Control of fruit flies (Diptera:Tephritidae) using an environmentally safe methods in Shendi area, Sudan.

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Dedication

To the spirit of my **Father**, *to my* **Mother** *for all unconditional love and guidance shaped my life.*

*To my brother (***Esam***) and his support through my life and my dear* **sisters**.

To my **wife**, *for her accompanying through the steps of this thesis.*

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ABSTRACT

This work was carried out at Shendi area, River Nile State, from April 2012 to April 2014.

Field and laboratory studies were undertaken surveying and monitoring fruit flies species found during the period, with emphasis on their population dynamics. Pheromone traps and food bait traps were used for detection and monitoring of fruit flies. Application of spinosad as pesticide and zonatrac as flies attractant was done.

Results indicated that, fruit flies species found in the study area are the Asian fruit fly, *Bactrocera invadens* (Drew), Mango fruit fly, *Ceratitis cosyra* (Walker)and Mediterranean fruit fly *Ceratitis capitata* (Wiedmann) *Bactrocera invadens* was found to be the dominant fruit fly species in the study area It was observed that host diversity of edible fruits and overlapping of fruiting seasons are highly preferable by fruit flies, especially *Bactrocera invadens* which constitute a threat to fruit production and fruit exportation in the Sudan.

The Population abundance of fruit flies generally increase with the rainy season, High population was recorded during the humid months of July and August; while low population were recorded during March. Through the results of the First season, we noticed that *B .invadens* showed lower population in March (634.5±94.9) and grow up gradually until it reaches the peak in July and August (1869±48.5) and (1893±48.9) respectively.

C .capitata Was noticed during August, September and October .Its population Reached (287.8±32.4)(211.8±17.3)(195.8±23.1) respectively, the

mango fruit Fly *C .cosyra* was recorded through the year, but the highest month was August (296.3±38.5) While low population were recorded during March, the mango fruit Fly *C .cosyra* was recorded throughout the year but the highest count during August (296.3±38.5).

The second season 2013- 2014 the African fruit fly *B .invadens* peak was in August (1258.5±105.8) and also the lower number was catched in March (654.3±57.9). *C .capitata* was appeared in relatively few numbers since July (230.3±32.6) to November (206.3±8.7). *C.cosyera* in this season showed very low appearance, but the peak number was still in August (233.8±45.9).

The evaluation of the spinosad in controlling fruit flies the resulted in highly decrease of the insects number. It was found that, in April the average of insects numbers collected was (947.22and 1001.67) for the treated and untreated orchards respectively. The numbers of insect were found decreased gradual during the months of May, June, July and August in the treated orchards 904.7, 760.22, 609.6 and 452.7, respectively, while in the untreated orchards it the number increased rapidly, the average numbers were 1003.67 , 1103.67, 1336.67and 1468.67 respectively for the months May, June, July and August .The statistical Analysis of the result showed that the decrease of the insects number every month is not significant between April and May but it was decrease in a highly Significant at ($p>0.05$) rate all through the treatment period .The infestation level of mango fruits in the treated orchards was found 2% compared with 68% for untreated one.

The zonatrac traps were found attracted less number of insects compared with that attracted by the Methyl Euginol traps. The difference was highly significant. The means of insects catches were (1671±808) and (355±150) for ME and Zonatrac traps respectively. The insects attracted by the ME were four fold than that attracted by zonatrac. Results showed that, all insects found was only *Bacterocera invadens* and there was no *Bacterocera zonata* in Shendi area.

ملخص الاطروحة

اجريت هذه الدراسة في منطقة شندي بولاية نهر النيل في الفترة من ابريل 2012م الي ابريل 2014م تهدف الدراسة الي التعرف علي انواع ذبابة الفاكهة الموجودة بالمنطقة واستخدام طرق المكافحة الامنة بيئيا .شملت الدراسة التجارب الحقلية والمعملية كما اجري مسح حقلي استخدمت فيه المصائد الفرمونية والغذائية للتعرف علي انواع ذبابة الفاكهة الموجودة بالمنطقة ومدي كثافتها وكذلك تم استخدام الرش الجزئي بواسطة مبيد الاسبينوساد اضافة لاستخدام جاذب الزوناتراك.

اوضحت النتائج ان انواع ذبابة الفاكهة الموجودة بالمنطقة هي ذبابة المانجو وذبابة البحر المتوسط وذبابة الفاكهة الاسيوية وانها النوع السائد في المنطقة وطول السنة.

و تتواجد الافة خلال الاشهر الرطبة يوليو واغسطس بكثافة عالية بينما تتواجد بكثافة اقل في شهر مارس.من خلال النتائج تلاحظ انخفاض اعداد ذبابة الفاكهة الاسيويةفى الموسم الاول(2012 م-2013 م) في مارس (634.5±94.5) وتذداد تدريجيا حتي شهري يوليو واغسطس(1869±48.5) و(1893±48.9) علي التوالي ،بينما تتواجد ذبابة البحر الابيض المتوسط في اغسطس وسبتمبرواكتوبر (287.8 ± 32.4) ،(211.8 ± 17.3) (195.8 ± 23.1) علي التوالي بينما تتواجد ذبابة المانجو واعلي تواجد لها في اغسطس (296.3±38.5).

رصد اعلي تواجد لذبابة الفاكهة الاسيوية في الموسم الثاني(2013م-2014 م)كانت في اغسطس (1258.5 ± 105.8) بينما اقل عدد في مارس(654.3±57.9) ،بينما ذبابة البحر الابيض المتوسط ظهور نسبي من يوليو(230.3±32.6) وحتي نوفمبر(206.3±8.7)، اما ذبابة المانجو كان تواجدها في شهر اغسطس(233.8±45.9).

اما في دراسة تقييم دور الاسبينوساد في مكافحة ذبابة الفاكهة كشفت الدراسة ان متوسط الحشرات التي تم جمعها في ابريل (947.22) في البساتين المعاملة و(1001.67) في البساتين غير المعاملة بالاسبينوساد.اعداد الافة انخفضت تدريجيا خلال الاشهر من مايو ووحتي اغسطس في البساتين المعاملة 904.7، 760.22، 609.6 452.7 علي التوالي.بينما في البساتين غير المعاملة اظهرت النتائج اذدياد في اعداد الافة1003.67، 1336.6، 1103.67 ، 1468.67 علي التوالي لاشهر مايو ويونيو وايوليو واغسطس.واظهر التحليل الاحصائي في هذه الدراسة ان الفروق المعنوية بين شهري ابريل ومايو ليس كبيرا وحيث انخفض اعداد الافة بصورة كبيرة من مايو وحتي اغسطس.ايضا وجد

ان نسبه اصابه ثمار المانجو فى البساتين المعامله بمبيد الاسباينوسيد 2% مقارنه بالنسبه المرتفعه 68%للبساتين غير المعامله.

عند استخدام جاذب الزوناتراك تلاحظ ان الحشرات التي جمعها(355 ± 150) مقارنة بالمصائد المشبعة بفرمون االميثايل اجنول (1671 ± 808) وهو فارق كبير يصل للاربعة اضعاف.واثبتت الدراسة خلو منطقة شندي من ذبابة الخوخ.

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Chapter One

Introduction

Fruits and vegetables have potential to become an important source of income generation for African farmer through creating job opportunitities as well as improving their diet providing micronutrients and vitamins.

Horticultural production in most African is limited by many biotic and a biotic constraints. Biotic factors include, among others, heavy fruit fly infestation .Tephritidae is one of the most serious biotic constraints affecting horticultural production. They constitute enormous threats to fruits and vegetables production throughout the world (Mohamed, 2003).

More than 4000 species of fruit flies are known around the world ,two hundred among them, are considered as pests(White and Harries,1992).These pests are of highly economic importance due to the fact that, the female oviposits inside the sound fruits, causing the ovipunctures which lead to the entry of micro-organism and rottening of the fruits. This is beside the main damage of the developing stages inside the fruit which render them unsuitable for human consumption (Abass,1998).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 (Abass,2008).

Among the fruit flies found in the Sudan, *Ceratitis capitata* and *Ceratitis cosyra* are considered as devasting pests to the mango fruits all over the country, especially at Shendi, Senga and Sennar areas. In

addition, new species of the genus *Bactrocera* was reported from Blue Nile areas known as *Bactrocera invadens* (Drew, 2005).

Gubara and Abu Elgasim (2004) reported that the percentage of damaging due to the fruit flies infestation, ranged from 70-100% 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 the year 2007, the fruit flies problem became so severe to the extent that they were upgraded and added to the list of the notorious national pest of Sudan. (P.P.D, 2007).

Shendi area in the River Nile State is selected for the study because of the heavy infestation reported, and for availability of all host plants, mango, guava and citrus in the area.

General objectives

The general objectives of the study can be summarized as follows:

1/ Enable fruit growers in the area to improve their production through Improvement of fruit protection.

2/ Develop safe and environmentally sound techniques for fruit flies Management.

3/ Enhance the effort in upgrading domestic and export fruit marketing.

Specific objectives:

1- Using Methyl Euginol traps as monitoring and controlling tools.

