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Economic Evaluation of Integrated Management of Fruit Fly in Mango Production in Embu County, Kenya

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Abstract

This paper evaluated economic benefits of managing mango infesting fruit flies in Embu County, Kenya using Integrated Pest Management (IPM) strategy that composed of Male Annihilation Technique (MAT), protein bait spray, releases of exotic parasitoid Fopius arisanus and the use of augmentorium. The Difference-in-difference (DD) method was used to assess the impact of the mango IPM on magnitude of mango rejection and insecticide expenditure and net income. The study revealed that on average, mango IPM participants had approximately 54.5 percent reduction in magnitude of mango rejection; spent 46.3 percent less on insecticide per acre and received approximately 22.4 percent more net income than the non participants. These imply a high economic benefit from the application of the fruit flies IPM technology and mango farmers would profit significantly if the intervention is expanded to widely cover other mango growing areas in Kenya.

1. Introduction

1.1. Background

Mango (*Mangifera indica* L.) is the third most important fruit in Kenya in terms of area and total production (FAO, 2009). In the country, the crop is mainly grown by smallholder farmers as a source of food to meet their dietary (vitamins and mineral) needs and as a major source of household income. In 2010, the cummulative area under mango production was 34,371 hectares with total production of 537,315 metric tonnes worth US$ 97.6 million (HCDA, 2010). The fruit crop also accounted for 26 percent of the major fresh fruit trading at the export market. The main mango producing areas in Kenya are Coast, Eastern, Nyanza, Rift Valley and Central regions. In 2010, about 10,035 hectares were under mango production in the Eastern region, with a total production of 93,958 metric tonnes (HCDA, 2010). A recent study commisioned by the Agricultural Business Development (ABD) showed that mango farming in this region generates over US$30 million at farm level annually, and constitute 22% of farm household income in this region (Institution Development Management, IDM, 2010). In the Eastern region, Embu County ranks third in mango production. The area under mango production and total production in Embu County has risen from 3,553 hectares and 23,488 metric tonnes respectively in 2010 to 3,744 hectares and 42,995 metric tonnes in 2012 (HCDA, 2012). As an export crop, mango earns the country foreign exchange, acts as a source of food and household income for resource poor farmers. In 2010, mangoes earned Kenya US$70 millions in the domestic market and $10.1 millions in export earnings (Government of Kenya, 2012).

1.2. Economic importance of fruit fly in mango production and marketing

The production and marketing of mango are affected by a variety of factors of which pests and diseases are regarded to be one of the major constraints. Among the insect pests, fruit flies are known to be the most notorious (Ekesi et al., 2009; Ekesi and Billah, 2007; OleMoiYoi and Lux, 2004; Lux et al., 2003). In Africa, the economically important species belong to the genera; *Bactrocera*, *Ceratitis*, *Dacus*, and *Trirhithrum* (De Meyer *et al.,* 2014). The genera *Ceratitis*, *Dacus* and *Trirhithrum* are known to be indigenous to Africa and the *Bactrocera* are native to Asia. Female fruit flies that lay eggs under the skin of the fruits cause direct losses. The eggs hatch into larvae that feed in the decaying flesh of the crop. Infested fruits quickly rot and become inedible or drop to the ground. Beside the direct damage to fruits, indirect losses are associated with quarantine restrictions because infestation and sometimes the mere presence of the flies in a particular country could also restrict the trade and export of fruits to markets abroad (Bissdorf and Weber, 2005). Globally, an average of 20 to 30 percent of mango crop losses is attributed to fruit flies alone (Nboyine *et al.*, 2013). In Eastern and Southern Africa five indigenous fruit fly species (*Ceratitis cosyra, C. fasciventris, C. rosa, C. anonae,* and *C. capitata*) attack mango (Ekesi and Billah, 2007). Several surveys across the region showed 30 to 70 percent yield loss on mango due to these native fruit flies depending on the locality, variety and season (Ekesi *et al.,* 2009; Mwatawala *et al.,* 2006; Lux *et al.*, 2003). However, since the invasion of *Bactrocera invadens* in 2003 in East Africa, damage to mango has increased to over 80 percent (Georgen et al., 2011; Ekesi *et al.*, 2010; Ekesi *et al.*, 2009). The rapid spread and devastating impact of *B. invadens* is a serious concern to the mango industry in Kenya and Africa at large. Export of host fruit species of *B. invadens* such as mangos from Uganda, Tanzania and Kenya are already banned in Seychelles, Mauritius and South Africa. Trade of several horticultural produce between Africa and the US has been severely hampered by a US Federal Order banning importation of several cultivated fruits and vegetables from African countries where *B. invadens* has been reported (USDA-APHIS, 2008).

