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Use of plant clinic advice among farmers in Ethiopia: implications for sustainable pest management service

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ABSTRACT
This study examined the use of crop health advices that farmers received at village-based plant clinics and their determinants in Ethiopia. Data were collected from 210 randomly selected plant clinic users from three districts of Ethiopia, and analysed using descriptive statistics and a binary logistic regression model. Plant clinic users were smallholders with an average landholding of 0.8 ha, predominantly male, with a mean age of 46 years. Most recommendations for pest management were a combination of monitoring, cultural practices and pesticides, in line with Integrated Pest Management (IPM) principles. About 64% and 34% of the clinic users fully or partially, respectively, applied the recommendations. After visiting plant clinics, farmers demonstrated improved knowledge and practices in using pesticides, although no significant difference was observed between the types of pesticides they used. Stability of plant doctors, distance to plant clinics, and education significantly and positively influenced the use of plant clinic advice, whereas age was negatively associated. The findings suggest that plant clinics provide relevant and practical advice that address plant health problems of farmers. Thus, such project-based intervention should be fully integrated into regular programmes to ensure their sustainability.

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Plantwise; plant clinics; adoption; pest management; advisory service

Introduction

Increasing agricultural productivity to meet the ever-rising demands for food and other agricultural products without harming the environment, biodiversity, and quality of produce is a major global concern. Efforts aimed at addressing such critical issues face numerous challenges. The rising pest and disease problems are one of the major threats to the performance of the agricultural sector (Negussie et al. 2017; Tambo et al. 2020). Shiferaw et al. (2016) reported that in Ethiopia, the estimated pre- and post-harvest losses due to pests range between 30% and 50%. Globally, damage by pests causes losses estimated as high as 40% in annual crop production, while the damage on certain crops and in some hot-spot areas exceed this range (Flood 2010; Day et al. 2017; Savary et al. 2019). Reducing such huge crop losses, increasing agricultural productivity and quality of produce are critical to achieving the sustainable development goals of zero hunger and no poverty. However, the lack of access to timely and relevant advice on crop health problems poses a significant challenge to farmers in taking timely action to mitigate crop losses (Tambo et al. 2020). Similar to many other developing countries, there have been severe limitations in the management of crop pests in Ethiopia, largely due to the weaknesses of the pest management support services (MoANR 2016).

Another alarming situation is the impact of the ever-increasing misuse and excessive use of pesticides. Studies conducted by Negatu et al. (2016) and Mengistie et al. (2017) reported significant increases in the use of chemical pesticides in the last decade in Ethiopia. The recent outbreaks of new pests, such as the tomato leaf miner (*Tuta absoluta)* and the fall armyworm (FAW) (*Spodoptera frugiperda*), further aggravated the situation, as farmers tended to respond with heavy and inappropriate application of pesticides. Intensive pesticide application can increase the vulnerability of agricultural systems to pest outbreaks and lock in continued reliance on their use (Jepson et al. 2020). Studies conducted in Ethiopia (Negatu et al. 2016; Belay et al. 2017) revealed that farmers display poor knowledge and practices regarding safe use of pesticides and often violate recommendations, which include use of inappropriate storage facilities, disregarding safety instructions, failure to use protective equipment when applying pesticides and inappropriate disposal of empty pesticide containers. A recent study conducted in Iran (Bagheri et al. 2019) suggested that

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farmers' knowledge of pesticide use is the most important factor affecting pesticide use behavior, followed by attitudes and perceptions. On the other hand, safety behaviors in pesticide use were considered the most important determinants of the adverse health effects among farmers (Sharifzadeh et al. 2019). One of the major pathways to minimise pesticide risks is the adoption of integrated pest management (IPM), which offers a framework for managing economic, health and environmental risks, while minimising undesirable outcomes for crop production (Jepson et al. 2020).

Although Ethiopia's extension system has one of the strongest extension agent-farmer ratios found in the world (Ragasa et al. 2013) and complementary structures, such as farmers' training centres (FTCs), there are gaps in the government extension system in providing sufficient plant health diagnostic and advisory services to enable farmers cope with the rising pest threats (MoANR 2016). This situation calls for a pluralistic approach that involves multi-stakeholder actors and alternative delivery methods for providing pest management advisory services to farmers. Plantwise, a CABI-led global programme, offers an alternative approach for addressing some of the critical gaps in plant health advisory services through its community-based plant clinics and other complementary services (Negussie et al. 2017). Plant clinics are primary plant healthcare services that operate from accessible locations frequented by farmers, such as local markets, village and cooperative centres, and farmer training centres (Bentley et al. 2009; Ghiasi et al. 2017; Negussie et al. 2017). In Ethiopia, plant clinics operate on a weekly or fortnightly basis; they can be held more frequently by integrating them into FTCs. Farmers whose crops experience plant health problems bring samples of their ailing crops to trained extension officers, referred to as plant doctors. The plant doctors examine the plant samples, make a diagnosis of the problem, and subsequently advise farmers on how to manage the problems, accompanied by a written prescription. For each consultation, plant doctors capture information about farmers, crops, and crop health problems, together with the recommendations given, in a record form. Thus, plant clinic records provide useful information on priority plant health problems of farmers as well as on the importance and changing status of crop pests (Finegold et al. 2014).

