

FRUIT FLY INFESTATION AND ITS IMPACT ON MANGO (*Mangifera indica*
L.) PRODUCTION IN OYAM DISTRICT, UGANDA

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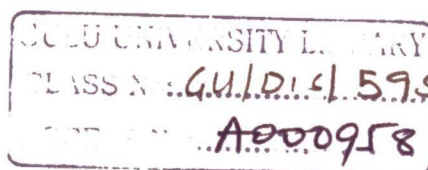
ODYOMO PATRICK, BSc. (Agric) (Mak)

(U 09/2235/MEP)

A Dissertation submitted in partial fulfillment of the requirements for the award of the Degree of
Master of Science in Applied Tropical Entomology and Parasitology of Gulu University.

November 2016

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DECLARATION

I Odyomo Patrick do declare that this dissertation is my original work and that it has never been presented for any academic award in any University or Institution of higher learning.

Signature 

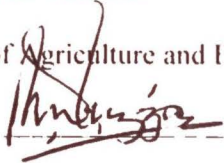
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DEDICATION

This work is dedicated to my late father Nafutal Opyene Ayo whose encouragement made me to enroll for the course. His burial was on the same day I sat the first-course unit test for this course.

ACKNOWLEDGEMENTS

- I would like to sincerely thank my supervisors, Dr Bill William Khizzah of the Department of Agriculture and Environment, Gulu University, Dr Richard Echodu and Dr Geoffrey Maxwell Malinga of the Department of Biology, Gulu University for their invaluable advice and guidance throughout the process of developing this dissertation.
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ACRONYMS AND ABBREVIATIONS

Anon.	Anonymous
BAT	Bait Application Technique
EPPO	European and Mediterranean Plant Protection Organization
ILO	International Labour Organisation
IPM	Integrated Pest Management
kg	Kilogram
KPP	Knowledge, Perceptions and Practice
masl	metres above sea level
MAT	Male annihilation technique
NAADS	National Agricultural Advisory Services
NARL	National Agricultural Research Laboratories - Kawanda
NARO	National Agricultural Research Organisation
SIT	Sterile Insect Technique
SPSS	Statistical Package for Social Sciences
USDA APHIS	United States Department of Agriculture - Animal and Plant Health Inspection Service
US\$	United States dollars

ABSTRACT

Worldwide, fruit fly infestation is a major constraint to mango production. In Oyam district northern Uganda, mango fruits drop on the ground due to fruit fly attack. This is disheartening and frustrates efforts to diversify agriculture. Despite the overwhelming economic importance of mangoes, efforts to assess the impact of fruit flies (Diptera: Tephritidae) have been minimal. In this study, the fruit fly species causing damage and their damage level on mango fruits and local perspectives on the pest were assessed. Matured mango fruits were collected from purposively selected 30 trees belonging to 10 mango varieties between May and July 2011, assessed for fruit fly damage and incubated individually. Knowledge and perceptions of smallholder's growers and fruit vendors on the fruit fly pest and their management practices were sought by use of semi-structured questionnaires and focus group discussions respectively. *Bactrocera invadens* and *Ceratitis rosa* were identified as the fruit fly species causing damage on mango fruits. *Bactrocera invadens* was the most abundant (99.4%). The percentage median levels of damage varied from 7.56 to 84.34 among the mango varieties. The most damaged mango varieties were Ddodo'Atik', Gleen and Alphonso, whereas the least damaged were Ddodo'India' and Ddodo'Total'. The infestation index for *B. invadens* was 53.42 adults/kg infested fruit and for *C. rosa* was 0.3 adults/kg infested fruit. The general knowledge about the fruit fly pest and the damage its cause was limited among the mango growers and fruit vendors. The results of this study indicate that *B. invadens* is the main species causing high damage and economic loss on mango fruits in Oyam district. The results further suggest that there is no proper management of fruit flies by mango stakeholders. This highlights the need to make the management of mango fruit fly pest a high priority in all the agricultural, marketing and developmental plans.

CHAPTER ONE

INTRODUCTION

1.1 Background

Fruit and vegetable production is a fast growing sub-sector in Africa, providing livelihood and employment opportunities to growers and exporters (Lux *et al.*, 2003a). Over the last two decades, diversification into high-value horticultural crops has become one of the major economic development strategies for poverty eradication in the sub-Saharan Africa (Weinberger and Lumpkin, 2007; Ekesi, 2010a). In East Africa, production of fruits and vegetables is recognized as a major source of income and has been accorded high priority in the national development plans of most of the countries in the region (Ekesi, 2010a).

Mango (*Mangifera indica*, Anacardiaceae) is one of the most consumed fresh fruits in the world. Global demand and market attractiveness for mangoes are increasing and this presents a window of market opportunity for producers of mango. In 2010, world import of mangoes was 1.2 million tonnes, valued at US\$ 1.4 billion (Nanakaan *et al.*, 2011). In Africa, mango constitutes about 50% of fruit production (Stefan *et al.*, 2003). Out of the 28.5 million tonnes produced in 2005 (Evans, 2008), Africa produced only 2.5 million tonnes, accounting for 8.7% of fresh fruits (Quartey, 2008).

In Uganda, agricultural diversification strategy has been central to the Government plan of the revitalization of horticulture for growth and economic development (Ekesi *et al.*, 2010). Hundreds of mango varieties of commercial values have been promoted countrywide by National Agricultural Research Organization, NARO (Sengooba *et al.*, 2005) and under National Agricultural Advisory Services (NAADS) programme (Anon., 2007a). Since then there has been a steady increase in mango production as a result of the improvement in the

export market, the growth of the food-processing sub-sector and increasing demand on the local, regional and export markets (Anon, 2009a). In Oyam district, as in Department of Agriculture Annual report of 2009, the strategy led to the increase in area planted with improved mango varieties from less than two hectares in 2006 to over 20 hectares by the end of the year 2009. This is in addition to growers having the local varieties in the backyard gardens. However, production and marketing of fresh fruits in Uganda are seriously affected by many insect pests (Sengooba *et al.*, 2005) and one of the major insect pests are the tephritid fruit flies (Anon, 2001). Thus the most challenging task in mango enterprise is to have pest free fruits for the market and export.

Tephritid fruit flies are recognized worldwide as the most important threat to horticulture (Ekesi and Billah, 2006). In many Africa countries, fruit fly infestation cause mango production losses that can exceed 80% (Ekesi *et al.*, 2006). In addition, fruit flies are quarantine pests. This makes the potential income from the production, processing and export of mango fruit not to be realized. This constrains the contribution of the mango subsector to regional and international trade volumes (Ekesi *et al.*, 2006).

1.2 Statement of the Problem

In Oyam district, tephritid fruit fly damage on mango fruits has widespread concern among farmers, government officials, fruit traders and distributors about the damage these insects inflict in mango production and marketing. The feeding of the flies larvae causes damage which renders mango fruits unmarketable and unfit for consumption. The fruits drop on the ground like stones (Figure 1.1) and mango producers and traders are reaping less profit due to low marketable supply attributed to fruit fly damage. This is very disheartening and is frustrating effort by smallholder farmers and government to diversify agriculture. It is also

hampering the commercial success of the improved mango varieties being promoted; the contribution of mango sub-sector to the rural economy and achievement of the national plan.



Figure 1.1: Fruit fly damaged mango fruits fallen on the ground

It is, therefore, important that effective fruit fly management strategies are implemented to realize the potential of incomes from trade in mango production. Unfortunately, this cannot be carried out because of lack of knowledge on the fruit fly species causing damage on mango fruits. In addition, information remains fragmentary on the magnitude of fruit fly problem and losses associated with the pest. There is also limited information on the local knowledge and perceptions on fruit fly incidence on mangoes and management practices.

Establishing the tephritid fruit fly status in Oyam district, located in the northern moist farmlands agro-ecological zone, will complement efforts in other parts of Uganda and support the development of a robust fruit fly management programme. Key components of any sustainable pest management strategy are by carrying crop loss assessment and correct identification of the pestiferous species, their distribution and seasonality (Jang *et al.*, 2003).

In Kenya and Tanzania, the fruit fly fauna, damage level and infestation rates have been well described (Ekesi *et al.*, 2006; Mwatawala *et al.*, 2006a). In Uganda, a previous study by Nakasinga (2002) has described the fruit fly fauna in the country and *Ceratitis* species have been recorded as the most pestiferous fruit flies. However, since the detection of *Bactrocera invadens* in Uganda in 2004 (EPPO, 2010), studies on fruit flies have been limited to the Central parts of the country (Nemeye, 2005; Okullokwany, 2006), hence data are lacking for the agro-ecological zone in the northern part of the Uganda.

Therefore, this study was undertaken to determine the fruit fly status in Oyam district with a focus on species, the level of damage on mango and the knowledge gaps on fruit flies as a pest of mango.

1.3 Objective

1.3.1. General objective

To assess the status of tephritid fruit fly pest in the mango production system in Oyam District.

1.3.2 Specific objectives

- i. To identify the species of tephritid fruit fly infesting mango fruits during maturation and ripening.
- ii. To assess the level of damage caused by tephritid fruit fly pest on mango fruit.
- iii. To assess the knowledge and perceptions of mango growers and fruit vendors and the management practices regarding fruit fly pest menace.

