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Determinants of intensity of uptake of alternative pest control methods: A case of small- scale tomato farmers in Kenya

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Inappropriate use of chemical pesticide in horticultural production is an emerging problem causing undesirable human health and environmental effects in developing countries including Kenya. Thus, objective of this study is to evaluate the determinants of the intensity of uptake of alternative pest control methods among small-scale tomato farmers in Nakuru County, Kenya. Multistage sampling procedure was used to select a sample of 384 tomato farmers. Data were collected using a semi-structured questionnaire administered by trained enumerators. Alternative pest control methods which were identified during the survey were categorized into four groups using principal component analysis. Determinants of the intensity of uptake of alternative pest control methods were estimated using multivariate tobit model. Group membership, age, education and number of training increased the intensity of uptake of alternative methods. Participation in off-farm activities and farm size decreased the intensity of uptake of alternative methods. These results indicate that farmers' awareness that involves comprehensive training programs and enhancing the capacity of farmer groups as change agents is warranted. Moreover, these research findings could also inform policymakers while formulating and implementing targeted interventions aimed at promoting the use of alternative pest control methods that minimize negative health and environmental effects from overuse of pesticides.

Key words: Alternative pest control, pesticides, intensity, food safety, multivariate tobit model.

INTRODUCTION

Tomato, *Solanum lycopersicum* L. is one of the chief vegetable crops in Kenya. It is rich in minerals and vitamins (C) which make it an imperative nutritional component among households in Kenya (Sigei et al., 2014). It is consumed either in raw form (salads) or processed form such as tomato paste or tomato sauce.

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Moreover, it contributes towards poverty alleviation through the creation of employment, income generation and earning foreign exchange (Sigei et al., 2014). Despite its crucial role in the development of the national economy, farmers are faced with insect pest and disease outbreak which is a major production constraint (Waiganjo et al., 2006). They cause crop loss leading to loss of farm income. Some of the common tomato diseases comprise mildew, blight, leaf spots and wilt. Examples of tomato pests include cutworm, leaf miners, nematodes, bollworms, *tuta absoluta*, spider mites, thrips, whiteflies and aphids (Desneux et al., 2010; Mueke, 2015; Sigei et al., 2014). To address this problem, farmers employ numerous methods including chemical methods for crop protection against pests and to prevent crop loss hence increasing agricultural output. However, small-scale farmers heavily depend on chemical pesticides to combat pest problem which has raised public concern due to food safety issues, adverse human health and environmental effects (Macharia et al., 2009; Macharia et al., 2013).

Alternative pest control methods such as mechanical control, planned crop rotation, biological control, cultural control and use of biopesticide could provide a pathway to minimize the use of chemical pesticides leading to improved food safety, human health and conservation of the environment. In spite of efforts by the government and non-governmental organizations to promote use of alternative crop protection methods, the intensity of uptake is still unclear. In addition, the role of risk perception, socio-economic and institutional factors in influencing the intensity of uptake of alternative pest control methods is still not clear in the empirical literature. As the studies focusing on households` determinants of intensity of uptake of alternative pest control methods are limited, thus the objective of this paper is to examine the determinants of the intensity of uptake of alternative pest control methods among small-scale tomato farmers in Kenya. Hence, it is on this background that the study is geared towards filling these knowledge gaps among small-scale tomato farmers in Nakuru County. Knowledge and information acquired through the study will enable policymakers to design effective research and educational programs aimed at promoting an alternative to pesticide use leading to improved human health and conservation of the environment.

Prior studies have described decision on adoption of environmentally-friendly pest management methods as dichotomous choice representing adoption or non-adoption of alternative pest management strategies. In such a scenario, individual practices have been aggregated prior to analysis so to assess the factors influencing the adoption decision. This has yielded useful insights on drivers of adoption of such crop protection methods. However, such models neglect the effect of factors on the intensity of adoption and diversity of pest management practices utilized. Thus using a ratio of number of practices adopted from a portfolio of pest control methods enables us to group farmers into different subgroups hence facilitating the understanding why fewer or more practices are adopted from a specific group and drivers thereof.

First, we use multivariate tobit model to explain factors influencing the intensity of uptake of alternative pest control methods paying particular attention to interdependence and diversity of pest control methods employed by farmers. Our results indicate significant complementarity and substitutability in the decision on the intensity of uptake of pest management strategies. Although there is a plethora of literature on the influence of a host of explanatory variable on adoption of alternative crop protection methods, our study provides new evidence on policy related variables such as farmers' perception of pesticide use hazards. The information acquired through the study could be used to design research and outreach programs geared towards promoting agricultural sustainability through use of eco-friendly crop protection methods.