One of the salient features of this approach is that it builds local staff capacity and makes use of existing organizational structures, social dynamics and frontline extension (crop protection) staff (Danielsen et al. 2013; Negussie et al. 2017). Therefore, plant clinics utilise field-based government extension staff and FTCs, which offer unique opportunities for such services in Ethiopia. Unlike other conventional extension approaches that push pre-packaged technologies to farmers (often using blanket approaches), community-based plant clinics provide a demand-driven service that addresses priority crop problems of farmers (Negussie et al. 2017). A study conducted on a different type of plant clinic approach in Iran (Ghiasi et al. 2017) confirmed that such facilities have a huge potential to support decision-making on technical, operational, and strategic matters. Another important feature of the Plantwise plant clinics approach is that it promotes safe, economical and practical recommendations that are guided by IPM principles (Danielsen et al. 2013); because plant doctors are supported and encouraged to recommend only locally registered and non-hazardous pesticides, unrestricted by international conventions.

Over 4000 Plantwise village-based plant clinics have been established in 34 countries (Tambo et al. 2020). In Ethiopia, such plant clinics were launched in late 2013, through the establishment of eight pilot plant clinics in the Oromia region. Based on preliminary assessments made by the government and other partners, the initiative was scaled out to Tigray and Amhara regions in 2014 and to Southern Nations Nationalities and Peoples (SNNP) region in 2017. In 2019, Dire Dawa administrative council and Benshangul Gumz region joined the programme. A further expansion of plant clinics continued within the original regions in response to the government's push to increase the reach of plant clinics in the country. Presently, there are about 170 village-based plant clinics operating across six regions of Ethiopia (CABI/MoA 2019). However, since the launch of plant clinics in Ethiopia, no systematically designed studies have been conducted to assess the use of plant clinic advices by farmers. Thus, using primary data obtained from plant clinic users from three regions of Ethiopia, this study examined the use of advice given to farmers at plant clinics and its determinants, and whether the recommendations were in line with IPM principles.

Methodology

Description of the study area

This study was conducted in Ethiopia between December 2018 and January 2019, and focused on three districts (Shashemene, Fogera and Seharti Samre) that were selected from the pioneer regions in launching the Plantwise initiative in Ethiopia - Amhara, Oromia, and Tigray. Shashemene is located in West Arsi zone of Oromia region, 275 km south of Addis Ababa. The district is one of the highly productive areas, producing a variety of crops. The major food crops include maize, wheat, teff, potato, barley, and haricot bean. Potato, tomato, onion, pepper and coffee are among the major cash crops grown in the area. Fogera is located in South Gonder, Amhara region, 625 km north of Addis Ababa and 55 km from Bahir Dar (the capital city of Amhara region), and is known for its suitability for rice production. Teff, maize, rice, wheat, finger millet, barley, lentil, and horse bean are the major food crops grown in the district. The major cash crops include horticultural crops, such as onion, tomato, garlic, and potato. The third study district, Seharti Samre, is located in Central Tigray, about 800 km from Addis Ababa. Major food crops grown in the area include maize, wheat, teff, sorghum, horse bean and barley, while cash crops include tomato, garlic, onion, potato, cabbage, and beans.

Sampling and data collection

The three study districts were purposively selected from the three regions. The main criteria employed in choosing the districts were the year the plant clinics were launched (2013 or 2014 - the first batch), the crops grown in the area and the representativeness of the farming system. Out of the two plant clinics in each district, one plant clinic from each was purposively sampled from Shashemene and Seharti Samre districts, while two plant clinics were selected from Fogera district. Systematic random sampling technique was used to select farmers from plant clinic records, whereby 70 farmers were sampled from each plant clinic in Shashemene and Seharti Samre districts, while 35 farmers were selected from each of the two plant clinics from Fogera district, bringing the total sample to 210 farmers.

A structured questionnaire was developed, pretested, and eventually administered to the randomly selected 210 farmers. The questionnaire was designed in a way that allowed the capturing of data on experiences and practices of farmers, both before and after visiting plant clinics. The questionnaire was administered by trained zonal or district crop protection experts through face-to-face interviews with the selected farmers, whereas regional experts served as supervisors for the data collection process. Although the questionnaire was prepared in English, the interviewers administered it to the farmers in their respective local languages. The main limitation of the current study is that it relied on plant clinic users' ability to recall information for the 'before' and 'after' scenarios. The researchers tried to address this limitation through further probing with farmers and cross-checking with the information in the plant clinic records.

Data analysis

SPSS 20 was used to analyse the data. Descriptive statistics such as frequency tables, means and percentage distributions were generated, while t-tests were used to make comparisons of means of some variables. A binary logistic regression model was employed to examine factors affecting use of plant clinic advice.

Model specification

Use of plant clinic advice was measured as a dummy variable (or dichotomous response variable), which assumes the value 1 if the clinic recommendation is fully used by a farmer, and the value 0 if partially adopted or not used at all. Partial adoption of certain recommendations was considered a deficiency as this could influence the effectiveness of the recommendations. The explanatory variables included selected demographic, socio-economic and institutional variables (continuous and categorical). In order to determine the effects of independent variables on the dummy dependent variable, a binary logistic regression model was employed. The logistic model is the standard or preferred method of analysis, when the outcome variable is dichotomous (Hosmer and Lemeshow 2000). It is a form of regression used when the dependent variable is a dichotomous categorical variable and the independent variables are of any type (nominal, ordinal, or scale variables).

