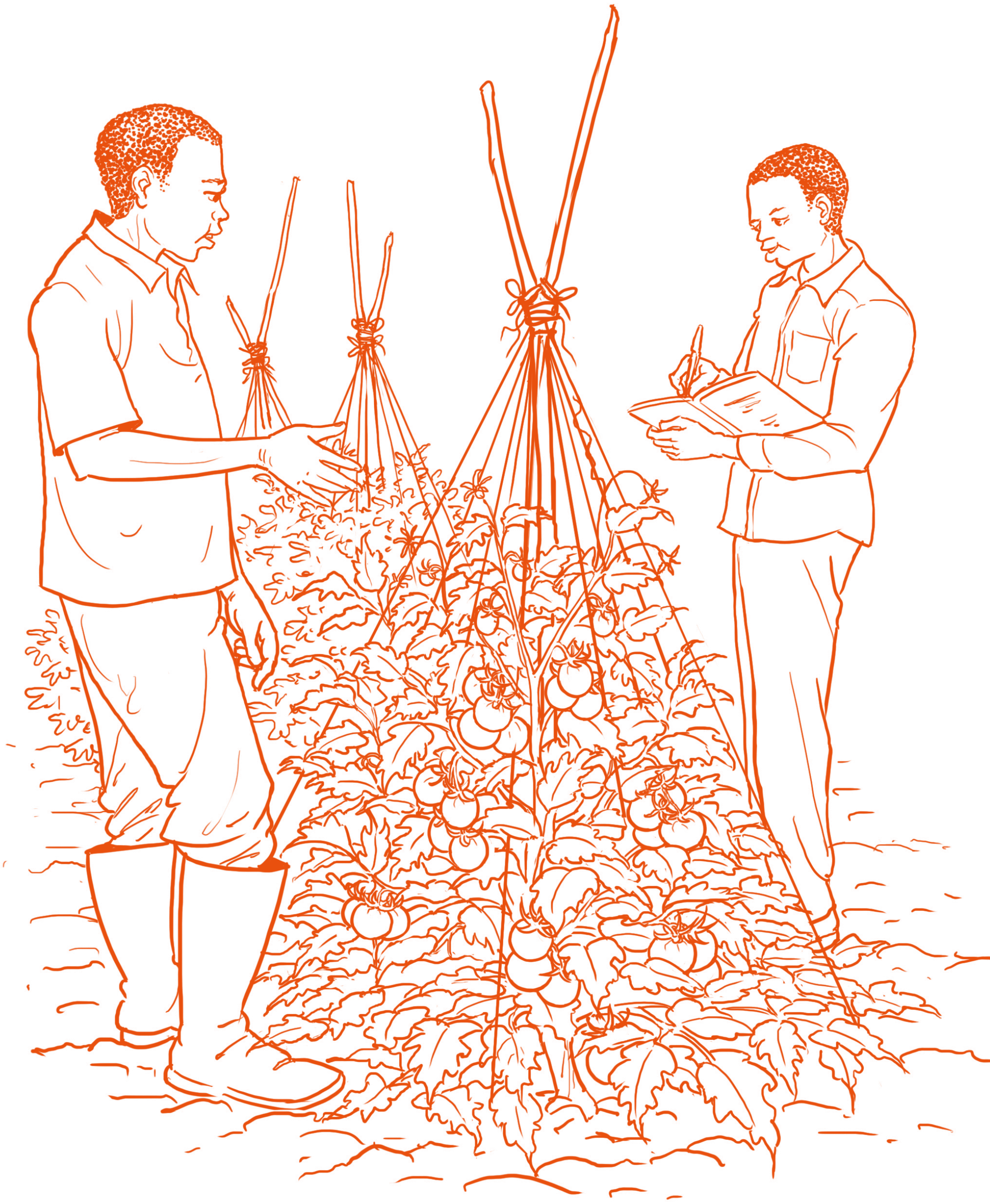
CABI WORKING PAPER 11

Impact of Plant Clinics on Disease and Pest Management, Tomato Productivity and Profitability In Malawi

August 2018



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EXECUTIVE SUMMARY

Tomato (*Lycopersicon esculentum)* is one of the most widely cultivated vegetable crops in Malawi and a crucial source of vitamins and mineral nutrition. However, tomato production has been more constrained by pests and diseases compared to other vegetable crops, resulting in low yields and returns among the smallholder farmers.

The Plantwise programme, involving the use of plant clinics, is an innovative approach to solve plant health problems in developing countries. Farmers participating in plant clinics are expected to benefit in terms of changes in knowledge, and management of crop pest and diseases leading to improved livelihoods. However, few studies have been carried out to assess the impact of plant clinics on farmers' enterprises. Impact assessment demonstrates and measures the outcomes of a given agricultural development initiative. This study therefore aimed to assess the impact of plant clinic activities in Malawi on tomato productivity. The AKAP sequence (Awareness, Knowledge, Adoption and Productivity) was used as a methodological framework to evaluate plant clinic impact among smallholders in Malawi. The data was collected from 738 households (279 users and 459 non-users of plant clinics) through household interviews using the open data kit (ODK) in August 2017 and subjected to data cleaning and transformation before analysis.

The data was analysed using R, SPSS and STATA procedures. The study revealed that both local and external sources of crop pest and disease information were important in Malawi, an approach which has been advocated as effective in managing insect vectors and bacterial/fungal pathogens in smallholder vegetable farming systems, such as Malawi. The plant clinics were shown to increase farmer-seeking and intervention behaviour of specific and knowledge-intensive agronomic solutions, compared to non-users who relied on local and more general sources of pest and disease management information. Users of plant clinics also recorded higher patterns in recognition of pathogen disease symptoms than non-users. Plant clinic attendees recorded significantly higher knowledge levels of red spider mite (RSM) of 19% compared to non-users (17%).

Plant clinics users demonstrated increased tomato yields and incomes in Malawi. Users of plant clinics increased yields by 20% compared to matched non-users. The gross margins for tomato farmers improved by 21% for users of plant clinics.

The plant clinics in Malawi enhanced the awareness and knowledge of tomato pests and diseases, which improved adoption of interventions and tomato yields in Malawi. Thus, this approach should be promoted and scaled up to improve the Malawi tomato sector through farmer training, awareness creation and capacity building on pathogens, pests and their effective management.

TABLE OF CONTENTS

ACRONYMS AND ABBREVIATIONS

AGRA	Alliance for a Green Revolution in Africa
ANOVA	Analysis of variance
BL	Blight
BWD	Bacterial wilt disease
CABI	CAB International
EB	Early blight
GM	Gross margin
HH	Household
LB	Late blight
MKW	Malawi Kwacha
ODK	Open data kit
PSM	Propensity score matching
RSM	Red spider mite
TFW	Tomato fruit worm
TLM	Tomato leaf miner
TLU	Tropical livestock unit
USD	United States Dollar

1 INTRODUCTION

Tomato (*Lycopersicon esculentum)* production is one of the major agricultural enterprises that most smallholder farmers practise globally. According to a report by the Food and Agriculture Organization (FAO), tomato remains a crucial vegetable crop with estimated at production at 126 million tonnes per annum (Arah *et al*., 2016). It is a major source of income and nutrition (vitamins and minerals) for most rural communities in Sub-Saharan Africa (SSA) (Tshiala & Olwoch, 2010; AGRA, 2017). Additionally, tomato production has led to the growth of agro-based processing industries, such as tomato paste (Many *et al.,* 2014). Therefore, improving smallholders' tomato production would make a considerable contribution to food security enhancement and poverty reduction (Ambecha*,* 2015). However, tomato growers are constrained by inconsistent production and low yields due to pest and disease infestation. Past studies have shown that pests and diseases are a major threat to the livelihoods of farmers in Sub-Saharan Africa because they cause substantial losses (Geddes, 1990; Rweyemamu *et al*., 2006). Over 90% of the Malawian population reside in rural areas and depend mainly on subsistence farming. Therefore, any crop loss, including those resulting from pests and diseases, can badly disrupt food security and the livelihoods of rural communities (Nyirenda *et al*., 2011). Changes in climatic conditions and sudden shocks exacerbate these losses further, threatening food security and farmers' livelihoods (Cilas, *et al*., 2016).