METHODOLOGY

Study area

The study took place in Nakuru County. It is among the leading tomato producing areas in Kenya with close proximity to Nairobi area which is among the largest urban tomato market. The county is located within the Great Rift Valley. It is situated at latitude 0˚13 and 1˚10` South and longitudes 35°28' and 35°36' East. The area receives bimodal rainfall. Long rains occur during the months of March to May. Short rains occur during the months of October to November (GoK, 2013). Agriculture is the major economic activity in the region. The main crops grown in the area include tomato, maize, beans, kales, wheat, carrots, peas, onions, french beans, strawberries, and other fruits. Figure 1 represents a map of the study area.

Sampling procedure and the data

The study employed a multistage sampling procedure to select the respondents. First, Nakuru County was purposively chosen. Subukia Sub-county was selected because it is one of the major tomato producing areas as guided by the agricultural extension personnel. Subsequently, Subukia and Weseges wards were randomly selected. Finally, farm households were selected using a simple random sampling method guided by a sampling frame generated by local agricultural extension officers. The sample consisted of three hundred and eighty-four households. Primary and Secondary data were used during the study. Primary data were obtained through a household survey which took place during the month of November 2017. A semi-structured questionnaire which was administered to the respondents by well-trained enumerators through face to face interviews was used for data collection. A pretest of the questionnaire took place before conducted the actual survey to test its suitability. Secondary data were obtained by reviewing the relevant literature. Subsequently, data were coded and entered into SPSS (version 20) and Stata (version14) software for analysis.

Table 1 summarizes the variables that are used in the

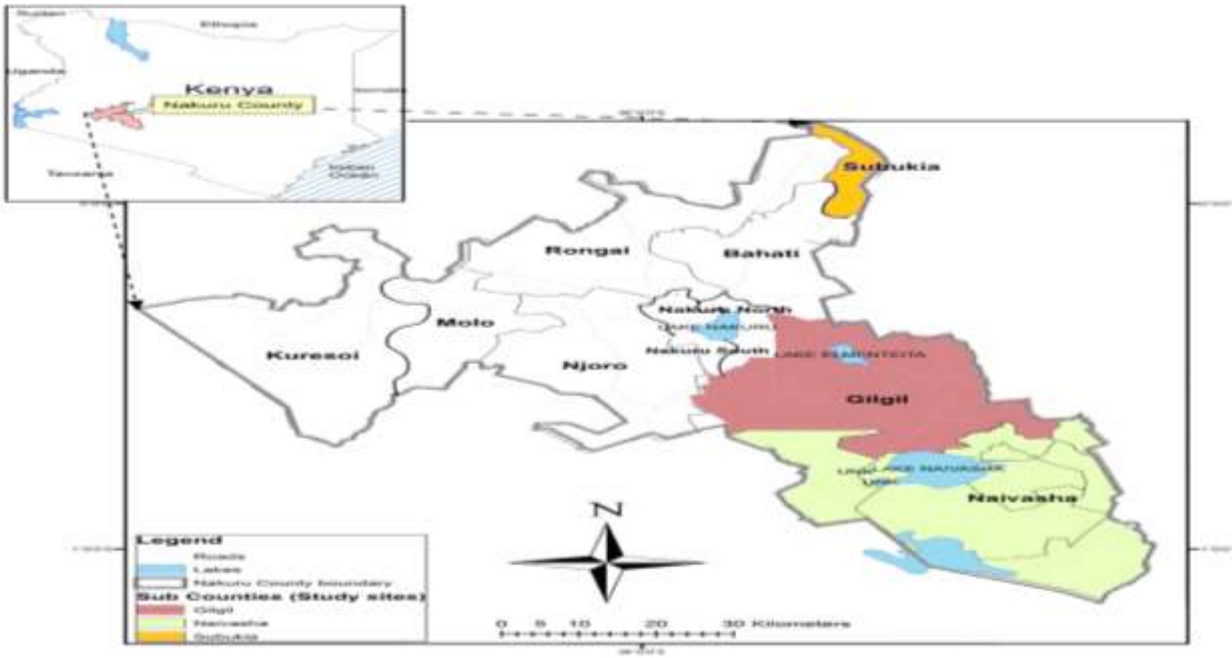

Figure 1. Location of the study area in Nakuru County, Kenya.

