Sudan University of Science and Technology

College of Graduate Studies

Survey of the Asian Fruit Fly (*Bactrocera invadens*, Drew, and White) (Diptera: Tephritidae), and Efficacy of two Plant Extracts against the Adults Fly

مسح لذبابة الفاكهة الآسيوية، وتأثير إثنين من المستخلصات النباتية ضد الحشرة الكاملة

A thesis submitted in partial fulfillment of the requirements for the M. Sc. degree in Plant Protection

By

Fatima Ali Mohammed Sabah

B.Sc. Agric. Plant Protection (Honors)

College of Agricultural Studies-Shambat

Sudan University of Science and Technology, November (2007)

Supervisor: Prof. Awad Khalafalla Taha Elhag

Department of Plant Protection

College of Agricultural Studies -Shambat

Sudan University of Science and Technology

September, 2015

الآية

قَالَ تَعَالَىٰ:

﴿ قُل لَّوۡ كَانَ ٱلۡبَحۡرُ مِدَادٗا لِّكَلِمَٰتِ رَبِّي لَنَفِدَ ٱلۡبَحۡرُ قَبۡلَ أَن تَنفَدَ كَلِمَٰتُ رَبِّي وَلَوۡ جِئۡنَا بِمِثۡلِهِۦ مَدَدٗا ١٠٩ ﴾

صدق الله العظيم

سورة الكهف(109)

DEDICATION

To my beloved mother.

To my dear father and brothers

To all my teachers and friends with love and respect.

Fatima

ACKNOWLEDGEMENTS

All thanks are due to Almighty Allah (SWT) who gave me health and strength and helped me tremendously to produce this work. I would like to express my thanks to my supervisor Prof. Awad Khalafalla Taha Elhag For helpful assistance, guidance, patience and keen interest and continuous participation throughout this study.

Grateful thanks are due to Waleed Elamin and Aisha Bakheet for their continuous and unlimited helps during this study.

Grateful thanks are due to all my colleagues for their assistance throughout this study. Thanks are due to staff members of the Plant Protection Department, College of Agricultural Studies. Specially Dr. Loai Mohammed Elamin and Ustaz Mohamed Elziber Hassan.

Thanks are also extended to the staff member of the Directorate of Plant Protection and Biological Control, Ministry of Agriculture in Khartoum State.

Thanks are also extended to all those who gave me hand and helped me in producing this work. Last, but not least I am greatly indebted to my family that backed and encouraged me throughout my life.

List of Contents

CHAPTER THREE

CHAPTER FOUR

CHAPTER FIVE

List of Tables

Title **Page No.**

List of Figures

Title **Page No.**

List of Plates

ABSTRACT

The first aim of this study was to monitor and survey the fruit fly species in an area north of Khartoum North Locality, during the period from January 2015 up to April 2015. A Survey was carried out using, the pheromone traps (Methyl Eugenol) and bait traps (guava juice), in the three areas in the Locality, Elkadaroo, Elfaki Hashim and Elkhogalab. The survey results showed that, there are two species of fruit flies , the Asian fruit fly (*Bactrocera invadens* Drew, and White), which was the dominant species (99.4%), in addition to the Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann) , which was found in a little population(124 flies only).

The second aim of this study was to investigate, through Laboratory experiments, the effect of seed ethanolic extracts of *Cassia occidentalis* L. (Coffee senna), and *Ricinus Communis* L. (Castor) on the adult Asian fruit fly (*B. invadens* Drew, and White) (Diptera: Tephritide).

In this study four concentrations (5%, 10%, 15%, and 20%) of Coffee Senna and Castor ethanolic seeds extract were used against the Asian fruit fly by using topical application and feeding methods, and the result taken after 24, 48, and 72hr. The results showed that, all tested concentrations of both plants caused higher mortality percentage when compared to control.

From the results, there are no significant differences between three concentrations (5%, 10% and 15%) of Castor after 72 hrs after exposure in topical application, while the highest concentration (20%) of Coffee senna seeds extract gave the higher mortality (90%) showed significant differences when compared with same highest concentration (20%) of Castor extract which gave only 63.3%. Also there are no significant differences between the highest concentration (20%) of Coffee senna extract and the standard

insecticide (Malathion) in topical application, while there are significant differences between the same concentration (20%) of Coffee senna extract and the standard insecticide (Malathion) in feeding method.

These results suggest that the topical method of application was more effective than feeding method, and Coffee Senna extract was highly effective than Castor extract.

.

ملخص البحث

هدفت هذة الدراسة أولا لمراقبة ومسح ذبابة الفاكهة في منطقة شمال محلية الخرطوم بحري خلال الفترة من يناير2015 إلي ابريل2015 لمعرفة الأنواع الموجودة. تم المسح باستخدام المصائد الفرمونية (ميثايل اجينول) والطعوم الغذائية (عصير جوافة)، في ثلاثة مناطق في المحلية، هي الكدرو والفكي هاشم والخوجلاب. أوضحت نتائج المسح أن هناك نوعان من ذباب الفاكهة ، الأول هو ذبابة الفاكهة الآسيوية *Bactrocera invadens*، حيث كانت هي النوع السائد في المنطقة(99.4%)،بالإضافة إلى ذبابة فاكهة البحر الأبيض المتوسط *Ceratitis capitata*، والتي وجدت بأعداد قليلة (124 حشرة فقط).

الهدف الثاني من الدراسة هو تقييم الأثر القاتل معمليا للمستخلصات الإيثانولية لبذور السوريب (*Cassia occidentalis* L.)، والخروع (*Ricinus communis* L.) علي الحشرة الكاملة ذبابة الفاكهة الآسيوية

(*Bactrocera invadens* Drew and white) (Diptera: Tephritide)

في هذه الدراسة استخدمت اربعة تركيزات (5%،10%،15%و20%) من مستخلصات بذور السوريب والخروع الايثانولية ضد ذبابة الفاكهة الأسيوية بواسطة الطريقة الموضعية وطريقة التغذية وأخذت النتائج بعد 24، 48 و 72 ساعة. أوضحت النتائج أن كل التركيزات المختبرة من كلا النباتين أحدثت نسبة موت عالية مقارنة بالشاهد.

من خلال النتائج لايوجد فروق معنوية بين الثلاث تراكيزات (5%،10%و15%) من مستخلص الخروع وذلك بعد 72 ساعة بعد التعرض في حالة المعاملة الموضعية، بينما اعلي تركيز(20%) من مستخلص السوريب اعطي نسبة موت عالية (90%) وكان هنالك فرق معنوي عندما تم مقارنتها مع نفس التركيز(20%) لمستخلص الخروع حيث اعطي 63.3%. اظهرت النتائج ايضا انه لايوجد فرق معنوي بين اعلي تركيز(20%) من مستخلص السوريب والمبيد القياسي (الملاثيون) في المعاملة الموضعية، بينما كان هنالك فرق معنوي بين نفس المستخلص ونفس التركيز(20%) في حالة المعاملة بطريقة التغذية.

اوضحت هذة النتائج ان طريقة المعاملة الموضعية هي الاكثر فعالية مقارنة بطريقة التغذية, وان مستخلص نبات السوريب هوالاكثر فعالية مقارنة بمستخلص نبات الخروع.

CHAPTER ONE

INTRODUCTION

Fruit flies of the family Tephritidae (Trypetidae) are the most serious insect pests of wide range of fruit and vegetable crops throughout the world. In Sudan, there is an increase in the size of the production of fruits and vegetables as a result of gaining more importance as export crops and for local consumption. However, their production is seriously affected by a number of insect pests, fruit flies are among of these major pests that cause economic damage in fruits and vegetables.

Horticultural crops represent about 12% of the national agricultural income. The estimated total fruit production in Sudan is about 1.9 million tons in a cultivated area of about 186.000 ha. Fruit production in Sudan needs very little agro-chemicals thus the fruit are relatively free of chemical residues which if certified could give a comparative edge and a comparative advantage in international markets (Bashir and Imam, 2010).

In recent years, fruit production is greatly hampered by fruit flies worldwide with a loss above 30%. Also, the loss of fruit production in many African countries was estimated between 30-80%; however it reached about 100% during outbreak years (Mohamed, 2003). In addition to causing direct losses in the yield and marketability, fruit flies pose as significant threats to quarantine security and thus to international trade in fruit and fresh vegetables worldwide (El-Aw *et al.*, 2008).

Sudan, like some other African countries was facing a large problem with fruit flies during the last few years. Nearly 40 fruit fly species were recorded in Sudan, the most serious ones are those attacking mango (*Mangifera indica*), guava (*Psidium guajava*) and Citruses. In recent years, fruit

production has been seriously hampered, mainly, because of the sudden and persistent outbreak of some fruit fly species (Ali *et al.*, 2008).

The situation is far more serious in international trade, since infestation may cause importing countries to reject an entire shipment or more worse may have to lose the market (Abbas, 2008).

Gubara and Abu Elgasim (2004) reported that, the percentage of damage due to fruit flies infestation ranged from 70 to 100% on guava in the Northern State, while in the River Nile State the damage percentage reported was 65% on guava and orange and 85-90% on mango.

In 2007, the damage due to fruit flies became so severe to the extent that they were added to the list of the notorious national pests of the Sudan (Abdelmagid *et al.*, 2012).Moreover, there is no quarantine strategy and standing recommendation for the control of fruit flies in Sudan, and insecticide spraying may not be encouraged because of the risk of fruit contamination (Mohamed and Ali, 2008).

In August 2008, a 2 days' workshop on fruit flies problem in Sudan was held in Khartoum by the National Plant Protection Directorate, in participation with Sudanese Universities, Agricultural Research Corporation and participants from ICIPE in Nairobi. Several research studies on the biology, ecology and control of fruit flies were presented in the workshop, and further research needed was highlighted.

Objectives of the present study were carried out to:

- Collection and identification of adult fruit flies occurring in the area (Elkadaroo, Elfaki Hashim, and Elkhogalab) under investigation.
- To evaluate under laboratory condition the activity of ethanolic seed extracts of coffee senna *Cassia occidentalis* and Castor *Ricinus Communis* against the adult fruit fly.

CHAPTER TWO

LITERATURE REVIEW

2.1 Asian fruit fly (*Bactrocera invadens*)

2.1.1 Taxonomic status

True fruit flies belong to Order Diptera, Family: Tephritidae (= trypetidae, According to European and early American authors, this family includes more than 4000 species assigned to 500 genera. Approximately, 250 of them are of economic importance and are associated with fruits and vegetables (Mohamed and Taha, 2008 and PHA, 2011). The identification and bionomics of harmful and beneficial fruit flies of economic importance has been monographed by White and Elson-Harries (1992). At present, there is no generally accepted higher classification of the family, but three sub families are currently recognized: Dacinae, Trypetinae and Tephritinae, each of which is divided into a number of sub tribes. Provided illustrated keys for the identification of species of economic significance, based on adult and larval characters.

Most species of Tephritidae which attack fruits belong to the genera: *Anastrepha, Ceratitis, Bactrocera, Dacus*, and *Rhagletis*. *Bactrocera* is the most economically significant genus, with about 40 species which are considered as important pests (White and Elson-Harris, 1992).

The genus *Ceratitis* belongs to sub family Dacinae, tribe ceratitidini, and sub tribe ceratitina, while the genera *Dacus* and *Bactrocera* belong to sub family Dacinae, tribe Dacini (Drew, 1989).

2.1.2 Distribution

The family Tephritidae is represented in all the continent regions but the major pest genera have a limited natural distribution (Drew, 1989).In Africa, a member of the genus *Bactrocera* was detected in 2003 at the Keny an coast (Lux *et al.,* 2003) and later described as *B. invadens* Drew, Tsuruta and White (Drew *et al.,* 2005). The pest is believed to be native to Sri Lanka (Drew *et al.*, 2008) and has rapidly expanded its geographical range, now reported from 28 African countries, including the Indian Ocean Archipelago of the Comoros (Drew, 2005; French, 2005; Vayssieres, 2005; Ekesi *et al.*, 2006; Mwatawala, *et al.*, 2006; Ekesi *et al.*, 2007; Abanda, 2008 and Rwomushana *et al.,* 2008)

The genus *Ceratitis* is endemic to the Afro tropical region and contains about 56 species considered as polyphagous (Copeland *et al.*, 2006).

Clarke *et al.*, (2005) recorded that *B. dorsalis* complex of tropical fruit flies contains 75 described species, and they are largely endemic to Southeast Asia. Within the complex, small numbers of polyphagous pests are of international significance, including *B. dorsalis, B. papayae, B. carambolae,* and *B.philippinensis.*

In Sudan, fruit flies were reported at Khartoum State by Venkatraman and Elkhidir (1965). Ali (1967), found fruit flies in the Northern region (Shendi, Hudeba), Khartoum, Kassala and the southern region (Yambio, Meridi, Yei, and Juba). Now it is wide spread in Sudan, occurring in all regions of fruits and vegetables.

Deng (1990) stated that, *Ceratitis cosyra* has been recorded in Khartoum, while Beji (1996) recorded it from Kassala. Recently it has been recorded in eastern, western and central Sudan (Ahmed, 2001; Elhewaris, 2003, and Bashir, 2007).

2.1.3 Host Range

Generally, fruit flies are polyphagous with host plants such as apple, guava, banana, date palm, orange, papaya, peach, eggplant, tomato and cucurbits (Averill, 1996).

B. invadens is an emerging polyphagous fruit fly pest, and in Africa, it has been reported to attack over 43 fruit species from 23 families with mango being one of the most preferred cultivated hosts (Ekesi, 2007, Rwomushana *et al.*, 2008, Mwatawala *et al.,* 2009 and Goergen, 2011). Direct damage to mango due to *B. invadens* has been reported to range from 30-80% depending on the cultivar, locality and season (Ekesi, 2006; Rwomushana *et al.*, 2008 and Vayssieres, 2009). In addition to the direct losses, indirect losses attributed to quarantine restrictions have been enormous. The direct and indirect damage continue to have wide reaching socio-economic implications for millions of rural and urban populations involved in the mango value chain across Africa. The pest has been described as "a devastating quarantine pest" by the Inter-African phytosanitary Council (French, 2005).

In Sudan, fruit flies were first reported by Venkatraman and Elkhidir in 1965 on egg-plant (*Solanum melongena*) and guava (*Pisidium* sp).

Ali (1967) reported that, nine species of fruit flies were found in Sudan, of which five are well known pests of economic crops in many parts in Africa. Schmutterer (1969) reported that, the family Tephritidae was considered the fourth group of insect pests causing serious damage to fruit crops in Sudan. Among the fruit flies were *Dacus* species which highly infest Cucurbitaceae and *Ceratitis* spp. Which constitute the major pests of guava, citrus (orange, tangerine, and grape fruit), mango, and egg-plant.

Siddig (1984) and Deng (1990) reported that, the fruit fly *C. Capitata* is the major pest of guava. According to Beji (1996) the main species of fruit flies

found in Kassala and Gash Delta are *Dacus* spp. (*Dacus ciliatus*, *Dacus cucurbitae* and *Dacus longistylus*) on water melon and melon, *C. capitata* and *C. cosyra* on guava and mango.

