P make small changes to clinic accessibility and setup that may have the potential to improve attendance and the farmers' experience at the clinics. First, we recommend that PW-P introduce mobility options to increase access to the clinics, perhaps rotating to different markets or employing strategies to reach farmers who live far from any market. Second, we recommend that plant doctor training be offered to more AOs and that regular AOs be encouraged to use a similar process for diagnosis and adopt clinic practices during their regular extension work to capitalize on activities already taking place. Finally, we recommend that PW-P hold each clinic in a shaded area with a stable setup (including sufficient chairs and a sturdy umbrella and table) to further encourage attendance.

2. Explicitly include activities that facilitate and encourage women's participation

Because women in Pakistan have particular needs, we recommend that PW-P include explicit activities in its programming that encourage and facilitate women's participation. For example, the few women plant doctors we were able to contact said that to do their job they needed the program to provide reliable and safe transportation. At present, encouraging women's participation without including programmatic elements that cater to their specific needs leaves women unable to fully participate in the system. We recommend that PW-P collaborate with the GOP to gather groups of women in the field of agriculture to help identify the specific challenges they face and ways in which the program and the GOP could support their ability to safely and efficiently work in public spaces.

C. Impacts

The quantitative results of the impact evaluation at the farm level suggest that PW-P contributed to improvements in intermediate outcomes and some final outcomes for all crops for plant clinic users. The evidence indicates that farmers who attend plant clinics are applying some positive practices as a result of the program. We also investigated the results of the program on agricultural production for the most relevant crops in the sample. While we did not find impact on productivity for the average farmer, we do find positive and statistically significant impacts on yields and value of yields for farmers who reported having plant a health issue. These farmers also exhibit larger positive impacts on cultural practices compared to those not reporting plant health issues. These results are highly relevant given that farmers with plant health issues are exactly the farmers the program intends to benefit.

It is worth noting that as with any quasi-experimental evaluation, there is always a risk that estimated program impacts are driven by self-selection of farmers into the program. That is, it is possible that the positive impacts found for plant clinic users are not driven by the benefits obtained from attending a plant clinic, but are due to plant clinic users having better characteristics in the first place. Nevertheless, we employ a series of strategies to reduce the potential threat of the impact estimates being driven by unobserved characteristics of program participants. First, we selected treatment and control areas that are similar in terms of their agroecological characteristics. Second, we use a filter questionnaire to ensure the farmers are similar in terms of key production variables (e.g., crops produced and areas). Third, we collect a rich set of covariates to use them as controls in our econometric specifications. Overall, we think that our empirical strategy is a close approximation to the true program impact even though the strategy assumes that there is no selection bias due to unobserved characteristics after controlling for all the variables we used.

D. Cost-Benefit Analysis

Our findings from the cost-benefit analysis show that PW-P provides good value for money. Also, according to cost data, PW-P has successfully transitioned an increasing proportion of operating costs to the GOP each year. In addition, qualitative data indicate that program implementers have taken the initiative in replacing materials as they become older or damaged. However, besides taking over the program’s funding, the GOP will need to gain knowledge about procedures and technical elements of implementation to ensure sustainability, for example updating clinic materials. Ultimately, sustainability will require GOP stakeholders to be specifically trained on how to implement and scale essential PW-P activities, including extension through clinics, plant doctor training, and the collection and use of data. We recommend focusing on capacity building in the following areas to maximize the likelihood of program efficiency and sustainability.

1. Improve and broaden plant doctor training

PW-P should invest in ensuring that certain officers throughout the GOP are equipped to deliver training to AOs that enables many more AOs to operate on the level of plant doctors. PW-P should also encourage a system that incorporates regular refresher trainings to maintain and enhance plant doctor knowledge. Because of the impression that plant doctors are better equipped than typical AOs to diagnose pests and diseases and give applicable recommendations, investing in further training of higher-level trainers who can then train a large cadre of AOs to have the same level of knowledge as plant doctors would be an efficient way to encourage the sustainability of arguably the most important element of the program. Doing so would also synergize the two roles and thereby lessen the impression among AOs that plant doctor activities are extra work.