1.4 Research Questions

The study addressed the following questions;

- i. Is it the presence of *Bactrocera invadens* fruit fly species that has led to increase in the magnitude of mango fruit damage?
- ii. What is the level of economic loss on mango fruits production that is due to tephritid fruit flies?
- iii. What are the mango producers' and traders' knowledge and perceptions on the effect of fruit fly on mango production?

1.5 Significance of the Study

Mango has been identified for its potential for diversifying rural household food security and income in northern Ugandan (Sengooba *et al.*, 2005), but there is limited information on the fruit fly pest status. The study aimed at generating important and useful information to stakeholders in decision-making and implementation of appropriate control and management programme for fruit flies, including in small holding mango production.

To the researchers, the information will be used to set research priorities and allocation of resources. To policy makers, in Local Government and Central Government, a new dimension for future up-scaling of fruit fly management strategies has been provided. To the extension workers, the findings form a basis of training farmers on fruit fly pest management. Likewise, funding agencies are provided with a better insight of where their financial resources can be invested. To the student, the study has added to the existing knowledge about fruit fly pest and in particular in Oyam district.

Other players to benefit are the fruit traders, processors, transporters, input suppliers and consumers which will use this information for decision-making in successful mango production and marketing. This will contribute to improvement in livelihoods, through improvement in rural households' financial base and ability to withstand stresses to production induced by weather changes and the damage they cause.

1.6 Scope and limitation of the Study

The study was conducted in Oyam district where mango production and marketing is on the increase, during mango fruit maturation period of May to July 2011. The study covered two of the seven sub-counties that were reported by the Oyam district Department of Agriculture (2009) to produce the highest volume of mangoes. The study focused on direct effects of fruit fly pest particularly on mango production, and knowledge, perception and practices among small-scale mango producers and fruit vendors.

Lack of proper farm records on the respondents' side was a limitation during data collection. The scope of the study did not permit carrying out the study in more than one district that would allow in-depth statistical analysis due to logistic constraints. Interview data from the two selected sub-counties were pooled, and hence, no comparison and tests of significance could be applied. For this reason, informative descriptive research method was used.

CHAPTER TWO

LITERATURE REVIEW

2.1 Mango production

Mango (*Mangifera indica*, Anacardiaceae), is the second most internationally traded tropical fruits (De Meyer *et al.*, 2010a). Worldwide production exceeded 35 million metric tonnes in 2009 (Nanakaan *et al.*, 2011). In Uganda, mango seeds were introduced sometimes before 1900, with superior varieties being introduced from India in 1907, 1948 and from Puerto Rico in 1991. It is an important income generating crop and the most widely distributed of all fruits. Areas of highest intensity are those in the relatively hot and dry northern and eastern regions where different varieties of mangoes are grown and where there are better fruits (Musana and Rubaihayo, 2001; Sengooba *et al.*, 2005).

Most of the varieties grown in Uganda are consumed locally and are of inferior quality with little commercial value. Three common types of mangoes include the small canopy mango varieties (e.g., Florigon, Glenn, Dancan, Early Gold, Erwin, Palmar, and Palvin), the medium canopy and fairly early yielding varieties (e.g., Zillate, Pinero, Alfonso, Apple, Kent, Keitt) and the large canopy and fairly early yielding varieties (e.g., Boribo, Ssejjembe, Bire). Bire, Ssejjembe, Ssu and Kate are some of the local selections (Musana and Rubaihayo, 2001; Sengooba *et al.*, 2005).

Mangoes are grown largely by peasant farmers on homestead gardens, sidewalks and orchards. More than 80% of the producer comes from smallholders who produce for the local and export markets to obtain the much-needed cash income for improving household food security and livelihood (Sengooba *et al.*, 2005). Export value of fruits and vegetables in Uganda is estimated at US \$ 12.5 million, equivalent to 4% of the total export value in 2005

(Anon, 2011). However, the production of mango is threatened by the attack of many insect pests, including fruit flies of the family Tephritidae ((Musana and Rubaihayo, 2001).

2.2 Tephritid fruit fly species

Sub-Saharan Africa is a reservoir of 915 fruit fly species (White and Elson-Harris, 1992) and the home of several species of highly damaging tephritid fruit flies (Lux *et al.*, 2003b). Pest species of tephritid fruit flies in Africa are classified as native and invasive species. These belong mainly to four genera: *Bactrocera*, *Ceratitis*, *Dacus* and *Trirhithrum* (De Meyer *et al.*, 2010a). Previous surveys by Lux *et al.* (2003a) across Sub-Saharan Africa showed that mango fruits are attacked by native fruit fly species such as *Ceratitis cosyra* (Walker), *C. capitata* (Wiedemann), *C. fasciventris* (Bezzi), *C. rosa* (Karsch), and *C. anonae* (Graham) and *C. quinaria* (Bezzi).

The intensification of fruit trade has led to the introduction of alien fruit fly species in Africa (De Meyer *et al.*, 2010a). Among the species are *Bactrocera invadens*, native to Asia continent. This was recorded for the first time on the African mainland in Kenya, in 2003 (Lux *et al.*, 2003b) and subsequently detected in other African countries (Ekesi *et al.*, 2006). In Uganda, it was first detected in July 2004 (EPPO, 2010).

Bactrocera invadens has already become a pest species of major concern to fruit growers in the continent (Lux *et al.*, 2003b). The species attacks a wide variety of crops including mango, guava, pumpkin, melon, tomato, citrus and cashew nuts (De Meyer *et al.*, 2010b). Due to a broad range of plant hosts and its high invasive ability, the species causes much damage throughout the world. It has displaced native fruit fly through resource competition and aggressive behaviours by adults (Ekesi *et al.*, 2009).

2.3 Life cycle of tephritid fruit flies

Adult fruit flies mature sexually between four and ten days after emergence and begin to mate almost immediately. Soon after mating, the female uses her sharp ovipositor to lay her eggs in fruit by piercing it to a depth of 2 to 5 mm before ovipositing. The banana-shaped eggs are deposited in batches of 3 to 8, depending on the species. The eggs hatch into tiny white maggots (larva) within 3 to 12 days, depending on the temperature. Larval development is completed within the fruit and fully-grown larvae then drop into the soil where they pupate. The duration of the pupal stage ranges from 10 to 20 days, depending on climatic conditions. In different countries, depending on the climatic conditions and abundance of host fruits, fruit flies may complete more than a dozen generations in a year (De Meyer *et al.*, 2010b). The developmental stages, therefore, take place in three places: in the plant fruits, on the ground and in the soil (Marques, 2008).

In Uganda, past research activities on fruit fly species prevalence was outside the northern moist agro-ecological zone (Nemeye, 2005, Okullokwany, 2006), hence the need to determine the fruit fly species causing damage on mango fruits and that which is dominant. Correct identification of the pestiferous species is a key component of any sustainable pest management strategy (Jang *et al.* 2003).

2.4 Fruit fly damage symptom

Tephritid fruit flies have a polyphagous habit. The females cause direct damage by puncturing the fruit skin to lay eggs underneath (White and Elson-Harris, 1992) which may leave 'sting marks' which may be accompanied by gum-like exudates as in Figure 2.1. During the oviposition, fruit rotting bacteria from the internal flora of the fly are introduced into the fruits. The bacteria cause the tissue surrounding the eggs to rot. This oviposition

puncture on the skin reduces the quality and market value of the fruit (Vayssières *et al.*, 2009a). The rotten tissues make it easier for the larvae to feed inside the fruit resulting in a soft mushy mess. This accelerates maturation of the fruit which may detach and fall on the ground or may remain hanging on the tree and ripen prematurely (Ekesi and Billah, 2006).



Figure 2.1: A mango fruit with signs of fruit fly infestation and damage in a grower's garden

Fruit damage can also be recognized by juice flowing through the ovipositor orifice when manually pressed, by the presence of a softened or rotten circular area (Fernando *et al.*, 2006) or by blemished spots on the fruits (Manrakhan and Price, 2001). Damage symptoms vary from fruit to fruit (Vayssières *et al.*, 2009b). When infested fruits are cut opened, fruit fly maggots are seen and the flesh is damaged (Ekesi *et al.*, 2010).

In Uganda, past research studies (Nemeye, 2005, Okullokwany, 2006), have not assessed mango growers' perceptions regarding mango fruit infestation and damage. Perceptions by farmers and other stakeholders regarding pests are important as they may influence decision making and method of control regarding the pest. It also helps in knowing the farmers'

attitudes in taking the necessary control measures and whether the appropriateness and relevancy of the technical advice given to them tally with their own views of the effect of the control measures (Ntow *et al.*, 2006).

2.5 Economic losses and impact of fruit flies

Losses that fruit flies cause include direct damage to fruits and fruit vegetables. Fruit flies compete with humans for food resources, thus create a negative impact on sustainable rural livelihoods. Besides the direct damage to fruits, indirect losses are associated with quarantine restrictions that are imposed by importing countries to prevent entry and establishment of unwanted fruit fly species. This limits export of fresh fruits to large lucrative markets (Ekesi and Billah, 2006; Ekesi *et al.*, 2010). The restrictions seriously threaten the income, food security and livelihood of millions of families that produce and sell fresh fruits and vegetables (Drew *et al.*, 2005). This has significant impacts on agriculture, in terms of the loss of potential production and markets, and the high economic costs for their control (Jang, 2007).