Table 1. Description of variables in the multivariate tobit model.

Variable	Description
Dependent	
Intensity of uptake	Ratio of the number of practices adopted from each group of alternative pest management methods (ranging from 0 to 1)
Independent	
Age of household head	Age of the household head in years
Gender of household head	Gender of the household head where 1= male, 0 = otherwise
Education of household head	Number of years of schooling of the household head
Household size	Number of people living in the household for the last six months.
Off-farm income	Participation in the off-farm activity where 1= yes, 0 = No.
Farm size	Total farm size in acres
Risk perception with respect to human health	Perceived pesticide use hazards on human health where 1=strongly disagree, 2= disagree, 3= uncertain, 4 = agree, 5= strongly agree.
Group membership	Number of groups that the farmer belongs to.
Extension contact	Number of contacts with extension service provider.
Credit access	Access to credit where 1= yes, 0= otherwise
Training	Number of training on pest management that the farmer participated in.
Customer orientation	Attitude towards customer`s demand during tomato production and marketing where 1=strongly disagree, 2= disagree, 3=uncertain, 4=agree, 5= strongly agree.
Information source	Dummies of the main primary source of information on pesticides use and agriculture in general (fellow farmers, pesticide retailer, pesticide company and media).

econometric analysis. They were derived from review of previous studies (Zyoud et al., 2010; Hashemi and Damalas, 2011; Kassie et al., 2013; Rahman, 2013; Khan and Damalas, 2015; Mengistie et al., 2015; Riwthong et al., 2016; Sharif et al., 2017). Risk perception with respect to human health and customer orientation was measured using a five-point Likert scale ranging from 1(strongly disagree) to 5(strongly agree). To generate a score for each concept, several items relating to each construct were analyzed using factor analysis. The results from factor analysis are presented in Appendix A Table A1. Cronbach`s alpha coefficients were evaluated to check the reliability of the unobservable concepts (Mackenzie et al., 2011). The composite reliabilities of the constructs ranged from 0.40 to 0.54. The Kaiser-Meyer-Olkin (KMO) test (values ranged from 0.50 to 0.67) showed that the sample was relatively adequate and suitable for factor analysis. In addition, continuous explanatory variables were subjected to variance inflation factor test (Appendix A Table A2) to examine the problem of multicollinearity. The VIF values were less than the recommended threshold value of less than 5 (Hair et al., 2011) hence multicollinearity was not an issue (Table 1).

Analytical framework

Farmers use a variety of alternative methods in crop protection. Examples of alternative (non-chemical) pest control methods include; cultural methods, biological control and use of biopesticides. Cultural methods involve pest management by manipulation of the environment or implementation of preventative practices. It includes; planting disease-resistant varieties, planned crop rotation, weeding, pruning and mulching to mention but a few. Biological methods refer to use of other organisms to manage pests (insect, weeds and diseases). It involves predation, parasitism, herbivory and other natural mechanisms. Biopesticides are crop protection products which are obtained from natural materials such as animals, plants, and bacteria. Thus farmers are faced with various pest control methods which may be adopted simultaneously and or sequentially as supplements, complements or substitutes. This implies that the number of methods adopted may not be independent but interdependent. Therefore, farmers will choose a set of strategies that maximize expected utility. Accordingly, the decision on the extent of adoption is multivariate and applying univariate approach might exclude relevant information contained in interdependent and concurrent adoption decisions (Ali et al., 2012).

Consistent with Mugi-Ngenga et al. (2016), the study initially employed Principal Component Analysis (PCA) to categorize different pest control strategies into groups. It is a statistical technique for discovering unidentified trends and simplifying the description of a bundle of interrelated variables by decreasing dimensionality of data. It performs a covariance analysis between factors and identifies a pattern of association between variables which in this case are pest control strategies.

Subsequently, multivariate tobit model was used to analyze the role of risk perception, socio-economic and institutional characteristics on the intensity of uptake of non-chemical pest control methods. The model concurrently estimates the effect of a set of explanatory variables on each of the dependent variables while allowing the stochastic error terms to be interrelated (Ma et al., 2006; Gillespie and Mishra, 2011). Contrary, univariate tobit models ignore such correlation of disturbance term as well as the relationship between the intensity of adoptions of diverse pest control strategies. This might lead to bias and inefficient estimates. The multivariate regression can be written as follows (Ali et al., 2012);

$$Y_{ij}^{*} = X_{ij}\beta_i + \varepsilon_{ij}, \text{ Where, j= 1,..,M and i = 1,…,n} \quad (1)$$

$$Y_{ij} = Y_{ij}^{*} \; if \; Y_{ij}^{*} > 0, 0 \; if \; otherwise \quad (2)$$

Where, j=1,..., M represents available alternative pest control strategies.