2. Increase the collection and use of data

PW-P should focus on building capacity to promote data-driven action using the data collected in POMS on the part of decision makers through protocols that outline quick, coordinated response to potential outbreaks and chronic issues as soon as they have been identified in the field. PW-P could also benefit from working with GOP officials to enhance the quality of data collection and ensure that PW data are incorporated into overarching data systems. Collecting data on indicators is clearly a priority in the agricultural system already; however, PW-P could further build the capacity of the GOP to analyze and react to the data collected on an ongoing basis.

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Appendix A. Additional Impact Estimates

Table A.1. Impacts on Agricultural Practices (Wheat)

Outcome of interest	Impact estimate	Mean control	Mean clinic users	*N*
Rotated crop	-0.03	0.79	0.76	1799
Planted improved planting material or variety	0.00	0.72	0.72	1799
Planted with certified planting material	0.03	0.62	0.65	1799
Removed all plant residue prior to planting	-0.00	0.94	0.94	1799
Planted early	0.04**	0.54	0.58	1799
Implemented intercropping	0.01	0.01	0.02	1799
Times checked for pests/diseases	-0.45	52.82	52.37	1799
Log of times checked for pests/diseases	0.01	3.10	3.11	1786
Weeded in a timely manner	0.03	0.77	0.80	1799
Removed volunteer crops	-0.00	0.63	0.63	1799
Removed infested or damaged material	0.00	0.90	0.90	1799
Used trap crops to protect crop	0.01	0.08	0.08	1799
Burnt crop residue to control pests/diseases	0.01	0.68	0.69	1799
Use traps	0.02	0.06	0.07	1799

Note. Impacts are estimated using the inverse-probability-weighted regression adjustment (Doubly-robust estimator). Robust standard errors are in parentheses. *** p<0.01; ** p<0.05; * p<0.1.

Table A.2. Impacts on Agricultural Practices (Cotton)

Outcome of interest	Impact estimate	Mean control	Mean clinic users	*N*
Rotated crop	-0.01	0.77	0.76	738
Planted improved planting material or variety	-0.03	0.77	0.74	738
Planted with certified planting material	-0.01	0.76	0.74	738
Removed all plant residue prior to planting	0.00	0.97	0.97	738
Planted early	0.02	0.73	0.75	738
Implemented intercropping	0.01	0.01	0.02	738
Times checked for pests/diseases	-1.36	83.79	82.43	738
Log of times checked for pests/diseases	0.00	3.95	3.95	737
Weeded in a timely manner	0.01	0.90	0.92	738
Removed volunteer crops	-0.05**	0.80	0.75	738
Removed infested or damaged material	-0.00	0.96	0.95	738
Used trap crops to protect crop	-0.01	0.06	0.05	738
Burnt crop residue to control pests/diseases	0.03	0.79	0.82	738
Use traps	-0.01	0.05	0.04	738

Note. Impacts are estimated using the inverse-probability-weighted regression adjustment (Doubly-robust estimator). Robust standard errors are in parentheses. *** p<0.01; ** p<0.05; * p<0.1.

Table A.3. Impacts on Agricultural Practices (Rice)

Outcome of interest	Impact estimate	Mean control	Mean clinic users	*N*
Rotated crop	0.04	0.81	0.85	600
Planted improved planting material or variety	-0.03	0.70	0.67	600
Planted with certified planting material	0.02	0.54	0.56	600
Removed all plant residue prior to planting	-0.04	0.90	0.86	600
Planted early	0.03	0.36	0.39	600
Implemented intercropping	-0.00	0.01	0.01	600
Times checked for pests/diseases	-2.84	30.34	27.49	600
Log of times checked for pests/diseases	-0.07	2.82	2.75	598
Weeded in a timely manner	0.02	0.75	0.77	600
Removed volunteer crops	0.03	0.56	0.59	600
Removed infested or damaged material	0.06**	0.86	0.92	600
Used trap crops to protect crop	0.04*	0.06	0.09	600
Burnt crop residue to control pests/diseases	-0.07	0.59	0.52	600
Use traps	-0.01	0.05	0.04	600

Note. Impacts are estimated using the inverse-probability-weighted regression adjustment (Doubly-robust estimator). Robust standard errors are in parentheses. *** p<0.01; ** p<0.05; * p<0.1.