Agricultural extension and advisory programmes are key policy instruments used to promote agricultural productivity in many countries as they play a key role in ensuring information flow across the chain, thereby enhancing the performance of the whole agricultural supply chain system (Chimoita *et al*, 2017). However, farmers require more specific knowledge and awareness of how to manage the pests and diseases in their fields. Conventional extension systems may not provide specific knowledge-based management for pests and diseases, mainly because extension services have to support farmers who face an array of agricultural challenges. Extension services often lack the information needed, especially about emerging pests and diseases. Furthermore, emerging pests and diseases require continuous development of knowledge that incorporates lifelong learning platforms. Innovative communication and extension approaches are thus needed to support farmers in dealing with these challenges.

The Plantwise approach, developed in the early 2000s by the Global Plant Clinic Alliance, led by CAB International, is an example of such innovation. Plant clinics were first piloted by CABI in Bolivia in 2003 (Danielsen and Kelly, 2010) with ten plant clinics established between 2003 and 2007 supported by three key institutions including CIAT (International Centre for Tropical Agriculture), PROINPA (Promotion and Research of Andean Products) and UMSS (Public University of San Simón) (Bentley et al., 2009). Due to the success of plant clinics, they were expanded to other vulnerable regions of the world, especially in Asia and Sub-Saharan Africa, though at different rates and in different ways. The approach is demand-driven because farmers seek these services based on existing plant health problems (Danielsen *et al*., 2011). In Malawi, plant clinics started officially around 2013, though with earlier pilots. Managed by agricultural extension agents (plant doctors), plant clinics try to respond to farmers' demands for technical advice to solve plant health problems (Bentley *et al*., 2018). The clinics are usually organised in proximity of farmer accessible public places, such as local markets. Based on diseased plant sample diagnosis, plant doctors give advice and recommendations to farmers on how to manage crop pests and diseases. They operate twice a month at a local market place. The mandate of the plant clinics includes, but is not limited to: a) identification of the cause of plant health problems and prescription of management options; b) field visits and inspection of pest and disease problems; and c) advice and guidance to farmers for the management of plant health problems.

In Malawi (2014-2015), over 4030 farmers from 137 villages were given practical advice through the clinics on how to manage maize streak virus, cassava mosaic virus, head smut, ground nut rosette, banana bunchy top virus diseases, witch weed, and the maize stalk borer (CABI, 2015). There have been over 2400 queries from farmers on about tomatoes during the period since 2014. The main diagnoses included red spider mite, bacterial wilt and late and early blight.

The expected outcome of the plant clinic approach is that farmers' knowledge and management of pests and diseases will be enhanced, which will improve agricultural productivity, translating into increased incomes in the long run. Assessment of the impact of plant clinics at farm level presents complex problems around attribution and the high degree of mutuality in the farming system. This is a common challenge faced in assessments of new agricultural innovations (Becerril and Abdulai, 2010). In addition to the problem of ability to isolate the attribution, the situation is complex because the productivity-enhancing effect of a new technology requires adoption of a package of measures rather than one technique (Karanja, *et al*., 2003). There is therefore a need for a variety of approaches that unpack direct and indirect, expected and unexpected impacts of plant clinics.

Some studies have been conducted to establish outcomes for plant clinic users in Bolivia (Bentley *et al*., 2011) and Bangladesh (Harun-Ar- Rashid *et al*., 2010). Both studies provided a strong indication of positive outcomes due to participation in plant clinics. However, both studies lack the rigor of impact evaluation, which deal with attribution by incorporating a counterfactual group. Recently, a few more studies (Brubaker *et al*., 2013 and Silvestri and Musebe, 2016) were conducted using the rigorous impact evaluation methods in Uganda and Rwanda.

This study sought to assess the impact of plant clinics in improving farmers' knowledge, yields and adoption of pest management practices in Malawi. Specifically, we examined whether users of plant clinics were: 1) more aware of tomato pests and diseases; 2) more knowledgeable about pests and diseases; 3) adopted more practices to combat pests and diseases; and 4) had higher tomato yields and gross margins than non-users of plant clinics. This information is an incentive for promotion and upscaling the plant clinic model of extension to other areas within the country and to more countries.

2 MATERIALS AND METHODS

Analysis of the plant clinic data prior to the survey work indicated that maize and tomato were the most frequent crops brought to the plant clinics. Initially maize with stem borer was considered as a suitable crop for study, but concerns were raised by the team in Malawi about using maize as the basis for this study. 1) Possible discrepancies or confusion in the diagnosis, therefore in the plant clinic data for maize following the recent fall armyworm outbreak. 2) Concern over the time delay in seeing effects of clinic advice, which in maize can lead to the destruction of the plant. A decision was therefore made to study tomato as this was the second most prevalent crop in the records. Tomato still gave a sufficiently large sample size, and it is grown in many areas of Malawi, ensuring data could be collected from more than one plant clinic site.

2.1 Sampling strategy and survey implementation

The distribution of the farmers that attended the plant clinics and brought tomato affected by the following pests and diseases: tomato leaf miner, bacterial wilt, early blight, late blight, red spider mite and tomato fruit worm indicated site selection. Data for this study was collected from 11 districts and 14 sectors spanning eight agro–ecological zones of Malawi. A sample of 738 households were interviewed; out of which 279 were users of plant clinics (hereafter 'users') and 459 were non-users of plant clinics (hereafter 'non-users' or control). The same site characteristics of the clinic user sampling sites were used to select the non-user sites to be sampled. The control group were as similar as possible to the treatment group in terms of socio-economic (pre-intervention) characteristics. The characteristics considered were: agro-ecological zone, socio-economic conditions (e.g. level of literacy), crops grown, pests and diseases, distance to market/populated area and potential for spill-over effects into the non-clinic user area. The proportion between users and non-users was approximately 1:1.6 with more control respondents to ensure that a matched group could be created. From a gender perspective, 538 surveys were conducted with male-headed households and 200 with female-headed households.

The household survey was conducted in July 2017, in line with the cropping season and included information about: household size and composition; household assets; tomato yield; agricultural inputs and labour use for cropping; interventions for pest management; sources of information for pests and diseases; market; and access to credit. Data collection was done by trained local enumerators, through face-to-face interviews conducted using tablets with the open data kit (ODK) application.

In terms of distribution of respondents across the districts, Mzimba district had the highest proportion (42.95%) of the sampled households, followed by Ntcheu (15.18%), Machinga (14.91%) and Dowa (11.52%) (Table 1). Other districts included: Balaka (4.47%), Salima (3.66%), Mulanje (2.17%), Thyolo (2.03%), Lilongwe (1.49%), Zomba (0.81%) and Dedza (0.81%). This reflected the location of plant clinic users who had brought tomato to the clinics, as well as non-users who farmed in the same agro-ecological zones as the clinic users.

Table 1: Distribution of the sampled households (users and non-users of plant clinics) across 11 districts in Malawi

	Users		Non-users		Total
Districts	**N**	**% district respondents**	**N**	**% district respondents**	**N**
Balaka	31	94	2	6	33
Dedza	6	100	0	0	6
Dowa	25	29	60	71	85
Lilongwe	11	100	0	0	11
Mulanje	16	100	0	0	16
Mzimba	125	39	192	61	317
Ntcheu	32	29	80	71	112
Salima	12	44	15	56	27
Thyolo	15	100	0	0	15
Zomba	6	100	0	0	6
Machinga	0	0	110	100	110
Total	**279**	**38**	**459**	**62**	**738**

All the households in Machinga were non-users. This was balanced by Mzimba district where most sampled households were plant clinics users.