Heavy mango fruit loss due to fruit fly infestation has been experienced by fruit producing communities of Africa (Lux *et al.*, 2003a). Previous surveys across eastern and southern Africa showed that yield loss on mango due to native fruit flies can range between 30 to 70 percent depending on the locality, variety and season (Mwatawala *et al.*, 2006a; Ekesi *et al.*, 2009). For instance, out of 1.9 million tonnes of mango produced annually in Africa about 30-50% is destroyed by fruit flies (Ekesi *et al.*, 2009).

In Ghana, production losses due to *B. invadens* have been estimated to over 40% (USDA-APHIS, 2008). In Benin, the recorded yield loss due to fruit flies ranges from 12-50% for mangoes (Vayssières *et al.*, 2005). Unfortunately, the monetary estimates of fruit fly damage are not available for most countries (White and Elson-Harris, 1992) and this includes Uganda. Export of potential host species of *B. invadens* such as mango, avocado and cucurbits from Uganda are already banned in Seychelles, Mauritius and South Africa (USDA-APHIS, 2008). This is largely because, with global trade and passenger travelling, fruit fly pests are easily translocated (Ole-MoiYoi and Lux, 2004).

In northern Uganda, there has been no thorough study to quantify the level of damage on mango fruits due to fruit fly pests. This constrains decision making on the fruit fly pest management strategies. There is, therefore, need to determine the level of damage, hence the economic loss. Crop loss assessment is a key component of any sustainable pest management strategy (Jang *et al.*, 2003). Assessing crop losses is one of the first factors to be considered when justifying decision making for a particular integrated pest management strategy. This helps in defining the pest status of a particular insect and in defining plans of action or strategy for future research priorities, preferences and allocation of resources (Youm and Owusu, 1998).

Crop losses from pests may be quantitative and/or qualitative. Quantitative losses result from reduced productivity, leading to a smaller yield per unit area. Qualitative losses may result from reduced content of valuable ingredients, reduced market quality, reduced storage characteristics due to contamination of the harvested product with pests, pest parts or toxic products of the pests. Crop losses may be expressed in absolute terms (kilogram/hectare, financial loss/ hectare) or in relative terms as percentage loss (Oerke, 2006).

2.6 Fruit fly control methods

Management of a complex of fruit fly species is unlikely to be successful if based on a single management technique; therefore, an integrated pest management (IPM) approach offers the best method to improve the economics of the production system. This is by reducing yield losses and enabling growers to comply with stringent quality in the export market (Lux *et al.*, 2003b). The fruit fly control methods are categorized into pre-harvest and post-harvest control methods. Pre-harvest control for fruit flies includes Bait Application Technique (BAT), Male annihilation technique (MAT), Orchard sanitation, mechanical technique, Biological control technique and soil inoculation technique (Ekesi *et al.*, 2010).

Baiting technique method targets adult flies, mainly females and aims at attracting and killing them before they infest fruits (Ekesi *et al.*, 2010), either by spray or by solid bait station combined with appropriate insecticides since adult fruit flies need protein for the reproduction function. This is less time consuming and less demanding of labour, however, it is quite expensive and inaccessible to a large number of fruit and vegetable growers in Africa (Ekesi and Billah, 2006).

Male annihilation technique (MAT) involves using of para-pheromones as perimeter trapping that aims at reducing male fruit fly populations to low levels such that mating does not occur or opportunities are reduced to low levels. These attractants are currently being used in fruit fly management in many countries in Africa (Ekesi and Billah, 2006). In Kenya, infestation on mango was reduced by 39.8 to 46.8% through the use of this method (Ekesi *et al.* 2010).

Orchard sanitation involves collecting all fallen fruits, removal of fruits with dimples and those that ooze clear sap, picking overripe fruits as they attract fruit flies and are good

breeding sites for fruit flies and destroying by burning or burying them at least 60 cm deep or feeding to pigs or poultry. Each fruit can produce up to 400 fruit flies (Ekesi and Billah, 2006). The mechanical technique involves wrapping or bagging of individual fruits with newspaper or plastic bags. The bags must not have any holes to prevent oviposition. The method prevents adult fruit flies from laying eggs in the fruits leading to the production of fruits that are free from fruit flies (Ekesi *et al.*, 2010).

Biological control methods include the use of hymenoptera parasitoids, entomopathogenic fungi and predatory ants (Ekesi *et al.*, 2010). Predatory weaver ants (*Oecophylla longinoda* Latreille) (Hymenoptera, Formicidae), shown in figure 2.2, contribute to the management of fruit flies by disrupting fruit fly egg-laying on the fruit and fruit fly mating, release pheromone that acts as oviposition deterrent, prey on the puparia, pupating larvae and on newly emerged flies (Ekesi and Mohamed, 2011). The ants have contributed significantly to fruit fly reduction in mango in Benin (Van Mele *et al.*, 2007).



Figure 2.2: The weaver ant *Oecophylla* a biological control agent for fruit flies (Photo: Paul Van Mele)

The egg parasitoid wasps (*Fopius arisanus* Fullway) of Hawaii origin lay their eggs in fruit fly eggs or larvae and the host is killed when the parasitoid larval development is completed (Ekesi and Billah, 2006). The parasitoid has proven promising against *B. invadens* and up to 40% parasitism has been recorded in Kenya (Ekesi *et al.*, 2010). Entomopathogenic fungus

(*Metarhizium anisopile*) is used worldwide for controlling different kinds of insect pest, kill pupating fruit fly larvae (Ouna *et al.*, 2010). Efficacy of *Metarhizium anisopile* has been demonstrated in suppressing adults and pupating larvae of several fruit fly species in the genera *Ceratitis* and *Bactrocera* in Kenya (Ekesi *et al.*, 2010).

Other methods are early fruit harvesting when fruits are mature green (Ekesi *et al.*, 2010), Sterile Insect Technique (SIT) and soil inoculation with neem cake and other botanical formulation to kill pupating larvae (Ekesi and Billah, 2006). Post-harvest control methods include fumigation, heat treatment, and irradiation (Ekesi and Billah, 2006).

In spite of the availability of the fruit fly management strategies, smallholder farmers still suffer from higher losses due to fruit fly infestation. No thorough study has been conducted in the northern agro-ecological zone of Uganda to assess mango growers' knowledge and use of available fruit fly pest management strategies. This stresses the importance of establishing the level of knowledge among mango stakeholders on the available management strategies developed by research being used elsewhere with a focus on smallholder and fruit traders located in Oyam district.

2.7 Importance of Knowledge, Perceptions and Practices (KPP) in pest control

Farmers' decision about crop protection depend among others on their knowledge and experience with pests, the damage inflicted, as well as on their awareness of the existence of natural enemies (Heong *et al.*, 2002; Segura *et al.*, 2004). Farmers often have a life-long experience of growing their crops built up through regular observations and exchange of information during formal and informal actors' network (Van Mele and Van Chien, 2004).

Evaluating farmers' KPP in pest management can help in setting research agendas and identify gaps between farmers' knowledge and scientists' knowledge. It is also useful for planning campaign strategies and developing messages for communication against crop pest (Van Mele *et al.*, 2001). Integrating farmers' techniques and their indigenous knowledge about the insect pests are needed in developing processes to improve farmers' pest management practices (Nyeko *et al.*, 2007). Conducting surveys on farmers' KPP can provide farmers with alternative viewpoints on the crop protection constraints facing them in their efforts to increase and sustain mango fruit production (Madisa *et al.*, 2010).

It is widely acceptable that innovation communication on fruit fly research would be more robust when more farmers' KPP are taken into consideration (Heong *et al.*, 2002; Segura *et al.*, 2004). Unfortunately, there is always limited knowledge and awareness among the stakeholders along the mango value chain on tephritid fruit fly in terms of the species concerned, their economic impact and management strategies (Anon., 2009b). Besides, relatively few scientists' papers address farmers' knowledge, perceptions and practices, yet this is in many cases, a major component of pest management (Van Mele *et al.*, 2001). In the northern agro-ecological zone of Uganda where Oyam district is located, no thorough study has been conducted to assess the mango growers' perceptions on the seriousness of fruit fly pest on their mango production.

Lack of adequate information about farmers' KPP in pest management is one of the major constraints upon establishing an integrated pest management (IPM) programmes (Van Mele, 2000). Reliable information needs to be obtained in order to appreciate fruit producers' practices and to assess opportunities and constraints for decision-making at the farm level

(Abdullahi *et al.*, 2011). This information guides the selection and implementation of appropriate pest control strategies (Van Mele, 2000).

In studies conducted in Ghana, 60% of the interviewed producers agreed that fruit fly was a serious pest and that it decreased fruit production (Kwasi, 2008), and 75% of the mango farmers perceived fruit flies as the second major pest that caused a lot of problems leading to yield reduction in the mango enterprise (Abdullahi *et al.*, 2011). In Benin, the majority of growers interviewed perceived 20–45% of their production to be lost due to fruit flies, with one-fifth reporting even higher losses (Sinzogan *et al.*, 2008).