Ahmed (2001) and Elhewairs (2003) also reported *C. cosyra* as a major pest of mango in central Sudan and Blue Nile areas, while Bashir (2007) reported it in western Sudan (Abu Gobiha).

Among the fruit flies found in Sudan, *C.capitata* and *C. cosyra* are considered as devastating pests to fruit trees: mango, guava, and citrus all over the country especially at Shendi, Senga, and Sennar, beside a new species of the genus *Bactrocera* which was reported from Blue Nile areas as *B. invadens* (Drew *et al*., 2005).

2.1.4 Damage and economic importance

The damage to crops caused by fruit flies results from oviposition in fruits and soft tissues of reproductive parts of certain plants, feeding by the larvae, and decomposition of plant tissue by invading secondary microorganisms. Larval feeding in fruits is the most devastating. Mature attacked fruits may develop a water soaked appearance. Young fruits become distorted and usually drop prematurely. The larval tunnels provide entry points for bacteria and fungi that cause the fruit to rot. Maggots of other fruit flies attack young seedlings, succulent taproots, and stems and buds of host plants (Mahmoud, 2011).

According to Lux *et al*., (2003) nearly 1.9 million tons of mangoes are produced annually in Africa. About 40% of the harvest is lost due to fruit flies. Fruit infestation rates vary among countries and seasons, ranging from 5-100%. Other factors, such as the strict quarantine and the maximum residue levels set by the European Union (EU) are affecting the production and export of fresh mangoes from Africa. According to data presented during the

meetings of the FAO Inter-Governmental Sub-Group on Tropical Fruits held in Australia in 1999 and Costa Rica in 2001, mango exports are estimated at 35,000 – 40,000 t annually and worth over 42 million US $. In Sudan, mango is leading the horticultural exports. Although mango production is more than 600,000 t, only 6000 t is exported in the best cases. This is only 1% of the total production (Elgozuli, 2008).

In Sudan, fruit flies of the family Tephritidae (Trypetidae) are considered as destructive pests of a wide range of fruit and vegetable crops throughout the country.

Schmutterer (1969) reported that, the symptoms vary from host fruit to another *e.g.* the infestation appears as dark spots in citrus and as black sunken areas in the lower half of the guava fruit.

The level of infestation varied with location, ranging from 3.0 to 97.2 flies per kg of fruit. There was a significant inverse relationship between numbers of flies per kg of fruit and elevation at which fruit was collected, suggesting that *B. invadens* is a predominantly lowland pest (Ekesi *et al.*, 2006).

The level of infestation in Sudan varied with location, ranging from 26 to 207.3 flies per kg of fruit. There was a significant inverse relationship between numbers of flies per kg of fruit and elevation at which fruit was collected (Mardi, 2008).

In the River Nile State, the damage to mango and guava was estimated to range from 85% to 98%. Also, the percentage of damage due to fruit flies infestation reached 70-100% on guava in the Northern State (Gubara and Abu Elgasim, 2004).

2.1.5 Biology of the fruit flies

Adult fruit fly' females lay their eggs beneath the skin of suitable hosts, especially in physiologically mature, ripening or ripe fruits. The stages at

which eggs are laid depend on the fruit fly species and the host plant attacked. The eggs are laid singly or in a cluster. Some species such as *C. capitata*, and several *Anastrepha* and *Rhagoletis* species, have been shown to use oviposition deterrent pheromones to signal their co-specifics that the fruit has been already attacked (Averill and Prokopy, 1989). The hatching larvae shed their skins twice as they feed and grow, and the third instar larva emerges from the fruit and drops to the ground. The larvae of most fruit feeders can jump along the ground to find suitable sites for pupation. At the completion of the third instar, the larval skin hardens to form a puparium with inactive fourth-instar larvae inside (Christenson and Foote, 1960). Eventually the larva within the puparium sheds its skin, forms a pupa, from which the adult will later emerge. The emerging adults tend to crawl upward through the soil, usually at an angle. They make use of cracks and crevices that lead to the surface, especially when the soil is hard and compact (Christenson and Foote, 1960). The newly emerged adults require a carbohydrate energy source and water in order to survive. In addition, they search for a protein source for egg maturation. After mating and a pre-oviposition period, which varies with species, the female starts laying eggs, and a new cycle begins. The duration of the different stages varies with fruit fly species, host plant and climatic conditions. Tropical species in the genera *Ceratitis, Bactrocera*, *Dacus* and *Anastrepha* are multivoltine.

2.1.6 Monitoring and control of fruit flies

2.1.6.1 Monitoring

Mohamed and Ali (2008) and Mohamed and Taha (2008) mentioned that, homemade traps with methyl eugenol lure were used to attract the adult males of *B. invadens* in Sudan. Gubara *et al.,* (2009) adapted that, the para pheromone trap 95% TC (methyl eugenol 95% TC) with 3 ml of mixture of

80% methyl eugenol and 20% of malathion 57%, by volume in a cotton wick (4 cm long X 1cm diameter) was applied for controlling the adult males of *B. invadens* in Sudan.

Also, Bashir (2007) reported that, extracts of mango *M. indica*, guava *P. guajava* and Sidir, *Zizyphus spinachristi* can attract *C. cosyra*. Rosseler (1989) mentioned that, ammonium acetate, 1, 4-diaminobutane (putrescine) and tri--methylamine (FA-3) are used as long-lasting dispensers for attracting fruit flies. Males of *C. cosyra* do not respond well to Tri med-lure (TML), Cuelure or Methyl Eugenol (ME). However, they respond to Terpinyl Acetate and several terpinoids, while females respond to food baits as Nulure (Lux *et al*., 2003).

Males of *Ceratitis rosa* and *C. fasciventris* respond very well to TML where *B. invadens* is attracted to ME and respond to Nulure.

One of the most effective mechanical control methods is bagging the fruits to exclude egg laying (Hill, 1983).

2.1.6.1.1 Methyl Eugenol (ME)

The first use of specific bait attractant for males of fruit flies was (ME) for *bactrocera zonata* in 1912 (IAEA, 2003). Methyl eugenol (ME) occurs naturally in more than 450 plant species from 80 families, *e.g*. (Canellaceae (*Canella winterana* stems), Fabaceae (*Acacia farnesiana*), Lamiaceae (*Ocimum* spp.) etc…) that grows mainly in the tropics and is a fundamental nutrient of some *Bactrocera* spp. (Aluja and Norrbom, 1999; Vayssieres *et al*., 2007 and Tan and Nishida, 2012). Derw and Hooper (1981) reported more than 40 species of Tephritidae responding to ME. In addition to being a powerful fruit fly attractant, ME is commonly added to processed foods as flavoring agent (*e.g.* jellies, chewing gum, relish and ice cream, and as a fragrance in several cosmetic products).

In order to control *B. dorsalis* complex, methyl eugenol (ME), a highly potent male attractant, was extensively used with great success, especially in male annihilation programs (Steiner *et al.,* 1970). Recently, it was found that the consumption of ME enhances the mating competitiveness of males (Hee and Tan, 1998). According to Chuang and Hou (2008), the attract-and-kill system containing ME incorporated with toxicants is presently the most commonly used technology for field monitoring and fruit fly control in Taiwan. Also, Vayssieres *et al.,* (2007) mentioned that, the MAT has been used successfully in eradicating several *Bactrocera* spp. Such as the oriental fruit fly, *B. dorsalis* from Rota and Japan and the papaya fruit fly, *B. papaya*, from Australia. It is also the current method used to eradicate infestations of *Bactrocera* spp. In California and Florida. The specific method of formulating and constructing bait stations in each of these programs in individually tailored to local conditions and resources, but all consist of a mixture of ME with toxicant and a carrier matrix in which it is applied. The MAT bait stations that were used in French Guiana were made of absorbent fiberboard block. These blocks were soaked in a mixture of ME and ultra-low volume Malathion (96%) (3:1 vol/vol) and then hung by a wire in host trees throughout the area in which the population had been detected. The males attracted by the ME, consume a small portion of the mixture (although contact is sufficient) and are killed by the Malathion. Very high levels of male mortality (near 100%) are needed in MAT programs for an effective reduction in the fruit fly infestation rate, requiring a thorough distribution of the bait stations throughout the area (Vayssieres *et al.,* 2007).

2.1.6.1.2 Bait Application Technique (BAT)

Food baits based on protein solutions, fermenting sugar solutions, fruit juices and vinegar have been used since 1918 for the capture of adult fruit fly of

several species (IAEA, 2003). Worldwide, the use of protein baits mixed with insecticide, termed as the bait application technique (BAT), is one of the main methods of fruit fly control. The technique works on an attract and kill principle, whereby adult flies (in particular females) in search of food (protein) to mature sexually are attracted to the bait and are killed by an insecticide mixed with the bait, either upon contact or following ingestion of the mixture. Such poisoned bait mixtures limit the use of insecticide and at the sometime increase efficacy of control. Baits that have been found to be effective against fruit flies are hydrolysed yeast or vegetable proteins. Poisoned baits can be applied either as foliar sprays (aerial or ground) or in discrete containers known as bait stations. Bait stations are currently being used in some fruit fly management programmes. The use of bait stations further limits the release of insecticide in the environment as well as limiting residues on fruits (Mangan and Moreno, 2007 and Manrakhan and Kotze, 2009).

2.1.6.2. Control of fruit flies

2.1.6.2.1 Cultural control

The principal cultural control method used for controlling this pest is field sanitation. Field sanitation directed towards the destruction of all unmarketable and infested fruits. Infested fruits should be buried 3 feet under soil surface with addition of sufficient time to kill larvae. Harvesting of fruits weekly also reduces food sources from which large populations may develop by keeping the quantity of ripe fruit on the trees to a minimum. Other procedures that reduce the amount of in-field breeding of flies should be used (Heppner, 1985).

2.1.6.2.2 Legislative control

Quarantine laws aimed at preventing the entry and establishment of flies in areas where they do not occur have been established and are vigorously enforced. The United States (US) Government has strict laws regulating the movement of certain commodities to prevent the establishment of fruit flies into the continental US. Also, the Japanese Government restricts the entry of commodities attacked by these pests into their country (Mahmoud, 2011).

2.1.6.2.3 Biological control

Biological control is the use of natural enemies to control pests. Common natural enemies of fruit include predators, *e.g.* Ants and lizard, Opiine parasitoids and pathogens, e.g. *Metarhizium anisopliae*, *Beauvaria bassiana* and *Bacillus* spp. (Wharton, 1989 and Ekesi *et al.*, 2005). Although they can't always prevent economic damage, they are important for managing these pests. Often the effectiveness of natural enemies is adversely affected by farming practices, such as the use of broad spectrum insecticides (Ekesi *et al.*, 2005).

2.1.6.2.4 Chemical control

The chemical or the insecticidal methods of control of fruit flies fall under three main categories: spray the adults with suitable insecticides, trapping of the adult flies by means of a chemical attractant and bait spray that insecticide mixed with bait (Ali, 2007).

Steven *et al.*, (2000) found that, spinosad, a bacteria-derived toxin, and phloxine B, a red dye with phototoxic properties, can significantly control the Mediterranean fruit fly, *C. capitata* (Wiedemann) in the Hawaiian Islands. Because of their environmental safety, this approach should be considered for eradicating incipient populations of this invasive species of fruit fly. Spinosad

and phloxine B were found to be effective up to 1 week; Malathion remained effective at least for 2 weeks.

Barry *et al.,* (2004) noticed that, fipronil and imidacloprid have a potential as insecticidal coatings in either plastic or biodegradable spheres in attract- and -kill system for controlling *Rhagolestis mendax*. Adult populations of different fruit flies can be reduced with insecticidal protein-bait sprays (Steck, 2000). Bait sprays have proved useful but are more effective for suppression than eradication where cover sprays are becoming increasingly unacceptable according to World Trade Organization (WTO) and other environmental organizations regulations.

2.2 *Cassia occidentalis* L. (Coffee senna)

Cassia species (Family: Caesalpinaceae) are annual under shrub grows all over the tropical countries. Traditionally, the leaves of *Cassia* species are popular as pot herb. It is used as natural pesticide in the organic farming, and also *Cassia* species contain chrysophanic acid-9-anthrone which is an important fungicide (Singh *et al*., 2013).

The genus *Cassia* comprises more than 40 species which are economically important in the production of timber, gum, tanning, dying materials and fish poisons. In the Sudan, this genus is represented by at least 13 species (Omer *et al*., 2012).

2.2.1 Taxonomy

Family: Caesalpinaceae

Genus: Cassia

Species: occidentalis

S. N: *Cassia occidentalis* L.

C. N: Coffee senna

2.2.2 Plant description

Coffee senna is an erect somewhat branched, smooth, half woody herb or shrubby plant, about 0.8 -1.5 meters in height. The flowers are yellow about 2 cm in length and borne on auxiliary and terminal racemes. Seed pods are narrow and semi-flattened about 10 cm long, thickened and containing about 40 or more brown to dark-olive, ovoid seeds about 4 mm long. The species is distinguished by a fitted odour, absence of spines. Leaves with 3 - 7 leaflets about 2–10cm long and 0.6–4cm wide. Flowers with 10 fertile and sterile stamens, 6 or 7 fertile anthers and cylindrical seeds (Podsilva, 2003).

2.2.3 Geographical distribution

Coffee senna grows throughout the tropics and subtropics including the United States from Texas to Iowa eastward, Hawaii, the Pacific Island territories, Puerto Rico and the U.S. Virgin Islands. It appears to be of South American or New World origin (Singh *et al.*, 2013). *C. occidentalis* are most commonly found in savannah areas of Africa and is utilized for various purposes. This plant is found in many parts of the Sudan and commonly known as Soreib (Mariod and Matthäus, 2008).

2.2.4 Cultivation

Cassia occidentalis can flower and fruit throughout the year or only periodically, depending on rainfall and temperature conditions and seasons. In cold or dry climates, the life cycle of *C. occidentalis* is completed in 6 to 9 months. In warm, continually moist areas, however, plants may last a full year. Well-dried seed stored in airtight containers remain viable for more than three years. Seeds should be treated to enhance germination. The distal end of each seed should be nipped, or the seed can be immersed in concentrated sulphuric acid for 10 minutes and then rinsed with plenty of water. Seed should germinate between 5 and 36 days after sowing. *C.*

occidentalis is planted in hedges and as an ornamental, but has the potential to become a weed in farmland, and is often found in disturbed areas. It should therefore be managed carefully. The species can be controlled with broadleaf herbicides (Dharani *et al.*, 2010).