1.3. Integrated Management of Mango Fruit Flies

In Kenya, the commonly used method of controlling fruit flies by many farmers is intensive insecticide cover sprays. This is not only highly costly to the growers but damaging to the health of the farmer workers, the environment and non-target beneficial organisms. Early mango harvesting is also practised to evade fruit fly attack but this is not effective for certain fruit fly species such as *B. invadens and C. cosyra* that can infest both the immature and mature green mangoes (Ekesi & Billah, 2007). Due to economic importance of mango fruit fly, efforts have been made by the International Centre of Insect Physiology and Ecology (*icipe)* in collaboration with national (Kenya Plant Health Inspectorate Service (KEPHIS), Kenya Agricultural Research Institute (KARI) and Ministry of Agriculture) and international partners (University of Bremen, Max Planck Institute of Chemical Ecology, USDA), to develop

Integrated Pest Managemet (IPM) package to address the fruit fly problem in Africa. The fruit fly IPM package is aimed at enhancing sustainable mango production and marketing by reducing economic losses at the farm level, insecticide usage and increasing supply of quality mangoes to meet the requirements of domestic and export markets and in an effort to raise the profit margins of the producers thus improving their livelihood. By definition IPM is a systematic and repeated application of pest-surveillance and control measures to reduce economic impact of diverse insects, pathogens, nematodes, weeds and animals that damage agriculture (Sterner, 2008). The *icipe* developed fruit fly IPM package is a combination of various fruit fly management techniques; these include the use of male annihilation technique (MAT), application of protein bait spray, use of fungus-based biopesticide (although not included in this particular trials), releases of exotic parasitoids, and orchard sanitation that encompass the use of Augmentorium (Mohamed et al., 2008, 2010; Ekesi et al., 2010, 2014). The MAT involves use of carriers (fruit fly traps) containing male lure (methyl eugenol) combined with an insecticide which are distributed at regular intervals over a wide area in the mango orchard to reduce the male population of fruit flies to a low level that mating does not occur or is extremely reduced (Ekesi *et al.*, 2010; Ekesi & Billah, 2007; Allwoods *et al*., 2002). Protein baiting technique is based on the use of proteinous food baits combined with an insecticide, applied to localized spots, one square metre spot in the canopy of each tree in the orchard when fruits are 1.3cm in size. Spraying is done weekly until the very end of harvest (Ekesi & Billah, 2007). The proteinous substance attracts the adult fruit flies, mainly females, from a distance to bait spray droplets. The fruit flies ingest the bait along with a toxic dose of insecticide, killing them before they infest the fruits (Ekesi *et al.*, 2010; Prokopy *et al*., 2003). Biopesticides are applied to the soil within the dripline of the canopy to kill the soil dwelling pupariating larvae and puparia. The egg parastoid *Fopius arisanus,* was released in Nthagaiya and Karurumo sub-locations in Embu County during the implementation of the IPM trials. *Fopius arisanus'* females destroy fruit flies by laying eggs on fruit flies' eggs in previously damaged mango fruits. The parasitoid eggs hatch to produce larva that grow by feeding on the internal tissue of the flies' larva ultimately killing the fruit flies (Ekesi *et al.*, 2010; Hanna *et al.*, 2008). Orchard sanitation is the cultural method used to prevent fruit flies build up. The method involves collection of infested fruits found on the trees or fallen on the ground and depositing them in an augmentorium (Ekesi *et al.*, 2010). An augmentorium is a tent like screen structure designed to sequester fruit flies emerging from infested fruits but at the same time allows the escape of the parastoid wasps via a screen on the top to re-enter the field thus conserving the natural enemies of fruit flies (Ekesi & Billah, 2007).