Model specification. The logistic regression estimates the probability of a certain event occurring. The logistic regression model characterizing adoption of plant clinic advice by the respondent households is specified as follows:

$$\text{Prob}\ (Y = 1) = \frac{e^{\beta 0 + \beta 1\ X\ 1 + \beta 2\ X\ 2 + \dots\ \beta i\ X\ i + \varepsilon}}{1 + e^{\beta 0 + \beta 1\ X\ 1 + \beta 2\ X\ 2 + \dots\ \beta i\ X\ i + \varepsilon}} \tag{1}$$

As the outcome of logistic regression is binary, Y needs to be transformed. Thus, from equation (1), we arrive at a simple linear regression equation through logit transformation (Gujarati 1995; Hosmer and Lemeshow 2000):

$$\log\left[\frac{P}{1-P}\right] = \beta_0 + \beta_1\ X_1 + \beta_2\ X_2 + \dots\ \beta_i\ X_I + E \tag{2}$$

where P is the probability that Y = 1, which means a farmer adopts plant clinic advice, 1 – P is the probability that Y = 0, which means a farmer partially adopts or does not adopt plant clinic advice, β_0 = is constant of the equation, X_1, X_2, … , X_I *are the independent variables (predictors),* whose description and hypothesis are provided in Table 1,

Table 1. Description of variables included in the logit model.

Variable (Code)	Description	Type	Hypothesis
AGE (X_1)	Age of respondent farmer in years	Continuous	Negative
Educatn2 (X_2)	Respondent farmer's education (farmer has education = 1 and 0 otherwise)	Dummy	Positive
Gender2 (X_3)	Gender of respondent farmer, 0 for female, 1 for male	Dummy	Positive
HHsize (X_4)	Number of all members residing in the respondent's household.	Continuous	Positive
Landownd (X_5)	Size of land owned by respondent farmer household (in ha).	Continuous	Positive
Dista2PC (X_6)	Distance from respondent farmer's residence to plant clinic location in km.	Continuous	Negative
Numbvisit (X_7)	Number of clinic visits made by the respondent farmer or his household member	Continuous	Positive
StabPD (X_8)	If the trained plant doctor continued serving the same plant clinic (never changed) = 1, and 0 = otherwise.	Dummy	Positive
Dist2agrod (X_9)	Distance from respondent's residence to agro-dealers shop in km	Continuous	Negative

$\beta_1 + \beta_2 + \ldots \beta_i$ are the coefficients that have to be estimated from the data, i – number of independent variables, $\left[\frac{P}{1-P}\right]$ is odds ratio in favour of adoption of plant clinic advice and ε is the error term.

Description of independent variables and working hypotheses

A review of the literature and empirical research findings on the adoption of agricultural technologies, the current researchers' knowledge of the study areas were used for developing working hypotheses for the explanatory variables. Description of explanatory variables related to sampled farm households' demographic, socio-economic, and institutional characteristics, which were hypothesised to influence farmers' adoption decisions, on a *priori* grounds, are outlined in Table 1. These variables were included in the logistic regression model.

Results and discussion

Farmers' demographic and socio-economic characteristics

Farmers from 29 villages visited the four surveyed plant clinics and, on average, each plant clinic was visited by farmers from close to eight villages, with variations across regions. The average distance from the farmers' (henceforth referred to as plant clinic users) residences to the nearest plant clinic was approximately 2.9 km, with a range from 10 m to 15 km (Table 2). The majority of the plant clinic users (90.5%) were located within a radius of 5 km from the plant clinic sites. This distance shows that most plant clinic users were clustered around villages close to the plant clinics, thus suggesting the need to have more of such facilities in each district to bring services closer to users.

The mean age of plant clinic users was 46 years, with a range of 24–83 years (Table 2). Only 12% of the plant clinic users were below 35 years of age. This finding implies that the use of plant clinic services is quite limited among the youth, which could be related to the challenges of land ownership among rural youth. A study carried out in Southern Ethiopia (Bezu and Holden 2014) confirmed that the youth in rural Ethiopia have limited access to agricultural land because of land scarcity and land market restrictions. Respondents' farming experience varied between 1 and 70 years, with an average of 26 years. Only 10% of the respondents had 10 years and less farming experience, which suggests that plant clinic users tended to be those with a wealth of farming experience. In total, 93% of the interviewed farmers were heads of households, while 7% were other household members. This proportion implies that plant clinic users tended to be heads of households, the majority of whom were male. The majority (92%) of the sampled respondents were male farmers and only 8% were female (Table 2). Similar to many other developing countries, the agricultural extension programmes in Ethiopia mainly focus on male farmers (FAO 2019); female heads of households and farm managers are less likely to receive extension services, when compared to their male counterparts (Ragasa et al. 2013). A comprehensive analysis of plant clinic datasets from India and Ghana (Williams and Taron 2020) showed that 13% and 29%, respectively, of plant clinic users were women. This finding suggests the need for deliberate and targeted measures aimed at boosting women's participation in plant clinic services. Moreover, there is a need for a more comprehensive gender analysis involving more women and plant clinics across regions to understand gender dynamics, which can vary with changes in socio-economic set-up and over time. In addition, analysis of the entire plant clinics records in Ethiopia may give a different picture.

Table 2. Selected demographic and socio-economic characteristics of the surveyed farmers.

Variables	Mean	Range
Distance to plant clinic (km)	2.9	0.01–15
Age (years)	46	24–83
Farm Experience (years)	26	1–70
Gender	Number	Percent
Male	193	92
Female	17	8
Educational level	Number	Percent
No education	116	55
Has education	94	45
Family size	Mean	Range
Number of household members	6.5	2–12
Farm size	Mean	Range
Total land area owned (ha)	0.80	0.25 –2.5

Table 3. Farmers' source of information on crop pest management before and after launch of plant clinics.

Source of information for farmers	Before the launch of plant clinics (number and percent of farmers)	After launch of plant clinics (number and percent of farmers)
Conventional extension workers	103 (50)	16 (7)
Plant doctors (plant clinics)	–	157 (75)
Neighbours (other farmers)	74 (35)	8 (4)
Combination of conventional extension worker, Agro-dealers, farmers & radio/TV	23 (11)	–
Plant doctors & combination of others	–	20 (10)
Agro-dealers	10 (4.5)	9 (4)

Table 4. Source of advice/information on pesticide for the surveyed farmers.