2.2.5 Chemistry

Chemical constituents isolated from *C. occidentalis* including sennoside, anthraquinone glycoside, fatty oils, flavonoid glycosides, galactomannan, polysaccharides, and tannins (Yadav et al., 2010). The stem, bark and leaf extract of *C. occidentalis* have been found to contain important phytochemicals such as anthraquinones, carbohydrates, glycosides, cardiac glycosides, steroids, flavanoids, saponins, phytosterols, gum and mucilage (Colle et al., 2003). This plant also include wide range of chemical compounds such as achrosin, aloe-emodin, emodin, anthrones, apigenin, aurantiobtusin, campesterol, cassiollin, chryso-obtusin, chrysophanic acid, chrysarobin, chrysophanol and chrysoeriol (Dave and Ledwani, 2012). Terpenoids, flavonoids and anthraquinone derivatives have been detected in active fractions obtained from the leaf extract. Also in a separate investigation, new C-glycosidic flavonoids (*C. occidentalins* A, B and C) were isolated from this plant (Dharani et al., 2010).

2.2.6 Medicinal uses

Cassia occidentalis leaves are used for the treatment of yaws, scabies, itches and ringworm among the Yoruba tribe of southwestern Nigeria. In addition to this, the leaves are also known to be effective against jaundice, headache and toothache. Infusion of *C. occidentalis* leaves is used as an effective treatment for hepatitis among the rural dwellers in northern part of Nigeria (Taiwo *et al*., 2013). Also *C. occidentalis* leaves have ethno medical importance like wound healing, treatment of sores, cutaneous diseases, bone fracture, fever,

and throat infection , it also used as a diuretic and in the treatment of snake-bite (Yadava and Satnami, 2011).

2.2.7 Uses in pest control

The leaves of this plant are used for various disease treatments as well as in the control of some stored product insects especially in many parts of Africa (Abdullahi, 2011). In Senegal, the leaves of *C.occidentalis* are used to protect cowpea seeds against *Callosobruchus maculatus*. Both fresh and dry leaves as well as whole and ground seeds had no contact toxicity on the cowpea beetle, in contrast, seeds oil induced an increase in mortality of *C. maculatus* eggs and first larval instars at the concentration of 10 ml/kg cowpea (Lienard, *et al.*, 1993). In addition, coffee senna has been used to reduce the number of mosquitoes indoors at night (Paisson and Jaenson, 1999) and for the control of a large variety of insects (Dweivedi and Kumar, 1998)

2.2.8 Other uses

Coffee senna is used as a flowering shrub for landscape purposes. It is also used as a coffee substitute, where it has some medicinal uses as seeds are brewed into the coffee-like beverage which is used for asthma (Nassar *et al.*, 2011).The leaves are widely used as a leaf vegetable and are eaten either raw or mixed with coconut, chilli, and onion (Nassar *et al.*, 2013). The gum derived from seed endosperm can be potentially utilized in a number of industries to replace the conventional gum (Gupta *et al.*, 2005).

2.2.9 Animal toxicity

Several animal studies have demonstrated the toxicity of the fresh and / or dried / roasted beans (seeds). Ingestion of large amounts of the seed pods by grazing animals has caused serious illness and death. Cattle, sheep, goats, horses, pigs, rabbits, and chickens have been shown to be susceptible to poisoning by *Cassia* spp. (Rowe *et al.*, 1987). Also all parts of the plant are

toxic, most poisoning occurs when animals eat the pods and beans, or fed green chop containing *Cassia* plants. The toxic effects are seen on skeletal muscles, liver, kidney and heart in animals. One interesting attribute of *C. occidentalis* poisoning in animals is its propensity to cause different manifestations of toxicity in different animal species. However, the physiologic systems involved in toxicity depend also upon the dose of the beans consumed. When the dose is low the animal develops features of mild liver damage and myodegeneration and at higher doses hepatic degeneration may be rapidly fatal before myodegeneration has time to develop (Vashishta *et al*., 2009).

2.3 *Ricinus communis* L. (Castor)

Castor plant, *R. communis* L. is a species of flowering plants in the spurge family; Euphorbiaceae, which contains a vast number of plants mostly native to the tropics (Moshkin, 1986). It belongs to a monotypic genus *Ricinus*. The name *Ricinus* is a latin word for tick. The plant is named probably because its seed has markings and a dump at the end that resemble certain tick (Weiss, 2000). While castor is mostly agreed to be a native to Africa, by cultivation it has been distributed through not only all tropical and subtropical regions, but also in many of the temperate countries of the globe. Castor plant varies greatly in its growth and appearance. It varies in growth habit, colour of foliage, stems, seed size and colour and oil content, so that varieties often bear little resemblance to one another. Castor may be large perennials often developing into small trees, others behave as short-lived dwarf annuals and every gradation between these extremes can be found. The tree and short-internodes types are commonly referred to as giant and dwarf castor types, respectively (Weiss, 1983). However, castor grows at an amazingly fast rate, if they are situated in full sun and provided with ample fertilizer and water.

2.3.1 Taxonomy

Family: Euphorbiaceae

Genus: *Ricinus* L.

S.N: *Ricinus communis*

C.N: Castor

2.3.2 Description of Castor Seed

The capsule contains three seeds which may be elongated, oval or square in shape. The seed has a tiny and brittle testa (seed coat) enclosing a white kernel. The seeds may be coloured white, dark brownish-red, brown, dark Chocolate, red or black but usually several colours occur as very attractive mottle on the testa. The seed vary greatly in size, from a few millimeters to nearly 250mm long and in breadth from 5 to 16mm. 100 seeds varies in weight from 9 to 100g (Salihu, 2013a). The variation is not only among varieties but from different racemes. In general, the seed weight increases as the total number of seeds produced per plant decreases (Salihu, 2013b).

In some varieties, castor seeds may have a dormancy period of several months while freshly harvested seeds of some can germinate without special treatment. However, large seeded castors often germinate earlier compared with tiny seed (NCRI, 2014). The dormancy in some castor can be broken by soaking for 24hrs in water or removing the caruncle and pierce the testa at the site. Germination is epigeal with the cotyledons coming out above the soil and expands as green leaves.

2.3.3 Economic importance

Castor is an important oilseed crop with great utilitarian value in industry, pharmaceutical and agricultural sectors. The seeds contain between 40% and 60% oil. Its oil is unique among vegetable oils because the oil is the only commercial source of a hydroxylated fatty acid. The presence of hydroxyl

groups and double bonds in the ricinoleic acid imparts unique chemical and physical properties on castor oil that makes the oil a vital industrial raw material. In the last couple of years, demand for castor oil has kept increasing in the international market, assured by more than 700 uses, ranging from medicine and cosmetics to biodiesel, plastics and lubricants. The oil has advantages over petroleum base oils, especially at high and low temperatures because of its high boiling and low melting points (Ogunniyi, 2006 and Mutlu, 2010). Besides reducing greenhouse gases because of its high oil content, it produces relatively high crop yield with relatively low input. In the eastern part of Nigeria, the castor seeds are used to prepare a fermented food condiment called OGIRI (NCRI, 2013).

2.3.4 Castor oil in medicine and cosmetics

Castor oil is one of natural products that fight several ailments. It contains active ingredients that make it take central position in production of several medicinal and cosmetic products (Bolaji, 2014).Castor oil is very effective when it comes to treatment of skin problems like sunburn, acne, ringworm, wrinkles and fine Lines dry skin and stretch marks. It also prevents infections like warts, boils, athlete's foot and chronic itching. The oil is good skin moisturizer and disinfectant of wound. Castor oil is mixed with coconut or almond oil to initiate hair growth, thicken of eyebrows and eyelashes. The oil boosts blood circulation to the follicles, leading to faster hair growth. The oil also has omega-6 essential fatty acids, responsible for healthy hair. The oil is also used for correction of bald patches and hair darkening.

2.8.5 Other uses of castor

Castor meal and husk for animal feed: Detoxified castor meal can be used as feed (ICOA, 1989). Castor meal detoxified by boiling could be added up to 100gkg-1 in broiler finishin; 2g diets without deleterious effects (Ani, 2009).

Castor meal detoxified by autoclaving can replace up to 67% of the soybean meal in sheep rations (Pompeu, 2009). The husk is a low value by-product that can be used as roughage for ruminants. A sample castor husks containing a considerable amount of seed fragment (60g kg-1) was evaluated for feeding dairy goat. When hay was completely replaced by castor husks, there was reduction (27%) in milk but increase (28%) in lipid concentration. The husks were not subjected to any detoxification process and no symptom of toxicity was observed (Refaat, 2009). Castor meal as an organic fertilizer: The use of castor meal as organic fertilizer is very advantageous because of high N content, fast mineralization, and anti-nematode effects. The mineralization castor meal was evaluated to be 7 times faster than bovine manure and 15 times faster than bagasse of sugarcane. Castor meal has been reported to promote the growth in wheat and castor plants (Gupta, *et al.*, 2010 and Lima, 2011). Castor husks can also be used as organic fertilizer but must be blend with an N-rich organic material to provide a better nutrient balance for plant growth (Lima, 2006 and Lima *et al.*, 2011).

CHAPTER THREE

MATRIALS AND METHODS

3.1 The Study Area

This study was carried out at different Guava Orchards at " Elkadaroo , Elfaki Hashim and Elkhogalab areas", in Khartoum North Locality, Khartoum State (Figure, 1).

3.2 Survey and Monitoring of fruit flies

This survey was carried during the period from January to April 2015 in a number of Guava Orchards, to identify the fruit flies in the study area. In each selected orchad, two types of traps were used, a bait trap and a pheromone trap.

The bait trap: was locally made of cylindrical plastic container with one hole; the trap was baited with guava juice (Plate, 1).

The pheromone trap: was also locally made of square plastic container with four holes. The trap was baited with: four parts of Methyl Eugenol (ME) as attractant for fruit flies, and one part of Malathion as a poison of fruit fly (Plate, 2).

The traps were hung at a height of 2 meters above ground in strong branches in Guava trees. Distances of 50 meters were determined between each 2 traps. The traps were inspected weekly, and the caught flies were collected using a hairbrush. At the same time, the bait was replaced each week with newly mixed solution. Data were recorded weekly.

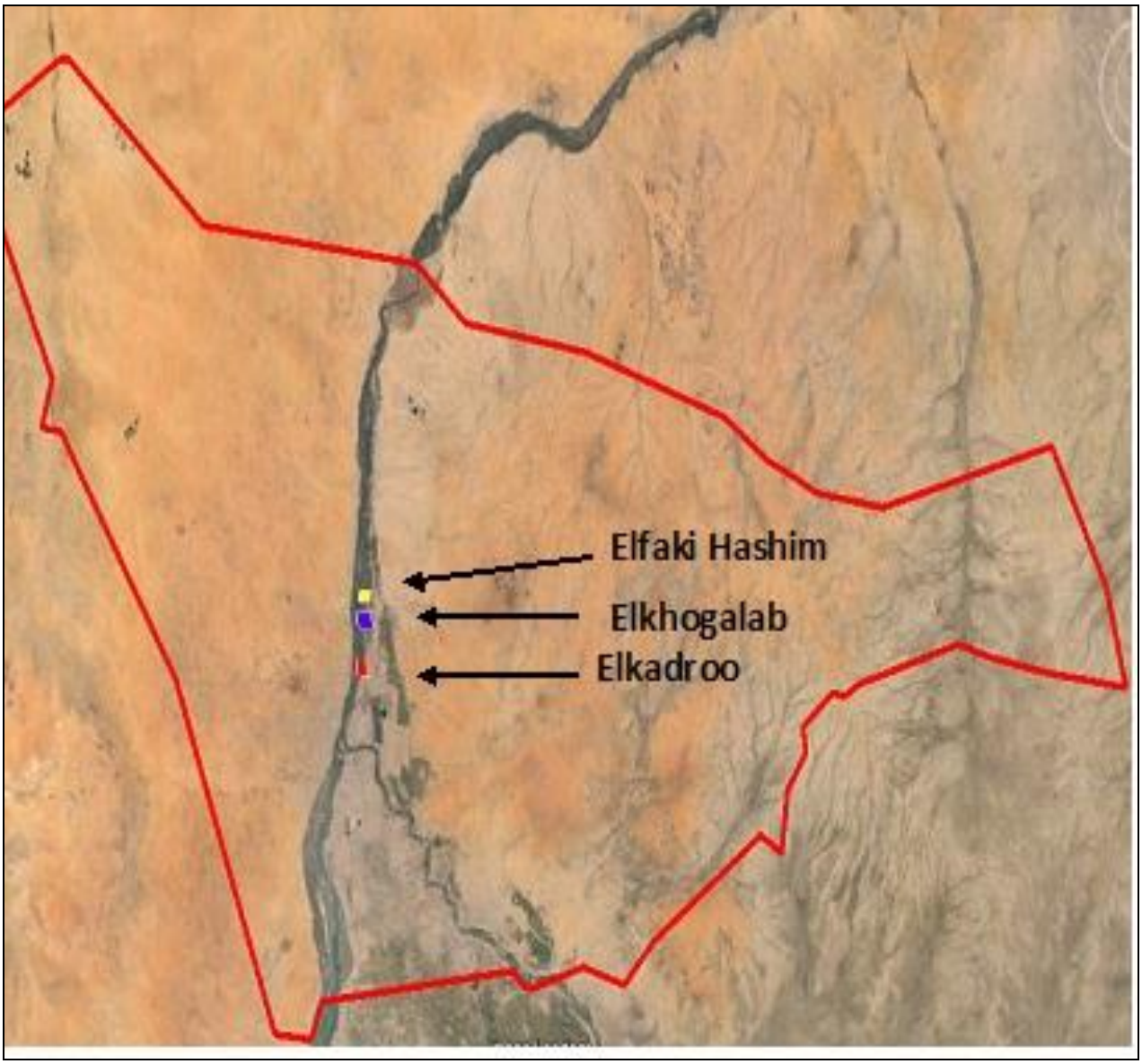


Figure 1. The Study area in Khartoum North locality, Khartoum State.

Plate 1. The bait trap

Plate 2. The pheromone trap

3.3 Laboratory experiments

These experiments were conducted at the Entomology Laboratory, Department of Plant Protection, Faculty of Agricultural Studies- Shambat. The experiments were made to test the efficacy of the ethanolic seeds' extracts of two plants: *Cassia occidentalis* L. (Plates, 3 & 4) and *Ricinus communis* L. (Plates. 5 & 6), against the adult fruit fly *B. invadens*.

Plate 3. ***Cassia occidentalis***

Plate 4. ***Cassia occidentalis*** **(Seeds)**

Plate 5. ***Ricinus commuins***

Plate 6. ***Ricinus commuins*** **(Seeds)**

3.4 The equipments and materials used in this study

3.4.1 Equipments

1. Plastic cages
2. Sensitive balance
3. Hand sprayer
4. Refrigerator
5. Sokhlet extractor apparatus
6. Rotary evaporator
7. Camera
8. Petri-dishes
9. Brush
10. Marker pen
11. Gloves
12. Pipette and micropipette
13. Registration form

3.4.2 Materials

1. Coffee senna seeds
2. Castor seeds
3. Sand
4. Malathion 57%
5. Ethanol 99.7%
6. Distillied water
7. UHU (Sticker)
8. Muslin cloths and Cotton
9. Soap
10. Beakers
12. Cylinder

Plate 7. The equipments used in this study

3.5 Rearing of fruit flies

The culture of the fruit fly *B. invadens* used in the present experiments was obtained from infested fruits (Plate, 8), collected from El Kadaroo area. Collected fruits were brought to the laboratory in plastic containers (25 ×18 × 18 cm) screened with light cloth netting for ventilation, and provided with moistened sand layer for larval pupation. After pupation, the emerging adults of fruit flies were maintained in rearing cages (25 × 18× 18 cm) (Plate, 9) and provided with a mixture of Yeast and sugar (3:1) under laboratory conditions, at 29^{o}± 1 C and 41± 5% relatitve humidity.

