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Research Application Summary

Adoption of integrated pest management strategy for suppression of mango fruit flies on household welfare in selected counties in Kenya

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Abstract

Horticultural farming is the fastest growing agricultural sector in Kenya. Despite this, the production and marketing of mangoes is hampered by fruit fly infestation that is responsible for high pre and post-harvest losses. To reduce the losses, cost of production and increase the profit at producer level, International Center for Insect Physiology and Ecology (ICIPE) developed and disseminated Integrated Pest Management (IPM) strategy for suppression of mango fruit flies in selected counties in Kenya. Despite the rapid uptake of mango IPM strategy, the role of socio-economic and institutional variables influencing adoption was not clear in literature. This study was conducted to fill this gap. The general objective of this study was to contribute towards improved market access and improved livelihood through enhanced adoption of IPM technologies for suppression of mango fruit flies in selected counties in Kenya. Data were collected using a semi-structured questionnaire on a sample of 660 mango farmers from Embu, Meru, Machakos and Makueni Counties. The study employed a multi-stage sampling procedure technique. STATA software was used for data analysis. Multivariate Probit model method was used for data analysis. The results of Multivariate probit indicate that off-farm income, distance to nearest market for inputs, credit access and access to extension services had a positive effect on the adoption of IPM strategies opposed to age of the household head and intercropping. Group membership and the number of trees per acre had mixed results. There is need to link mango farmers to credit institutions, have appropriate demand driven extension services and trainings that impart relevant skills that enhance the adoption of new farming technologies.

Keywords: Adoption, fruit flies, integrated pest management, Kenya, mango

Résumé

L'horticulture est le secteur agricole qui connaît la croissance la plus rapide au Kenya. Malgré cela, la production et la commercialisation des mangues sont entravées par l'infestation de mouches des fruits qui est responsable de pertes élevées avant et après récolte. Pour réduire les pertes, les coûts de production et augmenter les bénéfices au niveau des producteurs, le Centre international pour la physiologie et l'écologie des insectes (ICIPE) a développé et diffusé une stratégie de lutte intégrée contre les ravageurs pour la suppression des mouches des mangues dans certains comtés du Kenya. Malgré l'adoption rapide de la stratégie de lutte intégrée contre les ravageurs de la mangue, le rôle des variables socio-économiques et institutionnelles influençant l'adoption n'était pas clair dans la littérature. Cette étude a été menée pour combler cette lacune. L'objectif général de cette étude était de contribuer à l'amélioration de l'accès au marché et à l'amélioration des moyens de subsistance grâce à une meilleure adoption des technologies de lutte intégrée contre les ravageurs pour la suppression des mouches des mangues dans certains comtés du Kenya. Les données ont été recueillies à l'aide d'un questionnaire semi-structuré sur un échantillon de 660 producteurs de mangues des comtés d'Embu, Meru, Machakos et Makueni. L'étude a utilisé une technique de procédure d'échantillonnage à plusieurs degrés. Le logiciel STATA a été utilisé pour l'analyse des données. La méthode du modèle Probit multivarié a été utilisée pour l'analyse des données. Les résultats du probit multivarié indiquent que le revenu hors exploitation, la distance au marché le plus proche pour les intrants, l'accès au crédit et l'accès aux services de vulgarisation ont eu un effet positif sur l'adoption des stratégies lutte intégrée contre les ravageurs par opposition à l'âge du chef de ménage et à la culture intercalaire. L'appartenance à un groupe et le nombre d'arbres par acre ont eu des résultats mitigés. Il est nécessaire de relier les producteurs de mangues aux institutions de crédit, de disposer de services de vulgarisation adaptés à la demande et de formations qui transmettent des compétences pertinentes qui améliorent l'adoption de nouvelles technologies agricoles.