2.2 Methods of data collection

To assess plant health problems farmers experienced in their tomato fields, farmers were asked to mention tomato health problems they had experienced in the previous years. After this, each farmer was shown 21 symptoms in photos related to six health problems (tomato leaf miner – 4 photos, early blight – 4 photos; late blight – 4 photos; tomato fruit worm – 3 photos;(red spider mite – 3 photos and bacterial wilt – 3 photos). Every individual farmer identified the symptom (from the photo) seen on the farm. This was followed by questions on interventions used to treat the pest or disease. In this study, data on symptoms of six health problems were collected, but for in-depth assessment of the knowledge levels; we choose the blight (early and late) and red spider mite to represent disease and pest, respectively. The selection was based on literature (Nyirenda *et al*., 2011) and occurrences in the current study. The two problems are prevalent and are of economic importance in the tomato sector in Malawi.

2.3 Data processing

Data were first subjected to cleaning, exploration and the preparation of software and procedure-compatible datasets prior to analysis. Boxplots of key variables were used to detect outliers, followed by generation of dummy variables, composite variables (summing of binary columns), unit standardisations (conversion of yields into kg/ha), data transformations and creation of comma separated value (csv) dataset files. Microsoft Excel csv file formats were needed for implementation in the R statistical environment, while dummies were needed for regression procedures.

The framework used in this study to assess the impact of the plant clinics (the AKAP sequence-Awareness and Knowledge, Adoption and Productivity) was adopted from previous work done in evaluating the impact of technology adoption on smallholder tomato productivity (Anderson, 2007; White, 2009a, b; Prowse and Snielsveit, 2010).

Awareness and knowledge were measured in terms of the capacity of farmers to recognise symptoms of presence of several tomato diseases. Farmers were shown pictures of tomato plants affected by tomato pests, fungal and bacterial diseases for various tomato parts (fruits, leaves, stems) and disease stages. The awareness of the presence of a problem and knowledge of suitable interventions is a major pre-requisite for adoption of interventions (Hatfield and Karlen, 1994). The disease total knowledge score measure was created by allocating (weighting) and summing up three components of farmer knowledge of the pest and disease, including experience score (25%), knowledge score (25%), and the intervention score (50%). The data matrix arising from the scoring was processed using Microsoft Excel User Defined Functions and a nested conditional COUNTIF procedure (Appendix 1).

Adoption of pest management practices were measured by the number of correct practices for tomato pest and disease management that the farmers implemented. The rationale is that users of plant clinics are likely to have access to a greater array of information about intervention options than the non-users of plant clinics; in turn, this would lead to a greater adoption of pest management practices and/or more appropriate pest management practices for the pest in question. The study also expected to find that users of plant clinics were likely to adopt more agronomically-specific and knowledge-intensive tomato pest and disease management approaches (e.g. use of commercial pesticides), compared to local and more general management practices.

Productivity was measured in terms of tomato fruit production per hectare (ha). The rationale is that users of plant clinics on average would have a greater knowledge of the practices to put in place. This would help them to prevent/contain the impact of tomato pests and diseases on their fields and therefore stabilise or increase tomato yields. The management of tomato pests and diseases leads to enhanced agronomic efficiency, and hence improved tomato production and yields.

This study followed the principles and procedures of propensity score matching (PSM) recommended in assessing impact by several authors (White 2009a, b; Caliendo and Kopeinig 2008). For the purpose of this study, R software was used to compute the correct match from the total sampled households (N=738) using 1-to-1 matching and a caliper of 0.03. Using the MatchIt package, with a ratio of 1:1, out of the total sampled households (738), 558 households were generated as the correct match. The results of the matching quality tests are presented in Appendix 2. The various explanatory variables used in PSM were as follows: age of household head; age squared; on-farm participation (household head); education level of household head; area cultivated with tomato (ha); total land size; tropical livestock unit (TLU); number of credit sources; dependency ratio; natural log (Ln) dependency ratio; importance of farm to household income; and household size. The choice of these variables was based on economic theory and empirical studies on adoption and impact of agricultural technologies. Further, after obtaining the correct match of 279 users and 279 non-users, balancing tests were executed. Table 2 shows the variable selection for various regression procedures in the study.

Table 2: Description and selection of matching and regression model variables

Variables	Procedure			Considerations (intervention adoption and yield effects)	Measurement type
	1-1 Matching	Logit (RSM & Blight intervention adoption)	Yield (multiple linear Regression)		
Gender of household head	X	X	X	Gender differences can affect participation in plant clinics, advice uptake and yields	Dummy (1=Male, 0=Female)
Age/Age squared	X	X	X	Younger farmers are more likely to seek new information and adapt to new technologies than older farmers, which can influence yields	Numeric (Years)
Education level	X	X	X	Well-educated farmers are more likely to visit plant clinics for specific interventions than less well-educated farmers. This process can increase yields and gross margins as better-educated farmers are likely to invest in profitable tomato sectors and market portfolios	Ordered categorical (None (0); Primary school (1); Secondary school (2); College/vocational training (3); university (4)
Household Size	X	X	X	Farmers with more household members can likely visit the clinic to seek more types of advice, which can increase yields and profits	Numeric
Access to extension services	X	-	-	Extension service is likely to boost advice seeking and adoption and tomato production. This can also increase gross margins	Dummy (1=Yes, 0=No)
Participation in off-farm activities	X	X		Off-farm income can influence farmer interest and investments in tomato cultivation, thus the propensity to adopt interventions to increase yields	Dummy (1=Yes, 0=No)
Tropical livestock Unit (TLU)	X	X		Livestock ownership can have a positive effect on tomato production. Manure can be used for soil fertility and livestock/ livestock products: sales can influence investments in tomato production	Numeric (dimensionless number/unitless). Refers to 250 kg of livestock
Number of credit sources	X	X	X	More credit influences investment in the tomato sector	Numeric
Area of land allocated for Tomato (Ha)	X	X	X	Tomato land area shows the level of interest in tomato cultivation	Numeric
Total land (Ha)	X	-	-	Total land area is a proxy of wealth influences, investments and flexibility in tomato production	Numeric
Dependency ratio/Log dependency ratio	X	X	-	A high dependency ratio can influence participation in tomato production	Numeric

Variables	Procedure			Considerations (intervention adoption and yield effects)	Measurement type
	1-1 Matching	Logit (RSM & Blight intervention adoption)	Yield (multiple linear Regression)		
Use of improved seed	-	X	X	Use of improved inputs and their access is linked positively to tomato cultivation and seeking plant clinic services	Dummy (1=Yes, 0=No)
Importance to farm income	-	X		If tomato is important in farm income contribution, farmers are likely to attend clinics	Dummy (1=Yes, 0=No)
Experienced shocks	-	X	X	Shocks, e.g. climate negatively affects tomato production	Dummy (1=Yes, 0=No)
Own experience as knowledge	-	X		Farmer experience affects production and plant clinic attendance	Dummy (1=Yes, 0=No)
Plant clinic as a source of knowledge	-	X		Attendance in plant clinics positively affects tomato production	Dummy (1=Yes, 0=No)
Labour cost	-	-	X	High input levels enhances productivity, which compensates for cost increases	Numeric (MWK/ha)
Seed cost	-	-	X		
Fertiliser cost	-	-	X		
Pesticide cost	-	-	X		-
On-farm type	-	-	-	-	-

X = Included in procedure, - = Not included in procedure

2.4 Data analysis and statistical approach

The matched households were used for further analysis to explore the differences between the users and the non-users of plant clinics. In assessing impact we specifically compared users of plant clinics with closely matched non-users in the following variables: productivity and gross margins; knowledge levels; and sources of information. Differences between these two groups were attributed to use of the plant clinics. A major area of interest was whether users of plant clinics had higher knowledge levels in terms of identifying health problems and applying the correct interventions. Sources of information were analysed using frequencies and cross-tabulation. The number of different sources of information were counted and compared between gender and plant clinic categories using ANOVA. The awareness of pests and diseases was analysed using frequencies and sub-setted using gender and plant clinic categories.