3.6 The plant materials

3.6.1 Collection and preparation of the plant materials

The seeds of Coffee senna (*C. occidentalis*) and Castor (*R. communis*) were collected from Shambat area. Both plant materials were brought to the Entomology Laboratory where they were washed and shade- dried. After complete dryness, the plant samples were crushed by a mortar and pestle, to prepare the powders for the extraction processes.

3.6.2 Extraction Procedure

Extraction processes were conducted at the Chemistry Laboratory, College of Agricultural Studies – Shambat. 60 grams of each of the previously prepared powders of Coffee senna and Castor seeds were divided equally into 3 parts. Each part was placed separately in a thimble and placed in an extraction chamber of a Soxhlet extractor apparatus (Plate, 10), and then extracted with 500 ml of Ethanol (99.7%) for each sample. The extraction continued for 6 hours, and the Ethanol solvent was removed off the crude extract by Rotary Evaporator (Plate, 11). The obtained crude materials for the two plants were weighed and carefully stored for the experiments.

Plate 8. Infested guava fruits

Plate 9. Rearing plastic containers

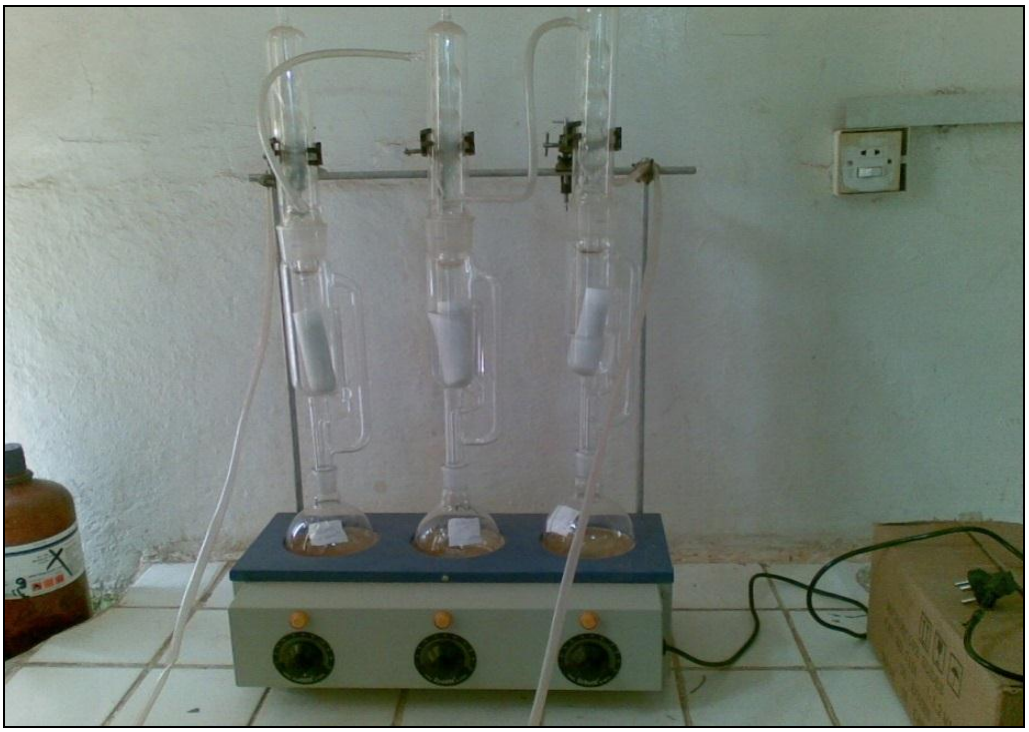


Plate 10. Soxhlet extractor apparatus

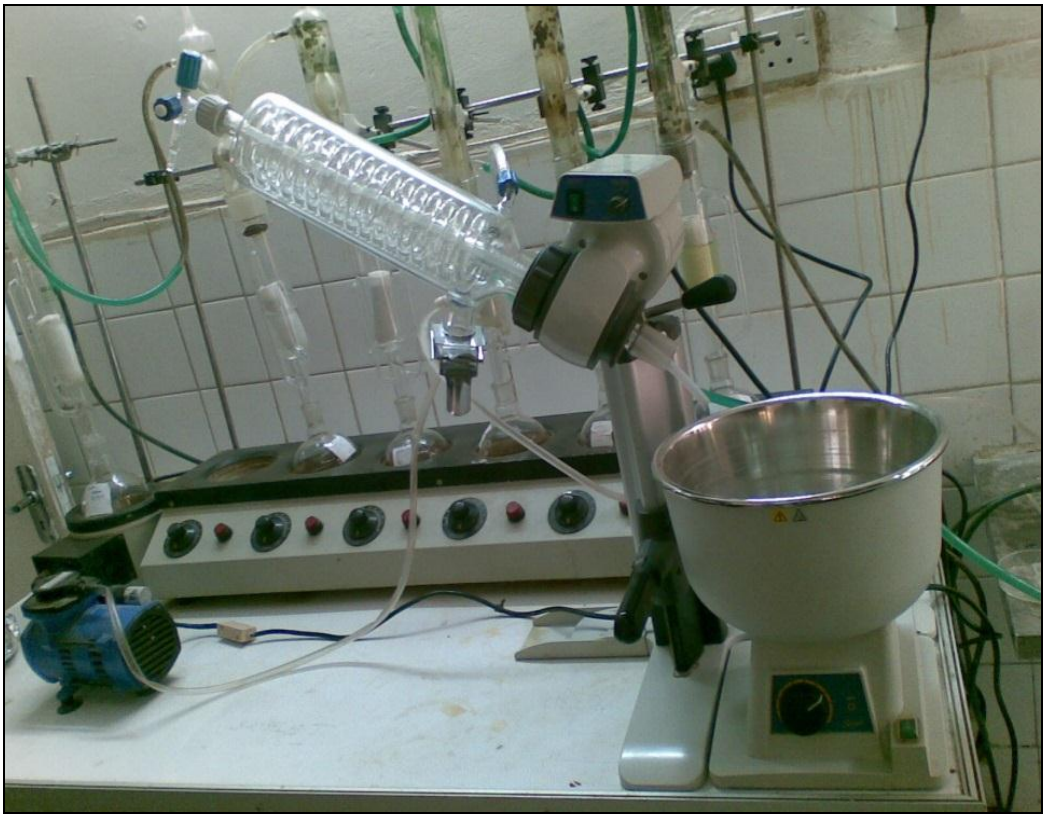


Plate 11. Soxhlet and rotary evaporator

3.6 Bioassay tests

The stock solutions from the ethanol extracts of Coffee senna and Castor seeds were prepared. Based on preliminary tests, the concentrations to be tested were determined as follows: 5%, 10%, 15% and 20%.

3.6.1 Topical application

In the application of this experiment, the method of Wright (1971) was applied according to the modifications of Sukontason *et al.*, (2004), and Mansour *et al.*, (2012) and according to the method of Bachrouch and Benjemaa, (2012), with modification. The adult fruit flies of *B. invadens* used in this experiment were placed in a refrigerator for two minutes before treatments, to make them inactive and easily handled during the treatment. A micropipette was used to apply 1$^{\mu}$L of the desired concentration on the mesothorax surface of the adult. Thirty adults were; used with each of the 4 concentrations of each plant extracts. Each treatment was replicated 3 times.

Also, 30 adults were treated with the Malathion 57% E.C. as a standard. In addition, 30 adults were used as control. In control treatment, 1$^{\mu}$L of distilled water was topically applied to the dorsal mesothorax of each adult of the control. All treated adults were kept in the plastic cages during treatment period, and fed with a mixture of sugar and yeast at a ratio of 3:1. A small piece of cotton was soaked with water and placed in a Petri-dish, inside the cages, as a source of water supply for the flies. Adults mortality counts were recorded after 24, 48 and 72 hours after application.

3.6.2 Feeding application

In this experiment feeding method according to Adam (2013) was followed. Adults of the fruit fly *B. invadens* were also used in this experiment. Five pairs of the fruit fly adults (5 males and 5 females) were selected and used in this test. 15ml of each concentration of both Coffee senna and Castor seeds

ethanolic extracts were mixed with 60ml of Guava juice. A small piece of cotton was soaked in 20 ml of the mixture of each concentration, and placed in a Petri-dish as feeding media for the adult flies. In addition other piece of cotton was soaked in water only was placed in a Petri-dishes as water supply for the flies. The petri dishes were placed inside the cages containing 5pairs of adult flies. Additionally 5 pairs of fruit fly adults were used as control, in which guava juice was only used. Each treatment was replicated three times. Mortality count was recorded after 24, 48 and 72 hours of exposure.

3.7 Statistical analysis

The obtained data were statistically analyzed according to analysis of variance (ANOVA) using Mstatc program and Duncan Multiple Range Test was used for means separation.

CHAPTER FOUR

RESULTS

4.1 Survey and Identification of fruit fly species in the Study area

The results of the survey and identification indicated that, only two species of fruit flies were found in the 3 locations in the study area, Elkadaroo, Elfaki Hashim and Elkhogalab. The species found were, the Asian fruit fly, *B. invadens*, (Plate, 12 & 13), and the Mediterranean fruit fly, *C. capitata*, (Plate,14). The numbers of each species caught in the 2 types of traps in each area are shown in Tables (1-3), and in figures (2-4). According to the results shown in tables (1-3) and figures (2-4), there was a significant difference between the numbers of *B. invadens* (1,333) and that of the other species *C. capitata* (124) caught in the bait traps. Also, there was a significant difference between the numbers of *B. invadens* caught in the pheromone traps (20,630) and those in the bait traps (1,333).

Plate 12. The Asian fruit fly *Bacterocera invadens* (male)

Plate 13. The Asian fruit fly *Bacterocera invadens* (female)

Plate 14.The Mediterranean fruit fly *Ceratitis capitata*

Table 1. Numbers and species of fruit flies caught in each trap throughout experimental period (Elkadaroo area).

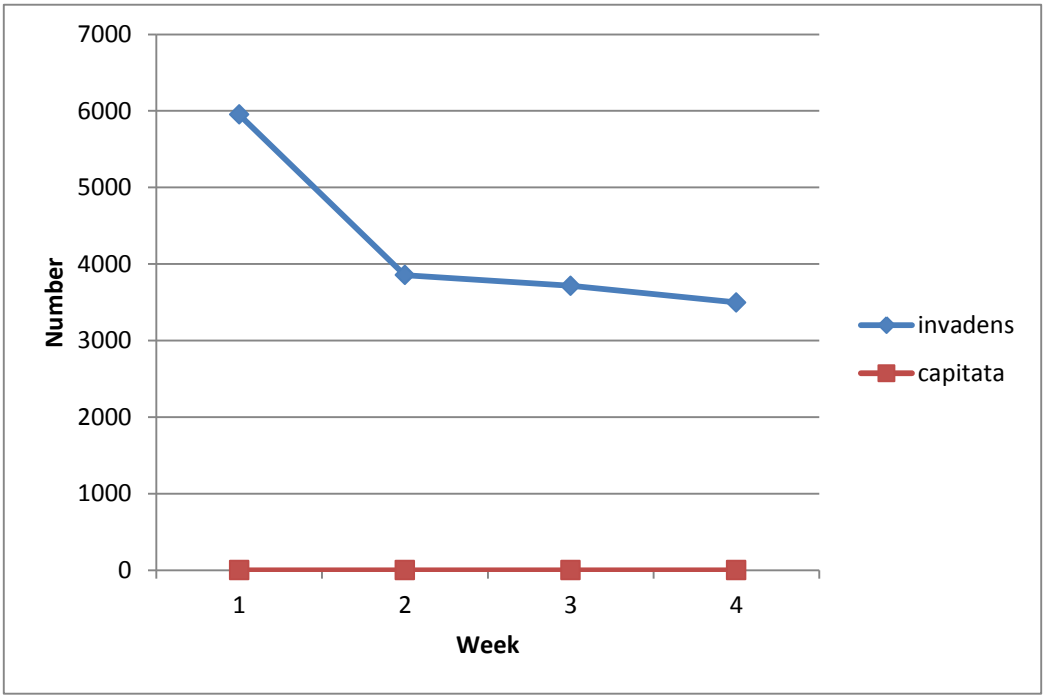
Week	Bait trap		Pheromone trap
	B. invadans	*C. capitata*	*B. invadans*
1	338	55	5952
2	273	16	3854
3	280	15	3714
4	179	11	3497
Total	1,070	97	17,017

Table 2. Numbers and species of fruit flies caught in each trap throughout the experimental period (Elfaki Hashim area)

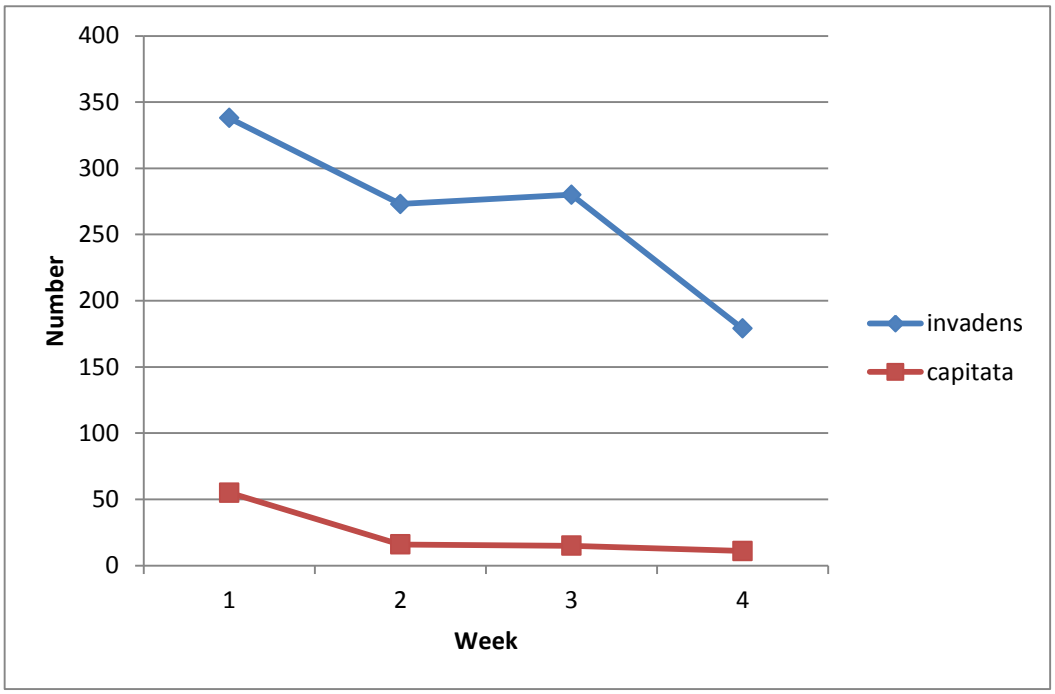
Week	Bait trap		Pheromone trap
	B. invadans	*C. capitata*	*B. invadans*
1	169	12	364
2	41	1	340
3	8	1	305
4	30	2	245
Total	248	16	1,254