The purpose of this study was to assess the economic effect of the fruit fly IPM application under smallholder setting to determine the impact of the intervention on marketable mango produce loss, insecticide expenditure and net income accrued from mango farming.

2. Materials and Method

2.1. Study Area

This study was conducted in Embu East District (presently Runyenjes sub-county) in Embu County. The sub-county lies between 1,000 – 2,070 meters above sea level and has a total area of 253.4 square kilometres, of which 177.3 square kilometres is arable land. According to the 2009 population and housing census, the study area has a total population of 115,128 persons and average family size of six. The average farm size in the sub-county is 1.2 hectares and farm families are estimated at 30,000, out of which 3030 are mango growers (MoA, 2010; IDM, 2010). The area is characterized by three main agro-ecological zones namely: Lower Highlands, Upper Midland and Lower Midland. Rainfall is bimodal with the long rainy season occurring in March/June and short rainy season in October/December, with an annual rainfall of 800 mm – 1500 mm. The soils are generally fertile, well drained, extremely deep, dark reddish brown to dark brown and friable clay with humic top soils; mainly humic nitisols and andosols (Jaetzold *et al.*, 2006). Agricultural production in this sub-county is mainly subsistence and rain fed. Mango is considered one of the most important cash crops in this area.

2.2. Data Collection and Sampling

Data were collected from two purposively selected sites: (1) Intervention area (Sub-locations where farmers participated in fruit fly IPM) and (2) Control area (non participating fruit fly IPM farmers). The fruit fly IPM intervention participants and non participants were drawn at random from lists obtained from Runyenjes Sub-county agricultural office. A total of 276 mango farmers (138 farmers for each group) were sampled and a structured questionnaire administered to each in their farms by trained enumerators. Data were collected in two scenarios; 'before' and 'after' the fruit fly IPM package intervention. A baseline study was conducted in 2011 before the intervention to establish the existing situation in function of variables defined for the IPM package. A follow up survey was then conducted after the intervention in 2012 and a total of 257 mango farmers were re-interviewed; 121 participants and 136 non participants. The number of mango farmers interviewed during follow up survey was lower than baseline due to unavailability of household members even after repeated attempts, exclusion of those with obvious data errors and refusal by some respondents. The baseline and the follow up surveys measured the same variables, only at different times.

2.3. Data Analysis

This study employed Difference-in-difference (DD) estimation model to evaluate the economic impact of fruit fly IPM package on magnitude of mango produce rejection due to fruit fly infestation, insecticide expenditure and net income. Two years panel data (2011 and 2012) were used for this purpose. The DD model is an appropriate tool in solving the problems arising from non-random selection of program participants and non-random placement of the program; achieved by having two comparable groups, participants and non participants (Simwaka *et al*., 2011; Yamano & Jayne, 2004). The model can be used with repeated cross- section or panel data. DD essentially compares the participants (with) and non participants (without), before and after intervention by using pre intervention baseline survey and post intervention data (Khandker *et al*., 2010). To estimate the DD in determining the impact of the mango IPM intervention, regression analysis was used. The analysis was done at two levels: (1) with the basic assumption that other socio-economic variables do not change with time (unconditional) and, (2) these variables vary across the years and may affect the outcome of interest (conditional). The model to estimate the effect of fruit fly IPM is expressed as (Khandker *et al*., 2010);

$$Y_i = \alpha + \beta T_i + \gamma t_i + \delta T_i * t_i + \varepsilon_i \quad (1)$$

$$Y_i = \alpha + \beta T_i + \gamma t_i + \delta T_i * t_i + \lambda_i X_i + \varepsilon_i \quad (2)$$