Source of advice/information about pesticide	Before launch of plant clinics (number and percent of farmers)	After launch of plant clinics (number and percent of farmers)
Plant doctors (plant clinics)	NA	147 (70)
Conventional extension workers	95 (49)	22 (11)
Neighbours (fellow farmers)	77 (39)	6 (3)
Agro-dealers	13 (6)	13 (6)
NGOs	6 (4)	–
Plant doctors, conventional extension workers, agro-dealers & radio/TV	–	12 (6)
Others (Combination)	4 (2)	9 (4)
Total	195 (100)	209 (100)

Concerning educational status of plant clinic users, over half (55%) of the respondents had no formal education. Over one-third (37.5%) had attained basic education, while only 6% and 1.5% had attained secondary school and college/university level education, respectively. This proportion shows that lack of education did not prevent farmers from seeking advice from plant clinics. However, as reported later in this paper, education appeared to affect adoption of plant clinic advice. In the sample, the average household size was 6.5, with a range of 2 to 12 members (Table 2). On average, the surveyed farmers had less than 1 ha of land and this varied between 0.25 ha and 2.50 ha. This finding showed that plant clinic users were typical smallholder farmers. Only 11 respondents (5%) rented out land, while 129 respondents (61%) rented in land from others, indicating scarcity of farmland in the study areas, and thus, the majority of the farmers largely relied on renting in land for farming.

Sources of information on crop pest management

As presented in Table 3, before the launch of plant clinics in the study areas, farmers largely relied on conventional extension workers (government extension workers who were not trained on field diagnosis of pests and giving good recommendations), and fellow farmers for information on crop pest management. Agro-dealers were the least identified source of information, both before and after the launch of plant clinics in the study areas. Despite the boom in the use of mass media, they seemed to play a limited role in disseminating pest management information in the study areas. Presently, plant clinics have become a major source of information on pest management.

Likewise, conventional extension agents were reported to be a major source of information related to pesticides before the launch of plant clinics, while plant doctors (plant clinics) have become the main source of such information after the launch of plant clinics (Table 4). Fellow farmers were reported as the main source of information about pesticides for over a third of farmers (39%) before the launch of plant clinics, but their role has declined at present. Less than 6% of the surveyed farmers relied on agro-dealers for advice on the use of pesticides, both before and after the launch of plant clinics. This low percentage possibly suggests that the primary concern of agro-dealers is selling pesticides, and not necessarily providing advisory services on their proper use.

The main sources of pesticides for the surveyed farmers during the survey period were agro-dealers (68%), cooperative union (24%), and government (19%). Regional governments play an active role in supplying pesticides to farmers, particularly in Tigray. The average distance between farmers' residences and the nearest agro-input supplier shop was 6 km, varying between 0.5 km and 15 km. This finding indicates that many farmers had to travel some distance to get to agro-dealer shops. About 39 farmers (19%) reported not having agro-dealer shops within their vicinity, suggesting the need for encouraging agro-dealers to establish local retail shops or to promote delivery of such inputs through cooperative unions, or other options.

Information about plant clinics and farmers' visit to get the service

The majority of the farmers (70%) learnt about plant clinics from plant doctors. Roughly, 13%, 9.5%, and 4.5% heard about plant clinics from

Table 5. Plant health problems diagnosed at sampled plant clinics.

Problems identified	Number of farmers responded	Percent
Wheat yellow rust (*Puccinia striiformis*)	35	29
FAW (maize) (*Spodoptera frugiperda)*	21	17
Maize stalk borer *(Busseola fusca)*	20	17
Wheat stem rust (*Puccinia graminis)*	10	8
Late blight (potato, tomato) (*Phytophthora infestans)*	7	6
African bollworm (cotton, tomato) *(Helicoverpa armigera)*	6	5
Onion thrips (*Thrips tabaci)*	6	5
Root rot (vegetables, cereals) *(Phytophthora species; Cochliobolus sativus)*	5	4
Early blight of tomato *(Alternaria solani)*	5	4
Powdery mildew (tomato, pepper) *(e.g., Erysiphe* spp., *Sphaerotheca* spp.)	5	4
Total	120	100

fellow farmers, both from plant doctors and fellow farmers, and agro-dealers, respectively. Farmers did not mention announcements made at places of worship and other public events, which were often reported by plant doctors as important avenues for publicizing plant clinic services. Apart from improving their services, promoting farmers' familiarity with plant clinics services is crucial for enhancing the impacts of such facilities (Ghiasi et al. 2017). Thus, the use of all available means of communication to create awareness about plant clinics among farmers and other stakeholders is important.

The majority of the surveyed farmers (80%) visited plant clinics in 2015 and 2016. Respondents (or their household members) visited plant clinics, on average, 2.40 times, since their launch. The majority of the farmers (77%) visited plant clinics once or twice, while a few had visited plant clinics as many as 12 times. A study conducted in Kenya (Kansiime et al. 2020) showed that the reasons for the repeated visits of plant clinics included seeking for more clarification on recommendations, bringing a different problem after the previous recommendation worked, bringing the same problem that reoccurred, or because farmers did not implement the recommendation(s) the first time. In a study conducted in Ghana (Lamontagne-Godwin et al. 2017), about 67% of female and 69% of male farmers revisited plant clinics because they had previously received good advice. Thus, the reasons behind repeat visits under the Ethiopian context may need further investigation to understand motivations of farmers for making repeat visits to plant clinics.