Table 3. Numbers and species of fruit flies caught in each trap throughout experimental period (Elkhogalab area)

Week	Bait trap		Pheromone trap
	B. invadans	*C. capitata*	*B. invadans*
1	9	0	750
2	0	9	577
3	3	0	555
4	3	2	477
Total	15	11	2,359

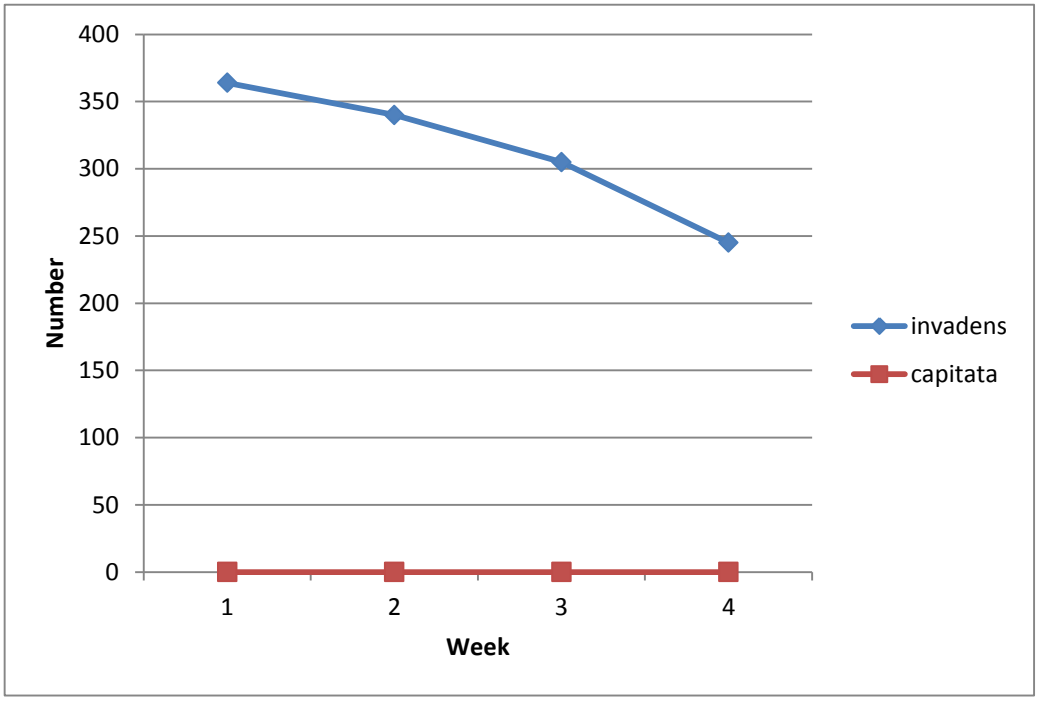


A. Pheromone trap

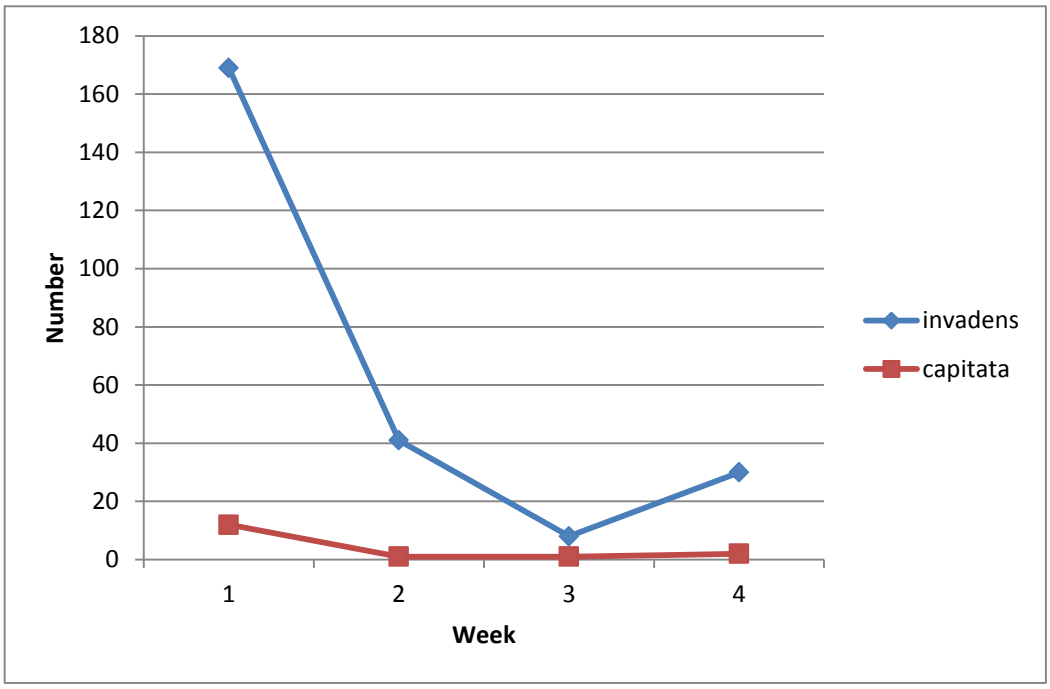


B. Bait trap

Figure 2. Numbers and species of fruit flies caught in each trap throughout experimental period (Elkadaroo area)

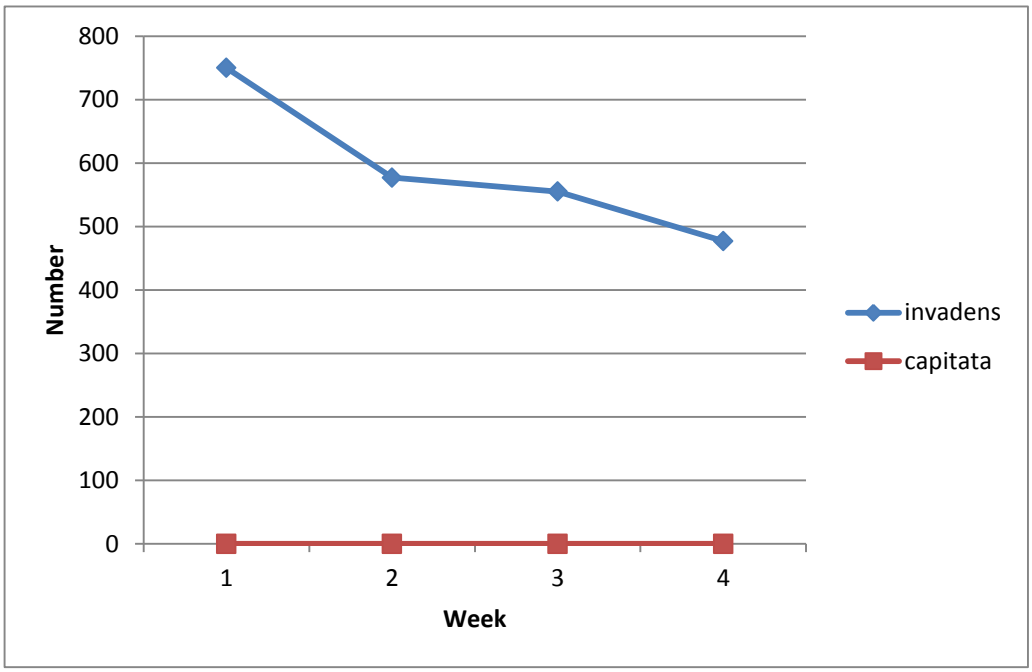


A. Pheromone trap

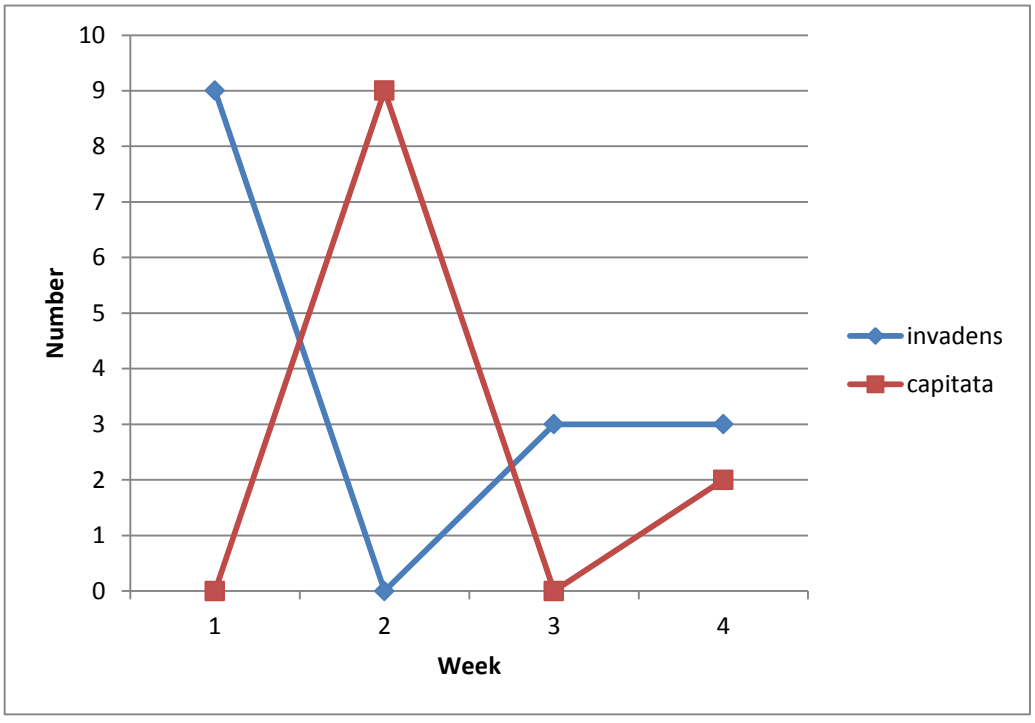


B. Bait trap

Figure 3. Numbers and species of fruit flies caught in each trap throughout the experimental period (Elfaki Hashim area)



A. Pheromone trap



B. Bait trap

Figure 4. Numbers and species of fruit flies caught in each trap throughout experimental period (Elkhogalab area)

4.2 Laboratory experiments

4.2.1 Effect of Coffee senna and Castor ethanolic seed extracts on mortality rate of the adults of the fruit fly *B. invadens* by topical application method after 24 hrs.

As seen in the table (4) and figure (5), all concentrations of the ethanolic seed extracts of Coffee senna and Castor gave significantly higher mortality percentage of the adult fruit flies than the control after 24hrs of exposure by using topical application. Additionally, all the increments in the concentrations of extracts were accompanied with an increase in mortality percentage. The mortality caused by the two highest concentrations of Coffee senna used in this study (15% and 20%) gave significant mortality percentage than other tested concentrations after 24hrs of exposure.

4.2.2 Effects of Coffee senna and Castor ethanolic seed extracts on mortality rate of the adults of the fruit fly *B. invadens* by using topical method after 48 hrs.

The results exhibited in the table (4) and figure (5) showed that all concentrations of the ethanolic seed extracts of Coffee senna and Castor gave significantly higher mortality percentage of the tested adult fruit flies than the control after 48 hrs of exposure by using topical application.

The highest concentrations of Coffee senna ethanol extract (20%) showed significant difference than all tested concentrations of Castor seeds ethanol extract after 48hrs of exposure. The mortality results obtained by concentration (10%) of Coffee senna gave similarly the mortality percentage (56.6%) scored by the highest concentration (20%) of Castor.

4.2.3 Effects of Coffee senna) and Castor ethanolic seed extracts on mortality rate of the adults of the fruit fly *B. invadens* by using topical method after 72 hrs.

As seen in the table (4) and Figure (5), all the concentrations of the ethanolic seed extracsts of Coffee senna and Castor gave significantly higher mortality percentage of the tested adult fruit flies than the control after 72 hrs of exposure by using Topical application. It can also be noted that, all the increments in the concentrations of the extracts resulted in an increase in mortality percentage. The highest concentrations (20%) of Coffee senna seeds extract gave (90%) and showed significant difference when compared with the same highest concentrations (20%) of Castor seeds extract which gave only (63.3%) after 72hrs after exposure.

It can also be noted that no significant difference between the highest concentration (20%) of Coffee senna seeds extract and standard insecticides (Malathion), while there are a significant difference between the same concentrations of Castor seeds extract.

Table 4. Means of mortality (%) among the adults of fruit fly *B. invadens* treated with Coffee senna and Castor ethanolic seed extracts by using topical application methods

Plant / Concentration		Time after exposure (hrs)		
		24	**48**	**72**
Coffee senna	5%	33.3 (5.8) d	43.3(6.5) de	46.6(6.8) de
	10%	40 (6.3) cd	56.6(7.5) cd	63.3 (7.9) bc
	15%	60 (7.7) b	66.6(8.1) bc	73.3(8.5) b
	20%	66.6(8.1) b	80(8.9) b	90(9.4) a
Castor	5%	16.6 (4.1) e	30 (5.4) f	40(6.3) e
	10%	30(5.4) d	36.6(6.0) ef	46.6(6.8) de
	15%	40(6.3) cd	46.6(6.8) de	56.6(7.5) cd
	20%	50(7.1) bc	56.6(7.5) cd	63.3(7.9) bc
Malathion		100 (10) a	100 (10) a	100(10) a
Control		0 (0.7) f	0(0.7) g	0 (0.7) f
SE±		0.39	0.31	0.25
C.V%		11 %	8%	6%
LSD		1.15	0.90	0.73

- Means followed by the same letter (s) are not significantly different at (P<0.05).