Where: Y_i is outcome of interest, in our case magnitude of mango rejection, insecticide expenditure and net income from mango production, T_i is the treatment dummy variable, t_i is the time dummy, X_i is set of socio-economic variables that may affect Y, the coefficient of interaction of $T_i * t_i$ (δ) gives the estimate of the impact of mango IPM on outcome Y, β accounts for average permanent differences between the treatment and control groups, γ is the time trend common to both treatment and control groups, λ is the coefficient of X_i and ε is the error term. The magnitude of mango rejection was determined as a percentage of quantity of mango not sold or consumed by participants and non participants of fruit fly IPM due to damage by the mango fruit fly. This was considered a more appropriate variable than the mango yield because mango tree exhibits biennial production nature that may require more than two year's data. The insecticide expenditure considered is the pesticide cost incurred per acre by the mango farmers in controlling mango fruit flies. Net income in this study refers to total revenue received from mango less variable production costs incurred per acre by mango farmers before and after the intervention. Among the independent variables, the socio-economic variables were: age, land under mango, mature mango trees, years in school, experience in mango growing, agricultural extension contact, distance to market, total livestock units, intercrops in mango plot, credit acquisition for mango production, dependency ratio and price of mango. Socio-economic data was analysed using descriptive statistics. Data thus collected were analyzed using STATA software. Before regression analysis, preliminary tests were done on the data and appropriate corrections employed to control for estimation bias. These tests were: normality, linearity, multicolinearity, heteroscedasticity and autocorrelation. For dependent variables; magnitude of mango rejection and insecticide expenditure, natural log transformation was used to correct deviation from normality. To correct for endogeneity in estimating the effect of the intervention on net income, the Two Stage Least Square (2SLS) method was used. Iterative Prais-winsten method was used to adjust for autocorrelation.

Using the DD, the impact of the fruit fly IPM intervention was also estimated by calculating the mean difference in magnitude of mango rejection, insecticide expenditure and net income between IPM participants and IPM non-participants after the intervention minus the mean difference in outcomes between the two groups before intervention. Table 1 displays the format, showing the groups being compared on the columns and the time periods on the rows. The DD in the table is the Diffrence-in-difference estimate (Ahmed *et al*., 2009).

[Table 1 here]

3. Results and Discussion

In estimating the impact of fruit fly IPM on magnitude of mango rejection, the findings in Table 2 showed negative and statistically significant ($p<0.01$) coefficient of both unconditional and conditional treatment effect of the intervention (interaction $T_i x t_i$), implying reduction in magnitude of mango rejection even in presence of other factors that may affect mango rejection. This indicates that farmers who participated in fruit fly IPM intervention had higher reduction in magnitude of mango rejection than the non participants. The result also showed significant ($p<0.1$) negative correlation between agricultural extension services and magnitude of mango rejection. A one unit increase in the number of times household sought agricultural extension services would likely result in approximately 9.4 percent reduction in magnitude of mango rejection. This seems to suggest that efforts by mango farmers in seeking agricultural extension services equiped them with knowledge on fruit fly control and were well updated on new pest management techniques. The other factors were not significantly correlated with magnitude of mango rejection.

[Table 2 here]

The mean mango rejection differences between mango IPM participants and non participants across the two time periods, DD estimate, in Table 3 was negative (-12). The DD estimate indicates that on average mango IPM participants had approximately 54.5 percent reduction in magnitude of mango rejection than the non participants (Table 3). The high reduction in magnitude of mango rejection for participants could be attributed to reduced fruit fly infestation. According to Ravikumar and Viraktamath (2007), the installed methyl eugenol baited traps were capable of attracting male fruit flies from a distance of 800 meters. Interview with farmers in the study area revealed that one trap could capture more than 2,000 fruit flies per week. Traps in conjuntion with bait sprays, that mainly reduces female fruit fly population, the parasitoid and use of augmentorium led to reduced infestation and consequently more reduction in magnitude of mango rejection for the participants than for the non participants. This may lead to an increase in quantity available for consumption and marketing. The results agree with Ndiaye *et al*. (2008) who observed that combination of home made bait, MAT used cooperatively at village level, particularly when combined with cultural methods reduce fruit fly losses by 90 percent under most conditions. The results are also consistent with Preciados *et al.* (2007) who postulated that IPM in mango reduces crop damage or rejects by 20 percent.