Regarding knowledge of pests, 48.1% of the respondent farmers interviewed in Ghana knew some species of fruit flies (Abdullahi *et al.*, 2011); 19.2% attested to knowing *C. cosyra* and 28.8% to *B. invadens*. This indicated that a reasonable number of the farmers were already aware of the presence of the African invader fly relative to other species in Ghana. About 61.5% of these farmers were found applying chemicals either as a single control strategy or alongside one or more other control measures whereas 76.9% of them had adopted cultural control measures. This suggested that the farmers generally had a fair knowledge of the damage and economic impact of fruit fly pests on crop production.

2.8 Importance of Vendors' activities in mango sub-sector

Vendors are those traders who operate from the street and occupy legally distribution stalls at a given area, selling different goods, which include fruits and vegetables ((Mitullah, 2003; Manyanhaire *et al.*, 2007). This is a kind of informal sector or trade which refers to employment and production that takes place in small, unregulated and/or unregistered

enterprises. This sector contributes up to 72% employment in sub-Saharan Africa (ILO, 2002).

Women especially those in urban places, take part in the informal sector mainly as vendors because the activity is in most cases, the only option open for them to earn income (ILO, 2002). The sector also blends very well with women's domestic reproductive roles due to its flexibility, low cost of entry and low skills requirement (Cheng *et al.*, 2005). Although most of the men have attained higher education than women, their participation in vendor activities is attributed to inadequate availability of jobs in the formal sector (Manyanhaire *et al.*, 2007).

In northern Uganda, it is common to find fruits like mangoes being sold at the roadside by vendors. Therefore, fruit vendors' key roles in mango sub-sector stressed the need to integrate them in this study in order to assess their perceptions on fruit flies as a pest of mango. The first detections of *B. invadens* fruit flies in Kenya and in Tanzania were obtained from mangoes collected from market places (Mwatawala *et al.*, 2004). Transporting infested fruits to markets, improper destruction of unsold fruits, throwing of infested fruits into a garbage bin, and transporting punctured fruit from infested zones to less infested zones promote an increase in fruit fly population and spread (Anon, 2007b). Passengers in cars, trains, ferries and buses are also a pathway (E-PPO, 2005) for fruit flies translocation (Olei-Moi Yoi and Lux, 2004).

CHAPTER THREE

MATERIALS AND METHODS

3.1 The study site

The study was conducted in two of the 12 sub-counties of Oyam district, northern Uganda (Figure 3.1, longitudes $32^{\circ}2'$ E and $32^{\circ}10'$ E and latitudes $2^{\circ}0'$ N and $2^{\circ}7'$ N), located approximately 300 kilometers north of Kampala. The district lies in the northern moist farmland agro-ecological zone and has approximate total land area of 2,289 km², of which 2140 km² is for human settlement and arable farming. The total population in the district is 366,200 (Census Projection, 2011). The landscape is gently rolling plains with an elevation between 1000 and 1524 masl, with a temperature range of 15–32°C. The mean annual rainfall is about 700 to 1700 mm which falls predominantly during April to October. Most of the land is arable farmland with some grassland interspersed with bush land (Wortmann and Fledu, 1999). Important crops grown include maize, beans, cassava, cotton, simsim, sunflower, soya beans, sweet potato, vegetables and fruits. Fruits include mango, citrus, avocado, pumpkin, pawpaw, banana and guava. Other economic activities are rearing of livestock, fish farming, small-scale fishing and trade (Oyam district - Department of Agriculture Annual Report, 2009).

According to the NAADS National performance report 2009/10, Oyam district rank among the districts where there is increased promotion of improved and high yielding mango varieties. Furthermore, it lies within an agro-ecological zone where limited research work on fruit flies has been undertaken. It is also an area with the potential for increased mango production and marketing which could be affected by an increase in fruit fly population and spread. Mango growers of Myene and Loro Sub-counties of Oyam district formed the population for the study.



Figure 3.1: The location of Oyam district in Uganda and the two sub-counties in Oyam district

3.2 Methods

3.2. 1 Sampling method

Multi-stage sampling technique was used in this study, whereby sampling was done using a combination of different sampling methods; hence four stage samplings were conducted.

During the preliminary stage, a meeting was held with the agricultural extension workers at

the district headquarters. This was to identify the sub-counties with high mango production in Oyam district and the common commercial mango varieties. In the first stage, Myene and Loro sub-counties were randomly chosen for the study from seven sub-counties (Aber, Acaba, Iceme, Loro, Kamdini, Minakulu and Myene) where mango production is prominent using simple random sampling technique. In the second stage, for each selected sub-county one parish was selected using simple random sampling technique forming a total of two parishes: Adyeda in Loro and Atek in Myene

In the third stage, a list of villages in the two parishes was generated with the assistance of local leaders. These were households in possession of mango trees with mango fruits at maturity stage, ripe or about to ripen (mature green) and have been in production for at least four seasons. A sampling frame of 549 mango producers (household heads) was compiled: 404 in Adyeda (Loro sub-county) and 145 in Atek (Myene sub-county). A sample of 138 household heads, later respondents, was selected from the sample frame using simple random sampling technique (Table 3.1). Each mango producer was therefore given an equal opportunity of being selected.

The sample size was determined using Cochran’s formula, $n = t^2 \times (p) (1-p) / d^2$ (Cochran, 1977), where, n is the sample size; t is the standard normal deviate at the selected confidence level value (which is 1.96 for 95 percent confidence level); p is the estimated proportion of the target population estimated to have characteristics being measured; d is the acceptable margin of error for proportion being estimated (which value is 5%). In this study, p equals to 10 percent, which is the proportion of farm families in possession of mango trees in Oyam district

$$\text{Sample size, } n = 1.96^2 \times 0.10 \times 0.90 / (0.05)^2 = 138$$

Table 3.1: Number of mango growers sampled for interview, Oyam district

Loro Sub –county			Myene Sub –county		
Parish	Village	Number of sampled Growers	Parish	Village	Number of sampled Growers
Adyeda	Abeibuti	8	Atek	Agunguarac	1
	Abero*	6		Alati “A”	3
	Acankomi	8		Alati “B”	3
	Adyeda	36		Araki East*	3
	Akaoidebe “A”	10		Araki West	2
	Akaoidebe “B”	9		Bobì	1
	Anyingenyinga*	3		Lango*	1
	Ayira	6		Omolo	3
	Barmwony	7		Opati “A”	1
	Ogugu*	14		Oyoalwak	1
	Culbanya	1		Teyao	9
				Zeriko*	2
TOTAL		108			30

(*) Selected villages for mango fruits sampling

Mango fruits collection was done in six out of 23 villages (Table 3.1). Three villages were selected from each of the two parishes using simple random sampling techniques. Formal visits were made to these villages to identify available mango varieties with farmers. Ten varieties were selected for fruit collection. Five varieties were local Ddodo varieties (Figure 3.2) with identification names as referred to in the local language. The naming is based on the

taste, shape, and texture of the fruit or origin of the variety. Other varieties were Bire, Gleen, Kent, Alphonso and Ngowe.



Variety Ddodo 'Total'



Variety Ddodo 'India'



Variety Ddodo 'Atik'



Variety Ddodo 'Amit'



Variety Ddodo 'Atokeagot'

Figure 3.2: Fruits of Ddodo mango varieties sampled for the study

The choice of these varieties was determined by their potential commercial values, abundance and availability during the study period and being hosts of fruit flies. For each of these varieties, three mango trees with matured fruits (unripe or ripe) were purposively selected giving a total of 30 trees and marked for harvesting. Consent and willingness for the mango fruits to be sampled were sought from the owners of the mango trees before being earmarked for fruit harvesting.

Two prominent mango fruit selling points along roadsides, Loro Trading Centre in Loro sub-county and Amwa Trading Centre in Myene sub-county, were also purposively selected for focus group discussions with fruit vendors.

3.2.2 Data collection

3.2.2.1 Mango fruits damage assessment

Between 2 to 5 fruits were harvested from each marked mango tree on a weekly basis at random and brought to the rearing facility in insulated cool boxes. The sampled fruits were individually weighed, counted and grouped in the rearing facility according to variety, date and sample site, and allocated sequence numbers and individually weighed. The fruits were bulked for 1-2 days to allow the development of larvae to the size that can be easily seen. The fruits were cut opened to check for the presence of fruit fly larvae. A fruit was considered damaged when at least one larva was observed inside the fruit as described in Vayssières *et al.* (2009c). The infested and non-infested fruits were separated, counted and data recorded.

3.2.2.2 Infestation indices

To assess the infestation indices, mango fruits that were found infested by fruit flies were randomly sampled and individually placed in wide-mouth rearing plastic containers, containing a thin layer of fine sterilized and moistened sand at the bottom. Overall, 34 kg of mango fruits out of the 80.5 kg (75 out of 177 in numbers) found damaged by fruit flies were incubated. The containers were covered with a piece of fine fabric mosquito net secured tightly with rubber bands to prevent the escape of larvae and any adult that emerged. The moisture content of the sand was maintained by adding water (Figure 3.3). The containers were checked daily until the emergence of adult flies. The rearing took 6 weeks.