- Means between brackets are transformed according to $\sqrt{X + 0.5}$

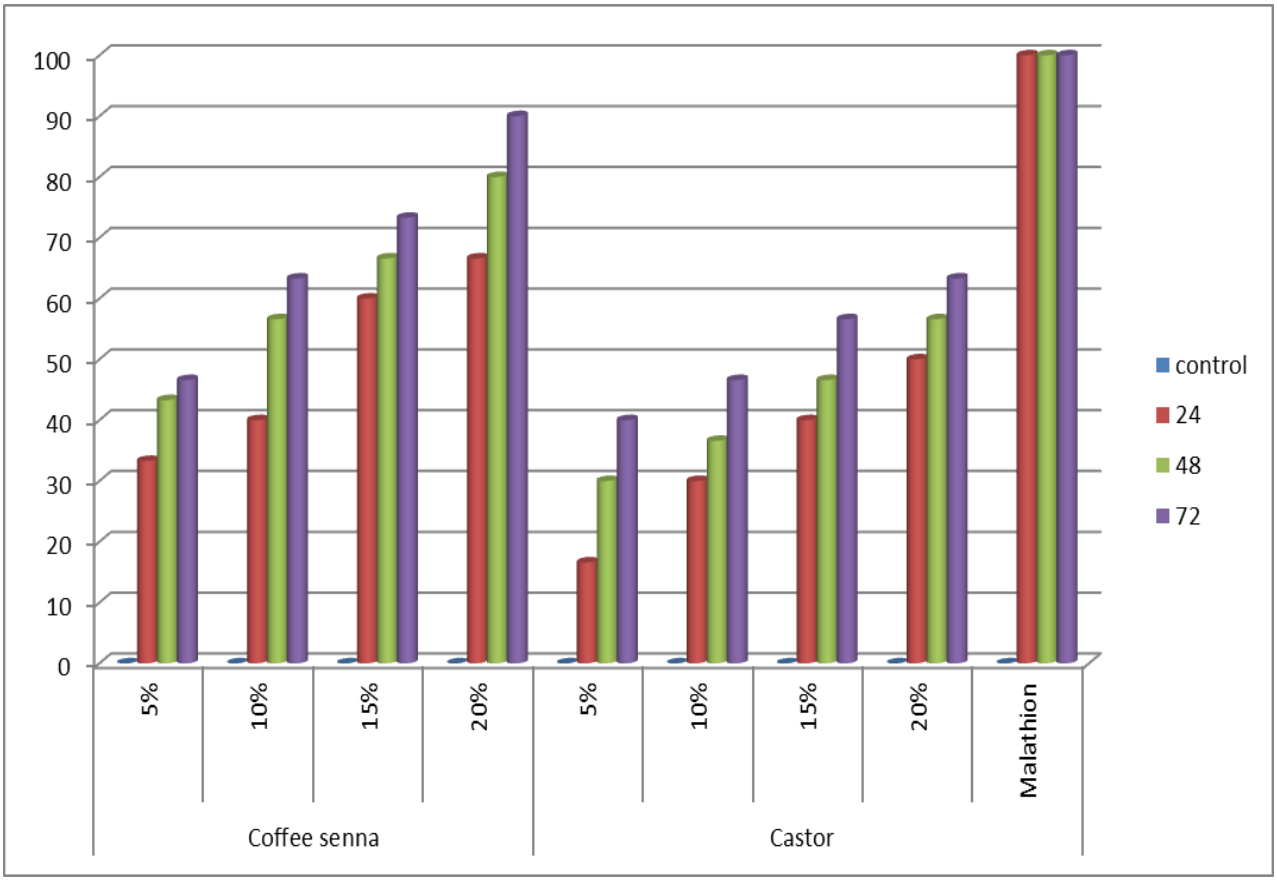


Figure 5. Effects of Coffee senna and Castor ethanolic seed extracts on mortality rate of the adults of the fruit fly *B. invadens* by using topical method after 24, 48 and 72 hrs.

4.2.4 Effects of Coffee senna and Castor ethanolic seed extracts on mortality rate of the adults of the fruit fly *B. invadens* by using feeding application method after 24 hrs.

The data presented in Table (5) and Figure (6) revealed that, each concentration of the ethanolic seed extracts of Coffee senna and Castor gave significantly higher mortality percentage after 24 hrs of exposure than the control. From the results we observed that there is no significant difference between highest concentrations of two plant extracts, but significant difference was reported between the highest concentrations and lowest concentrations in both tested plant extracts. The standard insecticide caused a significant mortality when compared with all concentrations after 24hrs.

4.2.5 Effects of Coffee senna and Castor ethanolic seed extracts on mortality rate of the adults of the fruit fly *B. invadens* by using feeding application method after 48 hrs

Results exhibited in Table (5) and Figure (6) showed that each concentration of the ethanolic seed extracts of Coffee senna and Castor showed significantly higher mortality percentage of the tested adult fruit flies (*B. invadens*) than the control after 48 hrs. The highest concentrations of the two plant extracts caused a significant mortality than the lower concentrations, and also there is a significant between standard insecticides (Malathion) and all tested concentrations.

4.2.6 The Effect of coffee senna and Castor ethanolic seed extract on mortality rate of fruit fly *B. invadens* by using feeding application method after 72 hrs.

As seen in the table (5) and Figure (6), all the concentrations of the ethanolic seed extracts of Coffee senna and Castor gave significantly higher mortality percentage of the tested adult fruit flies (*B. invadens*) than the control after 72 hrs of exposure by feeding methods.

The highest concentrations (20%) of the both plant extracts showed a significant mortality % than the lower concentrations after 72 hrs of exposure. The standard insecticide caused a significant mortality when compared with all tested concentrations.

Table 5. Means of mortality (%) among the adults of fruit fly B. invadens treated with Coffee senna and Castor ethanolic seed extracts by using feeding methods.

Plant / Concentration		Time after exposure (hrs)		
		24	**48**	**72**
Coffee senna	5%	20(4.4) cde	30(5.4) de	43.3(6.5) de
	10%	23.3 (4.8) cd	36.6 (6.0) cd	46.6 (6.8) cd
	15%	30 (5.5) bcd	50 (7.1) bc	56.6 (7.5) bc
	20%	43.3(6.5) b	60 (7.7) b	66.6 (8.1) b
Castor	5%	10 (3.2) e	20 (4.5) e	33.3 (6.6) e
	10%	16.6(4.0) de	26.6 (5.1) de	43.3 (6.6) de
	15%	36.6(6.0) bc	46.6 (6.8) bc	50 (7.1) cd
	20%	36.6(6.0) bc	53.3 (7.5) bc	56.6 (7.6) bc
Malathion		100 (10) a	100 (10) a	100(10) a
Control		0 (0.7) f	0(0.7) f	0 (0.7) f
SE±		0.52	0.41	0.30
C.V%		18%	12%	8%
LSD		1.52	1.21	0.89

- Means followed by the same letter (s) are not significantly different at (P<0.05).

- Means between brackets are transformed according to $\sqrt{X + 0.5}$

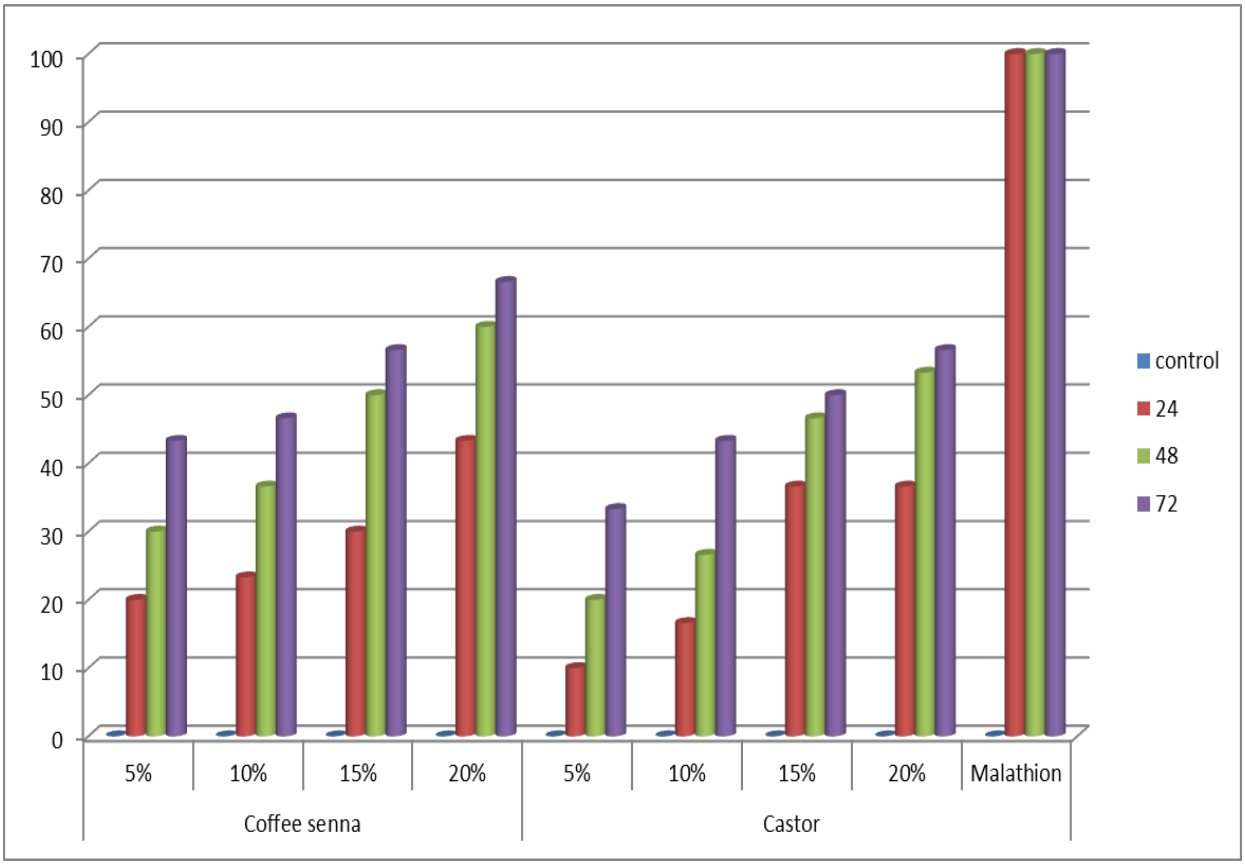


Figure 6. Effects of Coffee senna and Castor ethanolic seed extracts on mortality rate of the adults of the fruit fly *B. invadens* by using feeding method after 24, 48 and 72 hrs.

CHAPTER FIVE

DISCUSSION

Monitoring of fruit flies during January to April 2015 by using male pheromone and food bait attractants at guava orchards in the study area proved the presence of two species of fruit flies, *B. invadens*, and *C. capitata*. During this study, *B. invadens* was found to be the dominant species (99.4%) in the study area. The Asian fruit fly, *B. invadens* frequently shared the same fruit with the indigenous fruit fly species, but often occurred at higher numbers. Although it was recorded and identified in Sudan in the very recent years (Drew *et al.*, 2005), it seems that this species is spreading fast and replacing the already existed species. The present results illustrate the phenomena of displacement of fruit flies to each other as a result of competition. This finding was supported by Ali (1967) who reported that, *C.capitata* completely displaced *C. quinaria*. Then, *C. capitata* was replaced by *C. cosyra* which became the main dominant pest in many parts of the Sudan (Ahmed, 2001; Elhewaris, 2003; Bashir, 2007). In Kenya, Ekesi *et al.*, (2008) stated that, within 4 years of invasion, *B. invadens* displaced *C. cosyra* and has become the pre-dominant fruit fly pest of mango. Drew *et al.*, (2007) and Correia *et al.*, (2008) also reported that, mangoes were readily attacked by *B. invadens* and that it was competing strongly with *C. cosyra*. These results are also supported by the finding of Drew *et al.*, (2005) who reported that the Asian fruit flies, *Bactrocera* spp., are polyphagous and encounter interspecific competition with other polyphagous Tephritid flies that are already well established. The Mediterranean fruit fly, *C. capitata* has become more restricted in the horticultural areas (Safaan, 2005 and Safaan *et al.*, 2006). Mohamed (2004). Stated that *Bacterocera* species were found to be

the dominant species emerged from fruits infested with both fruit flies species, irrespective of which insect infested the fruit first. Duyck *et.al*, (2004 & 2007) reported that, the Asian fruit fly, *Bactrocera* sp. was able to displace *Ceratitis* flies, as observed in recent invasions.

The present results proved that, the pheromone trap (Methyl Eugenol), was significantly more effective in attraction of the male of *B. invadens*, while the Food bait attractants attract both males and females of the two species of fruit flies found in the study area. The number of attracted females of the two species was higher than males. This result can be attributed to the potency of Nulure to attract female more than male because it contains protein hydrolysate which is highly required by females for egg laying. Ali (2007) and Abdalla (2007) detected *B. invadens* in traps baited with Methyl Eugenol in many parts of the Sudan. Mohammed and Ali (2008) proved that, the para pheromone can be used for monitoring purposes and in management of the fruit flies.

Synthetic agrochemicals are responsible for ecological imbalance, food chain disruption, stream water contamination, resulting into human and animal toxicity and traces in agricultural products, even in breast milk. These agrochemicals also have pre-application hazards such as pollution process, occupational hazard and handling exposure. The exaggerated perception of such hazards has forced researchers to find comparatively safer alternatives for these chemicals.

Many plant extracts or products have proven to be as potent as many conventional synthetic pesticides and are effective at very low concentrations. On the other hand, botanical insecticides posses great advantages over synthetic pesticides in being more environmentally friendly

and accepted by the majority of farmers, governmental organizations and decision makers (Kelany, 2001).

This study also aimed to evaluate the effect of seeds ethanolic extracts of Coffee senna, *C. occidentalis*, and castor, *R. Communis* against the adult fruit fly *B. invadens.*

Concerning trials of topical application methods of biopesticides and insecticides were made previously by many workers against different stages of pests of agricultural and of medical importance (e.g. Sukontason *et al.*, (2004); Bachrouch and Benjemaa, (2012); Mansour *et al.*, (2012) and Isman and Seffrin (2014). Results of topical application in this study showed high efficiency of the plant extracts against the adult fruit fly, with up to 90% mortality. In addition the feeding testes against the adult fruit flies also showed efficiency of the extracts against adult flies, with up to 60% mortality

The results showed that, the ethanolic extracts of these plants mostly contain active compounds which are capable of controlling fruit flies. These results agreed with Lienard *et.al*, (1993) who found that, seeds of *C. occidentalis* increased the mortality of both eggs and first larval instars of cowpea beetle *Callosobruchus maculatus* F. In addition, Paisson and Jaenson (1999) reported that, *C. occidentalis* can also be used as a repellent, as it effectively reduces the number of mosquitoes indoor at night.

Seed ethanolic extract of *R. communis* was effective against the adult fruit fly *B. invadens* and gave mortality percentage up to 60% mortality. These agree with Khalil *et.al*, (2010) who stated that, seeds hexane, and methanolic extract of *R. communis*, was effective in controlling the white fly *Bemisia tabaci* (Homoptera: Aleyrodidae). Also, the results are in agreement with Elimam, *et.al*, (2009) who found that, using aqueous extract from leaves of *R. communis* have proven high larvicidal activity against larvae of *Anopheles*

arabiensis and *Culex quinquefasciatus*. Similar results have been observed by Upasani, *et al.*, (2003) who reported that castor bean leaf aqueous extract has insecticidal, ovicidal and oviposition deterrent effects on the Chinese bean weevil, *Callosobruchus chinensis* L.

CONCLUSION AND RECOMMENDATIONS

Conclusion

The study showed that, the Asian fruit fly, *B. invadens* is the dominant species in the study area. Methyl Eugenol traps provided to be an effective lure for trapping large numbers of *B. invadens* males. On the other hand, Food (Protein hydrolysate) traps as bait attractant played an important role in capturing the females of different fruit flies species. However, Food traps were not effective as the pheromone traps.