Crops presented and problems diagnosed at plant clinics

The major crops brought to the surveyed plant clinics included maize, wheat, tomato, onion, teff, and others. The sample crops varied from district to district based on agro-ecology and farming system. The records of crops taken to plant clinics suggested that farmers seemed to prioritize major food (cereal) crops and cash crops. Although we understand that farmers are rational and make decisions that serve their best interests, it is important to sensitize and encourage them to bring problems encountered on all crops, including those managed by female farmers.

As presented in Table 5, the most common plant health problems diagnosed at the sampled plant clinics included wheat yellow rust, FAW (maize), maize stalk borer, wheat stem rust, African bollworm (cotton, tomato), thrips (onion), late and early blights (potato, tomato), root rot (vegetables and cereals) and powdery mildew (tomato, pepper). However, it is important to note that these records are not exhaustive on the major pest problems one would encounter in those districts. Moreover, some farmers were unable to recall the specific problems diagnosed at plant clinics.

Type of pest management advice given to farmers by plant doctors

As indicated in Figure 1, upon presenting their plant health problems to plant clinics, the majority of the farmers (69%) were advised to use a combination of scouting/monitoring, cultural practices and pesticides, while 15% were advised to use monitoring/scouting and cultural practices. A few respondents (11%) were advised to use pesticides only, showing a limited focus on pesticides. These findings suggest that plant doctors were largely following IPM principles in giving recommendations. In 5% of the recommendations, farmers were advised to use seeds of resistant varieties in combination with cultural practices or pesticides. This piece of advice may suggest that resistant varieties are lacking for most of the plant health problems identified at the surveyed plant clinics, particularly for insect pests. There is also a need to raise awareness among the plant doctors regarding the available resistant crop varieties.

Use of plant clinic advice by respondent farmers

Out of the total farmers who visited plant clinics, 64% and 34%, respectively, fully or partially implemented the recommendations received from plant doctors. Only four farmers (2%) did not apply the recommendations at all. Such high adoption rates

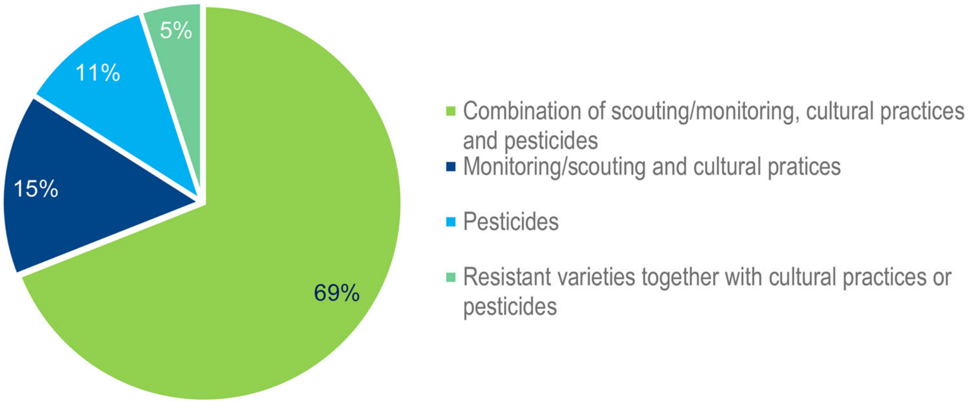

Figure 1. Type of recommendations given by plant doctors to farmers.

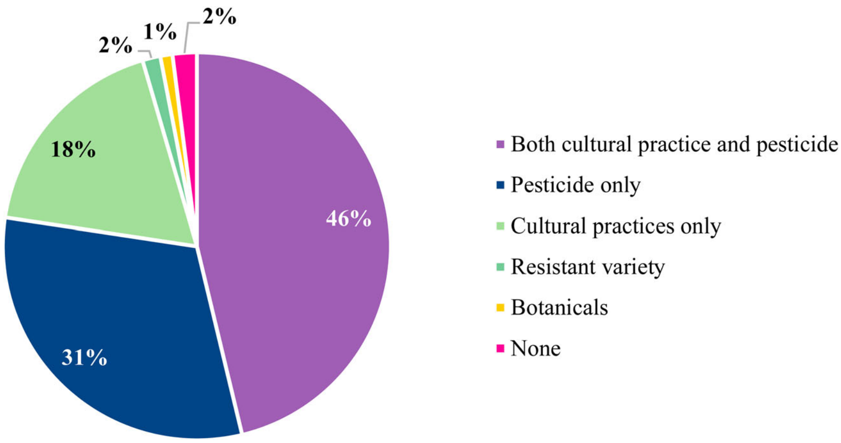

Figure 2. Type of recommendations implemented by farmers.

are expected as plant clinics provide a demand-driven service to farmers experiencing serious health problems of their crops. This is consistent with the findings of a study conducted in Rwanda (Tambo et al. 2020), which showed that plant clinics significantly increased the adoption of crop protection technologies to control devastating maize pests, such as fall armyworm and maize stalk borer.

Among those who implemented the recommendations given at plant clinics, 46% used both cultural practices and pesticides, while 31% and 18%, respectively, applied only pesticides or cultural practices. Only 2% used resistant crop varieties, while 1% used botanicals (Figure 2). As indicated above (Figure 1), although only 11% of the recommendations given by plant doctors were purely pesticides, more farmers (31%) reported actually using pesticides only. This finding showed that some farmers unpacked the recommendations and chose to apply pesticides solely. This trend calls for targeted efforts to educate farmers in the use of cultural practices and other non-chemical pest management options.