Figure 3.3: Rearing of larvae to adulthood in a rearing facility

Emerged adult fruit flies were allowed to stay in the containers for 3 to 4 days to achieve full adult characteristics to facilitate proper identification. They were provided with a honey-water aqueous solution in a ratio 1:10 (Marques, 2008), soaked in dinning tissue paper and placed on the roof of the net for them to feed on it. The adult flies were killed with aerosol insecticide, containing d-tetramethrin (0.03%w/w), cypermethrin (0.07% w/w) and d-Allethrin (0.002% w/w) as active ingredients. The dead adults of fruit flies were sorted and identified to species with the aid of a magnifying glass, counted and recorded.

The samples from each individual fruits were stored in plastic vials and preserved in 70% ethyl alcohol for later confirmation at the National Agricultural Research Laboratories (NARL), Kawanda - NARO through observation of the morphological features using the guides of fruit flies identification (Billah *et al.*, 2006). Fruit flies were reared at room temperatures following protocols used by Vayssières *et al.* (2008).

3.2.2.3 Interview

The impact of the fruit flies on mango fruit production was determined by interviewing 136 out of 138 sampled mango growers using semi-structured questionnaires. This was to obtain first-hand information on mango producers' knowledge, perceptions and management practices on the pest. Information obtained in the interview covered the fruit fly pest, damage caused and control efforts. Growers were asked to identify their major insect pest problems in mango production to evaluate the perceptions on challenges in mango production. Coloured photograph and images of adult tephritid fruit flies were used during the interviews to help verify growers' ability to identify the pests and the species of economic importance in the area.

Questionnaires were developed and pre-tested in two non-sampled sub-counties involving 12 mango producers. Minor adjustments were then made on the questionnaire. Three enumerators, selected based on their basic training, qualification in agriculture and like of rural environment, were trained on how to administer the questionnaires. Participation in interviews was based on the individual willingness and acceptance to answer questions. Questions were asked in the local language (Luo) while taking care to retain the original meanings. The individual interview took an average of 30 minutes for each mango grower. The questionnaire that was used is shown in Appendix I.

3.2.2.4 Focus Group Discussion

Focus group discussion was conducted with fruit vendors in Loro (with eight vendors) and Myene (seven vendors). This was to explore and understand fruit traders' knowledge, perceptions, beliefs, practices and experiences in mango fruit marketing. The focus group discussion (FGD) is a rapid assessment, semi-structured data gathering method in which a

purposely selected set of participants gather to discuss issues and concerns based on a list of key themes drawn up by the researcher/facilitator. This provided a fast way to learn from the target audience and is a cost-effective technique for eliciting views and opinions of prospective clients (Escalada and Heong, 1997). Information obtained from fruit vendors covered fruit fly pest, their damages on mango and management practices, and access to agricultural extension service. A checklist was developed for the focus group discussion (Appendix II) and the exercise took on average 40 minutes for each group.

The survey period coincided with mango fruit maturation and ripening of 2011 mango season. This was to cross-check growers' answers against the field observations. The interview was restricted to between 11.30 am and 14.30 pm since it was a peak period for agricultural activities. This was the appropriate time when respondents would be at their homes or selling fruits at the roadside. A return visit was scheduled if the designated mango grower was temporarily not available at the time of the interview. The data collection methods were based on procedures for analyzing agricultural problems and assessing farmers' KPP as described by Van Mele *et al.* (2001).

3.2.3 Data analysis

Variations in percent fruit damage levels among mango varieties were compared using Kruskal–Wallis ANOVA test in SPSS version 23, followed by a Bonferroni corrected Mann-Whitney U test as a pairwise comparison. Percent damage for each fruit variety was calculated as a ratio of weight of infested fruits to the total weight of collected fruits as described by Vayssières *et al.* (2009c). Because fruit samples were of varying sizes (both in weight as well as in the number of fruit pieces), quantitative data were expressed as infestation indices with the number of adult tephritids expressed per weight (kg) of fruits only

for infested samples as described by Mwatawala *et al.*, (2006a). These parameters made it possible to compare damage and infestation rates among the different mango varieties despite differences in the sizes of individual fruit samples.

Data obtained from the questionnaire interviews were exported and analyzed using descriptive statistics (frequencies and percentages). Percentages were based on the number of respondents, whereby the number of responses per variable was expressed as a percentage of the total number of respondents, i.e., 136 mango growers. Quantitative analysis approach was applied to qualitative data in order to provide conclusions that are applicable to a wider target population. The ranks were converted to scores by multiplying rank 1, 2, 3, 4 and 5 by score 5, 4, 3, 2 and 1, respectively. A relative weight (in percentages) was then computed for each constraint by dividing by the sum of scores for all the assigned ranked constraints by 15 and multiplying by 100. Missing data that occurred because the number of items ranked varied from farmer to farmer was taken as zero constraints. Analysis of relative weight gave useful insights about the perception of participating mango growers. Scoring was used for the vendors' response in each sub-county and mean values obtained. The analysis was conducted as described by Abeyasekera (2000).

CHAPTER FOUR

PRESENTATION OF RESULTS

4.1 Mango fruit fly species

A total of 1,880 adult flies belonging to two fruit fly species, *Bactrocera invadens* and *Ceratitis rosa* were recorded from the 75 incubated fruits (Figure 4.1). *Bactrocera invadens* was the most abundant species and accounted for 99.4% of the total emerged adults, while 0.6% of the total adult emergence was *C. rosa* species.

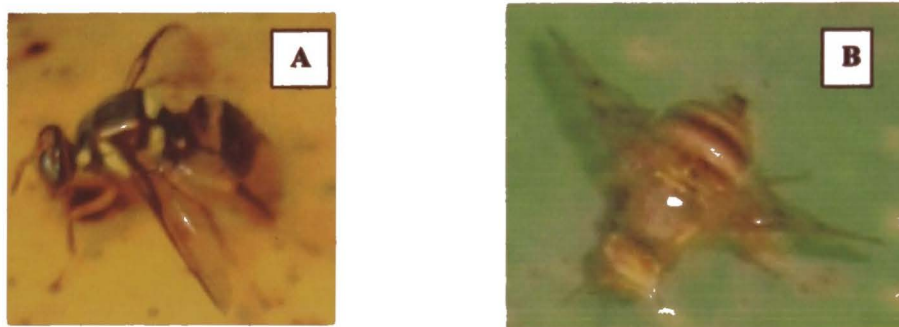


Figure 4.1: Adult of fruit flies: *Bactrocera invadens* (A) and *Ceratitis rosa* (B) observed in growers' field

4.2 Mango fruit damage

4.2.1 Variations in fruit damage among mango varieties

Overall, 349 mango fruits, weighing 151.4 kilograms were harvested from trees of ten mango varieties between May and July 2011. The level of fruit fly damage varied significantly among the 10 mango varieties (Kruskal–Wallis test, $H = 25.18$, $P = 0.003$, $df = 9$). The median percentage damage level varied from 7.56 (Interquartile range, IQR: 3.78-7.64) to 84.34 (IQR, 81.48-84.82). The most damaged mango varieties were Ddodo'Atik', Gleen and Alphonso, whereas the least damaged were Ddodo'India' and Ddodo'Total' (Figure 4.2).

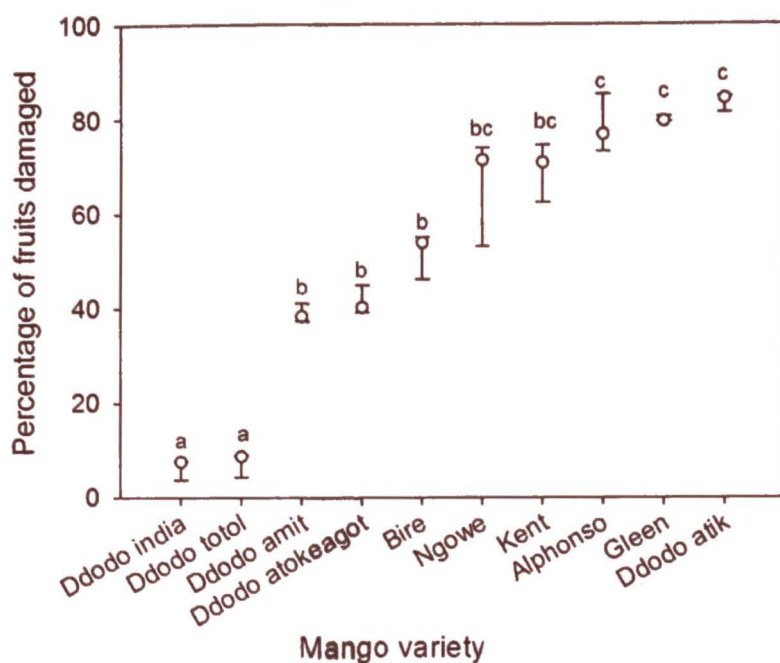


Figure 4.2. Fruit fly damage levels for 10 mango varieties sampled in Oyam district. Percentage damage values are expressed as median and interquartile ranges. Different lower-case letters above the bars denote significant differences among varieties (Kruskal–Wallis ANOVA followed by Bonferroni corrected Mann–Whitney U-tests).