2- Study the role of spinosad in controlling the fruit fly in Shendi area.

3- Use zonatrac and test its efficiency in as attractant of genus *Bacterocera*.

Chapter Two

Literature Review

2.1 Fruit flies

Fruit flies are major pests of several fruit and vegetable crops throughout the tropical and subtropical word. Nearly 35 percent of the known fruit fly species attack soft fruits of which mango, guava, citrus, ber, peach, and several cucurbitaceous vegetables are important.

2.2 Taxonomy

Fruit flies belong to order Diptera ,family Tephritidae. Most species of Tephritidae which attack fruits and vegetables belong to the genera *Anastrepha*, *Ceratitis* ,*Bactrocera* ,*Dacus* and *Rhogoletis* .*Bactrocera* was the most economically significant genus, with about 40 species considered to be important pests (White and Harris,1992, and Norrbon *et al*.,1999).

2.3 Distribution

The family Tephritidae is represented in all the regions but the major pest genera have limited natural distribution (Drew, 1989).Thus, *Anastrpha* occur in south and central America and Caribbean. *Bactrocera spp* are native to tropical Asia, Australia and south pacific *Ceratitis* and *Dacus* are native to topical Africa (Drew,1989).

In a few cases, species have been accidentally introduced and have become established outside these natural ranges, mainly as a result of human activity (White and Harris,1992).*Ceratitis spp.* attack wide range of fruit native to tropical Africa.*Ceratitis cosyra* has been recorded in the ivory coast, Kenya, South Africa, Tanzania, Uganda,

Zambia, and Zimbabwe, where it is more destructive than *Ceratitis capitata* and *Ceratitis rosa* (Lux and Kimani, 1998,Drew, 1989). Now, it is of wide spread in Africa sub-Sahara, occurring in at least 22 countries (CAB/EPPO,1999). *Ceratitis capitata* (weidman) has been established in all other world regions except Asia.

In Sudan, Fruit flies were reported at Khartoum State by Venkatraman and Elkhdir, 1965. Ali(1967)found fruit flies in the Northern region (Shendi,Hudeba), Khartoum, Kassala and the southern region (Yambio, Meridi, Yei and 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, Bashir, 2007).

2.4 Fruit damage &infestation

Most mango –producing countries are located in fruit flies areas, and producer suffer from the direct economic losses, resulting from the fruit flies damage (Aluja *et al.*, 1996).

Few insects have a greater impact on international marketing and world trade in agricultural produce than tephritid fruit flies (Hendrichs,1996).White and Elson –Harris (1992) reported 48 species of fruit flies attacking mango. The fruit flies include the genera *Anastrepha* (8 species), *Bactrocera* (30 species), *Ceratitis* (7 species) ,*Dirioxa*(2 species) and *taxotrypana* (1 species) .White and Elson – Harris (1992) had transferred all *Dacus spp* attacking mango to the genus *Bactrocra*. The common species reported on mango include *B. tryoni* (Frogatt) , *B. Zonata* (saunders) , *B. dorsalis* (Hendel) ,

B. Neohumeralis(Hardy), *B .jarvisi*(Tryon) and *B. fraunenfeldi*(Schiner).

2.5 Host plant

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

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 were found in Sudan, of which five are well known pests of economic crops in many parts in Africa. Schumutterer (1969) reported that, the family Tephritidae was considered as the fourth group of insect pest causing serious damage to fruit crops in Sudan. Among the fruit flies were *Dacus spp* which highly infest cucurbitaceae and *Ceratitis spp* which constitute the major pests of guava, citrus (orange, tangerine and grape fruit), mango, chillies (peppers),egg-plant and coffee berries.

Siddig (1984) and Deng(1990) reported that the fruit fly *Ceratitis 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 cucurbitate and Dacus longistylus*) on water melon and melon .*Ceratitis capitata* and *Certitis cosyra* on guava and mango.

Ahmed (2001) and Elhewaris (2003) also reported *Ceratitis 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, *Ceratitis capitata* and *Ceratitis cosyra* are considered as devastating pests to fruit trees, :mango, guava, and citrus all over the country especially at Shendi, ,Senga, Sennar beside a new

species, *Bactrocera invadens* which was reported from Blue Nile areas (Drew, 2005).

2.6 Biology of the fruit flies.

2.6.1 *Ceratitis capitata*(Mediterranean fruit fly)

The biology of *ceratitis capitata* is similar to that of *Ceratitis cosyra* (the mango fruit fly) (Hill,1983). The egg of *Ceratitis capitata* are laid in patches of about 1-10 egg, below the skin of the host fruit (Shoukry, and Hafiz,1979, White and Harrries,1992).Eggs are very slender,curved,1mm long, smooth and shiny white hatching after 2-4 days, or 3days in warm weather. (Thomas *et al.*, 2001).

Larvae pass through 3 larval stages or instars. They are white with a typical fruit fly shape elongate, cylindrical maggot which is cream colored. Anterior end narrowed and somewhat recurved ventrally, with anterior mouth hooks and flattened caudal end (Thomas *et al.*,2001 , Ronald,2007) Fully grown larvae measure about 1.3 cm in length and larval stages may last as short as 6-10 days or as long as 14-26 days depending on temperature and host (Ronald,2007). In Sudan larval stage takes 9-14 days (Abbas,1998).

Pupae are cylindrical, approximately 4 mm long and dark reddish brown .The duration of pupal period was 6-13 days (Hill, 1983, Ronald ,2007).pupae usually develop in the soil at an inch or two (1-2.5 cm) below the surface (Deng,1990).

The length of an adult fruit fly ranges between 3 to 5 mm. The general colour of the body is yellowish with brown tinge, espically on abdomen, leg and some marking on wings. Eyes are reddish purple. The oval shaped abdomen is clothed on the upper surface with fine, scattered black bristle, and has tow narrow, transverse, light colored bands on the

basal half. Wavy yellow band on scutellum runs across the base. The basal cells of the wing with spot and fleck shaped marks, giving articulate shape. (Schumutterer, 1969).

2.6.2 *Ceratitis cosyra* (mango fruit fly)

The female selects the mature fruits for egg-laying .The eggs are tiny, white and color and hatch after 1-2 days. Deng (1990) and Hill (1983), reported that the incubation period takes 2-4 days from egg laying until hatching.

The larva has three instars. The larva is white, except as appearances are altered by the color of the food within the alimentary canal. The larva has a typical fruit fly larval shape cylindrical-maggot shape, elongate, anterior end narrowed an somewhat curved ventrally, with anterior mouth hooks, ventral fusiform areas and flattened caudal end. The last instars larvae ranges from 7.5 mm to11.8 mm in length.

The larva of the melon fly is particularly distinctive in having a dark sclerotized horizontal line below the spiracle region on the caudal end, with a curved ridge on each side of it. No other known fruit fly larva has this combination of characters, plus other features of the anterior spiracles and cephalo-pharyngeal skeleton (Berg, 1979).Maggot are white, broader at the posterior end and pointed at the anterior end. When fully grown, they measure about 1-2 cm in length (lux and Kimani, 1998). Larval period takes 10-14 days (Hill, 1983).

Malio (1979) reported a pupal period of 12 days while Hill (1983), reported it as 14 days. The body color is yellow with black spot at the thorax, it has characteristic pattern of yellow wing bands and three black areas in the apical half of the scutellum. (White and Harris, 1992).

2.6.3 *Bacterocera invadens*

Bacterocera invadens was first found in Kenya in 2003 (lux *et* al.,2003) and somewhat later reported from Tanzania (Mwatawala *et al*., 2004). Although initially thought to be a variant form of *Bacterocera dorsalis* ,it was recognized as a distinct species (Drew, 2005).In that description, its native range was indicated as Sirilanka. Since its first discovery on the African mainland, it has rapidly spread and now it is found in several countries of eastern, central and western Africa. Recently, observation from southern Africa are also reported (correia *et al.*, 2008). A brief outbreak of Methyl Euginol responding species in Maurities in 1996, attributed to *B .dorsalis* (White *et al*.,2001),may have been this species. Available samples were re-examined but the results were inconclusive.

Females flies insert eggs under the skin of fruit in clusters of 10 to 50 about 1/25 to 1/8 inch below the fruit surface. The eggs are white, elongate, and elliptical .they hatch in 1-2 days. Larvae are legless, and resemble an elongated cone. The mouth is at the pointed end of the body. The third instars are about 2/5 inch long .The entire larval stage lasts for 11-15 days. The puparium is yellowish –brown and seed-like. Adults emerge in about 10 days. (Abdelmagid, 2010).

The color of the fly is highly variable but mostly yellow with dark markings on thorax and abdomen. Generally, the abdomen has two horizontal black stripes and longitudinal median stripe extending from the base of the third segment to the apex of the abdomen. These markings may form a "T" shaped pattern, but the pattern varies considerably. (Abdelmagid, 2010).