Mots-clés : Adoption, mouches des fruits, lutte intégrée, Kenya, mangue

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Introduction

Agriculture remains the main economic activity in many developing countries, Kenya being an example. Under horticulture, mango is an economically essential fruit crop as it is traded on domestic and international markets (Mohammed *et al.,* 2020). It is the third most important fruit crop in terms of land acreage and total production volumes after bananas and pineapples according to a value chain analysis that was conducted in 2009 in Kenya (FAO, 2009). Mangoes' potential yields are approximately 15-20 tons per hectare whose achievement is rare by most Kenyan farmers due to poor control of pests and disease attacks (Njuguna *et al.,* 2012). The fruit provides many smallholder farmers with employment opportunities, poverty reduction, food security and foreign exchange earnings (Diiro *et al.,* 2018). However, Kenya's mango production, quality and marketability are constrained by many problems, with fruit flies being a major threat to food security, poverty alleviation and agricultural livelihoods. Fruit flies are estimated to cause huge annual losses of approximately US $ 2 billion in fruit and vegetable production in Kenya (Ekesi *et al.,* 2016).

Following the wide damage caused by mango fruit flies, the International Center of Insect Physiology and Ecology (ICIPE)-African Fruit Fly Program (AFFP) developed and disseminated an Integrated Pest Management (IPM) package for suppression of mango fruit flies in Africa and particularly in Kenya (Muriithi *et al.,* 2016). However, IPM as newly introduced technology, farmers have limited information that limits its adoption. Despite its potential to improve mango productivity in Kenya (Muriithi *et al.,* 2018; Lapple, 2010).

Studies in other countries have revealed that the adoption of IPM strategies is beneficial to farmers. The decision to determine whether it is feasible and profitable for farmers to adopt and implement the IPM technology on their farms may not be instantaneous. This means that farmers could adopt IPM strategies the same year they were promoted or could do so after several years. Additionally, in the process of adoption the standing aspect explains why, at a point in time some farmers adopt while others are late or slow adopters and others are non-adopters. Several factors such as socioeconomic, institutional, cultural and social networks do affect the ability of farmers to adopt technologies. Therefore better understanding of the constraints that condition farmers' adoption behavior is important for designing and implementing policies that could kindle the adoption of mango IPM strategies (Kassie *et al.,* 2016).

Using Multivariate Probit model to explore the factors required for mango farmers to adopt IPM strategies, this paper contributes to the existing literature in the following ways; firstly, there is scarcity of literature on the contributing factors to the fast adoption of IPM strategies for control of mango fruit flies. This study analyses factors of adoption of mango IPM strategies that were introduced by ICIPE in selected counties in Kenya. Secondly, the empirical knowledge and information obtained from this study on factors that shape the pattern of adoption may be useful in designing relevant agricultural policies to strengthen and speed up technology dissemination of mango IPM strategies for control of fruit flies. Thirdly, IPM is a sustainable production intensification approach which does not rely on the inflamed use of insecticide. As such, its adoption could potentially allow farmers to increase their mango productivity and incomes, without increasing dependence on insecticides.

Materials and Methods

This study used data collected from 660 farm households across four selected counties in Kenya where awareness on IPM strategies was done by ICIPE, namely; Embu, Meru, Machakos and Makueni. Data were collected between November and December 2016 in collaboration with ICIPE. Well trained and experienced enumerators who had the knowledge of the local language administered structured survey questionnaires. The survey targeted the mango farmers who were supplied with the IPM strategies for control of mango fruit flies.

Multistage sampling procedure was employed in the study. In the first stage, four mango growing Counties (Embu, Meru, Machakos and Makueni) were purposively selected based on their production and high incidences of mango fruit flies. Each of the four counties was assigned an equal number of sample households, thus 165. This was followed by choosing sub-counties where IPM strategies had been distributed in which the survey could be conducted. In Embu County, studies were carried out in Runyenjes sub-county. In Meru County, studies were carried out in Central Imenti, North Imenti, South Imenti, and Tigania West Sub-counties. In Machakos County, Mwala and Kangundo were covered, while in Makueni County, studies were carried out in Makueni sub-county. This information was obtained from the County integrated development plans in every County in Kenya.

Trained enumerators collected a wide range of information on socioeconomic characteristics, agricultural assets, farmers income sources, mango production practices and related constraints, mango yields, number of years the farmer was aware of mango IPM strategies, damage levels and marketing, IPM knowledge and adoption or non-adoption, health effects of pesticides, social capital, networking and infrastructure and institutional factors.