According to its wide distribution and invasion in many areas, the invasive fruit fly *B. invadens* has now become one of the serious national pests in Sudan.

This study clearly demonstrates that, poth tested plants, *C. occidentalis* and *R. Communis* have lethal effects on the adults of the Asian fruit fly, *B. invadens*. However, ethanolic seed extract of the *C. occidentalis* seems to be much more toxic than the ethanolic seed extracts of *R. Communis.*

Recommendations

- Monitoring of the fruit flies using Pheromone traps is necessary for detecting the presence of the species found and their populations, because these are continuously changing.
- Farmers must be oriented to collect and remove the infested fallen fruits. Removal of fallen fruits contributes positively to reducing the infestation levels of fruit flies.
- Early harvesting of fruits reduces of infestation.
- Applications of legislative measures are important in preventing entry of infested fruits to the pest free areas.

- According to the results of the present study, ethanolic seed extracts of *C. occidentalis* can be recommended to be used for control of fruit flies, especially by topical application or as feeding lure. Nevertheless, further comparative studies should be conducted to evaluate the effects of these extracts with other organic solvents, and also on other insect pests. In addition, comprehensive studies are also required to specify the active ingredients of these plant extracts.

REFERENCES

Abanda, F-XN; Quilici, S.; Vayssieres, J.F.; Kouodiekong, L. and Woin. N, (2008). Inventory of fruit flies species on guava in the area of Yaounde, Cameroon. Fruits, 63: 19 – 26.

Abbas, A.M. (2008). Cultural practices to control fruit flies. Workshop of National Project for Control of Fruit Flies in Sudan, 27-28 August, 2008, Khartoum.

Abdallah, A. M. (2007) Monitoring, host range and economic impact of Tephritid fruit fly in the River Nile State, Sudan. M.Sc. thesis. Sudan Academy of Sciences. 64 pp.

Abdelmagid, F.M.; Abass, A.M. and Ali, E.E. (2012). Fruit flies review in Sudan from 1960-2011. TEAM 2nd International Meeting, "Biological invasions of Tephritidae and economic impacts", Kolymbari, Crete.

Abdullahi, N. (2011). Evaluation of the efficacy of different concentrations of mixed leaf powder of *Vittallaria paradoxa* and *Cassia occidentalis* against *Callosobruchus maculatus* F. (Coleoptera: Bruchidae) on stored cowpea seeds. Bajopas, 4 (1): 94 - 97.

Adam, A. I. (2013). Effect of Neem and Jatropha Seeds Ethanolic Extracts on Mortality of Asian Fruit Fly (*Bactrocera invadens*), (Diptera: Tephritidae).M.Sc. Thesis, Faculty of Agricultural Sudan University. 88 pp.

Ahmed, E. E. (2001). Studies on mango fruit fly *Ceratitis cosyra* in Central Sudan. M.Sc. Thesis, Faculty of Agricultural Sciences, University of Gezira, Sudan.

Ali, E. E. (1967). Studies on some Trypetidae of Economic importance in the Sudan, M. Sc. Thesis, Faculty of Agriculture, University of Khartoum, Sudan.

Ali, S. A. I. (2007). Detection and monitoring of some tephritidae of fruit trees and their host range in Abugubeiha, South Kordofan State. M.Sc. thesis, Sudan Academy of Sciences. 56 pp.

Ali, E. E.; Abbas, A. M.; Ahmed, H. M.; Abdurrahman, A. A. and Abdelmajid, F. M. (2008). Fruit Fly Review in Sudan from 1960-2008. Workshop of National Project for Control of Fruit Flies in Sudan, 27-28 August, 2008, Khartoum.

Aluja, M. and Norrbom, A.L. (1999). Fruit flies (Tephritidae): phylogeny and evolution of behavior. CRC. Press, Florida. U.S. 987pp.

Ani, A.O. and Okorie, A.U. (2009). Response of broiler finishers to diets containing graded levels of processed castor oil bean (*Ricinus communis* L.) meal. Journal. Animal. Physiology. Animal. Nutrition, 93:157 – 164.

Averill, A. L. and Prokopy, R. J. (1989). Host marking pheromones. In Fruit flies: their biology, natural enemies and control (A. S. Robinson and G. Hooper, (Eds.)). Elsevier, Amsterdam. 207-219 pp.

Averill, A. I. (1996). Effect of recent experience on forging in tephritid fruit flies. Journal of Insect Behavior, 9: 571-583.

Bachrouch, O. and Benjemaa, J.M. (2012). Labloratory efficacy of neem extracts on survival, fecundity and emergence rate of adults of *Ceratitis capitata* wied. (Diptera: Tephritidae).Regional Symposium on the Management of Fruit Flies in Near East Countries Hammamet, Tunisia, Nov 6-8.

Barry, J.D.; Polavarapu, S. and Teixeira A. F. L. (2004). Evaluation of traps and toxicants in an Attract-and-kill system for *Rhagolets mendax* (Diptera: Tephritidae). Journal of Economic Entomology, 97 (6): 2006-2014.

Bashir, H.A. and Imam, M.A. (2010). Status Report on Fruits and Vegetables Production and Processing Industry in Sudan. AARDO workshop on technology on reducing post-harvest losses and maintaining Quality of fruits and vegetables, Taiwan. 168-179 pp.

Bashir, Y. G. (2007). Studies on mango fruit flies in Kordofan Area, Sudan. Ph.D. Thesis, Faculty of Agricultural Sciences, University of Gezira.

Beije, C. M. (1996). Reports on field trip to Kassala and Gash Delta. FAO IPM Project GCP/SUD/025/NET, ARC, Wad Medani, Sudan.

Bolaji, S.Z.; Andrew, G. K. and Benson, A.O. (2014). Castor Oil Plant (*Ricinus communis* L.): Botany,Ecology and Uses. International Journal of Science and Research *(IJSR*) Vol 3, (5): 1333-1341.

Christenson, L. D. and Foote, R. H. (1960). Biology of fruit flies. Annual Review of Entomology, 5:171-192.

Chuang, Y. and Hou, R.F. (2008). Effectiveness of attract-and-kill systems using Methyl Eugenol incorporated with Neonicotinoid insecticides against the oriental fruit fly (Diptera: Tephritidae). Journal of Economic Entomology, 101(2): 352-359.

Clarke, R. A.;Armstrong, K.F.; Carmichael. A.E.;Milne, J. R.; Raghu, S.; George, R. K. and David, K. Y. (2005). Invasive phytophagous pests arising through a recent tropical evolutionary radiation The *Bactrocera dorsalis* Complex of Fruit Flies. Annual Review of Entomology, (50): 293-319.

Colle, F.; Kaminsky, R.; Nkunya, M. H.; Ogwal, E. N. and Brun, R. (2003). Trypanocidal activity of African plants. Journal of Ethnopharmacology, 5: 1-11.

Copeland, R.S.; Wharto, N. ; Robert, A. ; Luke, Q.; Meyer, D.E.M.; Lux S.; Zenz, N.; Machera, P. and Okumu, M. (2006). Geographic distribution, host fruit, and prasitoids of African fruit fly pests *Ceratitis anonae*, *Ceratitis cosyra*, *Ceratitis fasciventris*, and *Ceratitis rosa* (DipteraTephritidae) in Kenya. Annual Entomology. Society of America, 99(2): 261- 278).

Correia, A.R.; Rego, J.M. and Olmi, M. (2008). A pest of significant economic importance detected for the first time in Mozambique: *Bactrocera invadens* Drew, Tsuruta & White (Diptera: Tephritidae: Dacinae*). Boll. Zool Agr. Bachic Ser*., 40: 9-13.

Dave, H. and Ledwani, L. (2012). A review on anthraquinones isolated from *Cassia* species and their applications. *Ind. J. Nat. Prod. Resour*., 3 (3): 291- 319.

Deng, A. L. (1990). Studies on the behaviour, host range, seasonal abundance and chemical control of the med fly *Ceratitis capitata* (Wiedemann) in Sudan. M.Sc. Thesis, University of Khartoum.

Dharani, N.; Rukunga, G.; Yenesew, A.; Mbora, A.; Mwaura, L.;Dawson, I. and Jamnadass, R. (Eds.). (2010). Common antimalarial trees and shrubs of East Africa: a description of species and a guide to cultivation and conservation through use. The World Agroforestry Centre (ICRAF), Nairobi, Kenya, 96 pp.

Drew, R.A.I. and Hooper, G.H.S. (1981). The responses of fruit fly species (Diptera: Tephritidae) in Australia to various attractants. Journal of Wallingford Entomological Society, 20: 201 – 205.

Drew, R.A.I. (1989). The tropical fruit flies (Diptera: Tephritidae: Dacinae) of the Australian and Oceanian regions. Memoirs of the Queensland Museum 26, 521pp.

Drew, R.A. I.; Tsuruta, K. and White, I.M. (2005). A new species of pest fruit fly (Diptera: Tephritidae: Dacinae) from Sri Lanka and Africa. African Entomology, 13: 149-154.

Drew, R.A.I.; Roming, M.C.; Dorji, C. (2007). Records of Dacine fruit flies and new species of Dacus (Diptera: Tephritidae) in Bhutan. The Raffles Bulletin of Zoology, 55(1):21.

Drew, R.A.I.; Raghu, S. and Halcoop, P. (2008). Bridging the morphological and biological species concept: studies on the *Bactrocera dorsalis* (Hendel) complex (Diptera: Tephritidae: Dacinae) in south-east Asia. Biological Journal of the Linnean Society, 93: 217 – 226.

Ducyk, P.F.; David, P. and Quilici, S. (2004). A review of relationships between interspecific competition and invasions in fruit flies (Diptera: Tephritidae). Ecological Entomology, 29: 511-520.

Ducyk, P.F.; David, P. and Quilici, S. (2007). Can more K-selected species be better invaders? A case study of fruit flies in La Reunion. Diversity and Distributions, 13: 535-543.

Dweivedi, S. C. and Kumar, R. (1998). Evaluation of *Cassia occidentalis* leaf extract on development and damage caused by *Trogoderma granarium*, Khapra beetle. Journal of Ecotoxicology and Environmental Monitoring, 8: 55 –58.

Ekesi, S.; Maniania, N.K.; Mohamed S.S. and Lux, S.A. (2005). Effect of different formulations of *Metarhizium anisopliae* on three tephritid fruit flies and their associated endoparasitoids. Biological Control, 35: 83-91.

Ekesi, S; Nderitu, P. W. and Rwomushana, I. (2006). Field infestation, life history and demographic parameters of the fruit fly *Bactrocera invadens* (Diptera: Tephritidae) in Africa. Bulletin of Entomological Research, 96: 379–386.

Ekesi, S. and Billah, M.K. (2007). A field guide to the management of economically important Tephritid fruit flies in Africa. ICIPE science press, Nairobi, Kenya.

Ekesi, S.; Rwomushana, I.; Gordon, I. and Ogol, C.K. (2008). Host plants and host plant preferences studies for Bactrocera invadens (Diptera: Tephritidae) in Kenya, a new invasive fruit fly species in Africa. Annuls of the Entomological Society of America, 101(2): 331-340.

El-Aw, M.A.M; Draz, K.A.A; Hashem, A.G. and El-Gendy, I.R (2008). Mortality comparison among spinosad-, actara-, malathion-, and methyl- containing baits against peach fruit fly, *Bactrocera zonata* Saunders (Diptera: Tephritidae) under laboratory conditions. Journal of Applied Sciences Research, 4(2): 216-223.

Elgozuli, A. (2008). Mango Production in Sudan, Current Situation and Future prospects. Workshop of National Project for Control of Fruit Flies in Sudan, 27-28 August, 2008, Khartoum.

Elhewaris, M. O. (2003). Studies on the biology and ecology of *Ceratitis cosyra* (Diptera: Tephritidae) on mango fruits in Sinnar state, Sudan. M. Sc. Thesis, Faculty of Agriculture, University of Sinnar, Sudan.

Elimam, A.M.; Elmalik, K.H. and Ali. F.S. (2009). Larvicidal, adult emergence inhibition and oviposition deterrent effects of foliage extract from *Ricinus Communis* L. against *Anopheles arabiensis* and *Culex quinquefascatus* in Sudan. Tropical Biomedicine, 2: 130-139.

French, C. (2005). The new invasive *Bactrocera* species. in Insect Pest Control Newsletter, No. 65, International Atomic Energy Agency, Vienna, Austria. 19 – 20 pp.

Goergen, G.; Vayssieres J.F.; Gnanvossou D. and Tindo, M. (2011) *Bactrocera invadens* (Diptera: Tephritide), a new invasive fruit fly pest for the Afrotropical region: Host plant range and distribution in west and central Africa. *Entomological Society of America*, 40(4): 844-854.

Gubara, S. and Abu Elgasim, M. (2004). Fruit flies. Plant Protection Administration, Ministry of Agriculture and Forestry Bull., Nov. 2004.

Gubara, S.; Ahamed, J.; Hussein, F.; Abu Elgasim, M.; Mokhtar, A. and Bashir, Y.G.A. (2009). Evaluation of para pheromone trap 95% TC (Methyl Eugenol 95% TC) for mass trapping of *Bactrocera invadens* (Diptera: Tephritidae) in fruit trees. The 80th meeting of National pests and Diseases Committee, Agricultural Research Corporation, Wad Medani, Sudan.

Gupta, A.P.; Antil, R. S. and Narwal, R.P. (2010). Utilization of deoiled castor cake for crop production. Arch. Agronomic. Science, 50:389-395.

Gupta, S.; Sharma, P. and Soni, P. L. (2005). Chemical modification of *Cassia occidentalis* seed gum: carbamoylethylation, *CarbohydrPolym*, 59(4): 501 – 506.

Hee, A.K.W. and Tan, K.H. (1998). Attraction of female and male *Bactrocera papaya* to conspecific males fed with Methyl Eugenol and attraction of females to males sex pheromone components. Journal of Chemical Ecology, 24(4): 753-764.

Heppner, J. B. (1985). Larvae of Fruit Flies. II. *Ceratitis capitata* (Mediterranean fruit fly) (Diptera: Tephritidae). Entomology Circular No. 273. Fla. Dept. of Agr., Division of Plant Industry.

Hill, D. S. (1983). Agricultural insect pests of the tropics and their Control, 2nd Edition. Cambridge University Press, 386 pp.

IAEA. (2003). Trapping guidelines for area-wide fruit fly programmes. International Atomic Energy Agency (IAEA), Vienna, 48pp.

ICOA. (1989).The processing of castor meal for detoxification and de-allergenation.International Castor Oil Assoc.(ICOA), Cinnaminson, NJ.

Isman, M. B. and Seffrin, R. (2014). Natural Insecticides from the Annonaceae: A Unique Example for Developing Biopesticides in: D.Singh (ed.) Advances in Plant Biopesticides, Springer, India.

Kelany, I. M., (2001). Plant extracts and utilization of their Products for Safe Agricultural Protection and for reducing environmental pollution. Practice oriented results on the used and production of plant extracts and pheromones in integrated and biological of the 6th workshop, Cairo, Egypt.