2.6.4 *Bactrocera zonata*

Eggs are laid below the skin of the host fruit. These hatch within 1–3 days and the larvae feed for another 4–5 days. Pupation is in the soil under the host plant and adults emerge after1–2 weeks (longer in cool conditions). Adults occur throughout the year). For most *Bactrocera spp.,* it is the adults that are best able to survive low temperatures, with a normal torpor threshold of 7° C, dropping as low as 2° C in winter. *B. zonata*, however, overwinters in the larval or pupal stage (Fletcher, 1987)., Qureshi *et al*. (1993), investigating development of *B. Zonata* at different temperatures, showed that no stages developed at temperatures of 15° C or under, the optimum being at 25–30° C. Originally considered as an exclusively tropical fruit fly, *B. zonata* has now established in Egypt. This raises questions about its possible survival during periods of cold weather. White , Elson-Harris (1992).

2.7 Behavior of the fruit flies

2.7.1 *Ceratities capitata*:

Adults emerge from the pupal cases in large numbers early in the morning during warm weather and emerge more sporadically in cooler weather. They can fly short distance, but wind can carry them a mile or more away. Copulation may occur at any time throughout the day. Newly emerged adult are not sexually mature. Male often show sexual activity 4 days after emergence from the pupae. Most females are ready to mate 6-8 days after emergence from the pupa. Both sexes are usually active throughout the day (Schmetterer, 1969, Ronald, 2007). In Sudan, Deng (1990) studied the behaviour of the insect . He revealed that,
C. capitata make between 9-22 ovipuncture per fruit , larvae number per fruit was 60=36, and adult flies roasting at shady places feeding on

insect honeydew, juice of damage fruits and birds residues. The insect sexual activity was observed in the early morning and evening hours.

2.7.2 *Ceratitis cosyra*:

The study of *C. cosyra* adult feeding behaviour indicated that during the first two days after adult emergence both, sexes were found to feed only on sugar. Two days after adult emergence, females preferred more yeast (protein source) compared to males. In case of sugar, it was preferred more by males than females .Except for mating, no any nocturnal activity was observed for *C. cosyra* . Mating was found to occur 4 days after adult's emergence (Bashir, 2007).

2.7.3 *Bactrocera invadens*

Females begin to lay eggs about 8 days after emergence from the puparium. Under optimum condition, a female can lay more than 3,000 eggs during her lifetime, but under field conditions approximately 1,200 to 1,500 eggs per female is considered to be the usual production .Ripe fruits are preferred for egg laying, but immature ones may be also attacked. Adult flies live for many months (Ronald, 2007).

2.7.4 *Bactrocera zonata*

Adults of *B. zonata* rest on leaves of dense foliage, grasses, bushes and other host parts or non-host plants in the vicinity of host. During the warmer hours of the day they disperse and fly actively. Their eggs and larvae are well protected and found inside the host. And the soil provides a good shelter for the pupae. (White & Elson-Harris, 1992).

2.7.5 Seasonal abundance of fruit flies

Gupta *et al*, (1990) studied the seasonal fluctuation of *Dacus zonata* (*Bactrocera zonata*) and *Dacus dorsalis*(*Bactrocera dorsalis*).In semi-isolated peach, plum and picot orchard located in the mid-hill region of Himachal Pradesh, India during 1986 and 1987.Traps baited with methyl euginol and malathion captured male of both species from the second week of April until the second week of November during both years, through adult of *B. zonata* were caught. In 1986, peak adult activity occurred during the third week of June on apricot, the 4th week of June on plum and the second week of July on peach. In the Gazira State, *B .muaclens* was found to occur throughout the year and the species has several population peaks. The highest peaks were in March and August while the lowest populations were in April through June and in December. *Ceratitis capitata* existed all the year round and had distinct peaks of populations in March, August, September and October Also, *C. Cosyra* was detected in all months with relatively high population from the last week of February to the last week of march (Mohamed and Ali,2008).

In the earlier study by Ahmed (2001), *Ceratitis cosyra* in the Gezira showed population peaks in the humid months of July and August. *B .cucurbitae* in Gezira was found in relatively high population, during the months of September, October and November (Ahmed, 2001).From April through August this species was not caught by the culure baited trap (Mohamed and Ali, 2008).

In Kordofan, *C .cosyra* was present continuously and had its peaks in January, March and October (Bashir, 2007) In Khartoum and River Nile State, *Ceratitis capitata* was reported to have two population peaks, peak in August and September and the second in January and

February (Abbas,1998).Also in Khartoum, *D .cilatus* and *D. vertebratus* were found to breed throughout the year if cucurbit fruits were available Their peaks were in the cold season in November and January and they declined in the dry and the rainy seasons (Ali, 1967).

2.8 Ecological factors (Appendixies 1,2)

2.8.1 Temperature

The development of immature stage of tephritids is possible under temperature range 10-30˚c. A temperature of 45 c is the upper limit for few hours of survival of all stages of flies (Bess and Harmomoto, 1969). The role of the temperature as determinate of abundance in tephritids is mediated either directly or indirectly through its effect on rates of development, mortality and fecundity (Clark, 1957). Porkpy (1978) stated that, egg laying is usually restricted to a few weeks in summer.

2.8.2 Moisture

According to Batman (1972) the moisture is an important factor for the determination of abundance of tephritids and there was a high correlation between the availability of moisture measured by rainfall and peak number of fruit flies achieved each year. However, Vargus (1983) found negative correlation between total monthly rainfall and the number of *C .capitata.* Bateman (1972) stated that tephritids were rarely found in extreme dry parts of the world. This might be due to a limitation on the distribution of their host plant, rather than on the capacity for physiological adaptation. According to Nelson (1964), the survival rate of pupae at relative humidity of 60% and below was virtually zero. However, Shoukri and Hafiz (1969) reported that the effect of R.H on the pupal duration had no significance, though the

percentage of adult emergence was found to be high at 60% and low at 30% R.H.

2.9 Control of the fruit flies

2.9.1 Cultural control

The cultural controls are the oldest methods that have been used to manage pest population. They are preventive rather than curative; they are depending on long term planning. Also they are dependent on detailed knowledge of the bio-ecology of the crop. Pest natural controls environment relationship, most of which, in the past, were poorly understood .The results were very a variable and it was often difficult evaluate their effectiveness. Recently, after the increase of crop producers and crop protectionists knowledge about the bio ecological relationship within the crop system and the social demanding of organic farming, world gave more attention to the cultural practices as main item is very integrated pest control program. (Hill, 1983). Cultural control includes practices, Such as these below, may be regarded as part of the normal production system.

2.9.1.1 Cleaning of orchards

The collection and destruction of fallen damaged and overriped fruits is strongly recommended to reduce the reservoir of the resident population of fruit flies. Field sanitation should be the essential component in the control programs (Allwood *et al*., 2001). In China, *Bactrocera minax*, a highly destructive pest of citrus, is successfully controlled by large scale, area-wide practice of destruction of fallen fruits in orchards and village. In Sudan, Abbas (1998) concluded that cleaning of the orchards from infested and dropped fruits must be practiced to minimize the next season infestation by the fruit flies. The

cleaning of orchards or field sanitation terms should include the removal of other plants that can act as fruit fly alternative hosts. I deally it would best to avoid planting fruit fly prone trees (Michael, 2007).

2.9.1.2Ploughing

Ploughing inside orchards should adopt to improve soil physical conditions and facilitate plant root nutrition. This practice is found to contribute positively to the control of fruit fly, since the pupation of the flies mainly occurred in the soil. A series of laboratory experiment were carried out to investigate the fruit flies pupation habitats. It was mostly concluded that the larvae of flies showed a strong preference toward pupating in shaded rather than bright areas, in moist rather than dry soil, and in soil with larger particle sizes. (Ali, 1967, Abbas, 1998, Alyokhin *et al.*, 2001).The above findings, confirm that ploughing practice may control the fruit flies population, where a group of different age of pupae may be exposed to sun light, heat and natural enemies, leading to their death.

2.9.1.3 Irrigation

The flooding of orchards with water for different periods of hours was found effective in controlling the Mediterranean fruit fly population, as it impeded the pupae eclosion and adult flies emergence. The applicability of this cultural practice in fruit orchards is quite possible from time to time to control fruit flies pupae in the soil (Abbas, 1998). Laboratory studies to investigate the mortality rate of fruit flies pupae at different ages subjected to different periods of water immersion in different types of soil, showed high mortality rate in young pupae (1-4 days old) than the oldest pupae (5-7 days old). In the heavy clay soil 6 hours of water immersion impeded the eclosion of

75% of the pupae while, 12 hours gave the same result in the sandy and silt soil (Abbas, 1998 and Yokoyama, 2007).

2.9.1.4 Pruning

Pruning is usually carried out to shape trees and open up the centres, allowing free movement of air and sunlight into the tree. The ability of sunlight to penetrate the tree enhances the colour of the fruit and improves quality (Poffey and Owens, 2006).The behaviour of the adult fruit flies of roasting, mating and oviposition at shady places; make pruning of mango or citrus trees an effective practice to minimize the fruit fly damage. (Abbas, 1998).

2.9.1.5 Early harvesting

The term early harvest means; harvest of the fruits at full physiological maturity and before ripening, and harvest of the fruits before pest expectant outbreak .The ripe fruit of mango, guava and citrus was found to be more susceptible to fruit fly infestation than the mature or immature fruits (Abbas,1998 , Ahmed, 2001). So the harvest of the fruits at mature stage and then ripen them by artificial means is advisable to avoid their infestation by the fruit flies.