Y_{ij}^{*} = A latent variable which captures the unobserved preferences; X_{ij} = a set of independent variables (risk perception, socioeconomic and institutional characteristics); ε_{ij}= stochastic error term and Y_{ij}= observable variable denoting the ratio of the number of strategies adopted from available alternatives.

Equation 2 was estimated due to the latent nature of the dependent variable.

RESULTS AND DISCUSSION

Characteristics of farm households

Table 2 presents a brief description of interviewed households. The results show that small-scale tomato production is mostly male-dominated and with elderly people. The farm household heads had acquired a basic education (at least primary education) which is important in making farm decision relating to crop protection.

The farmers had an average of five members per household and seven years of farming experience. Majority of them cultivates land less than a hectare in area and belonged to at least one farmer group. In addition, the respondents had a minimum of one training program and had at least one contact with the extension service provider. The majority of respondents acquired information from other farmers.

Identifying and grouping alternative (non-chemical) pest management methods

In this study, majority of the farmers were using cultural methods as an alternative technique for dealing with the pest problem. However, none of the farmers utilized biological controls and biopesticides. Failure to use some of the alternatives to chemical pesticides was attributed to unavailability (41.93%), lack of awareness of other methods (28.13%), being ineffective (19.01%) and costly to use (10.94%). Ten non-chemical crop protection methods actively used by farmers were identified at the field during the survey. To facilitate further econometric analysis, identified practices were classified into four groups (components) using principal component analysis (Table 3).

The approach involves categorizing related practices into components to facilitate subsequent analysis by fitting the groups into the model and drawing conclusion. Unlike conventional techniques of grouping practices, use of principal component approach is favorable in drawing conclusion about a cluster in cases where few practices may represent the entire group. The approach is useful in reducing the dimensionality of data without losing much information. To arrive at the four principal components, orthogonal varimax rotation method (Goswami et al., 2012) was used so that lesser number of highly interrelated practices would be classified under each cluster for easy interpretation and generalization about

Table 2. A summary of household characteristics.

Variable	Mean	Std. Err.
Age of Household head	40.375	0.5934
Gender of household head (male=1)	0.7813	0.0211
Education of household head	10.8333	0.1446
Household size	4.3854	0.0934
Participation in off-farm activities	0.4219	0.0252
Farm size (acres)	1.7945	0.0710
Group membership	1.2630	0.0574
Extension contacts	1.0833	0.0486
Access to credit	0.4115	0.0251
Training	0.8984	0.0474

Table 3. Principal components of alternative methods of pest management.

Practices	Components				Communalities(%)
	1	2	3	4	
Crop residue destruction	0.785	0.065	-0.069	0.068	0.64
Irrigation	0.901	0.062	0.025	0.011	0.82
Efficient use of fertilizer	0.701	-0.366	0.049	0.015	0.64
Pruning	0.057	0.812	0.029	-0.032	0.67
Use of traps	0.004	0.827	-0.014	0.021	0.69
Intercropping	-0.023	-0.082	0.835	-0.017	0.74
Mulching	0.008	0.102	0.668	0.096	0.60
Weeding	0.146	-0.027	0.632	0.150	0.61
Crop rotation	-0.003	0.019	-0.003	0.910	0.83
Improved crop varieties	-0.055	0.013	0.064	0.837	0.74
Eigenvalues	2.006	1.274	1.124	1.051	
% Eigen values contribution	22.286	14.159	12.491	11.677	
Cumulative percentage	22.286	36.445	48.936	60.613	

Extraction method, Principal Component Analysis; Rotation method, Varimax with Kaiser Normalization.

the group. Consequently, Kaiser criterion was taken into consideration where components with Eigenvalues greater than one were retained (Kaiser, 1958). In this case, only variables with high factor loadings (greater or equal to 0.03) were considered for interpretation of the varimax rotation (Kamau et al., 2018). The clusters and their corresponding factor loadings (coefficients of linear combinations) are presented in Table 3.