[Table 3 here]

Table 4 summarizes the impact of mango IPM on insecticide expenditure. As indicated by the negative and statistically significant coefficient in both instances, the fruit fly IPM intervention reduced insecticide expenditure for the participants. Application of mango IPM techniques reduced insecticide expenditure by 46.3 percent (Table 3). This is attributed to bait sprays applied on localized spot in the canopy of each mango tree targeting the lower surface of the leaves to enhance persistence of bait activity. This weekly insecticide spot (one meter square) spraying that commences at the onset of fruit maturity to mango harvest, as explained by Prokopy *et al*., (2003) and Ekesi *et al.*, (2010), could have led to reduced spraying for fruit fly IPM participants and thus reduced insecticide expenditure. This contrasts with the blanket conventional insecticide spraying employed by non participants. The results are consistent with findings by Huelgas *et al*. (2008), who found that adopters of Three Reductions Three Gains (3R3G) initiative spent US dollar 8-12/ha/season less on insecticides than the non adopters. The results are in accordance to different studies by Baral *et al.*, (2006), Kumar *et al*. (2008) and Preciados *et al.* (2007) who observed, though using different analytical methods, that IPM reduced insecticide expenditure by 52.6 percent, 12.8 percent and 75 percent respectively.

[Table 4 here]

The results of effects of fruit fly IPM on net income are summarized and presented in Table 5. The positive and statistically significant coefficient clearly implies that even in presence of the other factors that may affect net income, farmers participating in mango IPM intervention received more net income than the non participants. On average participants received approximately 22.4 percent more net income than the non participants (Table 3). The increase in net income could be explained by the fact that reduced fruit fly infestation led to increased marketable volume due to improved quality of mango that fetch higher price. At the same time, reduced insecticide expenditure lowers total production costs thus most likely increasing the net income. These results are in agreement with Singh and Singh (2007), Singh (2011) and Gajanana *et al*. (2006) who, having used different analytical methods, found that IPM increased the net income from crop production by Rs 6848/ha, Rs 4038/acre and Rs 125,476/ha respectively.

[Table 5 here]

4. Conclusion

This paper reveals that there was significant difference in the levels of magnitude of mango rejection, insecticide expenditure for control of fruit fly and net income from mango production between participants of fruit fly IPM intervention and non participants. It is evident from our analysis that IPM for fruit fly management on mango generates substantial economic benefits to mango farmers in Embu County. The mango IPM intervention reduces mango rejections by 54.5 percent, insecticide expenditure by 46.3 percent and increases the net income by 22.4 percent. The policy implication is that this technology is an authentic tool in poverty alleviation considering the vital role mango plays in the County. On the basis of this study, such IPM technology for fruit fly control should be encouraged to cover the entire mango growing area in Embu and other counties. It is also vital that more funds be allocated to mango pest management research.

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References

Ahmed, A., Rabbani, M., Sulaiman, M., Das, N.C., 2009. *The impact of asset transfer on livelihoods of the Ultra poor in Bangladesh.* Dhaka, Washington DC: BRAC, IFPRI.

Allwoods, A.J., Vuet, E.T., Lebranc, L., Bull, R., 2002. Eradication of introduced Bactrocera species (Diptera: Tephritid) using male annihilation and protein bait application techniques. *Turning the tide: Eradication of invasive species* , pp. 19-25.

Baral, K., Roy, B., Rahim, K., Chartterjee, H., Mondal, P., Mondal, D., 2006. *Socio-economic parameters of pesticide use and assessment of impact of an IPM strategy for the control of eggplant fruit and shoot borer in West Bengal,India.* Tainan: AVRDC-World vegetable center.