2.9.1.6 Production at time of low fruit fly abundance

Fruit fly activity and population vary throughout the year .The seasonal abundance data is also varying within genus, specie and area of production. The time of production at low flies population could be practiced by cropping of early maturing varieties before flies peaks of population, or late mature after the lowering of insect population. Alternations in planting date and harvesting date can frequently result in plants escaping from damaging (Ferro, 1996).

In Sudan, Baladi variety of mango mature in April and May that makes this variety avoids the flies' infestation. While shendi variety mature in July and coincide with the peak of flies high population.

2.9.1.7 Use of trap crop

Crop mono cultures often damaged more severely by pest than when the same crop is grown in an area with other crops. However, there are cases where such diversity can aggravate pest problems. It is in this situation trap crop is important (Ferro, 1996). It is one of the effective cultural methods for controlling *B. cucuribitae* is planting of trap crops (Ronald, 2007).

2.10 Biological control

Biological control is potentially useful approach in suppressing fruit fly densities (Wharton, 1989, Knipling, 1992, Waterhouse, 1993 and sivinski *et al*., 1996). Recently, natural enemies were used to reduce the population of medfly, *C .capitatata* (Wongand Ramadan, 1992, Headricks and Godden, 1996).

2.10.1 Predators

some predators from different families such as *staphlinidae ,chrysopidae ,pentatomidae* and few mites were reported to prey on tephritids (Batman,1972).some earwigs were predators of *Bactrocera dorsalis* (Handel) in Hawaii(Marucci,1955);the Argentine ant , *Lridomyrmex humilis* (Mayr)Attacks *C. capitata* under laboratory conditions , and causes 50% mortality of the med fly pupae (Wong and Ramadan,1992).

The lizard, *Analis graham* (Gray) was introduced from Jamaica and Bermuda to control some fruit flies, but their role in controlling the pest

has not been indicated (Clasuesn, 1978). Bird and Rodents were reported to consume infested fruits resulting in a high level of larval mortality (Drew, 1987).

2.10.2 Parasitoids

Silvesteri(1914) reported that the history of classical biological control of tephritids using parasitoids dated back to the beginning of the 20th century when George compare was hired in 1902 by the Government of west Australia to search for natural enemies of medfly and travelled to Philippines ,China and Japan from where he crossed to California and finally to Europe . Many parasitoids species especially in the family *Braconidae* were used for the biological control of fruit flies (Wharton, 1989).

2.10.2.1 Fungi

The genera, *Penicillum*, *Serrata* ,and *Mucorae* were reported to cause considerable mortality to the larvae and pupae of *B .dorsalis* (Newel and Haramoto 1968). Studies carried out by Ekes *et al.* (2002) and Dimbi (2003) proved that *Metarhizium anisopliae* have very high potential in suppressing fruit fly population.

2.10.2.2 Bacteria

Bacillus thuringiensis (Beliner) sub species *dormadiensis*, when mixed with a protein diet and sugar and introduced as bait was found to kill *Anastrepha ludens* (Loewin) (Robacker *et al*.,1996; and Martinez.*et al*.,1997).

2.10.2.3 Nematodes

The medfly, *C .capitata* was susceptible to the entomopathogennic nematode *steinernema felitiae* (Filipjevi). Emerging adult and pupae were not susceptible to the nematode, but the third instars larvae

suffered high mortalities (50-90%) when exposed to high nematodes population (150.000-500.000 nematodes/cup) (lindegren and Vail ,1986). Field exposure of mature larvae to a dose of 500 nematodes /cm2, yielded high mortality of *C .capitata* (lindegren *et al* ;1990).

2.10.3 Sterile insect technique (SIT)

The sterile insect Technique (SIT) had been successfully used to eradicate fruit flies in several parts of the world. Early example were the eradication of the melon fly from the Mariana islands (Steiner *et al*., 1965). And kume island in Japan (Iwahasi, 1977) as well as the oriental fruit fly from Guam (Steiner et al., 1970) as result of which Japan had been declared free of the oriental and melon flies (Kawasaki, 1991) SIT had been extensively investigated in 13 species of tephritids (Hooper, 1989).

The use of SIT is not a simple procedure and involves a high degree of technical expertise, time and funds. There are several discrete components of the SIT that must be investigated to ensure success of the project and these have been reviewed by Hooper (1991).

The important components included: appropriate diets and mass rearing techniques to produces 500-1000 million individuals per week, suitable techniques to sterilize flies, handling transport and release methods, and the methods to evaluate the progress of the control or eradication programme. Sterilize insect technique has been attempted in Thailand (Sutant-Worg, 1991) and the Philippines (Manoto, 1991) on only a pilot scale.

2.10.4 Eradication

Most countries that are successful in horticultural industries do not have fruit flies or have embarked on procedures to totally eliminate

them. Avery good example in the state of California that has a huge fruit industry which is supported by an extensive fruit fly survey, detection and eradication services. Adventives populations of the oriental fruit fly, med fly, melon fly and several other species of tropical fruit flies are regularly intercepted and eradicated by the state authorities. The med fly was eradicated from Mexico (Hendrichs *et al.,* 1982) where government has expanded this to a large national campaign for the elimination of 4 species of native *Anastrepha* (Zavala *et al*.,1991) .

The medfly eradication programme in Guatemala has enables 57 % (62.000 km2) of the country to be free of the pest and is continuing to achieve total elimination (Linares, 1991). Eradication can be achieved by a number of means. Target population can be first reduced by insecticide cover spray or male inhalation technique or combination of all (Bateman, 1982).

2.10.5 Legislative control

Avoid transferring infested fruit, from a highly infested area to slightly infested area, or pest- free area without post harvest treatment such as quarantine disinfection and prevent planting of different types of hosts at one place, in order to break the food cycle of the fly around the year (FAO, 2004).

2.10.6 Chemical control

The chemical or the insecticidal methods of control of the fruit flies fall under three main categories: spray the adults with suitable insecticides, trapping of the adult flies by means of chemical attractant, and bait spray that in essence of an insecticide mixed with bait (Ali, 2007). The study of Deng (1990) tested three insecticides to control the

Fruit flies, resulted that methidathion (supracide) was the most effective compared to carbaryl (sevin) and cypermethrin (polytrin).

2.10.7 Trapping and bait spray of fruit fly

Different traps and lure have been developed and used over decades to survey fruit flies population. The first attractants for male fruit flies was methyl euginol (ME). For *Bactrocera zonta* followed by kerosene for Mediterranean fruit fly , *Ceratitis capitata*.(medfly)(Severin ,1913). In 1956, Angelica seed oil was used to trap med fly (Steiner *et al.*, 1957).

Beroza *et al*.,(1961) discovered trimedlure (TML) to be effective for *Ceratitis capitata*. Food bait based on protein, fermented sugar solution, fruit juices and vinegar had been used since (1918) to capture females of several fruit fly species. The Mc phail trap was the first device to be used with protein baits (Mc phail, 1939).Steiner traps were developed in 1957(*Steiner et al.*, 1957) and Jackson traps in 1971 for TML (Harris *et al.*, 1971). These traps are currently being used in various countries for fruit fly survey, control activities and eradication campaigns. Global trends in increasing food quality, revenue sources, fruit and vegetables trade, have resulted in an increased worldwide movement of fruit fly species this requires refinement of survey systems. These proven technologies include the use of synthetic food lure such as female attractants that can be used for several species. It is well known that bait-spray offers one of the most effective methods of control especially in the preovipoition stage when the flies require protein for egg maturation. This habit of the flies has been taken advantage of poison to kill them. A few branches and foliage in each tree in an orchard are swiftly sprayed so that the spray does not drizzle down, but is retained on the leaves as droplets. The various insecticides

employed were lead arsenate, Paris green ,potassium arsenate, sodium arsenate, copper carbonate, sodium flu silicate and tartar emetic; the insecticide were dissolved in syrup of cane sugar (Narayanan and Bartra, 1960). The fruit fly was attracted to the deposits of the protein materials, which contain nutrient essential for its sexual development, and quickly ingest enough to kill it. The contact action of the deposits and contamination of natural food sources also contribute to fly mortality (Narayanan and Bartra, 1960).

2.10.8 Spinosad

2.10.8.1 The active ingredient

Spinosad (Fig.1) (spinosyn A and spinosyn D) is a class of insecticides the discovery and characterization of the soil *actinomycete* (*Sccharopolyspora spinosa*) represented novel opportunity to develop portfolio of progressive insect management tools (Sparks *et al*., 1998). The active ingredient of spinosad is derived from a naturally excuring soil, dwelling bacterium, a rare actinomycete reportedly collected from soil in abandoned rum distillery on a Caribbean island in 1982 by vacationing scientist, It has not been found in nature since that time and was subsequently described as a new species, spinosad has been classified as an environmentally and toxicologically reduced risk insecticide (Cleveland *et al.,* 2001).