Appendix B. Impact Estimates: Non-participants and Non-eligible

Table B.1. Impacts on Agricultural Practices (All Crops)

Outcome of interest	Impact estimate	Mean non-eligible	Mean non-participants	*N*
Rotated crop	-0.02	0.75	0.73	2741
Used improved planting material or variety	0.01	0.73	0.74	2741
Planted with certified planting material	0.01	0.63	0.64	2741
Removed all plant residue prior to planting	0.02**	0.90	0.93	2741
Planted early	0.01	0.54	0.56	2741
Implemented intercropping	0.01*	0.03	0.04	2741
Times checked for pests/diseases	2.21	49.26	51.47	2741
Log of times checked for pests/diseases	0.01	3.08	3.09	2703
Weeded in a timely manner	0.02	0.73	0.75	2741
Removed volunteer crops	-0.01	0.56	0.55	2741
Removed infested or damaged material	0.01	0.82	0.83	2741
Used trap crops to protect crop	0.02**	0.06	0.08	2741
Burnt crop residue to control pests/diseases	0.01	0.61	0.62	2741
Number of good practices implemented	0.12*	6.40	6.53	2742

Note. Impacts are estimated using the inverse-probability-weighted regression adjustment (Doubly-robust estimator). Robust standard errors are in parentheses. *** p<0.01; ** p<0.05; * p<0.1.

Table B.2. Impacts on Seed Costs per Acre

Outcome of interest	Impact estimate	Mean non-eligible	Mean non-participants	*N*
All crops	0.03	7.79	7.82	2607
Wheat	-0.00	7.78	7.78	1187
Cotton	0.01	8.20	8.21	473
Rice	0.07*	7.72	7.79	612

Note. Impacts are estimated using the inverse-probability-weighted regression adjustment (Doubly-robust estimator). The seed costs are in natural logs. Robust standard errors are in parentheses. *** p<0.01; ** p<0.05; * p<0.1.

Table B.3. Impacts on Organic and Inorganic Fertilizer Use

Outcome of interest	Impact estimate	Mean non-eligible	Mean non-participants	*N*
All Crops				
Organic fertilizer used = 1	0.02	0.25	0.27	2742
Log of organic fertilizer in kg/acre	0.08	1.81	1.89	2742
Inorganic fertilizer used = 1	-0.00	0.98	0.98	2742
Log of cost of inorganic fertilizer per acre	0.01	8.71	8.72	2694
Wheat				
Organic fertilizer used = 1	0.03	0.28	0.30	1197
Log of organic fertilizer in kg/acre	0.16	1.88	2.04	1197
Inorganic fertilizer used = 1	0.00	0.99	0.99	1197
Log of cost of inorganic fertilizer per acre	0.00	8.69	8.69	1184
Cotton				
Organic fertilizer used = 1	-0.02	0.07	0.05	487
Log of organic fertilizer in kg/acre	-0.09	0.38	0.29	487
Inorganic fertilizer used = 1	0.01	0.98	0.99	487
Log of cost of inorganic fertilizer per acre	0.04	9.21	9.24	480
Rice				
Inorganic fertilizer used = 1	-0.01	0.99	0.98	407
Log of cost of inorganic fertilizer per acre	-0.13*	8.69	8.56	402

Note. Impacts are estimated using the inverse-probability-weighted regression adjustment (Doubly-robust estimator). Robust standard errors are in parentheses. *** p<0.01; ** p<0.05; * p<0.1.