4.2.2 Infestation indices among mango varieties

Bactrocera invadens emerged from all the incubated fruits (Table 4.1). Variety Ddodo‘Atik’ had the highest percentage of adult fruit fly emergence, while variety Ddodo‘Totol’ had the least percentage of adult’s fruit flies in the overall total emergence. Similarly, these two varieties recorded emergence of *Ceratitidis rosa* species. The mean number of adult *B. invadens* per kg of infested mango fruit was 53.4 and *C. rosa* had 0.3 adults per kg infested fruits. Overall, local varieties had 78 *B. invadens* adults per kg infested mango fruit and one *C. rosa* adult per kg infested mango fruit, whereas the improved variety had 34 *B. invadens* adults per kg infested mango fruit and zero *C. rosa* per kg mango infested fruit.

Table 4.1: Infestation indices for 10 mango varieties sampled in Oyam district

Variety	Average number of <i>Bactrocera invadens</i> adults per kg infested fruit	Average number of <i>Ceratitis rosa</i> adults per kg infested fruit
Ddodo 'India'	22.5	0
Ddodo 'Totol'	15.7	15.7
Ddodo 'Amit'	103.7	0
Ddodo 'Atokeagot'	35.9	0
Bire	15	0
Ngowe	22.1	0
Kent	43	0
Alphonso	28.1	0
Gleen	31.2	0
Ddodo 'Atik'	87.1	0.3
Overall	53.4	0.3

4.3 Knowledge, Perceptions and Practice

4.3.1 Profile of mango growers

Of the total respondents, 101 (74.3%) were males and 35 (25.7%) were females. Eighty-three (46.3%) of the respondents were aged between 36 and 55 years, 20 (22.1%) were 18–35 years and 43 (31.6%) were above 55 years. Eighty-three (61%) of the growers attended primary school education, 31 (26.5%) had secondary school education, and eight (5.9%) had post-primary school education, while 9 (6.6%) had no formal education. Seven (5.1%) of the respondents had landholding of more than four hectares, eight (5.9%) growers had between two and four hectares, while 121 (89%) had less than two hectares of land. A total of 83

(61%) growers were members of existing farmers' associations, while 53 (39%) were non-members to farmers' associations

4.3.1.1 Mango production profile

All (100%) the interviewed growers' had mango trees planted in the backyards of their homes. Seventy-six (55.9%) of the growers had less than 10 years of experience in mango production, while 54 (44.1%) growers had experience of more than 10 years.

4.3.1.2 Mango production constraints

The respondents reported several constraints that hindered mango production in the study area. This ranged from insect pest to difficulties in weed control in the mango gardens (Table 4.2). On being asked about the insect problems being faced in mango production, the growers' rated fruit flies (white larvae in fruits) as number one constraint (33.1%) followed by the weaver ants (Hymenoptera: Formicidae) at 31.2% and termites (*Macrotermes* spp Isoptera: Hodotermitidae) at 24.7%. Other insect pest problems that growers perceived to be minor included black biting ants (Hymenoptera: Formicidae) at 4.8%, mango seed weevils (*Stenochetus mangifera*, Coleoptera: Curculionidae) at 3.8%, mango scales (Hemiptera Coccoidea) at 1.4% and mango stem borer insects (Coleoptera: Cerambycidae) at 1%.

Table 4.2: Mango growers' perceived mango production constraints, Oyam district

Constraints	Frequency (N = 136)	Percentage of growers who	
		mentioned this as a constraint	rated this as their main constraints
Mango insect pest	132	97.1	36.8
Poor market for fruits	95	69.9	24.6
Bushfire	41	30.1	8.3
Expensive farm inputs	30	22.1	6.6
Destruction by strong storm	28	20.6	5.5
Mango Disease	22	16.2	4.1
Destruction by wild animals	17	12.5	3.8
Theft of ripe fruits	15	11.0	3.0
Limited knowledge	14	10.3	3.0
Small land holding	14	10.3	2.6
Difficulties in weeds control	11	8.1	1.7

4.3.1.3 Awareness about tephritid fruit fly pest

Only 2.9% of the interviewed mango growers reported they knew what adult fruit fly look like and none was able to relate adult flies to larvae. The description of adult fruit flies by the same respondents varied. These were that fruit flies were a black fly that lay eggs in fruits (1.5%); fruit flies resemble common houseflies (0.7%) and that fruit flies were bigger flies (0.7%). Various reasons were given by the respondents for inadequate knowledge of fruit flies. These were a lack of people to tell or train farmers (27%), low education level (12.7%) and limited opportunity for exposure (10.3%). A total of 47.1% had no idea on the lack of fruit flies control among them. The fruit fly larvae were referred to in the local language as

"kudi aeme atar" literally meaning white maggots in mango fruits, while the adult fruit flies had no local names in the study area.

4.3.1.4 Awareness about mango fruit damage and losses

A total of 55.9% of mango growers were aware of the symptoms of damage on mango fruit associated to fruit fly pest. The mentioned symptoms of damage were the presence of white larvae in fruits and fruits drop on the ground. On the extent of damage and loss of mango fruits due to fruit flies, 5.9% of the growers' perceived that damage was very serious ($> 70\%$ loss), 0.7% said it was serious (41 to 70% loss, 5.9% said it was moderate (21 to 40%) and 0.7% said it was low ($\leq 20\%$). The majority of the respondents (86.8%) had no idea on the extent of damage and loss of mango fruits due to fruit flies.

4.3.1.5 Fruit fly management practices

None of the growers had taken action to control tephritid fruit fly pests encountered on their mango trees. The reasons for not attempting to control fruit flies mentioned by respondents were the limited knowledge on suitable control techniques among growers (26.5%), non-availability of insecticide to control fruit flies (19.1%), lack of money to buy insecticide to control fruit flies (13.2%) and lack of equipment to spray fruit flies (3.7%). However, 37.5% of the interviewed growers had no reasons for not attempting to control fruit flies.

4.3.1.6 Mango growers' access to agricultural extension services

Only 5.9% growers interviewed had accessed agricultural extension information or advice on fruit flies. The various sources of advice were radios (five growers), fellow farmers through education tours/exchange visits (two growers) and farmers' training (one grower). For those growers that had not accessed extension information/advice, the reasons were that there were

few or no extension workers in their area (26.7% of them) and that the agricultural extension workers were staying at a far distance from the mango growers (67.4% of them).

4.3.1.7 Mango growers' future plan in mango production

The majority of the growers interviewed (94.8%) reported they were interested to continue with mango production despite the challenge of tephritid fruit flies. Various reasons were provided by the growers for their continued interest in mango production. These were because of the edible fruits for home consumption (86.3%), household income (70.6%), provision of shade (32.4%) and windbreak (22.1%) at home, and land security/ boundary markers (1.5%). Some of the growers were optimistic that there will be improvements in the markets for mango fruits in the near future (0.7%)

4.3.1.8 Way forward to improve mango production in Oyam district

In order to manage fruit flies for improved mango production, the interviewed respondents recommended many strategies. These included the need for mango growers to be trained (55.2%), distribution of appropriate pesticides and equipment (25.7%), provision of seedlings of less susceptible mango varieties to farmers (15.4%) and provision of adequate logistical support to agricultural extension workers (3.7%).

4.3.2 Fruit vendors

4.3.2.1 Profile and Mango fruit sales

The profile of 15 fruit vendors involved in focus group discussions in the two study locations of Loro and Myene sub-counties is as depicted in Table 4.3. The interviewed fruit vendors indicated varied education levels and experiences in fruit sale business. All the vendors indicated that mango fruits sale was their part time job.

Table 4.3: Profile of the fruit vendors interviewed from Loro and Myene, Oyam district

Factors	Responses	Frequency		Percentage		Mean percentage
		Loro (n = 8)	Myene (n = 7)	Loro	Myene	
Years in fruit sales	≤ 1 year	1	2	12.5	28.6	20.5
	1 to 5 years	4	5	50	71.4	60.7
	> 5 years	3	0	37.5	0	18.8
Education level	None formal	1	1	12.5	14.3	13.4
	Primary	5	4	62.5	57.1	59.8
	Secondary	2	1	25	14.3	19.6
	Post-secondary	0	1	0	14.3	7.2

4.3.2.2 Sources of mango fruits and fruit sales

From the result of the study, 19.6% (mean percentage) of the vendors indicated that the main source of fruits for their business was from their own mango trees. Other sources were from other mango growers within and outside Oyam district (74.1%) and from other vendors (6.3%). Roadside fruit marketing was the major fruit marketing method among fruit vendors. Road travellers were indicated to be the major buyers of mango fruits by the respondents (73%), while the local communities were the other category of buyers as reported by 27% the vendors.

4.3.2.3 Mango marketing constraints

The growers' perceived marketing constraints were many. These ranged from the internal damage of mango fruits by fruit fly white larvae to no payment for fruits by travelling passengers (Table 4.4).

Table 4.4: Perceived mango marketing constraints by fruit vendors, Oyam district

Marketing challenge	Scores		Mean score	Ranking
	Loro	Myene		
Internal fruit's damage by fruit fly larvae	5	5	5	1
High transport cost	5	3	4	2
Competition for fruits among vendors	3	3	3	3
High market dues	3	3	3	4
Poor market facilities	2	3	2.5	5
Non-payment by highway travellers	1	3	2	6

4.3.2.4 Post-harvest handling of damaged mango fruits and access to extension advice

The vendors' actions on mango fruits found infested with fruit fly larvae varied as presented in Table 4.5. Only one vendor received extension information and advice on fruit fly pest.

This was by participating in farmers' exposure tour to a research station.