With regard to the percentage of explained variance, the retained components explained 60.61% variability in the dataset. This presents a good fit indicating that the results from principal component analysis explained the data. Visually inspecting each column in Table 3 facilitates in understanding the contribution of each component in explaining the variability in the dataset. The first component explained 22.29% of the variance while the second, third and fourth components explained 14.16, 12.49 and 11.68% correspondingly.

Taking a closer look at each column in Table 3 helps to describe each cluster based on the strongly related practices. The first group (Component 1) comprises crop residue destruction, irrigation and efficient use of fertilizer all with positive factor loadings. Pruning and use of traps both with positive loadings belong to the second cluster (Component 2). The third component constitutes intercropping, mulching and weeding all with positive loadings. Finally, crop rotation and use of improved crop varieties belong to the fourth cluster both with positive coefficients of linear combination. The communality column represents the aggregate variance of each variable retained in the four components. In this case, all items in the principal components meet the minimum criteria (communality of above 0.6) as they accounted for more than sixty percent of the variance in the components (MacCallum et al., 2001). Table 4 provides a summary of groups of non-chemical pest control methods.

The most used cluster of alternative pest management

Table 4. Descriptive statistics of non-chemical pest management methods.

Categories of alternative methods	Percentage of users	Constituents
Crop management practices	98.70	Crop residue destruction Irrigation Efficient use of fertilizer
Preventive measures	97.14	Crop rotation Use of improved crop varieties
Control measures	95.32	Weeding Intercropping Mulching
Mechanical methods	66.23	Pruning Use of traps

methods was crop management practices with 98.7% of farmers utilizing it (Table 4). This group constitutes crop residue destruction, irrigation and efficient use of fertilizer. Maintaining field sanitation through crop residue destruction reduces the build-up of pests and spreading of insect and diseases to other crops. Avoidance of water stress through irrigation facilitates suppressing pest population which thrives well due to inadequate provision of water. Provision of adequate nutrients through fertilizer application that enhances crop growth alters soil pH, hence reducing crop susceptibility to pest (Filho et al., 1999; Mills and Daane, 2005; McGovern, 2015).

The second cluster (Table 4) with the highest number of users (97.14%) was preventive measures. It includes crop rotation (Banjo et al., 2010) and use of improved crop varieties (Karungi et al., 2011). Use of improved crop varieties (insect and disease resistant varieties) enhances crop resistance against pest attack while crop rotation minimizes pest population by altering their source of food or host (Veisi, 2012; Abang et al., 2014). The third group was control measures which entailed weeding, intercropping and mulching (Banjo et al*.,* 2010; Karungi et al., 2011; Bangarwa and Norsworthy, 2014) whose percentage of user was 95.32%. Weeding eradicates weeds and exposes soil-borne pests to natural enemies by bringing them to the ground. Intercropping reduces the attractiveness of the main crop to potential pests and may also act as a cover crop, hence preventing the growth of weeds. Similarly, use of mulch helps in controlling the growth of weeds and improves soil fertility (Knox et al., 2012) and regulates soil moisture by reducing water evaporation. Finally, the least used component (Table 3) was mechanical methods (66.23%) which comprised pruning and use of traps which belong to the mechanical method. For instance, removal and destruction of infected parts of the plant by pruning subdue pest reproduction and dispersion. For example, use of traps to capture and eradicate insects (for instance sticky traps) or trap crops to attract pest away from the desired crop contributes towards a reduction of the pest population by altering its habitat (Khan and Damalas, 2015; Jebapreetha et al., 2017).

Determinants of the intensity of uptake of alternative pest management methods

In order to determine the extent of usage of each group of non-chemical pest management methods by farmers, the number of methods used by a farmer in each group was expressed as a ratio of the total possible number of methods in each group (ranging from 0 to 1). The ratio was used as a proxy for the intensity of uptake of alternative (non-chemical) methods. Subsequently, multivariate tobit model was employed in estimating the determinants of the intensity of uptake of alternative pest management methods. Table 5 presents the results from multivariate tobit model. Majority of the correlation coefficients are strongly significant. The maximum correlation in absolute term is 39% which is relatively low. This indicates that the multivariate tobit model specification is vital, and disregarding such correlations would have led to inconsistent parameter estimates. Results from Table 5 indicate that there is significant complementarity (positive correlation) and substitutability (negative correlations) between the intensity of adoption decisions. Further confirmation from likelihood ratio test (Chi^2 (6) = 72.3927, p<0.01) of joint significance of correlation coefficients of the error terms rejects the null hypothesis of the independence of adoption decision, showing that it is more efficient to use multivariate tobit than the univariate tobit models. Moreover, Waldi *Chi-square* test results ($\chi^2(60)$ =171.63, p=0.0000) indicates that the model fitted data well and all the relevant variables were incorporated into the model.