Econometric specification of Multivariate Probit model. Farmers adopt a mix of techniques to deal with a multitude of agricultural production constraints rather than adopting a single technology. The limitation of most of the previous studies on adoption of IPM technologies was that they did not consider the possible inter-relationships between the previous practices. These studies mask the reality faced by decision-makers who were often faced with technologies that might be adopted simultaneously or sequentially as components, substitutes or supplements. Such adoption analysis is possible when technological adoption decisions are made exogenously. But, when decisions made in conjunction with the adoption decision are considered, this approach may under or over-estimate the influence of various factors on the adoption decision.

This suggests that the number of technologies adopted were not independent, but path dependent: the choice of technologies that were recently adopted by farmers was partly dependent on earlier technology choices. Thus, the decision was inherently multivariate probit (MVP) econometric technique, which simultaneously models the influence of the set of explanatory variables, while allowing the observable and/or unmeasured factors (error terms) to be freely corrected (Belderbos *et al.*, 2004; Lin *et al.,* 2005). In contrast to MVP models, univariate probit models ignore the potential correlation among the unobserved disturbance in the adoption equation. Failure to capture unobserved factors and inter-relationships among adoption decisions regarding IPM packages would lead to inefficient estimates.

Since the number of technologies adopted was expected to be path dependent, the choice of technologies adopted more recently by farmers could be partly dependent on preceding technology choices. Therefore, the decision to adopt was inherently multivariate and application of univariate modelling excludes useful economic information contained in interdependent and simultaneous adoption decisions.

The multivariate probit model was characterized by a set of binary dependent variables (T_{hj}), such that:

$$T_{hj}^{\bullet} = X_{hj}\beta_j + \mu_{hj} \quad (1)$$

and

$$T_{hj} \begin{cases} = 1 & if T_{hj}^{\bullet} > 0 \\ 0 & otherwise \end{cases} \quad (2)$$

Where j=1,...,m denotes the technology choices available (IPM components).

In equation (2), the assumption is that a rational h^{th} farmer has a latent variable, $T_{hj,}^{\bullet}$ which captures the unobserved preferences or demand associated with the j^{th} choice of the IPM components. This latent variable is assumed to be a linear combination of variable characteristics captured by the stochastic error term μ_{hj} (Lee, 1978; Maddala, 1983). The vector of parameters to be estimated is denoted by β_j.. Given the latent nature of $T_{hj,}^{\bullet}$, the estimations are based on observable binary discrete variables which indicate whether or not a farmer adopts another practice (if the error terms, μ_{hj} are with a standard normal distribution), the equation (8) specify univariate probit model, where information on farmers' adoption of several farming practices was possible , a more realistic specification was to assume that the error terms in equation (8) jointly follow a multivariate normal (MVN) distribution, with zero conditional mean and variance normalized to unit, where μ_{hj}~MVN(0,∑) and the covariance matrix ∑ is given by:

Results and Discussion

Descriptive and Inferential Statistics. Machakos County had the highest mean age of 59.0 years of mango farmers as compared to other counties besides having the highest mean distance of 116.42, in walking minutes, to the nearest credit institutions. The highest household size of 6

$$\begin{pmatrix} 1 & p_{12} & p_{13} \cdots\cdots p_{1m} \\ P_{12} & 1 & p_{23} \cdots\cdots p_{2m} \\ P_{13} & p_{23} & 1 \cdots\cdots p_{3m} \\ . & . & . \quad\quad . \\ . & . & . \quad\quad . \\ P_{1m} & p_{2m} & p_{3m} \end{pmatrix} \qquad (3)$$

members was witnessed in Makueni County. Meru County had the highest mean size of land of 4.48 acres (Tha) owned by mango farmers. The same county also witnessed the highest mean distance to the nearest market for input and output dealers of 96.49, in walking minutes, with the highest percentage of 83.77 for intercropping mango plants with other crops. Findings also showed that Meru County had the highest percentage of 33.12 of mango farmers who had formed mango farming groups. Further analysis revealed that Embu County had the highest distance of 90.18, in walking minutes, to the nearest extension services as compared to other Counties. Makueni County had offered the highest percentage of training (42.65%) to mango farmers.