Khalil, N. S; Elseedi H. R.; Saleh, M. A; Salama M. S. and. Hamed M. S (2010).Biocidal activity of some castor extracts against the whitefly *Bemisia tabaci* (Genn) (Homoptera: Aleyrodidae). Egypt. Academic Journal of biology. Sci., 2 (1): 31- 38

Lienard, V.;Seck, D.; Lognay, G.;Gaspar, C. and Severin, M. (1993). Biological activity of *Cassia occidentalis* L. against *Callosobruchus maculatus* F. (Coleoptera: Bruchidae). Journal of Stored Production Resoruce., 29 (4): 311 – 318.

Lima, R.I.S.; Severino, S.; Silva, M.I.L.; Vale, I.S. and Beltrao, N.E.M. (2006). Recipient's volume and substrate composition for castor seedlings production. *Ciencia Agrotecnol.*, 30:480-486.

Lima, R.I.S.; Severino, S.; Sampaio, I.R.; Sofiatti, V.; Gomes, J.A. and Beltrao, N.E.M. (2011). Blends of castor meal and husks for optimized use as organic fertilizer. Ind. Crops Production, 33:364-368.

Lux, S. A.; Ekesi, S.; Dimbi, S.; Mohamed, S.and Billah, M. (2003). Mango-infesting fruit flies in Africa: perspectives and limitations of biological approaches to their management, In Neuenschwander , P., Borgemeister , C., and Langewald, Journal of Biological control in IPM systems in Africa. CABI Publishing, Wallingford, United Kingdom. 277–294 pp.

Mahmoud, M. E. E. (2011). Population Dynamics, Mass Trapping and Molecular Characterization of Major Fruit Flies (Diptera: Tephritidae) in Khartoum, Kassala, South Kordofan States (Sudan). Phd. Thesis, faculty of Science, University of Khartoum, Sudan. 164 pp.

Mangan, R.L. and Morno D.S. (2007). Development of bait stations for fruit fly population suppression. Journal of Economic Entomology, 100: 440-450.

Manrakhan, A. and Kotze, C. (2009). Attraction of *Ceratitis Capitata, C. rosa* and *C. cosyra* (Diptera: Tephritidae) to proteinaceous baits. Journal of Applied Entomology, 135: 98-105.

Mansour, S.A.; Bakr, R. F.A.; Hamouda, L.S. and Mohamed R.I, (2012). Adulticidal activity of some botanical extracts, commercial insecticides and their binary mixtures against the housefly, *Musca*

domestica L. (Diptrea: Muscidae), Egypt. Academic. Journal of Biological Science, 5(1): 151-167

Mardi, H. G. (2008) Field infestation and host utilization of the invasive fruit fly, *Bactrocera invadens* Drew Tsuruta& White (Diptera, Tephritidae) in Sudan. First Meeting of TEAM. Palma of Mallorca. 7-8th April, 2008.

Mariod, A. and Matthäus, B. (2008). Physico-chemical properties, fatty acid and tocopherol composition of oils from some Sudanese oil bearing Sources. Grasas y aceites, 59 (4): 321- 326.

Mohamed, A .H. and Ali, E.A. (2008). Evaluation of para- pheromones and three components food baits for mass trapping of fruit flies in fruit trees. The 78th Meeting of the Pests and Diseases Committee, Agricultural Research Corporation, Wad Medani, Sudan.

Mohamed, A.H. and Taha, A.K. (2008). Pheromones, para pheromones and food lure in fruit fly management. Workshop of National Project for Control of Fruit Flies in Sudan, 27-28 August, 2008, Khartoum.

Mohamed, S. M. A. (2004). Competition between Mediterranean fruit fly and Peach fruit fly in fruit fly infestation. Journal of the Egyptian German Society of Zoology, 43: 17-23.

Mohamed, S.A. (2003). Biology, host and host plant relationships of two *Psyttalia* species (Hymenoptera: Braconidae), parasitoids of fruit flies (Diptera: Tephritidae) in Kenya. M. sc. Thesis, University of Gezira, Sudan.

Moshkin, V.A., (editor). (1986). Castor (*Ricinus communis*). Amerind Publishing, New Delhi, India, 315pp.

Mutlu, H. and Meier, M.A.R. (2010). Castor oil as a renewable resource for the chemical industry. Eur. *J. Lipid Sci. Technol*., 112:10-30.

Mwatawala, M.W.; De Meyer, M.; Makundi, R.H. and Maerere, A.P. (2006). Biodiversity of fruit flies (Diptera, Tephritidae) at orchards in different agro-ecological zones of the Morogoro region, Tanzania. Fruits, 61: 321 – 332.

Mwatawala, M.W; De Meyer, M.; Makundi, RH. and Maerere, A.P (2009). Host range and distribution of fruit-infesting pestiferous fruit flies (Diptera, Tephritidae) in selected areas of central Tanzania. Bulletin of Entomological Research, 1- 13 pp.

Nassar, M. A. A.; Ramadan, H. R. H. and Ibrahim, H.M. S. (2011). Morphological characteristics of vegetative and reproductive growth of *Senna occidentalis* L. (Caesalpiniaceae). Research. Journal of Agriculture Biological Science, 7(2): 260-270.

Nassar, M. A. A.; Ramadan, H. R. H. and Ibrahim, H.M. S. (2013). Anatomical structures of vegetative and reproductive organs of *Senna occidentalis* (Caesalpiniaceae). Turky. Journal. Bot., 37: 542 552.

NCRI. (2013). Castor Breeding, National Cereal Research Institute, Nigeria. Annual Research Review. 203-223pp.

NCRI. (2014). Castor Breeding, National Cereal Research Institute, Nigeria. Report of castor germ plasm collections and stakeholder identification, In Moshkin, V.A., (editor). Castor (*Ricinus communis*). Amerind Publishing, New Delhi, India. 85 – 92 pp.

Ogunniyi, D.S. (2006). "Castor Oil: A vital industrial raw material. Bioresour. Technology, 97(9): 1086-1091.

Omer, S. A.; Al-Olayan, E. M.; El-Amin, M. H., Hassan, Z. K.; Daghestani, M.H. and Mohammed, O. B. (2012). Experimental *Cassia senna*

intoxication in Lohmann broiler chicks. Journal of Medical, Plants Research, 6 (17): 3306 - 3310.

Paisson, K. and Jaenson, T. G. T. (1999). Plant products used as mosquito repellents in Guinea Bissau, West Africa. *Acta Tropica*, 72: 39– 52.

PHA. (2011). The Australian Handbook for the identification of fruit flies. Version 1.0. Plant Health Australia (PHA). Canberra, ACT, 214pp.

Podsilva, V. (2003). Gastric cytoprotective antiulcer effects of the leaf of methanol extract of *Senna occidentalis* (fabaceae) in rats. Journal of Ethno pharmacology, 82: 69-74.

Pompeu, R.C.F.F. (2009). Substituicao do farelo de soja pela torta de mamona destoxificada em dietas para ovinos: Valor nutritivo e desempenho bioeconomico.Ph.D. Diss. Univ. Federal doCeara, Fortaleza. (In Portuguese, with English abstract.).

Refaat, A.A. (2009). Correlation between the chemical structure of biodiesel and its physical properties. Int. *J. Environ. Sci. Technol*., 6:677-694.

Rosseler, Y. (1989). Insecticidal baits and cover sprays, 329-335 pp. In: A.S. Robinson and G. Hopper (Eds), Fruit flies: their biology, natural enemies and control. World Crop Pests, vol.3 B. Elsevier publisher, Amesterdam, The Netherlands.

Rowe, L. D.; Corrier, D. E.; Reagor, J. C. and Jones, L. P. (1987). Experimentally induced *Cassia roemeriana* poisoning in cattle and goats. Am. J. Vet. Res., 48: 92-97.

Rwomushana, I.; Ekesi. S. G. I. and Ogol C.K.P.O (2008). Host plant preference studies for *Bactorcera invadens* (Diptera: Tephritide) in Kenya, a new invasive fruit fly species in Africa. Annals of the Entomological Society of America, 101: 331 – 340.

Saafan, M.H. (2005). Field evaluation of some attractants for attracting the adults of Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann) and Peach fruit fly, *Bactrocera zonata* (Saunders) in citrus orchards. Egyptian Journal of Agricultural Research, 83, 1141.

Saafan, M.H.; Foda, S.M. and Mohammed, A.A. (2006). Ecological studies on fruit flies on different hosts at Fayoum governorate, Egypt. Agricltural Researech, 84(2): 323

Salihu, B. Z.; Gana, A. K.; Amosun, A.; Shaahu, A.; Agboire S. A.; Apuyor, B.O. and Oliseh, A. (2013a). Morphological Characterization of Castor (*Ricinus communis* L.) Accessions. Proc. Agricultural Society of Nigeria. 308-316 pp.

Salihu, B. Z.; Gana, A. K.; Agboire S. A.; Isong, A. E. and Shaahu, A.; (2013b). Genetic Divergence, Principal Components and Clustering Analyses of Some Agronomic Characteristics of Eleven Castor (*Ricinus communis* L.) Accessions. International Journal of Science and Research. 2:129 – 132.

Schmutterer, H. (1969). Pests of Crops in Northeast and Central Africa, with Particular Reference to the Sudan. Gustav Fischer Verlag. Stuttgart and Portland. USA, 269 pp.

Siddig, S. A. (1984). Insect pests of fruit crops and their control in the Sudan. Acta Horticulture, 143:387-395.

Singh, S.;Singh, S.K. and Yadav, A. (2013). A review on *Cassia* species: pharmacological, traditional and medicinal aspects in various countries. AJPCT, 1 (3): 291- 312.

Steck, G. J. (2000). *Ceratitis cosyra* Walker (Diptera: Tephretidae). Entomology circular No. 403. Fla. Dept. Agric and Consumer Services. Division of Plant Industry.

Steiner, L.F.; Hart, W.G. and Harris, E.J. (1970). Eradication of the oriental fruit fly from Marina Islands by methods of male annihilation and insect sterile release. Journal of Economic Entomology. 63: 131-135.

Steven, L.; Peck, G. and McQuate, T. (2000). Field Tests of Environmentally Friendly Malathion Replacements to Suppress Wild Mediterranean fruit fly (Diptera:Tephritidae) Populations. Journal of Economic Entomology, 39 (2) 280–289.

Sukontason, K.L; Boonchu, N.; Sukontason, K. and Choochote, W. (2004). Effects of Eucalyptol on house fly (Diptrea: Muscidae) and Blow fly (Diptrea: Calliphridae). Rev. Inst. Med. Trop. S. Paulo 46(2): 97-101.

Taiwo, F. O.; Akinpelu, D. A.; Aiyegoro, O. A.; Olabiyi, S. and Adegboye, M. F. (2013). The biocidal and phytochemical properties of leaf extract of *Cassia occidentalis* L. Africa. Journal of Microbiology Research, 7 (27): 3435 – 3441.

Tan, K.H. and Nishida, R. (2012). Methyl Eugenol: Its Occurrence, Distribution, and Role in Nature, Especially in Relation to Insect Behavior and Pollination. Journal of Insect Science, 12(56): 1-60

Upasani, S.M.;Kotkar, H.M. and Maheshwar, V.L. (2003). Partial characterization and insecticidal properties of *Ricinus Communis* L. foliage flavonoids. In: Pest Management Science, 59, (12) 1349-1354.

Vashishtha, V.M.; John, T.J. and Amod, K. (2009). Clinical and pathological features of acute toxicity due to *Cassia occidentalis* in vertebrates. Ind. Journal Medical Research, 130: 23-30.

Vayssieres, J.F.; Goergen, G.; Lokossou, O.; Dossa, P. and Akponon, C. (2005). Anew *Bactrocera* species in Benin among mango fruit fly (Diptera: Tephritidae) species. Fruits, 60: 371 – 377.

Vayssieres, J.F.; Cayol, J.P.; Perrier, X. and Midgarden, D. (2007). Impact of Methyl Eugenol and malathion bait stations on non-target insect population in french Guiana during an eradication program for *Bactrocera carambolae*. Entomologia Experimentalis Applicate, 125: 55-62.

Vayssières, J.F.; Korie, S. and Ayegnon, D. (2009). Correlation of fruit fly (Diptera: Tephritidae) infestation of major mango cultivars in Borgou (Benin) with abiotic and biotic factors and assessment of damage. Crop Protection, 28: 477-488pp.

Venkatraman, T. V.; and ElKhidir, E. I. (1965). Outbreaks and new records (Sudan). *FAO Plant Protection Bull*., p. 22.

Weiss, E.A. (1983). Oilseed crops. Longman Group Ltd., 660 pp.

Weiss, E.A. (2000). Oilseed crops. (2^{nd} ed.). Blackwell Science, Oxiford, 384 pp.

Wharton, R.H. (1989). Control; classical control of fruit-infesting tephritids, in: Robinson, A.S.; Hooper, G, (eds.) Fruit flies; their biology, natural enemies and control. World crop pests 3(B). Amsterdam, Netherlands: Elsevier, 303-313.

White, I. M. and Elson-Harris, M. M. (1992).Fruit flies of economic significance their identification and bionomics. C. A.B international Wallingford, 602pp.

Wright, J.W. (1971). The WHO Programme for the Evaluation and Testing of New Insecticides. Bull. WLD. *Org*., 44: 11-12.

Yadav, J.P.; Arya, V.; Yadav, S.; Panghal, M.;Kumar, S. and Dhankhar, S. (2010) *Cassia occidentalis* L.: A review on its ethnobotany, phytochemical and pharmacological profile. *Fitoterapia*, 81: 223 - 230.

Yadava, R. N. and Satnami, D. K. (2011). Chemical constituents from *Cassia occidentalis* Linn. Ind. Journal of Chemical, 50B:1112-1118.

APPENDICES

Appendix (1):

Table.1: Analysis of variance table (One way ANOVA table)

	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob.
Between	9	169.665	18.852	41.311	0.0000
Within	20	9.127	0.456		
Total	29	178.792			

Appendix (2):

Table.2: Analysis of variance table (One way ANOVA table)

	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob.
Between	9	171.067	19.007	67.562	0.0000
Within	20	5.627	0.281		
Total	29	176.694			

Appendix (3):

Table.3: Analysis of variance table (One way ANOVA table)

	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob.
Between	9	177.199	19.689	106.426	0.0000
Within	20	3.700	0.185		
Total	29	180.899			

Appendix (4):

Table.4: Analysis of variance table (One way ANOVA table)

	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob.
Between	9	162.738	18.082	22.638	0.0000
Within	20	15.975	0.799		
Total	29	178.712			

Appendix (5):

Table.5: Analysis of variance table (One way ANOVA table)

	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob.
Between	9	161.988	17.999	35.547	0.0000
Within	20	10.127	0.506		
Total	29	172.115			

Appendix (6):

Table.6: Analysis of variance table (One way ANOVA table)

	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob.
Between	9	153.440	17.049	62.989	0.0000
Within	20	5.413	0.271		
Total	29	158.854			