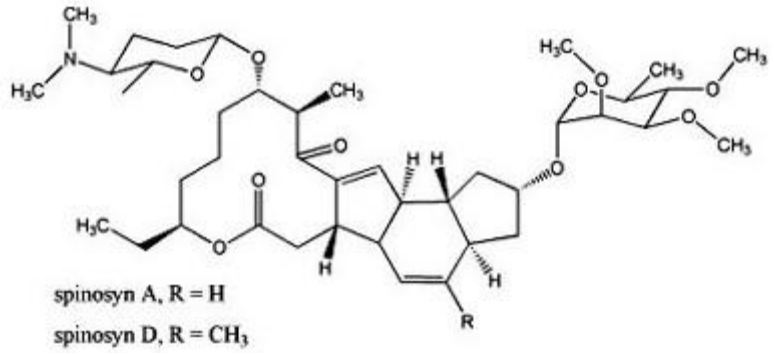

Fig (1) structure of spinosad

2.10.8.2 Mode of action:

Spinosad kills susceptible species by causing rapid excitation of the insect nervous system, leading to involuntary muscle contraction, prostration with tremors and paralysis .These effects are consistent with the activation nicotinic acetylcholine receptors by mechanism that is clearly naval and unique among known insect control products,Safaty ,oral, rate,: acute, >3600mg/kg, dermal, rate, acute: 5000mg/kg These values refer to the active ingredient. Toxicity has to be determined for each formulation as well. Formulations are usually significantly less toxic than the active ingredients. Spinosad also has an effect on GABA receptors function that may contribute further to its insect activity reported by Schmutterer and Hiiber (2005).

2.10.9 Zonatrac

Product Name: Zonatract Product code: PCT-ZONA-250

Russell IPM has launched an innovative fruit fly control system Zonatrac, to combat invasive fruit fly species. It is male specific lure and kills system based on methyl euginol attractant, which can be successfully used for the control of peach fruit fly, African Invadens fruit fly, Oriental fruit fly and other fruit fly species. Zonatrac is an innovative system which is consist from blend of Methyl Eugenol (49%) and Spinosad (2%) in an

emulsified wax formulation for attract and kill males of Bactrocera species such as *B. zonata* and *B. invadens* and *B. dorsalis* and other Tephritid flies attracted to Methyl Euginol and 6-8 weeks depending on environmental condition and fruit fly species. (Kafu *et al*.,2012).

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Chapter Three

MATERIAL AND METHODS

3.1 Area of study

Field observation were mainly conducted in Shendi which is located on the River Nile State, lies between latitude 16° 42` North and longitude 33° 26` East and altitude 360m, the annual rain fall mean ranges from (14) to (60) mm, occurring mainly during the period from July to September . (Fig. 2)

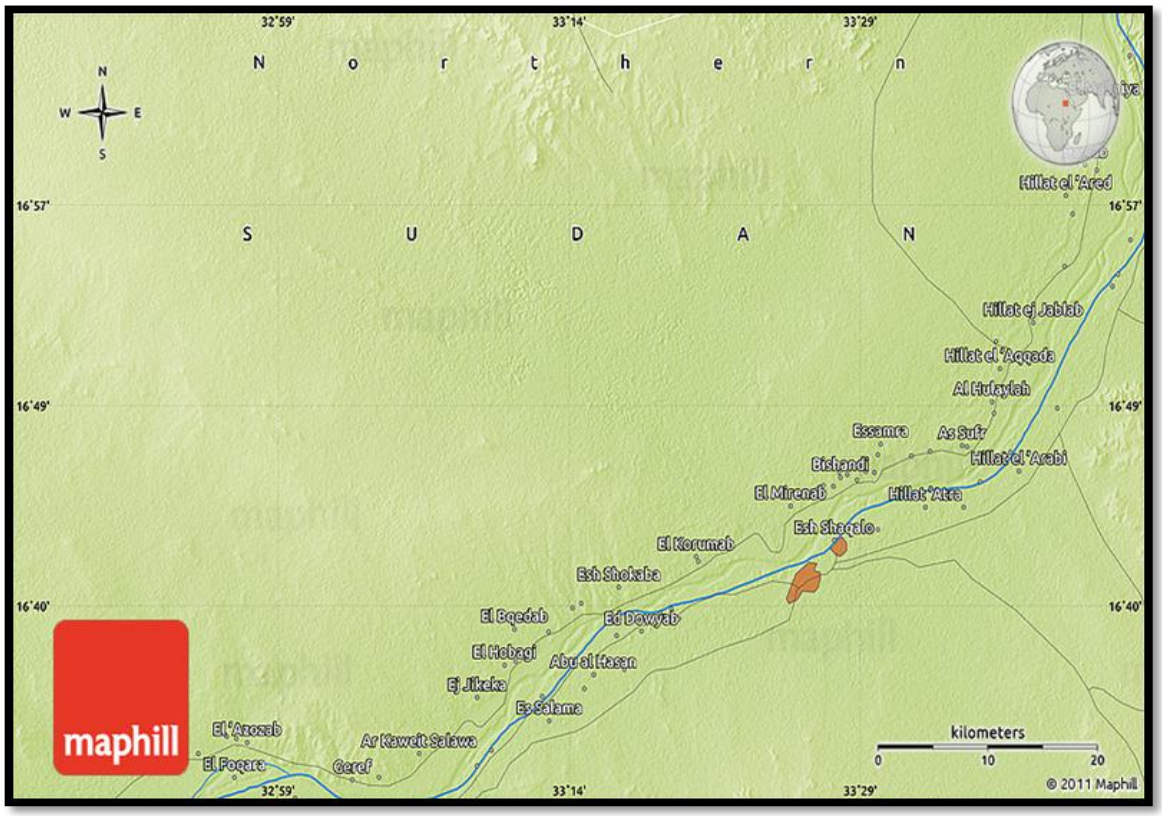

Fig. (2) Map of study area

The climate of the experimental site is semi arid, relatively cool and dry in winter, with maximum and minimum temperatures ranging from 34 to 36°C and 14 to 16°C Respectively and hot in summer with maximum and minimum temperature ranging from 40 to 46° C and 20

to 22 respectively, relative humidity (RH) Ranges from 50 to 75% in the rainy season and far below 50% otherwise. (Apendixies 1, 2).

3.2 Field Survey

Field surveys were carried out to determine the following:

1/Study the abundance and population of the fruit flies.

2/Evaluation the role of spinosad against fruit fly.

3/Develop an IPM for the mango grower.

3.3/Abundance of fruit fly in two season: Traps preparation

3.3.1 phermone traps prepration

Lynfield traps were manufactured locally which is a plastic box with four hole per 2 cm and was then put a piece of gauze cylindrical shape with a diameter of 1-2sm and length of 4 cm by connecting thin wire attached to cover the trap. So that the high level of taste with openings stomach .Plate (1), Methyle euginol was mixing with pesticide malathion 57% ratio of 4: 1, respectively, and then

A / been put 3 ml of solution in each trap

B / traps attached by wire to a shady tree branch

C / supply trap the solution of each month, a period when the bait is effective and former uses the same size and proportion with taking readings.

Plate (1). Lynfield trap baited with Methyl euginol.

3.3.2 Food bait traps

For one liter of bait mixture, 40 gm of yeast (as a source of protein) was added to 25gm of sugar (as a source of carbohydrate) and 4ml of Malathion (57% EC) and made it up to a liter with water. Two hundred and fifty ml of bait solution was dispersed per trap, each trap was serviced every 10 days and the bait was replaced with freshly mixed solution.

3.3.3 Placement of the traps

The traps were hung approximately 2 meter from the ground in shaded areas and the position of each trap was fixed throughout the study period.

3.3.4 Collection of specimens from traps

The trap catches were collected every 10 days by replacing the bottle part containing the catches in the Para pheromone traps. In the case of liquid food bait traps, the baits with specimens were poured through

a sieve or tea strainer to separate the specimens. The specimens were collected carefully from each trap with a soft brush. They were then preserved in a vial containing 70 % alcohol until needed. Identification and counting of the flies were carried out in the laboratory.

3.4 Evaluation of spinosad (Fig .2)

Four orchards were selected in Shendi area (3 treated +1 control) and each one included mango, citrus and guava. To monitor the fruit fly population, 4 methyl euginol traps were used before and during the execution of the experiment. The plot design was one hectare with a buffer area of 100 meters between plots.

3.4.1 Application method

The first spray was applied at early fruit set stage and repeated at 10 days using a knapsack sprayer. The solution was sprayed on the lower half and anterior of the selected tree on the south eastern side, this area known to be less exposed to the sunlight in after noon, in addition, it provides resting place for the adults of fruit flies .The surface area treated was being about 1 m square .Treated alternate trees or alternate rows only, the dose 1.25L diluted in 8.75L of water giving a spray volume 10 L and applied as scattered droplets. Plate (2)

Plate(2). Partial Application of the spinosad in manogo Orchards

3.4.2 Efficacy Assessment

Hundered healthy undamaged fruits from 10 trees in the centre of the treated plot with GF-120(spinosad) were marked and tagged, the same was done for the control plot. All 100 fruits recorded were collected at harvesting stage, and then the number of damaged fruits was counted to calculate percent infestation. Any missing or dropped tagged fruit were recorded.