Across regions, farmers from Seharti Samre district of Tigray region demonstrated highest adoption rates, whereby 84% of the respondents fully implemented the recommendations given by the plant doctors, while 16% adopted them partially. On the other hand, 57% and 50%, respectively, of the farmers from Shashemene district (Oromia) and Fogera district (Amhara) reported fully using the recommendations. Such differences among districts could be partially explained by the stability of plant doctors (continuous service at the same place) and better agro-chemical supply by the government, in the case of Tigray region.

The majority of the farmers (98%) who implemented the recommendations of the plant doctors indicated that the advice worked effectively for them, which possibly suggests that plant doctors were giving relevant and practical advice. Those farmers who did not implement the recommendations provided some reasons for not implementing them, including that the recommended inputs were expensive, they lacked cash to buy the inputs, recommendation was too complicated to implement, or they were not confident of its effectiveness.

About 86% of the respondents thought that plant clinics provide useful services, which were practical, while 12.5% indicated that the services were 'somehow useful'. Only a single farmer felt that the services were not useful at all. Almost all farmers (99%) indicated having received adequate time and attention during their visits to the plant clinics. The overwhelming majority of the respondents (97%)

Table 6. Differences in use of plant clinic advice across regions.

Level of adoption	Oromia/Shashemene (% of farmers)	Amhara/Fogera (% of farmers)	Tigray/S/Samre) (% of farmers)
Fully adopted/used	57	50	84
Partially adopted	41	46	16
Did not adopt/use	2	4	–

indicated that they would visit plant clinics again, when they face crop pest/disease problems. These results are corroborated by findings in a study by Ghiasi et al. (2017), which showed that service relevance, service usefulness, and service quality were among the major factors affecting farmers' willingness to use plant clinic services in Iran.

Farmer-to-farmer dissemination of plant clinic advice

When lateral dissemination of clinic advice was examined, the results revealed that close to two-thirds of the farmers (62%) had shared the advice they received from the plant clinics with fellow farmers. Each one shared the information with up to 30 farmers and an average of eight (8) farmers. This finding shows the prevalence of substantial farmer-to-farmer lateral dissemination of plant clinic advice. This also points to the fact that relying solely on plant clinic records as an indicator of the number of farmers reached by plant clinics could underestimate the reach and coverage of plant clinic services.

Views about use and suitability of plant clinic locations and timing for female farmers

When respondents were asked if they thought that visiting and using clinic services was useful for female farmers, the majority (98%) responded in favour, while only 2% believed that it was not useful or necessary for female farmers. Likewise, 94.5% of the respondents believed that married women should visit and make use of plant clinic services, while only 5.5% said there was no need for them to visit plant clinics. The latter group claimed that men are responsible for such farm-related information, plant clinic locations were far from their residences, and women are responsible for domestic activities.

Likewise, an overwhelming majority (98%) of the respondents felt that plant clinic services timings and locations were suitable and accessible to both male and female farmers, which may suggest that these were carefully chosen in consultation with the community. However, it is important to note that the majority of the interviewed farmers were male farmers and the responses of female farmers could be different. Thus, further investigation might be needed to understand why actual participation of female farmers in plant clinic services was found to be low (Table 6).

Views about limitations and weaknesses of plant clinic services

When asked to outline limitations of the services provided by plant clinics, some farmers indicated irregularity and lack of daily services (plant clinics operate weekly or fortnightly), lack of pesticides and personal protective equipment (PPE) supply by the plant clinics, unavailability and/or high price of the recommended pesticides, gaps in field visits and follow-ups by plant doctors. This suggests the need to consider provision of plant clinic services more frequently (on a daily basis, where possible), and the need to closely work with agro-dealers to enable them provide the required agro-inputs at affordable prices, and accessible places. The study suggests that existing extension structures such as FTCs and three frontline extension agents in each rural *Kebele* (village) provide an opportunity to integrate and run plant clinics more frequently and regularly.

Use of pesticides and pest management practices

Type and amount of pesticides used by farmers

Farmers reported using one or more of the pesticides listed in Table 7, under column 1, before visiting plant clinics, while they shifted to the ones in column 2, after visiting plant clinics, listed from the most frequently used to the least frequently used. However, no major differences were observed between the types of pesticides that the surveyed farmers used before visiting a plant clinic and the ones they used after the visit. In particular, the majority of the insecticides that farmers were using before and those being recommended at the plant clinics were 1 A carbamates and 1B organophosphates, with the exception of lambda cyhalothrin (Karate), which is a pyrethroid IRAC 3 A and is considered slightly safer than the accumulative effects of carbamates and organophosphates in the human body. The range of modes of action was also very limited, which could be due to what is available in the locality. The main difference observed following plant clinic visits was that farmers tended to use different forms of similar products, with similar modes of action, instead of using the same product repeatedly. Looking at the current Ethiopian pesticide registration list, one would expect several other pyrethroids (cypermethrin, deltamethrin) and neonicotinoids (imidacloprid, etc) being recommended,

Table 7. Name/type of pesticides used by respondent farmers before and after visiting plant clinics.