Multivariate probit model. Multivariate Probit model was used to identify socio-economic and institutional factors that shape the patterns of the IPM components for suppression of mango fruit fly. Table 1 presents the results of Multivariet Probit model. The results in the lower panel of Table 1 on correlation coefficients of error terms indicate that there are complementarities which indicate a positive correlation between different IPM components utilized by mango farmers. The results support the assumption of interdependence between the different mango IPM strategy adoption options. The results also indicate log likelihood ratio test based on log likelihood values which revealed significant correlations Wald chi^2 (62) = 93.77; probability > chi^2 = 0.0113. Thus the explanatory power of the Multivariate Probit model had a fairly strong effect.

The age of the household head was negatively associated with the adoption of fruit fly traps and biological control strategies ($p<0.01$). This means that older farmers are less likely to adopt fruit fly traps and biological control. As age advances farmers may not find it easy to use fruit fly traps due to their relative immobility and a decline in cognitive abilities of farmers. Additionally, it may be challenging to elderly farmers to learn, adjust and adopt with ease the newly introduced IPM strategies that are effective and convenient for the control of crop pest and diseases. This corroborates findings by Taklewold *et al.* (2012), who noted that age negatively affects the probability of adoption and use of new farming technology employed in the control of pests and diseases in vegetable production because of inflexibility in the adjustments to technology changes.

Table 1. Inferential results for farm, farmer, and institutional characteristics

County socio-economic variables		Embu	Meru mean	Machakos	Makueni	Pooled Mean	F-stat
Age of household head		59.31	57.92	59.6	52.77	57.72	10.50***
Household size		4.02	4.74	4.65	5.71	4.71	20.58***
Farm size (acres)		2.71	4.48	4.36	4.26	3.9	7.62***
Education (yrs)		9.39	8.96	9.86	9.6	9.46	1.66
Number of Trees		66	62	52	19	52	1.8
Income (KES)		264899	204061	223830.9	267864.7	240052.1	0.43
Assets (KES)		5520956	554508	4563020	4744044	5103934	0.65
Institutional variables							
Market dist. (minutes)		59.63	96.49	53.05	34.34	60.87	6.88***
		(71.67)	(197.3)	(106.78)	(68.99)	122.68	
Credit dist. (minutes)		101.32	86.83	116.42	90.32	99.81	3.38**
		(77.99)	(85.87)	(107.74)	(67.68)	(87.69)	
Extensiondist (minutes)		90.18	72.29	74.61	84.91	80.65	4.41***
		(56.03)	(61.41)	(58.75)	(48.08)	(56.95)	
Institutional and farm characteristics	**Descriptive**	**Percentage**					**chi2**
Intercropping	Never intercropped	22.75	16.23	17.68	23.53	20	3.93***
	Intercropped	78.25	84.77	84.32	78.47	80	
Group membership	Non-group members	88.36	66.88	80.11	92.65	81.97	39.85***
	group members	11.64	33.12	19.89	7.35	18.03	
Training mango farmers	Never received training	14.81	17.53	30.39	42.65	25.45	39.87***
	received training	85.19	82.47	69.61	57.35	74.55	

Note: **, *** represents (p<0.0 5) and (p<0.01) respectively.
: Figures in brackets represent standard deviations.