Table B.4. Impacts on Pesticide Use

Outcome of interest	Impact estimate	Mean non-eligible	Mean non-participants	*N*
All Crops				
Pesticide use = 1	0.02	0.71	0.72	2742
Number of applications	0.06	1.65	1.72	2742
Log of cost per acre	0.05	7.20	7.25	1963
Days used in pesticide application	0.26*	2.30	2.56	2742
Use pesticide in red list	0.01	0.03	0.03	1963
Wheat				
Pesticide use = 1	0.04*	0.75	0.79	1197
Number of applications	0.07	1.04	1.11	1197
Log of cost per acre	0.04	6.64	6.68	929
Days used in pesticide application	0.17	1.85	2.02	1197
Use pesticide in red list	0.01	0.01	0.02	929
Cotton				
Pesticide use = 1	-0.01	0.98	0.96	487
Number of applications	-0.06	4.75	4.68	487
Log of cost per acre	0.09	8.41	8.51	471
Days used in pesticide application	-0.41	4.98	4.57	487
Use pesticide in red list	-0.02	0.07	0.05	471
Rice				
Pesticide use = 1	-0.06*	0.85	0.80	407
Number of applications	-0.15	1.47	1.32	407
Log of cost per acre	-0.12	7.12	6.99	340
Days used in pesticide application	-0.23	2.30	2.07	407
Use pesticide in red list	0.01	0.02	0.03	340

Note. Impacts are estimated using the inverse-probability-weighted regression adjustment (Doubly-robust estimator). Robust standard errors are in parentheses. *** p<0.01; ** p<0.05; * p<0.1.

Table B.5. Impacts on Yields and Value of Yields, by Crop

Outcome of interest	Impact estimate	Mean non-eligible	Mean non-participants	*N*
PANEL A. PRODUCTIVITY OUTCOMES				
All crops				
Log of value of production per acre (PKR/acre)	-0.03	11.29	11.26	2561
Log of net income	-0.03	10.99	10.96	2479
Wheat				
Log of value of production per acre (PKR/acre)	-0.02*	10.86	10.84	1187
Log of net income	-0.02	10.57	10.55	1187
Cotton				
Log of value of production per acre (PKR/acre)	-0.01	11.35	11.35	473
Log of net income	-0.05	10.85	10.80	425
Rice				
Log of value of production per acre (PKR/acre)	-0.02	11.48	11.47	382
Log of net income	0.00	11.29	11.29	377
PANEL B. COST OUTCOMES				
All crops				
Log of total cost per acre	0.01	9.54	9.56	2607
Log of seed cost per acre	0.03	7.79	7.82	2607
Log of inorganic fertilizer cost per acre	0.01	8.72	8.73	2580
Log of pesticide cost per acre	0.06	7.19	7.26	1896
Log of paid labor cost per acre	0.03	8.47	8.50	1757
Wheat				
Log of total cost per acre	0.00	9.38	9.38	1187
Log of seed cost per acre	-0.00	7.78	7.78	1187
Log of inorganic fertilizer cost per acre	0.00	8.69	8.70	1175
Log of pesticide cost per acre	0.04	6.64	6.68	925
Log of paid labor cost per acre	0.03	8.17	8.19	767
Cotton				
Log of total cost per acre	0.07	10.24	10.31	473
Log of seed cost per acre	0.01	8.20	8.21	473
Log of inorganic fertilizer cost per acre	0.03	9.24	9.28	467
Log of pesticide cost per acre	0.08	8.46	8.54	461

Outcome of interest	Impact estimate	Mean non-eligible	Mean non-participants	*N*
Log of paid labor cost per acre	0.07	9.18	9.25	362
Rice				
Log of total cost per acre	-0.09*	9.57	9.47	382
Log of seed cost per acre	0.02	6.71	6.72	382
Log of inorganic fertilizer cost per acre	-0.08	8.69	8.60	377
Log of pesticide cost per acre	-0.04	7.09	7.05	320