Gross margins were calculated to estimate the profitability of tomato production in Malawi. Gross margins (GM) were limited to the difference between total revenues and total variable costs in tomato farm enterprises (Malawi Kwacha ha^{-1}). The gross margin analysis was anchored on a number of assumptions, e.g. fixed costs like land, equipment and machinery were not treated as inputs as they are shared across other farm enterprises. To compute the gross margins, the following equation adopted from Tekele (2010) was used for this study:

$$GM_j = (P_j Y_j - \sum P_i X_i)$$

Where:

GMj = Gross margin of enterprise *j, Pj* = Output price of enterprise *j, Yj* = Output of enterprise *j,*

Pi = Price of input *i, Xi* = Amount of input *i* used.

The following are the labour and input components that were included in the tomato gross margin computation: seed cost; fertiliser cost; pesticide cost; and labour (land preparation, planting, weeding, spraying, thinning and harvesting) cost, expressed in MWK ha-^{1}.

Means and ANOVA were used to compare the knowledge levels, gross margins and yields by gender and plant clinic attendance. The determinants of adoption of RSM and blight diseases was assessed using logit regression by including gender, age, on-farm participation, TLU, dependency ratio, household size, use of improved seeds, shocks and sources of knowledge on pest and disease management. Multiple linear regression modelling was used to determine the effect of different variables on tomato yield, including farmer socio-demographic characteristics, input costs, and tomato pest and disease knowledge scores (RSM and blight).

3 RESULTS AND DISCUSSION

3.1 Sources of information

Results showed that households accessed information on pests and diseases from a variety of sources (Table 3). The most important sources of information were extension officers, farmers' own experience, relatives, plant clinics and consultation with neighbours and friends. The extension officers were unique a separate source of information from plant clinics in the study. The use of local sources of information, including own experience and neighbours, declined slightly with plant clinic attendance, which increased the use of technical sources of information such as agricultural media programs, books, and mobile SMS.

In terms of number of information sources, users had significantly (p=0.0001) more sources of information sources (2.4) compared to non-users (1.9). This could be attributed to the effect of plant clinics, which encouraged farmers (users) to seek information from more diverse and specific sources than non-users. Farmers accessing plant clinics are therefore more likely to improve their information-seeking behaviour for specific interventions than non-users. There were no differences in the diversity of information sources with respect to gender.

Non-users of plant clinics utilised their own experience and consultation with relatives, neighbours and family members more than users with 151 vs 107 and 125 versus 77, respectively. Another difference observed was that there were more non-users using extension officers (155) than users (120). In addition, 23 non-users used lead farmers compared to 10 users of plant clinics. These results indicate than non-users of plant clinics rely more on their own experience and advice from neighbours and family members compared to users of plant clinics. On the other hand, users of plant clinics seemed to prefer plant clinics and agricultural programmes on the radio. This points to plant clinics playing a key role in providing useful information for managing tomato health issues.

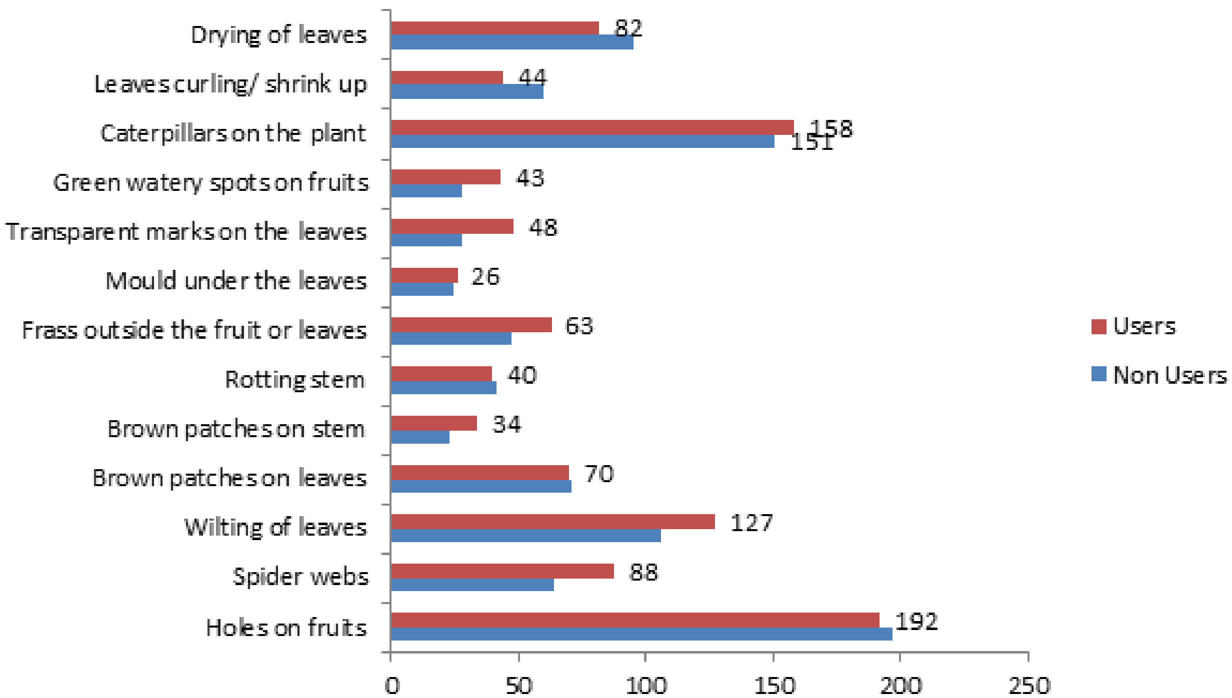
Table 3: Sources of information on tomato pests and diseases

	Non users		Users		Total (N-558)		Rank
	N	%	N	%	N	%	
Extension officers	155	28	120	22	275	49	1
My own experience	151	27	107	19	258	46	2
Plant clinics/plant doctors	0	0	247	44	247	44	3
Neighbours, friends and family	126	23	77	14	203	36	4
Agricultural programmes on the radio	63	11	79	14	142	25	5
Lead farmers	23	4	10	2	33	6	6
Agro-dealers	12	2	4	1	16	3	7
Another household member	5	1	3	1	8	1.4	8
School	3	1	5	1	8	1.4	8
Books/flyers/pamphlets	2	0	4	1	6	1.1	10
Demonstration plots/field days	4	1	1	0	5	0.9	11
NGO	4	1	0	0	4	0.7	12
Mobile SMS and Voice services	0	0	4	1	4	0.7	12
Agricultural shows	3	1	0	0	3	0.5	14
Newspapers/magazines/bulletins	2	0	0	0	2	0.4	15
Mobile van service	1	0	1	0	2	0.4	15
Farmer field schools	0	0	1	0	1	0.2	17
Womens' group	0	0	0	0	0	0	18
Agricultural programmes on the TV	0	0	0	0	0	0	18
DARs agronomist	0	0	0	0	0	0	18

3.2 Plant disease awareness

The awareness of the presence of a problem and knowledge of alternatives is a major pre-requisite for adoption of interventions (Hatfield and Karlen, 1994). Once aware and knowledgeable about plant health problems, a farmer is in a position to detect the presence of a health problem by recognising one or more symptoms that the affected plant exhibit. The results showed that all symptoms were recognised by both users and non-users (Figure 1). The most important tomato health problem experienced by farmers included holes on fruits, followed by caterpillars and wilting. All the symptoms assessed in this study were recognised by both users and non-users, but at different levels of intensity. Users recognised more (11 out of 13) symptoms than non-users. In addition, the users of plant clinics were better able to recognise the not-so-obvious symptoms, e.g., frass, and transparent spots, than the non-users. In terms of recognising the holes on the fruit and drying of the leaves, users and non-users were almost equal.