Table 2. Multivariate Probit results on the determinants of IPM strategy for suppression of mango fruit fly in Kenya

Variables/ Strategies	Fruit_fly_traps		Food_bait_spray		Biopesticides		Biological control		Orchard sanitation	
	Coef.	Std eror	Coef.	Std error	Coef.	Std error	Coef.	Std error	Coef.	Std error
Socioeconomicfactors										
Gender	0.0307	0.1766	0.1428	0.1898	0.1528	0.2419	0.0092	0.2211	0.0766	0.2086
Age	-0.0074*	0.0043	-0.0027	0.0046	-0.0005	0.0067	-0.0100*	0.0055	-0.0022	0.0054
Education	-0.0096	0.0138	0.0014	0.0143	0.0017	0.0208	0.0176	0.0169	0.0099	0.0167
Hhsize	0.0102	0.0262	0.0089	0.0278	0.0083	0.0405	0.0174	0.0332	0.0266	0.0333
Offincm	0.0370	0.1240	0.0707	0.1305	0.4140*	0.2137	0.2126	0.1595	-0.0685	0.1475
Lasset	-0.0071	0.0477	0.0189	0.0500	0.0281	0.0730	0.0373	0.0593	0.0542	0.0585
No. of mangoTrees	0.0023*	0.0012	0.0016	0.0013	-0.0004	0.0018	-0.0032**	0.0014	-0.0016	0.0014
Intercropp	-0.2554	0.1269	0.0464	0.1308	0.2299	0.1799	0.0733	0.1549	-0.0523	0.1541
Institutional factors										
Mktdist	0.0008	0.0011	0.0018	0.0013	0.0050**	0.0025	0.0003	0.0014	-0.0014	0.0012
Crdtaccess	-0.0599	0.1170	-0.0044	0.1229	0.3459	0.1681	0.2710*	0.1437	0.1731	0.1422
Extndist	0.0001	0.0009	0.0012	0.0010	0.0006	0.0014	0.0025*	0.0012	0.0017	0.0011
Group membership	-0.0009**	0.0005	0.0450**	0.0004	-0.0001	0.0004	-0.0003	0.0004	-0.0017	0.0004
Training	-0.4175***	0.1205	-0.4011***	0.1314	-0.0036	0.1768	-0.1660	0.1536	-0.2370	0.1538
Constant	0.9189	0.8322	0.2509	0.8694	0.2081	1.2420	0.7011	1.0261	0.3375	1.0154

Note: ***, **, * = significant (P<0.01), (P<0.05) and (p<0.1) respectively.

Table 3. Cont.: Multivariate Probit results on the determinants of IPM strategy for suppression of mango fruit fly in Kenya

Rho2	0.2687***			
Rho3	0.1391***	0.2421***		
Rho4	0.1859***	0.2433***	0.3366***	
Rho5	0.1148***	0.3252***	0.2857***	0.3455***
Number of observation	660			
Log likelihood	-1408.1676			
Wald chi^2 (62)	93.77			
Prob > chi^2	0.0113			
Likelihood ratio test of rho2=rh03=rho4=rho5=rho32=rho42=rh052=rho43=rho53 Rho53=rho54=0 chi2 (10)=245.659				
Prob > chi^2 = 0.0000				

Note: ***, **, * = significant (P<0.01), (P<0.05) and (p<0.1), respectively.

Household heads that had access to off-farm income are more likely to adopt the use of biopesticides (p<0.1). Off-farm income such as salaried employments and business that provides the farmer with extra income enables the purchase of farm pest and disease control inputs required on the farm. Contrary to this finding, Raghu *et al.* (2014) reported that the relationship between off-farm income and technology adoption was negative. Since off-farm activities divert time and effort away from agricultural activities, it reduces investment in new technology and availability of labor.

The number of mango trees had a positive relationship with the adoption of fruit fly traps (p<0.1) and a negative relationship on adoption of biological control (p<0.05). Large numbers of mango trees become so costly when using imported wasps for control of fruit flies on the farm, hence resulting in a decline in the adoption of biological control. The use of fruit fly traps on the large number of mango trees helps to cover a wide area of fruit fly control, hence minimizing the cost of pest control. Erbaugh *et al.* (2010) identified the number of trees as an important variable positively influencing the adoption of new technologies in Uganda. Often IPM adopters operated with larger number of mango trees for commercial purposes hence, sought more effective and less costly pest control strategies in order to improve their mango enterprise profitably (Korir *et al.,* 2014).