Bissdorf, J., Weber, C., 2005. *Guide to non-chemical pest management in mango production.* Hamburg: Pesticide Action Network (PAN) Germany.

De Meyer, M., Mohamed, S., White, I.M., 2014. *Invasive fruit fly pests in Africa*. Retrieved September 16, 2014, from http://www.africamuseum.be/fruitfly/AfroAsia.htm

Ekesi, S., Mohamed, S., Hanna, R., 2010. Rid fruits and vegetables in Africa of notorious Fruit Flies. CGIAR SP-IPM Technical Innovation Brief No. 4: 1-2

Ekesi, S., 2010. *Combating Fruit Flies in Eastern and Southern Africa (COFESA): Elements of a Strategy and Action Plan for a Regional Cooperation Programme.* World bank.

Ekesi, S., Billah, M.K., Nderitu, P.W., Lux, S.A., Rwomushana, I., 2009. Evidence for Competitive Displacement of *Ceratitis cosyra* by the invasive Fruit Fly *Bactrocera invadens* (Diptera:Tephritidae) on Mango and mechanisms contributing to the Displacements. *Journal of Economic Entomology Vol 102(3)* , 981-991.

Ekesi, S., Billah, M., 2007. *A Field Guide to the Management of Economically Important Tephritid Fruit Flies in Africa.* Nairobi: Icipe Science Press.

Food and Agriculture Organization, 2009. *Value chain analysis of the tropical fruit subsector:The case of mango production,processing and trade in Kenya.* Rome: FAO.

Gajanana, T. M., Krishna Moorthy, P.N., Anupama, H., Raghunatha, R., Kumar, G.T., 2006. Integrated Pest and Disease Management in tomato: An economic Analysis. *Agricultural Economic Research Review* , 269 – 280.

Goergen, G., Vayssières, J.-F., Gnanvossou, D., Tindo, M., 2011. *Bactrocera invadens* (Diptera: Tephritidae), a new invasive Fruit fly pest for the afrotropical region: host plant range and distribution in West and Central Africa. Environmental Entomology 40: 844-854.

Government of Kenya, 2012. *Kenya's LAPSSET Corridor Mango Production Investment Opportunity*. Nairobi: Government Printers.

Griesbach, J., 2003. *Mango growing in Kenya.* Nairobi: World Agroforestry Centre.

Hanna, R., Bokonon-Ganta, A., Gnanvossou, D., Saizonou, S., 2008. Releases of Fopius Arisanus for effective & sustainable Fruit Fly Control in Africa. *Fighting Fruit and Vegetable Flies Regionally in Western Africa No. 6* , p. 3.

Huelgas, Z.M., Tempton, D., Castanar, P., 2008. *Three Reductions, Three Gains (3R3G) Technology in South Vietnam: Searching for evidence of Economic Impact.* Metro Manilla.

Horticultural Crops Development Authority (HCDA)., 2010. *2010 Horticultural Crops Production Report.* Nairobi: Government Printers.

Horticultural Crops Development Authority (HCDA)., 2012. *2012 Horticulture Validated Report.* Nairobi: Government Printers.

Institution Development Management (IDM)., 2010. *The Mango Sub-sector in Eastern Region: Results of Mango trees Census & Baseline Survey for Eastern Region.* Nairobi: Agricultural Business Development (ABD).

Jaetzold, R., Schmidt, H., Hornetz, B., Shisanya, C., 2006. *Farm management handbook of Kenya Vol.II: Natural conditions and farm management information Part C East Kenya Subpart C1 Eastern Province.* Nairobi: Ministry of Agriculture Kenya in cooperation with Germany Agency for Technical Cooperation (GTZ).