Figure 1: Clinic disaggregated frequencies of farmers that recognise specific signs of presence of pests and diseases in plants (N = 558)



With regards to disease awareness, there were no major differences in bivariate frequencies of recognition, which necessitated multivariate analysis of the response matrices. The findings, when considering recognition of all pests and diseases, not just blight or RSM, show generally that more users recognised more pathogen-based symptoms than non-users, who tended to recognise the presence of pests and pest damage more readily. Among pathogen-based symptoms, more users recognised green watery spots, transparent water marks and mould. This indicated that plant clinics had a significant role in training regarding more complex diseases, including pathogen-based symptoms.

The most important symptoms farmers reported they had seen were tomato fruit worm, followed by blight (both early and late) (Table 4). Differences between users and non-users of plant clinics were observed in cases reported for tomato leaf miner, red spider mites, fruit worm and late blight. This finding is important especially with respect to the red spider mite and tomato late blight disease, which are key tomato diseases in Malawi. Users reported fewer cases of red spider mite than the non-users.

Table 4: Frequency of health problems seen and reported by farmers in photo form

Photo	Tomato disease *	Non users (N=279)	Users (N=279)	Total (N=558)	Rank
1	TLM Caterpillar	110	119	229	7
2	TLM Adult moth	29	42	71	17
3	TLM Frass	146	143	289	6
4	TLM Caterpillar leaves	78	80	158	13
	Total cases **	***203***	***214***	***417***	
5	EB Whole plant	35	42	77	16
6	EB Brown spots	105	96	201	12
7	EB Brown patch stem	19	31	50	20
8	EB Fruit spots	107	115	222	8
	Total cases	***182***	***182***	***364***	
9	LB Whole tomato	36	26	62	18
10	LB Pale green leaves	27	27	54	19
11	LB Brown stem	106	112	218	9
12	LB Green watery spots	208	207	415	4
	Total cases	***44***	***54***	***98***	
13	RS Spider webs	106	96	202	11
14	RS Tomato leaves	99	105	204	10
15	RS Insect feeding	239	237	476	2
	Total cases	***215***	***216***	***431***	
16	TF Larvae	195	203	398	5
17	TF Fruits	272	274	546	1
	Total cases	***215***	***216***	***431***	
18	BWD Whole tomato	71	49	120	14
19	BWD Leaves	51	46	97	15
20	BWD Infected stems	234	231	465	3
	Total cases	***110***	***119***	***229***	

*TLM= Tomato leaf miner, EB= Early blight, LB=Late blight, =Red spider mites, TF=Tomato fruit worm BWD= bacterial wilt disease
**Farmers had multiple responses

3.3 Plant pest and disease knowledge

Overall, indices of knowledge scores of users of plant clinics were significantly higher (18.4) than those of non-users (14.7), for RSM and BL, (early and late blight) respectively (Table 5). This is an indication that plant clinics could have contributed to increased knowledge levels among farmers. The knowledge score for blight was lower than RSM, which is likely to be due to blight being a pathogen-based disease which, as stated above, farmers found harder to recognise. This shows the how plant clinic services contribute to the improvement of intervention knowledge levels of tomato RSM and BL (Table 5). The findings show that in terms of the knowledge structure, there were no differences in the experience and recognition scores. However, there were differences in the intervention knowledge scores. The study thus indicates that the plant clinics influenced intervention knowledge more than experience and recognition knowledge. Findings by (Rajendran and Islam, 2017) revealed that plant clinic users significantly increased their ability to identify and address crop problems, increasing their knowledge over a three-year period. Additionally, farmers would communicate crop problems and address crop problems by themselves.

Table 5: Mean scores of tomato disease scoring dimensions and total scores (%)

Clinic	RSM score			BL score			Total score	
	Experience	Recognition	Intervention	Experience	Recognition	Intervention	RSM	BL
Non-users	*8.1*	*7.5*	*1.8*	*3.4*	*5.2*	*5.0*	*17.4*	*13.6*
Users	*8.5*	*7.4*	*3.5*	*4.1*	*5.2*	*6.6*	*19.4*	*15.8*
Total sample	*8.3*	*7.4*	*2.7*	*3.7*	*5.2*	*5.8*	*18.4*	*14.7*
Significance	0.535	0.923	0.002	0.141	0.927	0.002	0.002	0.05

RSM = Red spider mite; BL= Early and late blight

Being able to distinguish infection symptoms and their vectors may encourage farmers to control insect populations and avoid the unnecessary use of fungicides and other pesticides that are ineffective against tomato diseases. Insect control must be practised before disease symptoms have started appearing in the crop, which requires a massive increase in farmers' knowledge about tomato diseases through field monitoring.

3.4 Adoption of tomato disease management interventions

3.4.1 Plant clinic attendance and adoption of interventions

Farmers adopted various tomato pest interventions to control RSM (Table 6). The users of plant clinics had more interventions (86) than the non-users (66). In addition, more users applied commercial pesticides (46) compared to non-users (35). Fewer farmers used non-chemical methods after attending plant clinics, including keeping fields weed free and hand picking insects, while knowledge-intensive adoption of approaches to disease treatment such as crop rotation, use of resistant varieties, intercropping with repellent crops, and the use of commercial sprays, were seemed to increase with clinic attendance (Table 6).

Table 6: RSM interventions used by farmers faceted by plant clinic attendance

RSM interventions	Non-users				Users			
	Spider web in leaves	Tomato leaves (spots and dried)	Fruit damage (insect feeding)	Total	Spider web in leaves	Tomato leaves (spots and dried)	Fruit damage (insect feeding)	Total
Plant resistant variety		4		4		2	4	6
Hand pick insects	1			1		-	-	-
Pull out infected crops		18	16	35	3	27	16	46
Rotate tomato crops	1		6	7	2	8	2	12
Keep field weed free		8	4	12		-	6	6
Intercrop with repellent crops	-	-	-	-	1	2	-	3
Avoid infected planting areas	-	-	-	-	-	2	-	2
Plant away from infested fields	-	-	-	-	-	-	2	2
Commercial spays	1	2	2	5	1	4	4	9
Control irrigation			2	2		-	-	-
Total	**2**	**33**	**31**	**66**	**7**	**45**	**35**	**86**

In total, 66 farmers had adopted interventions for early and late blight outbreaks. Among the non-users, there were 27 (41%) adopters of various interventions while among users there were 39 (59%) adopters, implying a larger proportion of users than non-users adopted blight management interventions. There was a higher proportion of use of commercial sprays among users than non-users in Malawi.

3.4.2 Determinants of adoption of red spider mite and blight interventions

Table 7 presents findings on determinants of adoption of blight interventions among smallholder tomato farmers in Malawi. There were 6 explanatory variables that were significant. These included: participation in on-farm activities; total land in hectares; number of credit sources; experience of shocks; access to plant clinics and own experience.

Table 7: Factors influencing adoption of blight (BL) interventions among tomato farmers

Blight (BL)-Intervention Decision (Yes=1 & No=0)	**Coef.**	**Std. Err.**	**T**	**P>t**
Gender of household head	-0.0688	0.0822	-0.84	0.403
Age of household head	0.0021	0.0017	1.24	0.217
On-farm participation household head (HH)	0.3123	0.1387	2.25	**0.025****
Importance of farm to HH income	0.0394	0.0253	1.56	0.120
Education level of HH	0.0496	0.0367	1.35	0.177
Area under tomato	-0.5312	0.3631	-1.46	0.144
Total land hectare	0.0350	0.0143	2.45	**0.015****
Tropical Livestock Unit	0.0113	0.0218	0.52	0.603
No. of Credit sources	0.0971	0.0486	2.00	**0.046****
Household size	-0.0107	0.0127	-0.85	0.397
Use of improved seeds	0.0572	0.0500	1.14	0.254
Experienced shocks	0.1171	0.0504	2.33	**0.020****
Own experience source	0.1309	0.0438	2.99	**0.003*****
Plant clinics/plant doctors	0.2353	0.04023	5.85	**0.000*****
Constant	-0.4297	0.2358	-1.82	0.069

**** significant at 1%, ** significant at 5%; N=558*

Participation of farmers in on-farm activities was significantly linked to increased adoption of blight interventions (Table 7). Farmers' own experience and visiting a plant doctor also had a positive influence on the use of blight interventions. Results indicate that tomato farmers used the technical information that they acquired on pest management practices from plant clinics. Therefore, plant clinics boosted awareness and best use of pest management practices. Caswell *et al.* (2001) postulated that availability of information reduces doubts about performance of a given agricultural intervention, and judgment may change from subjective to objective.