From Table 5, the age of the household head had a

Table 5. Parameter estimates of multivariate tobit model.

Variables	Crop management practices		Mechanical methods		Control measures		Preventive measures	
	Coefficient	R.S. E	Coefficient	R.S.E	Coefficient	R.S.E	Coefficient	R.S. E
Socioeconomic characteristics								
Age of household head	0.0023	0.0015	0.0032	0.0033	0.0037***	0.0014	-0.0011	0.0016
Gender of household head	0.0146	0.0370	0.0657	0.0818	0.0016	0.0382	0.0362	0.0369
Education of household head	0.0045	0.0055	0.0278**	0.0118	0.009	0.0056	0.0133**	0.0067
Household size	0.0129	0.0092	0.0180	0.0185	0.0065	0.0092	-0.0006	0.0092
Participation in off -farm activities	-0.0562*	0.0308	0.0385	0.0715	0.0112	0.0349	-0.0026	0.0302
Farm size	0.0017	0.0119	-0.009	0.0291	-0.0310**	0.0125	0.0067	0.0091
Farmer perception								
Risk perception with respect to human health	0.0040	0.0124	0.0504*	0.0259	0.0094	0.0134	0.0184	0.0145
Institutional characteristics								
Group membership	-0.0002	0.0133	-0.0042	0.0298	-0.0129	0.0127	0.0309**	0.0137
Number of extension contacts	0.0106	0.0176	0.0635	0.0407	-0.0133	0.019	-0.0023	0.0172
Access to credit	-0.0151	0.0324	0.0515	0.0679	0.0124	0.0329	-0.0233	0.0314
Number of training	-0.0028	0.0194	0.0438	0.044	0.0392*	0.0207	-0.0101	0.0183
Customer orientation	-0.0232	0.0149	0.0359	0.0292	-0.0162	0.0163	0.0379**	0.018
Informal information sources[1]								
Pesticide retailer	-0.0560*	0.0323	0.0189	0.0734	0.0467	0.0327	0.0152	0.0318
Pesticide company	0.0434	0.0699	-0.0462	0.2073	-0.0368	0.0663	0.0208	0.0593
Media	0.0364	0.0817	0.0961	0.1767	-0.0529	0.0614	0.0924	0.0651
Constant	0.5334***	0.0892	-0.3475*	0.2082	0.3620***	0.0950	0.6187***	0.1125
Model diagnostics								
Number of observations	384							
Waldi Chi^2 (60)	171.63***							
Log pseudolikelihood	-468.01							
rho12	-0.3935***	0.0506						
rho13	0.0289	0.0507						
rho14	0.0174	0.0541						
rho23	0.1315**	0.0534						
rho24	-0.0605	0.0560						
rho34	-0.1061**	0.0485						
Likelihood ratio test of rho12 = rho13 = rho14 = rho23 = rho24 = rho34 =0: Chi^2 (6) = 72.393, Prob. > Chi^2 = 0.0000								

***, **,* represents significant at 1, 5 and 10% levels respectively; 1 the base category source of information is fellow farmers. R.S.E = robust standard error. rhoij = correlation between error terms of any pair of multivariate tobit equations.

positive influence on the intensity of uptake of control measures at 1% significant level. Control practices such as weeding, intercropping and mulching are relatively labour-intensive and capital-intensive methods. To carry out these activities, a farmer may need capital to hire additional labour, purchase materials for mulching or seeds for intercropping. Thus, older farmers who may have accumulated social and physical resources over time may adopt higher numbers of control practices than young farmers who may lack such resources. Another possible explanation could be young farmers (unlike older farmers who solely rely on agriculture for income) may lack adequate time needed to implement activities such as weeding which require long working hours since they are engaged elsewhere (non-farm activities). This increases their preference for chemical methods which are considered less time consuming and more effective than alternative methods, hence lower number of control practices adopted. Similarly, In Greece, Damalas and Hashemi (2010) observed that young farmers displayed higher intensities of adoption of pest management practices related to Integrated Pest Management (IPM) than old farmers.