Khandker, S.R., Koolwal, G.B., Samad, H.A., 2010. *Handbook on impact evaluation: quantitative methods and practices*. World Bank Publications

Kumar, K., Sukanya, C., Nagaraja, G.N., 2008. Comparative analysis of IPM and non IPM technology in Redgram cultivation in North Eastern dry zone of Karnataka. *SAARC journal of agriculture Vol 6,* pp 1-12.

Lux, S.A., Ekesi, S., Dimbi, S., Mohamed, S., Billah, M., 2003. Mango infesting fruit flies in Africa: Perspectives and limitations of Biological Approaches to their management, in P. Neuenschwande, C.Burgemeister, J. Langewald, eds., *Biological Control in IPM Systems in Africa* (pp. 277-293). Wallingford, UK: CAB International.

Ministry of Agriculture., 2010. *Embu East District Annual Report.* Unpublished.

Mohamed, S.A., Ekesi, S., Hanna, R., 2010. Old and new host-parasitoid associations: parasitization of the invasive fruit fly *Bactrocera invadens* (Diptera: Tephritidae) and five other African fruit fly species by *Fopius arisanus*, an Asian opine parasitoid. *Biocontrol Science and Technology* 10: 183-196.

Mohamed, S.A., Ekesi, S., Hanna, R., 2008. Evaluation of the impact of *Diachasmimorpha longicaudata* on Bactrocera invadens and five African fruit fly species. Journal of Applied Entomology 132: 789-797.

Mwatawala, M.W., De Meyer, M., Makundi, R.H., Maerere, A.P., 2006. Seasonality and Host utilization of the invasive fruit fly, Bactrocera Invadens (Dip. Tephritidae) in Central Tanzania. *Journal of Applied Entomology 130(9-10)* , 530-537.

Nboyine, J.A, Abudulai, M., Nutsugah, S.K., Badii, B., Acheampong, A., 2013. Population dynamics of fruit fly (Diptera: Tephritidae) species associated with mango in the Guinea Savanna Agro-ecological Zone of Ghana. *International Journal of Agricultural Sciences*, 450-454.

Ndiaye, M., Dieng, E., Delhove, G., 2008. Population dynamics and on- farm fruit fly Integrated Pest Management in mango orchards in the natural area of Niayes in Senegal. *Pest management in Horticultural Ecosystems Vol 14* , pp 1-8.

Ole-MoiYoi, O.K., Lix, S.A., 2004. Fruit flies in sub-Saharan Africa: a long-neglected problem devastating tropical fruit production and a threat to horticulture beyond Africa. In: Proceedings of the 6th International Symposium on Fruit Flies of Economic Importance, pp. 5-10. Isteg Scientific Publications, Irene South Africa

Preciados, L., Bulayog, M.B., Nortarte, A., 2007. *Ex- Ante Impact Assessment on adoption of IPM strategies for mango in Region XI, Southern Phillipines.* ACIAR HORT.

Prokopy, R. J., Miller, N.W., Pinero, J.C., Barry J.D., Tran L.C., Oride L., 2003. Effectiveness of GF-120 fruit fly bait spray applied to border area plants for control of melon flies (Diptera:Tephritidae). *Journal of economic Entomology* , 1485-1493.

Ravikumar, P., Viraktamath, S., 2007. Attraction of Fruit flies to different colours of Methyl Eugenol traps in Guava and mango orchards . *Karnata Journal of Agricultural Sciences vol 20(4)*, pp 749-751.

Simwaka, K., Ferrer, S., Harris, G., (2011). Maize production differentials among Malawi rural households: A difference in difference estimate approach. *Journal of development and agricultural economics Vol 3(6)*, 222-229.

Singh, S., Singh. S., 2007. Economic evaluation of pest management technologies for sustainable cotton production in Punjab. *Agricultural Economic Research Review Vo.l20* , 77-86.

Singh, J., 2011. *Impact Assessment study of IPM Basmati Project for boosting diversification process in Punjab.* Mumbai: Navajbai Rata Tata Trust.

Sterner, R., 2008. Reducing the Uncertainity of Integrated Pest Management (IPM) economics. *Crop Protection Research Advances* , 163-181.