Land size and access to credit were found to positively influence the use of blight management practices. Nowak (1987) asserts that large farm owners are more flexible in terms of decision making. Additionally, these farm owners have greater access to discretionary resources and have more opportunities to use new agricultural interventions on a trial basis with more ability to deal with risks. Additionally, Feder *et al.* (1985) reported that households with bigger landholdings are able to afford new interventions and were well placed to cope with the technology loss. On the other hand, farmers who accessed credit were able to purchase the required inputs in an attempt to manage blight. Availability of credit among the farmers could therefore lead to an increase in the use of pest management practices. Previous studies have revealed the impact of credit access in promoting adoption of new agricultural technologies (Aikens *et al.,* 1975; Feder and Umali, 1993; Smale *et al.,* 1994; Cornejo and McBride, 2002; Simtowe *et al.,* 2009). Furthermore, the results show that farmers who experienced shocks at their farms significantly improved their use of blight management practices. This is a clear depiction that farmers made attempts to find the best solutions to counter blight, which was a major problem for them.

The area under tomato influenced the adoption of RSM management practices (Table 8). The adoption of RSM interventions was also significantly influenced by farmers' own experience as a source of information on pests and diseases, and attendance at plant clinics.

Table 8: Factors influencing adoption of red spider mite interventions among tomato farmers

Red Spider Mite (RSM)	Coef.	Std. Err.	T	P>t
Decision (Yes=1 & No=0)				
Gender of household head	-0.0334	0.0630	-0.53	0.596
Age of household head	0.0002	0.0013	0.12	0.904
On-farm participation of HH head	0.0898	0.1064	0.84	0.399
Importance of farm to HH income	0.0306	0.0194	1.58	0.116
Education level of HH	0.0462	0.0281	1.64	0.101
Area under tomato	0.7139	0.2785	2.56	**0.011***
Total land hectare	-0.0078	0.0110	-0.71	0.479
Tropical Livestock Unit	0.0219	0.0167	1.31	0.191
No. of Credit sources	-0.0062	0.0373	-0.17	0.867
Dependency ratio	0.0002	0.0002	1.28	0.201
Household size	0.0051	0.0097	0.52	0.604
Use of improved seeds	0.0188	0.0384	0.49	0.625
Experienced shocks	0.0602	0.0386	1.56	0.120
Own experience source	0.1019	0.0336	3.03	**0.003*****
Plant clinics/plant doctors	0.1212	0.0309	3.93	**0.000*****
Constant	-0.3519	0.1809	-1.95	0.052

**** significant at 1%, ** significant at 5%; N=558*

3.5 Impact of plant clinics on tomato yields and profitability

The average mean tomato yields for matched plant clinic users and non-users were 9,774 kg ha^{-1} and 8,141 kg ha^{-1}, respectively (Table 9). The difference was statistically significant at 5% level. These results indicate that the use of plant clinics increased yields by 20%. This led to increased income for users of plant clinics. Results indicate that users of plant clinics reported higher income (6884 USD ha^{-1}) as compared to non-users (5685 USD ha^{-1}). The costs of seed and labour were significantly higher among farmers who attended plant clinics. The higher costs of seed imply that farmers who attended plant clinics probably adopted better seed varieties and used more labour intensive practices to enhance tomato productivity. These findings are consistent with previous studies that have reported the positive impact of plant clinics on productivity/yields (Flood, 2010; Bentley *et al.,* 2011; Brubaker *et al.*, 2013; Ranjedran and Islam, 2017).

Table 9: Yield, input costs and income among matched plant clinic users and non-users

	Non-users	Users	Significance
Yield (kg/ha)	8141	9774	**0.0148****
Seed (USD/ha)	5	8	**0.011****
Fertiliser (USD/ha)	29	23	**0.024****
Pesticide (USD/ha)	19	22	0.275
Labour (USD/ha)	4	10	**0.000*****
Net income (USD/ha)	5685	6884	**0.033****

1 USD=725 MWK *** Significant at 1% ** Significant at 5%

Table 10 presents the regression results of the determinants of tomato yield. Results revealed that farmer age influenced tomato yields. An increase in age by one unit (year) reduced yields by 0.61 percent. It implies that as the farmer gets older, the prospect of labour provision and adoption of knowledge-intensive and emerging disease management approaches declines. Tomato production is a labour-intensive economic activity and therefore households who are advanced in aged may not be able to obtain sufficient labour on their farms. Furthermore, aged farmers can be more risk averse and therefore fear unexpected events, especially total crop failure.

Table 10: Multiple regressions on factors that influence yields among smallholder tomato farmers in Malawi

Yield	Coef.	Std. Err.	T	P>t
Farmers' Characteristics				
Gender of household head	0.2188	0.1748	1.25	0.211
Age of household head	-0.0061	0.0037	-1.67	**0.095***
Education level of household head	-0.0150	0.0784	-0.19	0.848
Household size	0.0180	0.0273	0.66	0.509
Land allocated under tomato (ha)	-0.1069	0.7867	-0.14	0.892
Number of credit sources	0.1429	0.1043	1.37	0.171
Use of Improved seeds	-0.1235	0.1078	-1.15	0.252
Experience of shocks	-0.4534	0.1052	-4.31	**0.000*****
Cost of Input				
Labour cost	6.13×10^{-6}	3.47×10^{-6}	1.77	**0.078***
Seed cost	2.45×10^{-6}	4.93×10^{-6}	0.50	0.620
Fertiliser cost	1.14×10^{-5}	2.51×10^{-6}	4.55	**0.000*****
Pest/herbicides	4.54×10^{-6}	2.44×10^{-6}	1.86	**0.064***
Pest and Disease Score				
Red spider mite (RSM) index	0.000038	0.0082	0.00	0.996
Blight (BL) index	0.0191	0.0063	3.02	**0.003*****
Constant	8.623741	0.3999	21.56	0

****Significant at 1%, ** significant at 5%, * significant at 10%; N=558*

Yields for farmers who experienced shocks in their farms showed a negative influence. If the farmer reported having experienced shocks, the results revealed that yields decreased by 45.34%. On the other hand, various costs of inputs (labour, fertiliser and pesticides) were found to have a positive influence on yields despite having a marginal influence. Implementation of the right intervention of pest management on blight increased yields by 1.91%. This was measured using a total index, which was computed by weighting the presence of the disease, recognition after being shown the picture and using the correct intervention to address the respective disease. Subsequently, the index for blight and red spider mite (RSM) showed significant differences at 1% statistical levels between users and non-users of plant clinics. Users of plant clinics had a higher score as compared to non-users. This is a justification that attendance at a plant clinic had a positive impact on yields since farmers were able to implement the right interventions to curb the challenge of pests and diseases as compared to non-users, thereby increasing yields.

4 CONCLUSION AND POLICY IMPLICATION

The study found that both local and external sources of tomato pest and disease information were important for tomato farmers in Malawi. Agricultural extension officers, the farmers' own experience and neighbours, friends and family were ranked the top three important sources of information. The government extension service, however, stands out as an important source for all farmers. Users of plant clinics had more sources of information than non-users; an implication that accessing plant clinics is likely to improve their information-seeking behaviour for specific interventions. Agricultural radio programmes, agro-dealers and mobile phone SMS are emerging as major pathways for plant health information access for farmers, especially those that attended plant clinics. Ways of integrating these new pathways and plant clinics need to be explored to exploit areas of synergy and complementarity.