3.5 Zonatrac traps preparation

In this experiment we selected three Orchards, 6 Traps (Lynfield) to each one , 3 baited with Methyl euginol, the other three baited with zonatrac. Readings were taken every 10 days and collect all the insects in all type of traps and counted. plate (3), plate (4).

Plate (3). Zonatrac container

Plate (4). Lynfield Trap Baited with Zonatrac.

Chapter Four

Result&Discussion

The present study provides information about many aspects of fruit flies in the Sudan, such as identification of the species, seasonal abundance, and development of an IPM for the fruit growers.

4-1 Seasonal abundance of the species

Monitoring of the seasonal abundance of the fruit flies species in Shendi area, was conducted by using pheromones and food bait traps during the period of April 2012- April 2014. Through the results of the first season, we noticed that *B .invadens* showed lower population in March (634.5±94.9) and grow up gradually until it reaches the peak in July and August, (1869±48.5) and (1893±48.9) respectively. *C .capitata* was noticed during August. Its population reached (287.8±32.4). The mango fruit fly *C .cosyra* was seen all through the year, but the highest number recorded in August (296.3±38.5). Table (1), Fig (3) .

Table (1). Seasonal abundance of fruit flies in Shendi area April 2012 - March2013

Month	*(B.invadens)*	(*C .capitata)*	(*C .cosyra)*
April	900.8±56.5	208±10.5	237.5±30.9
May	1057.3±131.2	232.7±6.5	240.3±40.3
June	1632.8±151.1	240±20.6	251.3±43.8
July	1869±48.5	268.3±28.9	283.5±47.8
August	1893±48.9	287.8±32.4	296.3±38.5
September	1725.3±57.8	211.8±17.3	234.8±45.1
october	1308±107.2	195.8±23.1	242.0±52.2
November	1044.5±159.5	185±17.5	187.8±17.1
Desember	1033.5±108.3	180.5±15.1	178.8±7.5
January	851.5±56.3	173.8±16.9	176.0±10.9
February	705.8±53.9	165.8±12.9	174.5±12.3
March	634.5±94.9	137.8±21.9	154.8±17.3

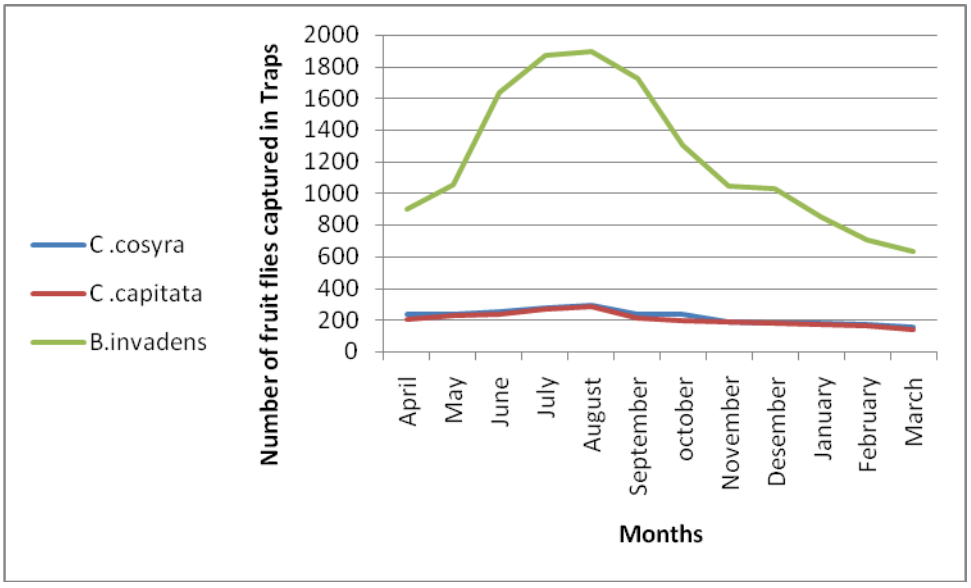

Fig. (3) Seasonal abundance of the three Fruit flies (*B .invadens,C .capitata, C.osyra*) in Shendi area from April 2012-March 2013

The second season April 2013- March 2014 the African fruit fly *B .invadens* abundance peak in August (1258.5±105.8) and also the lower number were catched was in March (654.3±57.9). *C .capitata* was appeared in relatively few numbers since July (230.3±32.6) to November (206.3±8.7). *C .cosyera* in this season showed very low appearance, but the peak number was still in August (233.8±45.9) High population of *B .invadens* and *C .cosyra* during August attributed to the high level of rainfall which results in high relative humidity and low temperature also for the availability of the host (mango). Also, high population of *B .invadens* and *C .capitata* during November may be attributed to moderate humidity and temperature and availability of guava fruits. Ali, *et al.,* (1965) stated that in the Gezira State, *B .invadens* was found to occur throughout the year and the species showed to have several population peaks. The highest peak was in August while the lowest populations were in April and December. This result supported by the finding of Ahmed, 2001, who reported that the population of *C .cosyra* largely dependent on the climatic factors, viz. temperature and relative humidity, and the peak of its population reported during August. Deng, 1990, and Abbas, 1998 also stated that the population peak of *C .capitata* was found to be during July, August and January.Table(2),Fig (4).

Table (2). Seasonal abundance of fruit flies in Shendi area April 2013 - March2014

Months	*B.invadens*	*C .capitata*	*C .cosyra*
April	847.5±134.6	193.5±19.3	227.8±18.1
May	865.3±109.2	193.5±24.3	228.3±21.9
June	1047.5±121.9	199.5±31.5	230.5±28.7
July	1175±131.8	230.3±32.6	228±40.3
August	1258.5±105.8	257.5±35.7	233.8±45.9
September	1005.3±117.9	183.3±5.4	188.5±26.4
October	873.3±56.2	201.3±13.9	191.8±17.4
November	864.5±43.9	206.3±8.7	183.5±9.5
December	810.8±55.7	183.3±6.9	177.5±10.7
January	763.5±56.2	147.5±5.5	177.8±9.3
February	724±29.8	134±6.7	172.5±9.5
March	654.3±57.9	131.3±11.6	165.5±7.3

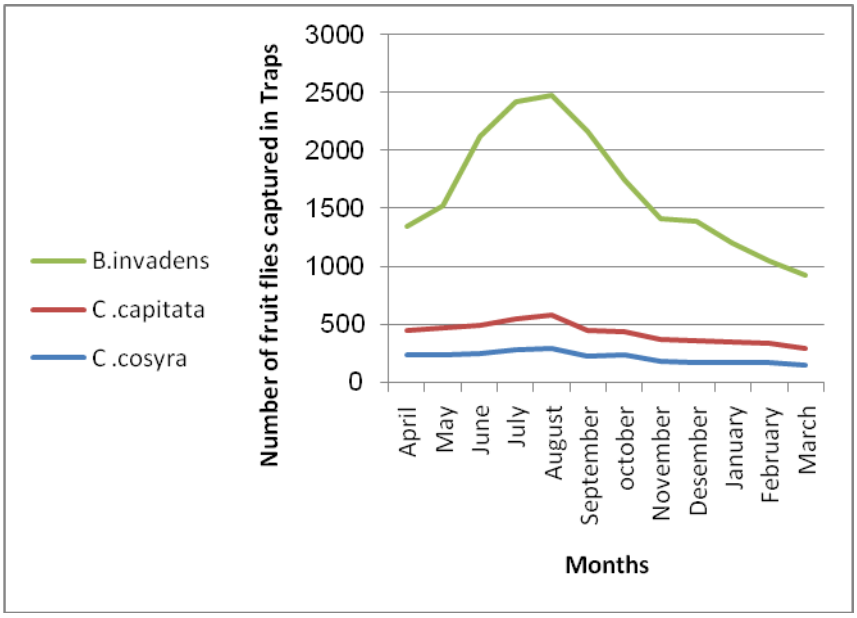

Fig. (4) Seasonal abundance of the three Fruit flies (*B .invadens,C .capitata, C.osyra*) in Shendi area from April 2013-March 2014

Comparison between the two seasons, revealed that the general population of the *B .invadens* and *C .cosyra* was lower in the second season. This different may due to the phenomenon of exchange of flowering in mango, When the amount of mango produced was less in the second season. But the increase of citrus production in the area and introduction of many new citrus orchards may cause the increase of the Mediterranean fruit fly population. The decline of the population of the fruit flies in the second season, (Fig 3&4) also may attributed to the of heavy rain in the first season, which created a suitable environment for the insects.