Distance to the nearest market for mango input positively influenced the adoption of biopesticides (p<0.5). Shorter distances reduce the transport cost incurred by small-scale farmers when purchasing biopesticides to be used on the mango farm for control of fruit flies. The income saved as a result of reduced transport cost may be used in acquisition of more IPM strategies required on the mango farm of small-scale farmer. Findings by Korir *et al.* (2015) in Embu County in Kenya, found out that distance to the nearest input market was positively associated with the probability of IPM adoption. This is also similar to the findings by Zou (2014) who noted that distant farmers have higher transaction cost for acquiring input thereby reducing the relative advantage of adopting new technologies.

Access to credit provided by dealers in agricultural credits had a higher likelihood of inducing use of biological control for suppression of fruit flies in mango orchard ($p<0.1$). Credit increases finances available to the farmers so as to take up new technologies especially those that command substantial investments like biopesticides and the use of augmentoriums in mango orchards. Credit could be sourced from formal credit markets (banks, micro-finances and savings and credit cooperatives) and the informal credit market (merry go round) that improves significantly the intensity of adoption. This result is consistent with the finding by Kinyangi *et al.* (2014) that new technology which requires capital that may be a constraint to farmers, present a shift in farmers' investment options. With more financial and other resources at their disposal, farmers are able to change their management practices in response to technological changes (Nhemachena *et al.,* 2014).

Households with access to extension services positively influenced the adoption of biological control strategy. The results indicate that there is a significant relationship between access to extension and use of biological strategies ($p<0.1$). Mango farmers who received extension services, particularly knowledge on biological control, adopted it. The control of mango fruit flies using biological control means that it does not require more labor and has minimal destruction to the environment. Extension agents act as a link between the innovators (researchers) of the technology and users of the technology. Farmers who have significant extension contacts have better chances of being informed of the updated IPM technologies for their own use on their farms. This result is consistent with the finding of Kinyangi *et al.* (2014), who noted that the acquisition of information about a new technology entices farmers to try and adopt the technology or innovation.

Membership to farmer group is more likely to influence the adoption of food bait spray and less likely to influence the adoption of fruit fly traps ($p<0.5$) each. The group-shared challenges involved in the use of fruit fly trap, such as the stolen traps in the orchard farms is more likely to discourage some of the farmers in using the strategy. Group membership enhances social capital in which security matters surrounding traps are discussed at length by farmers. Farmers within a social group learn from each other the benefits and usage of a new technology (Mignouna *et al.,* 2011). Mwangi and Kariuki (2015) noted that although many researchers have reported a positive influence of social groups on technology adoption, social groups may have a negative effect on technology adoption especially where free riders behavior exists.

Mango farmers who received training on IPM strategies were less likely to adopt fruit fly traps and food bait ($p<0.01$). Training organizations such as IPM clubs or NGOs train farmers on skills and knowledge about new farming techniques. The training on the use of fruit fly traps and foot bait spray requires more field demonstrations for the farmers to understand how best to apply the two strategies on the mango orchard. A farmer participating in training on IPM technology develops a positive impression about the new innovations. Wabbi *et al.* (2012) noted that receiving pest control training in Uganda increased the probability of Celosia adoption for control of striga weeds in sorghum. Through training, farmers perceive that IPM is good for crops due to the manner with which little or no pesticides are used hence, increasing the likelihood of adoption of new technologies (Ahsanuzzaman *et al.,* 2015).

Conclusion and Policy Recommendation

Adoption of IPM strategies was positively influenced by: number of mango trees, off-farm income, distance to the nearest market, distance to the nearest credit sources, distance to the nearest extension services, group membership and training of farmers. These variables contributed to the adoption of IPM strategies by reducing the transaction cost, enhancing information transfer and boosting the financial base of the small scale mango farmer. Farmers who had many mango trees had taken them as priority crops, a case that motivated them to use IPM strategies in order to attract international markets for quality produce.

Government extension officers and other development partners provide services that were found to be important factors in speeding up technology adoption. It is therefore important to strengthen extension services and improves the skill of extension officers. To enhance supply of quality information which then minimizes the risk of adoption of IPM technologies. Increased adoption of IPM strategies is also enhanced by participation in group membership of farmers in the locality. Therefore, farmers should be encouraged to form groups.

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