The plant clinics were shown to increase information-seeking behaviour of farmers for specific and knowledge-intensive agronomic solutions, compared to non-users who relied on local and more general sources of pest and disease management information. This observation suggests that plant clinics could motivate farmers to seek advice outside their traditional sources.

The participation in plant clinics contributed to increased knowledge of managing red spider mites and blight in tomatoes, which led to increased production and thus productivity. Users recorded significantly higher knowledge levels of RSM (19%) compared to that of the non-users with 17%. Similarly, users were more knowledgeable in terms of blight than the non-users with 16% and 14%, respectively. The higher score for RSM is possibly because the mite is easily seen and identified as compared to early and late blight. Though the levels of knowledge were generally low, the results show the contribution of plant clinic services towards improvement of knowledge levels of tomato RSM and BL. Low levels of knowledge could possibly be due to the complexity of managing RSM and BL in tomatoes, considering the many management practices on offer. Multivariate assessment revealed patterns of tomato disease occurrence and recognition in Malawi, which can be beneficial in adjusting the Plantwise approaches with maximum impact on tomato production and farmer welfare in Malawi.

There was an impact on the adoption of specific interventions for RSM and blight management. Users of plant clinics applied chemical products more than non-users. The study revealed a pattern of adopting specific and more knowledge-intensive interventions among farmers who attended plant clinics, compared to farmers who did not attend and were thus likely to retain local less specific and general management practices. This pattern was also noted for information-seeking behaviour, with farmers who attended plant clinics seeking information from wider sources, such as books and mobile SMS. Both local and knowledge-intensive systems have a role to play in pest and disease management for diverse sets of farmers in Malawi, and these should be integrated.

Plant clinics contributed to increased tomato yields and incomes in Malawi. Results showed that tomato yields increased by 20% while the net income improved by 21%. The yields in Malawi were influenced by farmer age (+ve), shocks (-ve), labour cost and blight knowledge (+ve). These results clearly showed that increased productivity is one of the direct benefits enjoyed by households adopting plant clinics in the short term. This is expected to have a multiplier effect in the long term as the incomes increase, which may trickle down to other households in the form of indirect benefits. The indirect benefits are likely to be increased food and nutritional security, poverty reduction and overall improved livelihoods. The continued use of plant clinics is encouraged to raise the yields and incomes further. The plant clinics in Malawi enhanced the awareness and knowledge of tomato pests and diseases, which improved adoption of interventions and tomato yields in Malawi. Thus this approach should be promoted, scaled up and integrated to improve the tomato sector in Malawi.

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APPENDICES

Appendix 1: Analysis of Pest and Disease Knowledge

1) Generating data from column headings in the excel pest and disease scoring file

A two-step process was used to extract column intervention headings (which can be numeric or text) into cells which are separated by commas. The comma separation enables the data to be separated into columns which can be analysed. This UDF (User Defined Function) is typed/copied in the Microsoft Excel VBA environment.

Getx = Join(Filter(Evaluate("=ÏF(" & Rng2.Address & "=""x""," & Rng1.Address & ",""V"")"), "V", False), ",")

End Function

This function is typed in the Excel worksheet which links with the VBA environment. The function extracts column headings into cells separated by commas which can be read as data and subjected to further analysis. The "x" represents the affirmative intervention (column identifications) responses.

=Getx($B$1:$D$1,B3:D3)

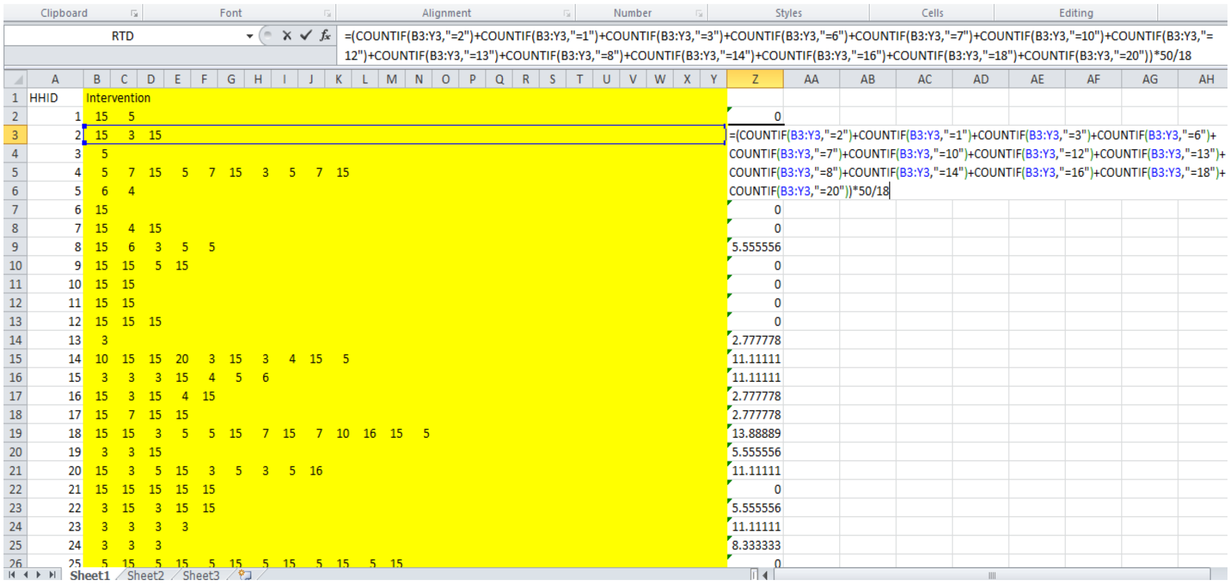
RTD =Getx($U$1:$KG$1,U13:KG13)

	A	B	JN	JO	JP	JQ	JR	JS	JT	JU	JV	JW	JX	JY	JZ	KA	KB	KC	KD	KE	KF	KG	KH
1	HHID	4	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Intervention
2	1																						15,5
3	2																						15,3,15
4	3					x																	5
5	4																						5,7,15,5,7,15,3,5,7,15
6	5																						6,4
7	6																						15
8	7																						15,4,15
9	8																						15,6,3,5,5
10	9																						15,15,5,15
11	10																						15,15
12	11	x																					15,15
13	12																						=Getx($U$1:$KG$1,U13:KG13)
14	13																						3
15	14	x				x																	10,15,15,20,3,15,3,4,15,5
16	15	x				x	x																3,3,3,15,4,5,6

2) Counting the correct disease interventions employed by farmers

The COUNTIF algorithm in Excel was used to count values (column numbers (1–21) identifying interventions) for red spider mite and tomato blight diseases. This procedure enables generation of counts resulting from specific values, in this case the correct intervention categories. To count the wrong responses, the corresponding wrong codes are replaced in the following formula:

=(COUNTIF(B2:Y2,"=1")+COUNTIF(B2:Y2,"=2")+COUNTIF(B2:Y2,"=3")+COUNTIF(B2:Y2,"=6")+COUNTIF(B2:Y2,"=7")+COUNTIF(B2:Y2,"=10")+COUNTIF(B2:Y2,"=12")+COUNTIF(B2:Y2,"=13")+COUNTIF(B2:Y2,"=8")+COUNTIF(B2:Y2,"=14")+COUNTIF(B2:Y2,"=16")+COUNTIF(B2:Y2,"=18")+COUNTIF(B2:Y2,"=20"))*(50/18)