B. invadens was found to be the dominant species in the study area (Fig 3&4) this was supported by (Abdelmagid, 2010), who stated that the regional survey of all mango production areas of Sudan, central, western and northern state indicated the presence of *B. invadens* and 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, 2005), it seems that this species is spreading fast and replacing the already existed species. These results also supported the finding of Drew, 2005 who reported that, the Asian fruit flies, *Bactrocera sp*. are polyphagous and encounter inter specific competition with other polyphagous tephritid flies that are already well established, also casual observations in western and eastern Africa suggest that *B. invadens* is largely displacing the native mango fruit fly (*Ceratitis cosyra*) in infestation of mangoes. similary this result supported by (Jose, *et al.*, 2013) who reported that a total of 3,368 adult fruit flies emerged from 3962 pupae collected from all the 5 fruit hosts' species, corresponding to an average mean of 85% of adult emergence. Four fruit fly species were recovered from the fruits collected *Bactrocera invadens*,

Ceratitis rosa, Ceratitis cosyra and *Ceratitis capitata. Bactrocera invadens* was the most abundant species and accounted for 96.9%.

4-2Evaluation of spinosad against fruit fly in shendi area

In this experiment four Orchards were randomly selected (three were sprayed with the spinosad compound and one was not treated as Control. In the period from April to August, 2012 pheromone traps were used to indicate the number of insects during the experiment period. The result revealed that, in April the average insects numbers collected was (947.22 , 1001.67) for the treated and untreated orchards respectively. The numbers of insect were found decreased gradual during the months of May, June, July and August in the treated orchards it was 904.7, 760.22, 609.6 and 452.7, respectively,while in the un treated orchards it was found increased rapidly ,the average numbers were 1003.67 , 1103.67, 1336.67and 1468.67 respectively for the months May, June, July and August.(Fig5) .The statistical analysis of the result showed that the decrease of the insects number every month is not significant between April and May but it was decrease in a highly significant rate all through the treatment period. Table(3) . According to these results, we observed that, the numbers of insects collected from the treated orchards was decreases significantly compared to that of untreated orchard, these, clearly showed the effectiveness of spinosad against the fruit fly.

Table (3). Effect of spinosad on the fruit flies trapped in shendi area.

Number of fruit Fly captured / Months	Treated orchard M±Sd	Untreated orchard M±Sd	Sig
APRIL	947.2±50.059	1001.7±167.26	0.26
MAY	904.7±25.958	1003.7±169.66	0.000
JUNE	760.2±32.797	1103.7±127.1	0.000
JULY	609.6±63.56	1339.7±60.39	0.000
AUGEST	452.7±54.52	1468.7±138.54	0.000
TOTAL	3.674	5917.5	0.000
SIG	0.000	0.000	0.009

Sig≤ 0.05

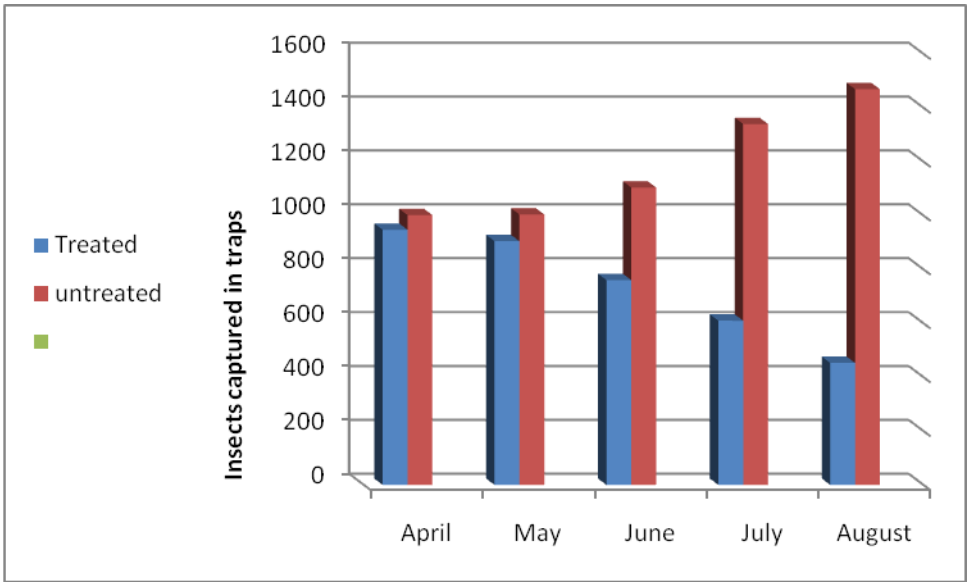

Fig. (5) spinosad efficiency against the fruit fly in shendi area from (April – August 2012)

The great reduction in the mango fruit infestation level was noticed when, the percent was 68% in the untreated orchards and it was 2% in the spinosad treated ones. Fig (6).

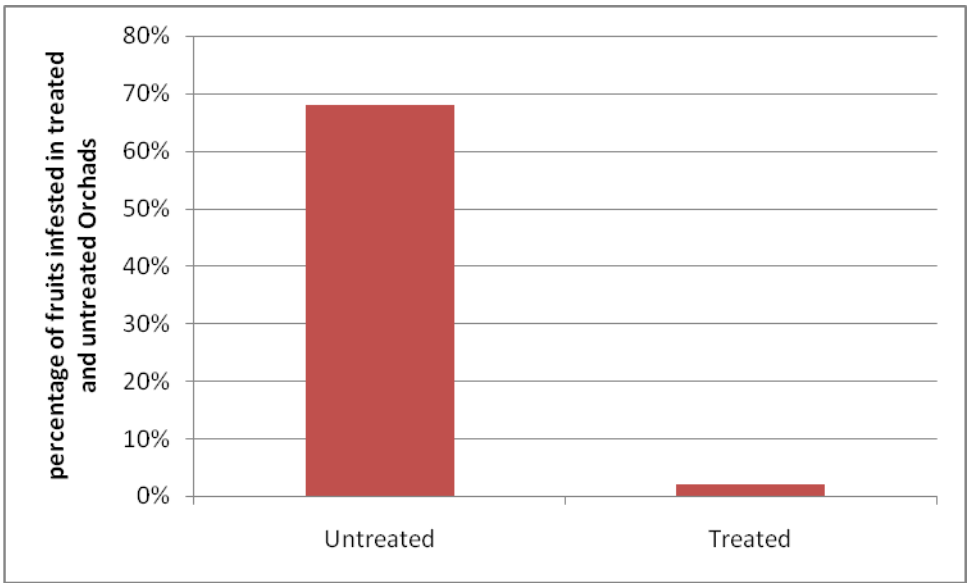

Fig. (6) Effect of spinosad on fruit flies infestation percentage in the mango fruits

This result was supported by (Temerak *etal.*, 2012) who report The efficacy of spinosad (GF120) as a bait application was evaluated in Egypt for the control of *Dacus ciliatus* (Loew) on three cucurbit crops; squash, snake cucumber and cucumber, the bait was also tested on mango for the control of *B. Zonata* (Saunders), The spinosad bait proved to be a very effective and viable alternative to Malathion could be a valuable tool within IPM programs for the control of both fruit fly in Egypt. The result was also supported by Sparks *et al.*(1998) who reported Spinosad is an insecticide, used for the control of caterpillars, thrips, beetle and fly pests in a range of fruit and vegetable crops, ornamentals, turf, and stored grains. Spinosad is used in agriculture, horticulture, forestry, and public health against a wide range of insects including *thrips*, Mediterranean fruit fly, olive fruit fly, codling moth,

caterpillars, leaf miners, Colorado beetle and potato worm. (Stark *et al*., 2004).

4.3 Efficacy of zonatrac in trapping fruit fly :-

The new fruitfly attractant Zonatrac used to evaluate its efficacy in the attraction of *Bacterocera spp* .and the other objective was to explore the entry of the Peach Fruit Fly *Bacterocera zonata* to Shendi area, the result of this experiment revealed that the traps of zonatrac were attracted less number of insects compared with that attracted by the Methyl euginol traps. Table (4), Fig (7).

The difference was highly significant. The means of insects catches were (1671±808) and (355±150) for ME and Zonatrac traps respectively.

The insects attracted by the ME were four fold than that attracted by Zonatrac. this could be explained by the fact that zonatrac is an innovative system which is consist from blend of Methyl Euginol (49%) and spinosad(2%) .(Kafu *et al*,2012) who also reported, Zonatrac showed results with efficacy more than 8 weeks. This system can be used successfully to combat various fruit fly species when applied for an area wide control.

The insect captured in the both types of the traps was taken to the laboratory to classify under E microscope and according to the definition of Drew (2005). The result was illustrated in table (4) showed that, all insects found was only *Bacterocera invedens* and there was no *Bacterocera zonata*. This result may oppose the finding of *Salah et al* (2012) who reported that, the peach fruit fly, *Bactrocera zonata* (Saunders) (Tephritidae), was captured in fruit fly detection traps during July 2011 in three locations in the Gezira area, Sudan.