USDA-APHIS [The United States Department of Agriculture, Animal and Plant Health Inspection Service], 2008. Federal import quarantine order for host materials of *Bactrocera invadens* (Diptera: Tephritidae), invasive fruit fly species. USDA-APHIS 3pp.

Yamano, T., Jayne, T. S., (2004). Measuring the impact of working age adult mortality on small scale farm households in Kenya. *World Development*, 91-119.

Tables

Table 1: DD estimate of average Mango IPM effect

Survey	**Mango IPM participants (I)**	**Mango IPM non participants (C)**	**Difference across groups**
Follow up	I_1	C_1	$I_1 - C_1$
Baseline	I_0	C_0	$I_0 - C_0$
Difference across time	$I_1 - I_0$	$C_1 - C_0$	$\boldsymbol{DD = [I_1 - C_1] - [I_0 - C_0]}$

Table 2: Impact of Mango IPM on magnitude of mango rejection

Model	**Unconditional**		**Conditional**	
	Coefficient	**t-ratio**	**Coefficient**	**t-ratio**
HHTYPE T_i	-0.248	-2.70***	-0.186	-1.80*
Befor_After t_i	-0.330	-4.90***	-0.331	-4.90***
InteractionT_i xt_i	-1.152	-10.95***	-1.146	-10.83***
Distance to market			0.006	0.26
Agriculture extension			-0.094	-1.91*
Years in school			-0.002	-0.21
Experience in mango growing			-0.005	-0.60
Mature mango trees			-0.0003	-1.27
Constant Term	3.093	56.21	3.144	23.90
R^2	0.7257		0.7315	
F	1237.6***		572.43***	

Dependent variable: *ln*(magnitude of mango rejection), *** Significant at p<0.01; * Significant at p<0.1

Table 3: DD estimate of average mango fruit fly IPM effect on the outcomes

Outcome	DD estimate	Percentage Change (%)
Magnitude of mango rejection	-12	54.5
Insecticide expenditure	-377	46.3
Net income (Kshs) from mango farming	2,051	22.4

Table 4: Impact of Mango IPM on insecticide expenditure

Model	Unconditional		Conditional	
	Coefficient	**t-ratio**	**Coefficient**	**t-ratio**
HHTYPE T_i	1.635	5.68***	1.599	5.44***
Befor_After t_i	-0.063	-0.25	-0.074	-0.29
InteractionT_i xt_i	-1.190	-3.97***	-1.223	-4.15***
Years in school			0.018	0.57
Age of household head			0.010	0.95
Agriculture extension			-0.114	-1.23
Credit			0.061	0.11
Total Livestock units			0.034	0.79
Experience in mango growing			0.002	0.13
Dependency ratio			-0.246	-1.24
Constant Term	4.751	17.81	4.118	5.05
R^2	0.3386		0.3469	
F	1017.04***		420.17***	

Dependent variable: *ln*(insecticide expenditure), *** Significant at $p<0.01$

Table 5: Impact of Mango IPM on net income from mango production

Model	Unconditional		Conditional	
	Coefficient	**t-ratio**	**Coefficient**	**t-ratio**
HHTYPE T_i	7773.17	6.32***	-10525.525	-1.40
Befor_After t_i	3245.765	4.86***	697.081	0.31
InteractionT_i xt_i	2864.225	2.15**	5928.902	1.80*
Price of mango			3389.024	2.24**
Years in school			195.695	0.96
Agriculture extension			-1811.070	-1.31
ln land under mango			-2089.812	-0.71
Intercrop count			13.803	0.02
Credit			-1050.390	-0.26
Distance to market			-152.019	-0.69
Experience in mango growing			-128.620	-0.65
Constant Term	-34.128	-0.05	-15557.630	-2.33
R^2	0.1786		-	
F	44.14***			
Wald chi2(10)	-		59.67***	

Dependent variable: Net income per acre, *** Significant at $p<0.01$; ** Significant at $p<0.05$; * Significant at $p<0.1$