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	Z
1	HHID	Intervention													
2	1	15	5												0
3	2	15	3	15											=(COUNTIF(B3:Y3,"=2")+COUNTIF(B3:Y3,"=1")+COUNTIF(B3:Y3,"=3")+COUNTIF(B3:Y3,"=6")+ COUNTIF(B3:Y3,"=7")+COUNTIF(B3:Y3,"=10")+COUNTIF(B3:Y3,"=12")+COUNTIF(B3:Y3,"=13")+ COUNTIF(B3:Y3,"=8")+COUNTIF(B3:Y3,"=14")+COUNTIF(B3:Y3,"=16")+COUNTIF(B3:Y3,"=18")+ COUNTIF(B3:Y3,"=20"))*50/18
4	3	5													
5	4	5	7	15	5	7	15	3	5	7	15				
6	5	6	4												
7	6	15													0
8	7	15	4	15											0
9	8	15	6	3	5	5									5.555556
10	9	15	15	5	15										0
11	10	15	15												0
12	11	15	15												0
13	12	15	15	15											0
14	13	3													2.777778
15	14	10	15	15	20	3	15	3	4	15	5				11.11111
16	15	3	3	3	15	4	5	6							11.11111
17	16	15	3	15	4	15									2.777778
18	17	15	7	15	15										2.777778
19	18	15	15	3	5	5	15	7	15	7	10	16	15	5	13.88889
20	19	3	3	15											5.555556
21	20	15	3	5	15	3	5	3	5	16					11.11111
22	21	15	15	15	15	15									0
23	22	3	15	3	15	15									5.555556
24	23	3	3	3	3										11.11111
25	24	3	3	3											8.333333
26	25	5	15	5	15	5	15	5	15	5	15	5	15		0

The list of correct interventions (codes 1–21) is shown below for both RSM and blight. The descriptions for the intervention codes for both RSM and blight are shown in the following section.

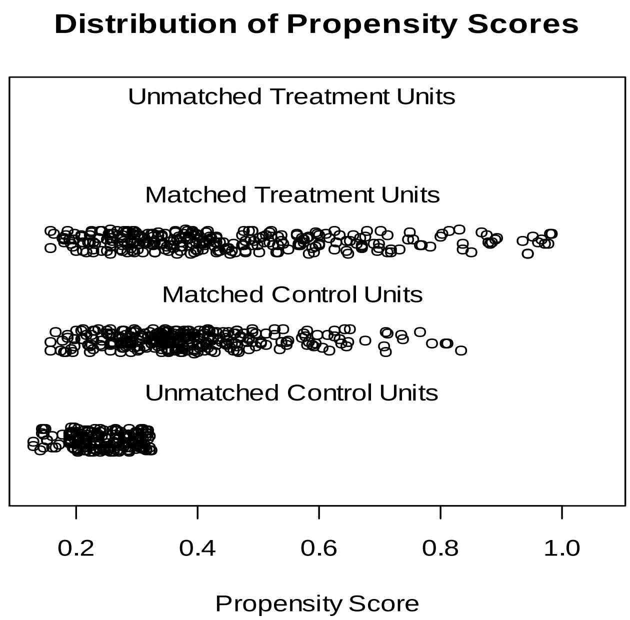
Correct intervention, otherwise wrong	
RSM	Blight
1	1
4	2
5	3
7	6
8	7
9	8
10	10
11	12
16	13
18	14
19	16
21	18
	20
	21

1. Plant tomato varieties with some resistance to the pest or disease
2. Ensure plants that you purchase are clean (not already infected)
3. Prune and destroy (e.g. by burning) parts of plant infested with the disease or insect
4. If insect pest is present then hand pick pest from the plant
5. Pull out infected plants with roots and surrounding soil and burn everything
6. Remove and burn all crop residues after harvest
7. Rotate tomato with crops that are not related to tomato (e.g. rotation is possible with crops such as beans and maize)
8. Keep the field weed free
9. Intercrop (or interplant) tomato with repellent non-host crops such as onion and garlic
10. Avoid planting in areas or fields with history of a disease or pest
11. Plant new crops away from infested fields

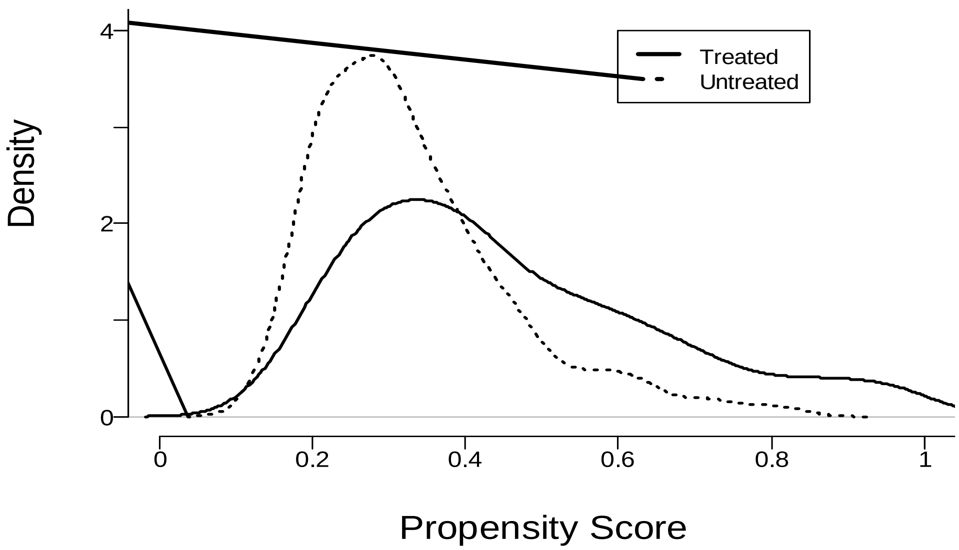
12. If disease is present in the crop then avoid movement of tools, soil or plants from one area or field to another
13. If disease is present then disinfect all tools after use in the fields
14. If disease is present then avoid furrow irrigation because this spreads the disease
15. If disease is present then apply wood ash in the affected holes after uprooting plant
16. Spray plants with commercial or purchased pesticides (fungicides or insecticides)
17. Spray plants with home-made products, e.g. neem-based products, pepper (chilli), soap solution or garlic solution (or other home-made solutions)
18. To control pests and diseases, space plants fairly far apart (100cm x 60cm)
19. Support beneficial insects, natural enemies and predators such as ladybugs, lacewing and predatory mites (e.g. by not spraying pesticides)
20. Use windbreaks or barrier crops between fields to protect tomato crop
21. Control how much water the crop is given (if irrigation is being used and depending on the pest or disease)

Appendix 2: Matching Quality Tests

Appendix 2.1 Distribution of propensity scores



Appendix 2.2 Propensity score distribution after matching



Appendix 2.3 Means comparisons before and after matching

	Before Matching			After Matching		
Variable	Treated (N=459)	Control (N=279)	T-value	Treated (N=279)	Control (N=279)	T-value
Age of household head	43.27	40.80	**0.0071*** **	43.27	42.87	0.702
Household size	5.94	5.39	**0.000*** **	5.58	5.41	0.196
Farm Size (ha)	1.86	1.44	**0.000*** **	3.34	3.29	0.653
Area under Tomato (ha)	0.54	0.35	**0.000*** **	0.14	0.138	0.841
Tropical Livestock Unit	3.02	2.04	0.1472	1.61	1.562	0.571
No. of credit sources	1.15	1.10	**0.0744* **	1.16	1.121	0.232
Dependency Ratio	106.76	108.56	0.7789	105.72	111.02	0.475
Gender of household head	0.9354	0.9237	0.5499	0.9354	0.9354	1.000
Education of household head	1.38	1.22	**0.000*** **	2.38	2.31	0.158
On-farm participation	0.9785	0.9695	0.7669	0.9785	0.9642	0.311
Importance of farm	1.33	1.29	0.3741	1.32	1.30	0.582
Age squared	2015	1809.8	**0.0112** **	2015	1988.65	0.775

****Significant at 1%, ** significant at 5%, * significant at 10%*

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