Table 4.5: Post-harvest handling of fruit fly damaged mango fruits, Oyam district

Marketing challenge	Score		Mean score	Ranking
	Loro	Myene		
Throwing away of damaged mango fruits	5	5	5	1
Mixing infested and non-damaged fruits for sale	4	3	3.5	2
Leaving damaged fruits under the mango trees	2	2	2	3
Burying of damaged fruits	1	1	1	4
Burning of fruit fly damaged fruits	1	0	0.5	5

CHAPTER FIVE

DISCUSSION OF RESULTS

5.1 Fruit fly species

Bactrocera invadens emerged in high numbers from incubated fruits compared to native fruit flies species *C. rosa*. The result of the study shows that *B. invadens* is most damaging and devastating mango fruit fly species in the study area. The finding confirms an earlier report that *B. invadens* is the most serious fruit fly pest in Uganda (Nemeye, 2005, Okullokwany, 2006), and is an important species of fruit fly responsible for extensive mango damage and economic loss across Africa (Ekesi, 2010b). In Tanzania, Mwatawala *et al.* (2006b) also revealed that the highest damage of mango fruits was by *B. invadens*. Similarly, in West Africa, *B. invadens* is a serious threat to mango value chain (Vayssieres *et al.*, 2009c). Currently, *B. invadens* is a species of great economic significance in Africa, where the increasing number of infested fruits indicates its destruction potential (Mwatawala *et al.*, 2006b). This is because of its polyphagous nature, its rapid spread, invasiveness and destructive nature, prevalence and predominance in all mango varieties (Drew *et al.*, 2005).

The low number of the emergence of native species, *C. rosa* found in this study confirms domination of *B. invadens* over the native *Ceratitidis* species. This gradual displacement phenomenon was observed in studies in Tanzania by Mwatawala *et al.* (2009a) where it was concluded that *B. invadens* dominated the native *Ceratitidis* species in terms of infestation. A similar phenomenon was observed in studies in Kenya (Ekesi *et al.*, 2006). The displacement mechanisms, according to the two authors, are the larvae competition for the same food resources in the same fruit and the aggressive behaviour of *B. invadens* that do not leave females of other fruit fly species to lay their eggs in the same fruits. In addition, the emergence of *C. rosa* from fruits of only two mango varieties: Ddodo 'Atik' and Ddodo

‘Total’ means the two varieties are preferable to the *C. rosa* species than others. There is no conclusive evidence on this preference in this study.

5.2 Mango fruit damage and infestation indices

The results of the present study indicate that fruit flies cause high damage and infestation on mango fruits but do not necessarily damage all varieties equally, indicating that some varieties are more susceptible to infestations than others. The high level of mango fruit damage and infestation rate revealed in the study is in an agreement with reports in studies carried in other parts of Africa. For example, in Kenya (Ekesi *et al.*, 2006), damage on mango fruits of up to 58.3% has been reported. Damage on mango fruits has been reported ranging from 20 to 61.7% in Tanzania (Mwatawala *et al.*, 2009a), 10 to 57% in Benin (Vayssières, *et al.*, 2009c) and between 60 and 85% in Ghana depending on the variety and season (Billah *et al.*, 2006). In Tanzania and in Kenya, an infestation index of 175.8 *B. invadens* per kg of mango fruits (Mwatawala *et al.*, 2006a, 2009b) and 104.3 *B. invadens* per kg of mango fruits (Rwomushana *et al.*, 2008) has been reported, respectively. In Central and West Africa, *B. invadens* species showed the highest infestation index in mango (Vayssières *et al.*, 2009a).

The reasons for the variation in damage levels and infestation indices for *B. invadens* among mango varieties found in the study is unclear. Several previous studies have shown that mango fruit peel firmness and thickness greatly affect oviposition preference of fruit flies (Rossetto *et al.*, 2006). For this reason, female tephritids have high preference for fruits with softer pericarp over those with hard pericarp for oviposition (Balagawi *et al.*, 2005) which might explain the difference in the levels of infestation and damage. This is an agreement to report by Griesbach (2003).

5.3 Knowledge, Perceptions and Practices

5.3.1 Mango growers

Results of the study indicated that mango fruit production is dominated by males (74.3%), while females represented only 25.7% of vendors. The majority of the respondents were in the active age, with a good number of them being youths. The involvement of young growers is a good sign for increased and sustainable mango production and a better opportunity for a successful avenue for creating employment in the study area (Badii *et al* , 2012).

The majority of growers had formal basic education, implying that most of the growers are sufficiently literate. This can improve the growers' access to agricultural information and enhance adoption of management practices. This is of an advantage because educated farmers are generally more open to innovative ideas and new technologies that promote positive change (Madisa *et al* , 2010). Improved crop production requires a high level of education from farmers in order to effectively implement the recommended practices (Crosby *et al* , 2000). The study also revealed the importance of mango as a source of household fresh fruits and income, as shade (esthetic value) in the community, in the creation of windbreaks in homesteads and institutions and as security marks on land under customary land inheritance. Similar findings were observed in Ghana by Kwasi (2008). However, the majority of farmers had small landholdings which limit the expansion of mango production.

5.3.1.1 Knowledge on fruit fly pest constraints in mango production

Fruit flies were perceived as a major insect pest constraint. Similar observation was made in Ghana by Kwasi (2008) and Abdullahi *et al* (2011). Similarly, in Tanzania, Mwatawala *et al* (2006b), found that production of high-quality fruits was hampered by insect pests, especially fruit flies (Diptera: Tephritidae), in addition to economic and developmental

constraints. Fruit flies are the most important and notorious insect pests that cause serious damage to fruit and vegetable crops in most tropical countries (Ekesi and Billah, 2006).

The result of the study has revealed widespread concerns among mango growers on the serious damage caused by fruit flies on their mango. Severe damage of fruits due to *B invadens* was reported in Kenya (Ekesi *et al.* 2006) and Tanzania (Mwatawala *et al.* 2006b). Studies by Mwatawala *et al.* (2004) and by Vayssières *et al.* (2005) indicated that smallholder farmers complained about the effects of fruit flies on their fruit production. These effects result in reduced quantity and quality, hence detrimental consequences on mango growers' earnings.

5.3.1.2. Knowledge of fruit fly pests

The study revealed limited knowledge about the fruit fly pest. Most of the mango growers did not know the adult fruit flies, but knew the larvae. In addition, none of them knew the link between fruit fly adults and the larvae, nor were they aware of the fruit fly species, including *B invadens* species. The larvae were popularly referred to as “*Kudi aeme atar*” which means the white maggots, whereas there was no name for an adult fruit fly. The limited knowledge among growers is an indication of lack of contact between mango growers and agricultural extension workers. This shows that growers do not personally take the initiative to look for extension service providers. They instead wait until there is a forum such as farmers' tour, training workshop or field day to meet or consult them, implying that the demand-driven approach for extension service provision does not appeal to most mango growers.

The mango growers need to improve their knowledge on economically important fruit fly species, especially for *B invadens*. According to Abdullahi *et al.* (2011), knowledge of the

presence of fruit fly is crucial in aiding the development of solutions to minimize their effect and for mango growers' acceptance of new innovations in combating these pests. Furthermore, it promotes farmers' collaboration with researchers in developing sustainable on-farm strategies to reduce the losses caused by the pest. Since fruit flies attack different crops in the same area, as noted by Kwasi (2008), their management must be based not only on a single crop such as mango, but should include wild and other commercially grown host plants.

5.3.1.3 Fruit fly management by growers

The study revealed that the mango growers in the study area do not undertake any fruit fly management measure. All the respondents (100%) used no control measure to reduce the effect of fruit flies on the mango trees to produce fruits that will meet the needs of their customers. The finding is consistent with findings of Kwasi (2008), and it indicates that the growers are ignorant of the control measures. The lack of appropriate pest management, as noted by Van Mele (2000), may be as a result of economic and structural reasons and probably due to the neglect of fruit growers by extension services of the responsible government ministries.

Complains from the majority of growers (69.1%) that predator weaver ants, *Oecophylla longinoda*, were serious insect constraints on their mango trees is an indication of limited knowledge among the mango growers on the importance of weaver ants in the control of fruit flies. The predator weaver ants have been shown to effectively suppress fruit flies on mango. The insects are generalist predators that patrol a tree continuously seeking prey and abundant populations control fruit flies effectively (Van Mele *et al.*, 2007). However, as noted by

Sinzogan *et al.* (2008), a majority of extension staff often have negative attitudes toward weaver ants and are unaware of their beneficial effects.

By growers suggesting various options as ways forward to address fruit fly problems in their area, it shows the will among them to control fruit fly pest once support is provided. Among the expectation the growers mentioned were the provision of insecticide and equipment for spraying their mangoes. This is an indication that growers are willing to use any available and affordable measures including pesticides to control the pest. However, indiscriminate pesticide use, as noted by Banjo *et al.* (2010), may lead to an extinction of natural enemies of fruit flies, the development of resistance to these and other pests as well as undesirable environmental consequences.