Education of the household head had a positive influence on the intensity of uptake of mechanical and preventive methods at 5% significant level. Preventive methods such as the use of improved crop varieties and mechanical methods (for instance, use of traps and pruning) require knowledge about the pest, the environment, and management techniques as well as special skills which can be acquired through formal education. Education increases information access, processing capability and the ability to apply the acquired information. As a result, better-educated farmers are able to implement such methods with ease which increases the number of practices adopted as compared to their counterparts. The findings are consistent with Khan and Damalas (2015) results on factors influencing cotton farmer`s adoption of an alternative to chemical pest control in Pakistan.

Participation in off-farm activities negatively influenced the intensity of uptake of crop management practices at 10% significant level. Crop management practices probably have a high demand for labour and management time spent on the farm. Therefore, farmers engaging in non-farm activities divert labour and time away from crop management activities which lower the number of crop management practices adopted. This observation is in line with Brauns et al. (2018)'s findings where participation in off-farm activities was positively associated with increased use of pesticides (decreased use of traditional hand weeding method) by farm households in China. Another possible explanation for the negative relationship could be due to a lower allocation of non-farm income to crop management activities as compared to non-agricultural activities which lead to a lower number of crop management practices being adopted. For instance, allocation of a higher proportion of off-farm income to household expenditure (due to large household size) reduces the available funds for investment in agricultural activities leading to a lower number of crop management practices adopted.

Farm size had a negative effect on the intensity of uptake of control measures at 5% significant level. Control measures such as weeding and mulching require higher investment in labour, and .as farm size increases it may become less feasible for the resource-poor farmers to meet the higher weeding labour and mulching materials requirement of the land under cultivation probably due to increased production cost and competition of labour with other farm activities. As a result, lower number of control practices will be adopted by farmers as farm size increases. On the other hand, small-scale farmers in Kenyan rural areas mostly rely on family labour to lower opportunity cost which increases the number of control practices adopted due to cheap family labour. In contrast, Zulfiqar and Thapa (2017) observed that increase in farm size resulted in higher number of land preparation and sowing practices being adopted by cotton farmers as a component of an innovative cleaner production alternative.

Farmer's pesticide use risk perception with respect to human health had a positive influence on the intensity of uptake of mechanical methods at 10% significant level. Farmers` negative attitude towards synthetic pesticide use due to previous adverse human health experience might motivate them to seek alternative methods of crop protection which do not endanger their health and the environment. For instance, previous ill-health experience as a result of chemical pesticide use may increase farmers` concern over health status hence increasing preference for an alternative to chemical methods. Mechanical methods such as use of traps and pruning are eco-friendly and thus may not pose a threat to human health unlike use of chemical pesticides. This increases the number of mechanical methods adopted by farmers who have heightened risk perception. Khan and Damalas (2015) associated heightened risk perception with the adoption of alternative pest control methods. In contrast, Tu et al. (2018) observed that farmers with higher risk perception were less likely to adopt eco-friendly rice production in the Vietnamese Mekong Delta due to fear of failure (uncertainty) of the new eco-friendly practices to achieve the desired outcome

Membership to a group positively influenced the intensity of uptake of preventive measures at 5% significant level. To adopt higher numbers of preventive measures such as use of improved crop varieties and crop rotation, a farmer may require credit, relevant information, training and other essential services. These services are easily accessible through cooperative membership due to economies of scale which enhance success in number of preventive practices adopted. Furthermore, group membership creates linkages which facilitate the exchange of ideas, experiences and new innovations which can increase the number of preventive practices adopted. These findings are consistent with Tu et al. (2018)'s findings where membership in the agricultural club had a positive influence on adoption of eco-friendly rice production in Vietnam such as integrated pest management methods.

Participation in training programs had a positive effect on the intensity of uptake of control measures at 10% significant level. To adopt a higher number of control techniques such as mulching, weeding and intercropping requires knowledge on the pest, its habitat and ways of suppressing it. This information can be accessed by participating in training. Demonstration of new methods through training programs enhances farmer`s skills and confidence in the new methods which may increase the number of control practices adopted. Correspondingly, Khan (2009) observed that participation in training was positively correlated with the likelihood of adoption of alternative pest management practices in Pakistan. Similarly, Williamson et al. (2003) reported that farmers who had undergone training (relative to untrained farmers) preferred alternative crop protection methods over synthetic pesticides as they had acquired information on adverse human and environmental effects of pesticide use through training.