Name/type of pesticide used in the below order		
Before vising plant clinics	After visiting plant clinics	Remark
Malathion (WHO III) 1B	Pyroxsulam (WHO III)	
Mancozeb (WHO U)	Endosulfan (WHO II) 2 A	Carbamate, which is not preferred chemical in terms of human & environmental safety
Endosulfan (WHO II) 2 A	Diazinon (WHO II) 1B	Organophosphates, which are not preferred due to their adverse health effects
Diazinon (WHO II) 1B	Malathion (WHO III) 1B	
Gold - Metalaxyl-M (WHO II)	Dimethoate (WHO II) 1B	
Dimethoate (WHO II) 1B	Mancozeb (WHO U)	
Lambdacyhalothrin 5% EC (WHO II) 3 A	Gold - Metalaxyl-M (WHO II)	
Pyroxsulam (WHO III)	Lambdacyhalothrin 5% EC (WHO II) 3 A	
Two or more of the above	Matco (Metalaxyl 8% + mancozeb 64%WP)	
	Fenitrothion (WHO II) 1B	Organophosphate IRAC 1B, not preferred chemical
	Carbaryl (WHO II) 1 A	Carbamate, IRAC 1 A, is not preferred chemicals
	Two or more of the above	

Ia = Extremely hazardous; Ib = Highly hazardous; II = Moderately hazardous; III = slightly hazardous; U = Unlikely to present acute hazard in normal use.

Table 8. Change in the amount of pesticides used by farmers before and after visiting plant clinics.

Period (before/after)	Respondents	Average amount of pesticides used annually (l or kg)	SD
Before visiting clinics	196	3.33	3.173
After visiting clinics	196	2.52	1.805

t-value = 4.251; df = 195; significance = 0.01.

although this depends on what is available among the local agro-dealers.

Although some studies conducted in other parts of Ethiopia (e.g., Negatu et al. 2016) showed a significant increase in the use of chemical pesticides, the current study showed a reduction in pesticides use among plant clinic users. As shown in Table 8, the paired samples t-test showed that there was a significant reduction in quantity of pesticides used by farmers after visiting plant clinics ($t = 4.251$; $P = 0.01$). Farmers, on average, used 3.33 litres (L) or kilograms (kg) of pesticides annually before visiting plant clinics as compared with 2.52 L or kg after receiving plant clinic advice. Although, it is not possible to attribute reduction in the use of pesticides entirely to plant clinic services, this finding may suggest that farmers have started to adopt rational use of pesticides and other IPM components.

Frequency and time of pesticide spraying

Farmers are often blamed for spraying high doses of highly toxic pesticides with high frequency without observing proper re-entry and pre-harvest intervals. Farmers were asked how often, on average, they sprayed pesticides during a given crop season, which typically should vary with the type of pesticide, crop, nature and severity of pest problem. As shown in Table 9, following plant clinic visits, farmers seemed to reduce the frequency of spraying pesticides, which could be attributed to the awareness and advice provided by plant doctors.

Concerning the time of spraying, before visiting plant clinics, one-third (33%) of the respondent farmers reported spraying pesticides at mid-day, regardless of the weather conditions (Table 9). Applying pesticides during high temperature increases the rate of evaporation and risk of vapor drift. This practice was significantly reduced to about 3% of the farmers, after visiting plant clinics. At present (after visiting plant clinics), close to 90% and 8% of the respondents, respectively, were spraying in the morning and late afternoon. Such substantial improvements in the time of the day in spraying could largely be attributed to the awareness and advices provided by plant clinics .

Likewise, there appears to be substantial improvements in awareness of and in observing pre-harvest intervals requirements. Before visiting plant clinics, only 14% of the respondents indicated knowing about PHI, compared to 41%, after visiting plant clinics (Table 10). Nearly all of those who were aware of PHI, reported observing the recommended PHI during the spraying of pesticides.

Factors affecting use of plant clinic advice

The Omnibus Test of Model Coefficient was used to assess the overall performance of the model, which is referred to as 'goodness of fit' test. In the first step, the results of the analysis without any of the independent variables in the model correctly classified 64.3% of the cases. When the predictor variables were included in the model, there was an improvement, whereby 70.2% of the cases were correctly classified, which suggests appropriateness of the model. The chi-square value was 40.317, with a

Table 9. Frequency of pesticide application and time of the day farmers spray pesticides.

Frequency of pesticide spray (N = 140)	Before vising plant clinics (during one crop season)	After visiting plant clinics (during one crop season)
Range	1 – 8 times	1 – 6 times
Average	2.85 times	2.40 times
Time of the day farmers spray pesticide	**Number and percent**	**Number and percent**
Morning	97 (49)	185 (89)
Mid-day	65 (33)	6 (3)
Late afternoon	35 (18)	16 (8)
Total	197 (100)	207 (100)

Table 10. Knowledge and use of PHI.

Know what PHI is	Before visiting plant clinics (number & percent of farmers)	After visiting plant clinics (number & percent of farmers)
Yes	30 (14)	85 (41)
No	175 (86)	124 (59)
	Observe PHI	
Yes	30 (15)	81 (40)
No	171 (85)	124 (60)

Table 11. Maximum likelihood estimates of logit model.

Explanatory variables	B (Estimated coefficient)	Wald statistics	Significance level	Exp (B) (Odds ratio)
Age*	−0.033	2.947	0.086	0.967
Gender2	0.922	2.021	0.155	2.515
Educatn2*	0.728	3.358	0.067	2.072
HHsize	−0.008	0.011	0.917	0.992
Landownd	−0.214	0.218	0.641	0.808
Dista2PC*	0.192	2.779	0.096	1.212
Numbvisit	0.113	1.755	0.185	1.119
StabPD***	1.996	19.688	0.001	7.360
Dist2agrod	−0.049	0.534	0.465	0.952
Constant	0.008	0.000	0.994	1.008
2 Log likelihood			182.499	
Model chi-square***			40.317	
Prediction power			70.20%	
Observations			171	

***, **, *Significant at P < 0.01, P < 0.05 and P < 0.10, respectively

P < 0.05. The other test of goodness of fit, Hosmer and Lemeshow test, also supports the model as being worthwhile. This chi-square test value was 6.367, with a significance level of 0.606 (which is larger than 0.05), indicating support for the model. In addition, the Cox & Snell R^2 and Nagelkerke R^2 values, which provide an indication of the amount of variation in the dependent variable explained by the model, were 0.210 and 0.288, respectively, suggesting that between 21% and 29% of the variability in the dependent variable is explained by this set of variables.