5.3.2 Fruit vendors

The study revealed that mango sale is a seasonal business and that vending in mango is a relatively new phenomenon. The study has also revealed that men, women, youth and children are involved in order to obtain money to help boost family incomes and thereby reducing poverty. This finding has demonstrated the importance of informal sector or trade in the local economy. The challenges faced by mango vendors that included fruit rotting, stiff competition among vendors for fruits, and price hikes by suppliers and transporters were observed in a study in Zimbabwe by Manyanhai *et al.* (2007).

5.3.2.1 Awareness about fruit flies

The study has shown that the fruit vendors had general awareness about the damage on mango fruits associated to fruit flies. The presence of white larvae due to infestation by fruit fly was perceived as a major constraint in mango fruit marketing. The study has revealed that

there is frequent transportation of mango fruits from within and from outside the study area. Poor post-harvest handling and disposal practices whereby no precautionary measures is undertaken by vendors to avoid spreading the pest to the pest-free area was revealed by this study to be a common practice in the study area.

5.3.2.2. Access to agricultural extension advice

The study has revealed that fruit vendors' access to agricultural extension advice is limited. This is justified by post-harvest handling practices among vendors, especially with respect to disposal of infested mango fruits. Similar shortcomings for extension advice were observed by Van Mele *et al.*, (2001) and Badii *et al.*, (2012). Lack of visits by agricultural extension services can result in the extension clients' inability to identify pests, poor pest management skills and lack of good knowledge of the use of pesticides (Elizabeth and Zira, 2009).

5.4 Impact of tephritid fruit fly pest on mango production in Oyam district

The occurrence and high levels of mango damage by tephritid fruit flies observed in this study suggest that fruit fly pests have a significant impact in the study area in many ways. First, as a result of infestations by fruit flies, large quantities of fruits simply drop and rot on the ground under mango trees. The fruit loss leads to the shortage of fruits which provide a cheap source of food nutrition, especially to mothers and children. According to Griesbach (2003), nutritionally, mango fruits contain almost all known vitamins and essential minerals which include thiamine, niacin, calcium and iron. The calorific value is mainly derived from sugars and is as high as that of grapes and higher than that of pears, apples and peaches. Generally, mango protein content is slightly higher than for other fruits except for avocado. With the increasing fruit fly pest threats on mangoes, the local people in the study area will have to adjust and develop new coping strategies during the period of food shortage which

coincides with mango fruit maturation and ripening. This may include looking for alternative sources of nutrients which have social, economic, cultural and political implications to the households, community and governments.

Secondly, the increase in infestation of mangoes by fruit flies, especially by *B. invadens*, without control has become an obstacle to continued access to better markets by growers and vendors. The fruits harvested for the market are becoming uneconomical and are usually exclusively for home consumption. This is because of loss of quality, rejections of fruits in the markets, and loss of lucrative market opportunities. The households linked to mango production and selling will continue experiencing a drop in their incomes. The process of sorting requires basic knowledge, is time-consuming and costly, and reduces the quantities of mango for the market. As a result of the pest, farmers will have to use much more resources into mango production than before.

Thirdly, with the limited efforts to control fruit fly pest, especially by government extension and research agencies, losses and damages to mangoes is continuously provoking independent control efforts by individual mango growers. These control measures are not effective, not known by other growers and not proven to be of any values in the control of fruit flies. This results in an ineffective fruit fly control and management. The researchers and agricultural extension workers are therefore under continuous pressure to bring out or disseminate appropriate management options to farmers and other stakeholders.

Lastly, the increase in mango fruit infestations by fruit flies is making some of the farmers to abandon their mango trees or gardens and to lose the desire to maintain and/or grow more mangoes. This has effects on the development and revitalization potential of mango industry.

and impacts negatively on the employment prospects of the informal job market. As noted by Jang (2007), loss of production of fruit fly host product has a significant impact on agriculture in terms of the loss of potential production and markets due to threats from fruit flies, and the high economic costs suggest their control are important impact areas. Therefore, large resources have to be mobilized for effective management of fruit fly pest.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

Based on the findings in this study, the actual mango damage (economic) loss due to fruit fly pests' attack in the study area ranges from 7.6 to 84.3% depending on mango variety. *Bactrocera invadens* is the fruit fly species highly associated with the high level of mango fruits damage. Both local and improved varieties are being attacked by fruit flies. In addition, there is limited knowledge on fruit fly control and management strategies among mango stakeholders.

Recommendations

Based on the results of this study, the followings are recommended:-

- i. Future research studies should aim at the *B. invadens* fruit fly species, susceptibility of existing mango varieties to fruit fly infestations, mango variety improvement, alternative fruit fly hosts and appropriate management strategies.
- ii. There is a need for the promotion of appropriate fruit fly pest management measures with emphasis on integrated pest management as this is a key to the development of the mango industry in the study area.
- iii. There is a need to incorporate a strong public relations policy into the activities of the fruit fly management related institutions including on fruits vendors.
- iv. Fruit management should be addressed to both local and exotic mango varieties since they all suffer fruit fly infestations and damage.

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APPENDICES

Appendix I: Questionnaires

Respondent No: _____ Date: ____/____/20____ Interviewer: _____

Name: _____

Sub-county: _____ Parish: _____ Village: _____

1.0 Profile of Respondent (Tick the Appropriate)

1.1 Age: 1. 15-35 years ☐ 2. 35 - 55years ☐ 3. 56 - 64 years ☐ 4. 65+ years ☐

1.2 Sex: 1. Male ☐ 2. Female ☐

1.4 What is your education level? i. None ☐ ii. Primary ☐ iii. Secondary (Lower) ☐
iv. Secondary (Higher) ☐ v. Tertiary Diploma/Certificate/Degree ☐

1.5 How large is your farm land (in Hactares)?

i. < 5 ☐ ii. 5 - 10 ☐ iii. > 10 ☐

1.6 Where have you grown your mangoes? 1. Backyard ☐ 2. Field ☐

1.7 Do you belong to any farmers' group or association? i. Yes ☐ ii. No ☐

2.0 Mango Production

2.1 For how long have you been a mango producer?

i. Less than 5 years ☐ ii. Between 5 – 10 years ☐ iii. More than 10 years ☐

2.2 Please name 5 major constraints you are facing in mango production? (Rank them)

Constraints					
Ranking					

2.3 Which are the 5 insects disturbing you in mango production? (Rank them)

Insect					
Ranking					

3.0 Farmers' Knowledge and Perceptions on Fruit fly pest

3.1 Have you ever seen an insect that resemble these one in the picture on these cards?

- i. Yes ☐
- ii. No ☐

3. 2. If yes, please name the species of mango fruit fly shown in the picture.

3.3 Please describe the relations between the insect and mango.

3.4 In your own assessment, what could be the level of mango fruit damage in your backyard garden/orchard due to this pest? (Use the fruit numbers to categorise)

- (i) Very serious (7-10 fruits out of 10 are infested) ☐
- (ii) Serious (5-6 fruits out of 10 are infested) ☐
- (iii) Moderate (3-4 fruits out of 10 are infested) ☐
- (iv) Low (1-2 fruits out of 10 are infested) ☐
- (v) No opinion ☐

4.0 Fruit fly pest control

4.1 a) Have you ever attempted to control fruit fly pest in your garden/orchard?

- i. Yes ☐
- ii. No ☐

(If yes continue to 4 2, if No go to 4 5) (Use table below to answers 4 2 a and 4 2 b)

4.2 a) If yes, which method(s) have you been using to control fruit fly pest?

b) How effective have been these control methods you have mentioned?

Method used	Effectiveness		
	Very	Fair	Not
i.			
ii.			
iii.			

4.3 If you were asked by a neighbour or a friend for advice, which of the above mentioned control methods would you recommend for him or her to use? (Give reasons)

Method	Reason(s)		
	I	II	III
i.			
ii.			
iii.			
No opinion			

4.4. If there is none, give reason(s) _____

5.0. Access to Agricultural extension advisory service

5.1. Have you ever been informed, trained or advised on mango fruit fly pest by any agricultural extension worker?

i. Yes ☐ ii. No ☐

5.2. If yes, what was the topics and by whom (or source)?

Topic	Source
i. _____	_____
ii. _____	_____

5.3. If no, what could be the reason(s)?

Reason	Ranking
i. _____	_____
ii. _____	_____
iii. _____	_____
No opinion	_____

6.0. Future Plan concerning Mango production

6.1. Are you still interested in mango production despite the damage by fruit fly pest?

i. Yes	☐	ii. No	☐
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Give reason(s) for your answer

i. _____
ii. _____
iii. _____

6.2. Please suggest what you think should be done in order to improve on fruit fly pest management in this area?

i. _____
ii. _____

THANK YOU FOR YOUR TIME

Appendix II Checklist for Mango Fruit Vendors

Sub county _____ Market point _____ Date _____

1.0 Brief introduction

- Explain purpose and scope of the discussion
- Introduction by participants

2.0 Short information background from participants about themselves

- i. Age
- ii. Sex
- iii. Level of education
- iv. Experience in fruits sale business

3.0 Major Topics

- Perceptions on the importance of fruit fly problem in their mango businesses.
- Knowledge on the fruit fly pest biology.
- Knowledge on the signs and symptoms of mango fruits infested by fruit fly pests
- Knowledge and understanding of movement and translocation of fruit flies within communities and outside
- Vendors' assessment of their likelihood of effectively managing tephritid fruit fly pests.
- What are the challenges in mango fruits vending business?