Customer orientation had a positive influence on the intensity of uptake of preventive measures at 5% significant level. Customer orientation involves understanding customer`s needs and creating value for the customers by offering high quality and safe food to others. To satisfy these needs (for instance large fruit size, blemish free andchemical free goods) a farmer may seek alternative methods of crop protection which are less detrimental to consumer health. Utilizing improved crop (such as high yielding and pest resistant) varieties and practising crop rotation may contribute towards meeting the customers' demands by minimizing chemical pesticide application due to health and food safety concerns. In return, farmers will gain access to lucrative markets offering premium prices for their products. Consequently, increased revenue due to the high market demand for their products will motivate farmers to adopt a higher number of preventive measures. Prior studies (Cameron, 2007; Buurma and Velden, 2016) have highlighted consumer demand as one of the major drivers of adoption of IPM.

Finally, pesticide retailer as a source of information had a negative effect on the intensity of uptake of crop management practices at 10% significant level. Efficient use of fertilizer, optimal provision of water through irrigation and maintaining sanitation through crop residue destruction may require special knowledge on crop production which the pesticide retailer may be lacking probably due to low levels of education or lack of training. This lowers the number of crop management practices adopted by a farmer who relies on pesticide retailer for information. Furthermore, pesticide retailers who are driven by profit motive are more likely to promote synthetic pesticide use and provide information on how to use the product relative to alternative methods which decrease the adoption of crop management practices. On the contrary, farmer to farmer exchange of information and ideas facilitates higher uptake of number of crop management practices probably due to vast knowledge on local production conditions acquired through farming experience as well as trust since they are known to each other. Additionally, the farmers providing information instil confidence in other farmers as they demonstrate new practices acquired through training, thus leading to the higher adoption of crop management practices. Similarly, Wagner et al. (2016) observed that farmers who relied on pesticide dealers for information on pest management were more likely to use synthetic pesticides than other alternative methods.

CONCLUSIONS AND POLICY IMPLICATIONS

Findings revealed that farmers` risk perception, socio-economic and institutional factors influenced the intensity of uptake of alternative pest control methods. The significant factors in explaining the intensity of uptake of crop management practices were participation in non-farm activities and access to information through pesticide retailer. The intensity of uptake of mechanical methods was significantly explained by education of household head and farmers` pesticide use risk perception. With regard to the intensity of uptake of control measures, age, farm size and participation in training were significant predictors. The intensity of uptake of preventive measures was significantly explained by education, group membership and customer orientation.

Technical support aimed at promoting the use of non-chemical methods could be provided through the farmer association to enhance access to information and relevant services. Local farmer institutions and service providers should be supported since they play a vital role in providing information, access to market and other relevant services. In addition, creation of awareness of alternative to synthetic pesticide through farmer groups and partnership with local service providers (such as pesticide retailers) to enhance uptake of non-chemical pest management methods is necessary. Provision of participatory training programs/seminars on alternative crop protection methods (for instance through farm demonstrations and farmer field schools) which are tailored to meet the specific farmers` needs could accelerate the adoption. Finally, promotion and implementation of new efficient integrated pest management approaches and other alternative methods via relevant government and non-governmental information dissemination channels to enhance effective adoption and reduce synthetic pesticide use to a bare minimum. Integrated pest management method is an all-inclusive technique which cost-effective, eco-friendly, guarantees yields and contributes towards sustainable agriculture.

ABBREVIATIONS

GoK, Government of Kenya; **IPM,** Integrated Pest Management.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Appendix A

Table A1. Factor analysis for describing human health risk perception and customer orientation concepts.

Constructs	Items	Factor Loadings	*CR*	*AVE*	KMO
Human health risk perception	Pesticide use is harmful to farm family health.	0.68			
	Pesticide use is harmful to the user`s health.	0.63			
	Pesticide use is harmful to other farmer`s health.	0.63			
	Improper pesticide use causes acute illness.	0.66	0.54	0.42	0.67
Customer orientation	It is important to have a strong focus on understanding customer`s needs during tomato production	0.80			
	It is vital to have a strong emphasis on customer commitment during tomato production.	0.80	0.40	0.64	0.50

CR= Composite Reliability, AVE = Average Variance Extracted, KMO =Kaiser-Meyer-Olkin.

Table A2. Variance inflation factor test results for continuous explanatory variable.

Variable	VIF	1/VIF
Age of household head	1.39	0.721675
Education of household head	1.18	0.844372
Household size	1.23	0.811646
Farm size	1.11	0.89881
Risk perception with respect to human health	1.04	0.964776
Group membership	1.07	0.93149
Extension contacts	1.36	0.737077
Training	1.37	0.728637
Customer orientation	1.05	0.954596
Mean VIF	1.2	