The maximum likelihood estimates from the logistic regression are presented in Table 11. Out of the nine explanatory variables included in the logistic model, four were found to influence significantly the use of plant clinic advice by the farmers. Stability of plant doctors was found to be the most important factor in significantly (P = 0.001) and positively influencing the use of plant clinic advice. In other words, recommendations provided by stable plant doctors (who worked at the same location since the launch of plant clinics) were more likely (by a factor of 7.360) to be adopted by the farmers, than advice given by those who have recently been transferred to the sites. This likelihood suggests that stability or continuous service in the same area helps plant doctors to build their pest management knowledge and skills, to understand farmers' crop health issues in the area as well as to establish good relationship with and nurture confidence among farmers. Thus, it is of critical importance to minimize turnover of trained plant doctors, as it directly affects the performance and quality of plant clinic services.

Distance to plant clinics, education, and age of farmers were significant at P < 0.10. Age of farmers was significantly (P = 0.086), but negatively associated with adoption of plant clinic advice. In other words, as age increased the probability of adopting plant clinic advice decreased. The odds ratio implies that a unit increase in the age of the farmer will reduce the probability of adopting plant clinic advice by 96.7%. This finding suggests that elderly farmers tend to be more risk averse and conservative, while young farmers could be more open to changes and may readily take up and try new technologies. It could also be related to the physical strength, or labour required to implement some of the recommendations given by plant doctors. This finding corroborates those of Teshome et al. (2019) who reported that age negatively affected adoption of improved potato varieties and associated practices in Ethiopia. However, in terms of access to plant clinic service, as the descriptive results showed, the majority of the visitors tended to be relatively older farmers.

As expected, the educational level of farmers was found to significantly ($P = 0.067$) and positively influence the use of plant clinic advice. In other words, farmers who had education were more likely (by a factor of 2.072) to adopt plant clinic advice than those with no education. This result is in agreement with findings of other studies (e.g., Leake and Adam 2015; Chandio and Jiang 2018), which reported that education favours adoption of improved agricultural technologies. Distance between the farmers' residences and plant clinic sites significantly ($P = 0.096$) and positively influenced adoption of plant clinic advice. The odds ratio implies that a unit increase in distance to plant clinic site will increase the probability of adopting plant clinic advice by 121%. This was a surprising finding as it was hypothesised that farmers in close proximity to plant clinics were more likely to adopt plant clinic recommendations. The positive association of adoption of advice and the distance to plant clinics could suggest that farmers who travel longer distances to seek plant clinic services could be more committed to adopting the recommendations they received from plant doctors.

Lack of a significant statistical association between the use of plant clinic advice and other variables, such as size of land holding and household size, possibly suggests that recommendations given by plant doctors were less demanding in terms of farmland and labour requirements. Although there seemed to be some positive association (whereby male farmers appeared to be more likely to adopt plant clinic advice), gender was not found to significantly affect the adoption of plant clinic advice. This finding corroborates results of the descriptive statistics, which showed that fewer women had access to plant clinic services, as compared with male farmers. Another interesting finding was the lack of a statistically significant association between number of plant clinic visits and adoption of plant clinic advice. The findings possibly suggest that repeated visits to plant clinics do not necessarily reflect effective use of recommendations given by plant doctors. Likewise, although distance from farmers' residences to the nearest agro-dealer shop was expected to affect negatively the adoption of plant clinic advice, the result showed a non-significant negative relationship. The negative association between the two variables implies that as the distance to agro-dealer shops increased the adoption of plant clinic advice decreased, which could be related mostly to the chemical recommendations. The lack of significant association could imply that besides chemicals, plant doctors were recommending alternative pest management options as demonstrated by the descriptive results.

Conclusions

Village based plant clinics can serve as an important source of information and timely and practical advice on pest management for farmers in the areas where they operate. Though plant clinics are open to all crops and all plant health problems, farmers tended to give priority to major food and cash crops which implies the need for wider awareness creation. Likewise, the reasons behind the limited use of the services by young and female farmers require further investigation. Analysis of recommendations given by plant doctors suggests that plant doctors were following the IPM principles while advising farmers on pest management options. However, some farmers decided to unpack and use only certain components of the recommendations provided by the plant doctors (such as pesticide), which calls for close follow up and education of farmers to consider pesticides as a last resort. In this regard, one of the positive outcomes is that a significant reduction was found in the amount and frequency of pesticides used by farmers after visiting plant clinics. However, significant differences were not observed between the type of pesticides that farmers were using before and after visiting plant clinics which may require further intervention. The reason behind limited recommendations of resistant crop varieties among the pest management advices given to farmers might require further investigation. High farmer-to-farmer lateral dissemination of plant clinic advice was observed, which suggests that the advice from plant clinics reaches more farmers than the figures obtained from plant clinic records. While a number of factors (including stability of plant doctors, distance to plant clinic, age and education) affected use of plant clinic advice by farmers, stability of plant doctors (continued service at the same clinic) was found to be the most important factor in this regard. Overall, the study suggests that plant clinics provide an important complementary approach for pest management advisory service. Thus, such project-based initiatives should be fully integrated into regular programmes to ensure their sustainability.

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Data availability statement

The data that support the findings of this study are available on request from the corresponding author, [Dr Negussie E. Gurmessa]. The data are not publicly available due to restrictions related to information that could compromise the privacy of research participants.

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