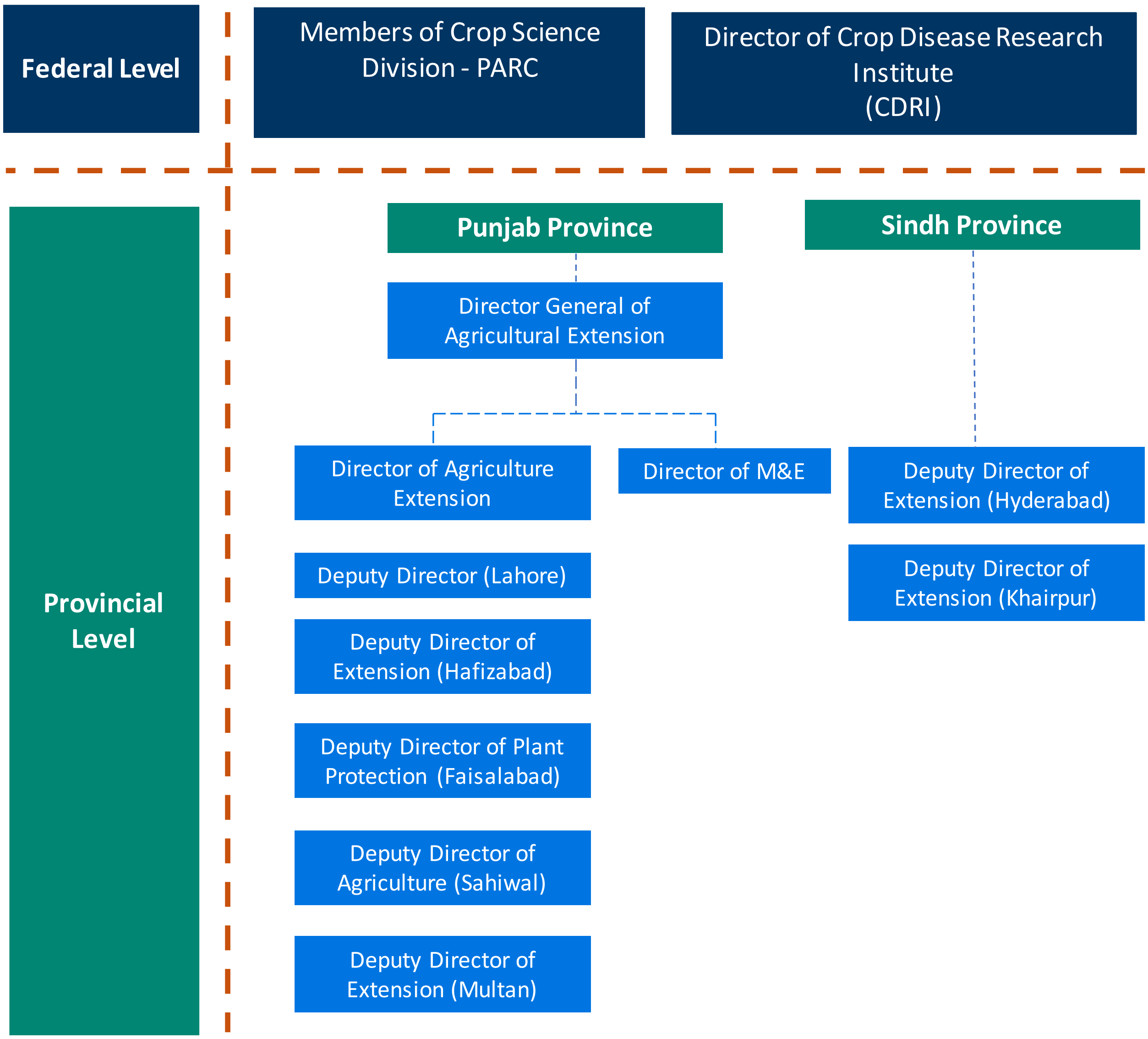
Note. Impacts are estimated using the inverse-probability-weighted regression adjustment (Doubly-robust estimator). Robust standard errors are in parentheses. *** p<0.01; ** p<0.05; * p<0.1.

Table B.6. Impacts on Value of Yields, and Costs for Farmers with Plant Health Issues

Outcome of interest	Impact estimate	Mean non-eligible	Mean non-participants	*N*
Panel A. All crops				
Log of value of production per acre (PKR/acre)	0.00	11.16	11.17	616
Log of total cost per acre (PKR/acre)	0.04	9.90	9.94	612
Log of net income	-0.05	10.74	10.69	561
Panel B. All crops—controlling for severity of plant health Issue				
Log of value of production per acre (PKR/acre)	0.00	11.16	11.17	616
Log of total cost per acre (PKR/acre)	0.04	9.90	9.94	612
Log of net income	-0.05	10.74	10.68	561

Notes: Impacts are estimated using the inverse-probability-weighted regression adjustment (Doubly-robust estimator). Robust standard errors are in parentheses. *** p<0.01; ** p<0.05; * p<0.1.

Appendix C. Organigram of officials



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