Table (4): Number of Fruit fly captured in ME Traps and zonatrac traps

Traps / 0rchards	ME Traps-m±sd		ZonatracTraps-m±sd	
	B.invadens	*B.zonata*	*B.invadens*	*B.zonata*
A	2403±712	-	325±256	-
B	1508±608	-	366±107	-
C	1102±636	-	375±105	-
Total	1671±808.2	-	355.7±150	-
T	6.20	-	7.07	-
Sig	00.00	-	00.00	-

Sig $\leq$ 0.05

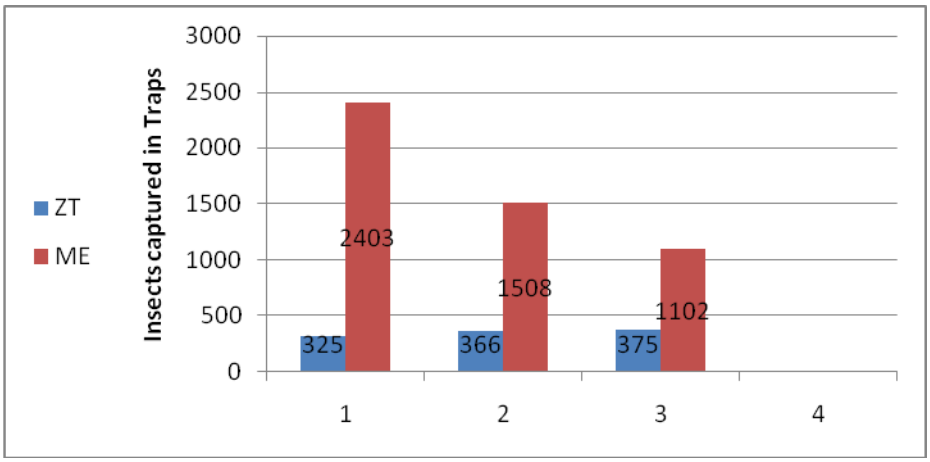

Fig.(7) Comparison between the number of trapped insects, by Methyl euginol and Zonatrac.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions:

1. Monitoring of Tephritidae fruit flies in Shendi area revealed the existence of three fruit fly species, Mango fruit fly, *Ceratitis cosyra*, Mediterranean fruit fly, *Ceratitis capitata* and Asian fruit fly, *Bactrocera invadens*.

2. The Asian fruit fly, *Bactrocera invadens* is the dominant species in Shendi area, found all year round.

3. The study showed that the fruit fly, *Bactrocera invadens* has two peaks, July and August while the other two species has in, august for *Ceratitis cosyra* and August and November for *Ceratitis capitata*.

4. The use of zonatrac traps showed that it was less effective than ME traps. Insect captured classificated in the laboratory revealed there is no *B .zonata* in Shendi area.

Recommendation :

1. Monitoring of the fruit flies using Pheromones traps is necessary for detecting the species found and their population, because the species and their population continuously changed.
2. Management of fruit fly should be based in environmentally safe packages like cultural practices, natural enemies, SIT, and safe pesticide (spinosad).

3. Zonatrac composition contains Methyle Eugenol(49%) and according to this result is not recommend to be used against fruit flies .

4. Strict quarantine measures are essential to prevent entry of infested fruits to free areas.

References

Abbas, A. M. (1998). Assessment of some cultural practices for the control of the fruit fly *Ceratitis capitata*. M. Sc. Thesis, University of Khartoum.

Abbas,M. A. (2008). Cultural practices to control fruit flies National project for control of fruit flies in Sudan, Workshop 26-27\8\2008.

Ahmed, E.E (2001). Studies on mango fruit fly *Ceratitis cosyra* in central Sudan. M.Sc. Thesis, Faculty of Agriculture Science University of Gezira.Sudan,62pp.

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, E.E.; Abbas, A.M.; Ahmed, H.M.; Abdelrhmann, A. A.; Abdelmajid, F.M. (2008). Fruit Fly Review in Sudan From1960-2008. National project for control of fruit flies in Sudan. Workshop 26-27\8\2008.

Ali, S. A. I. (2oo7). 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. PP 56.

Ali. A .k. Nayem, H, Aida, A. B, and Adel, Z. (2012). Evluation of the efficacy of Zonatrac system (lure and kill) to control peach fruit fly *Bactrocera Zonata* (saunder) by application of male annihilation technique.

Allwood, A. and Leblanc, L. (2001). Fruit fly control methods for Pacific Island Countries and Territories. Pest Advisory Leaflet No.40.

Aluja, M, Celedonio-Hurtodo, H., Liedo, P., Cabrera, M. ,Castillo, F., Guillen,

J. and Rios, E (1996). Seasonal population fluctuations and ecological implications for management of *Anastrepha* fruit flies (Diptera:Tephritidae) in commercial mango orchard in Southern Mexico. Environ. Entomy.89:654-667.

Alyokhin A.V.; Christian, M.; Russell, H. and Duan, J.J. (2001). Selection of pupation habitat by oriental fruit fly larvae in the laboratory , J. of Insect Behavior, Springer Netherlands.

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

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

Bateman, M. A. (1972). The ecology of fruit flies. Ann . Rev. Entomol. 17:493-517.

Bateman, M. A. (1982). Chemical method for suppression or eradication of fruit fly population in: Economic fruit flies of South Pacific region.(eds.Drew,R.A.I.,Hooper,G.H.S and Bateman, M. A,):115-128.,Queensland Department of primary Industries,Brisbane.

Beroza, M.N.Green, S.I.Getler,I.F.Steiner and D.H.Miyashita (1961).Insect Attractants : new attractant for Mediterranean fruit fly .J.Agric.Food Chem.9:361-365.

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

Berg GH. (1979). Pictorial key to fruit fly larvae of the family Tephritidae. San Salvador: Organ. Internac. Reg. Sanidad. Agropec. 36 pp

Bess, H. A. and F. H. Harmomoto (1969)contribution to the biology and ecology of oriental fruit fly *Dacus dorsalis* in Hawaii .Hawaii Agri.EXP.Sta .Tech.Bull31:251-285.

CAB/EPPO. (1999). International european and mediterranean plant protection on *Ceratitis cosyra*. distribution maps of plant pest. p. 292-294.

Cleveland, C.B., Mayes, M.A., and Cryer, S.A., 2001. An ecological risk assessment for spinosad use on cotton. Pest Mgt. Sci. 58:70–84.

Chu HF. (1949). A classification of some larvae and puparia of the Tephritidae (Diptera). Cont. Inst. Zool., Natl. Acad. Peiping (Beijing) 5: 93-138

Clark,L.R.(1957).The ecology of insect population in theory and practice .London Methuen,232pp.

Clausen, C .P. (1978) Tephritidae (Trypetidae :Trupaneidae) in :Introduced parasite and predators of Arthropod pests and weeds: a world Review (C. P. Clausen, ed.).U.S. Deparment of Agriculture, Handbook No.480:320-353.

Correia, A.R., Rego, J.M., Olmi, M. (2008). A pest of significant economic importance detected for the first time in Mozambique: *Bactrocera invadens* Drew, Tsuruta & White (Diptera: Tephritidae: Dacinae). Bolletino di Zoologia Agraria e di Bachicoltura Serie II, 40(1), 9-13.

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

Dimbi S. (2003) Evaluation of the potential of hyphomycetes fungi for the management of the African tephritid fruit flies *Ceratitis capitata*

(Weidemann), *Ceratitis cosyra* (Walker) and *Ceratitis fasciventris* (Bezzi) in Kenya. PhD thesis. Kenya University.

Drew, R.A.I. (1987). Reduction in fruit fly (Diptera: Tephritidae: Dacinae) population in their endemic rain forest habitat by frugivorous vertebrate .Australian Journal of Zoology 35: 283-288.

Drew, R.A.I. (1989). The tropical fruit flies (Diptera: Tephritidae: Dacinae) of the Australasian and Oceanian region. Memories of the Queansland Museum, 26, 1-521. (RAE 78:13).

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(1): 149-154.

Ekesi, S., Maniania, N. K. and Lux, S. (2002) .Mortality in three species of tephritid fruit fly puparia and adult caused by the entomopathogenic fungi ,*Metarhizium anisopliae* and *Beauveriae bassiana*. Journal of biocontrol science and technology.

Elhewaris, O.M. (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.

FAO (2004) .Peach fruit fly, *Bactrocera zonata* (saunders) TCP/RAB/2902.

Faiza, A. (2010) A Pest Management Approach to the Fruit Flies Problem in Shendi Area. Department of Crop Protection Faculty of Agriculture University of Khartoum.

Ferro, D. N. (1996). Cultural control, IPM World Textbook, University of Minnesota press.

Fletcher B.S. (1987) The biology of dacine fruit flies. Annual Review of Entomology 32, 115–144.

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

Harris, E. J. S. Nakagawa and T.Urago (1971).Stickly traps for detection and survey of three tephritids .J.Econ .Entomol. 64:62-65.

Headricks, D. H. and Godden ,R.D. (1996) .Issues concerning the eradication or establishment and biological control of mediterranean fruit fly *ceratitis capitata* (Weidmann) (Diptera:Tephritidae), in California ,Biological control,6:412-413.

Headricks, J. (1996) Action programs against fruit flies of economic importance :session overview .in :Fruit fly pests :A world Assessment of their Biology and management (Mc pheron, B. and Steck ,G.eds.).St .Lucie press,Delray Beach ,FL,USA.513-519.

Headricks, J., Ortiz, G., Liedo, P. And Schwarz, A. (1980). Six years of successful medfly program in Mexico and Guatamalaproceedding of the CEC/IOBC International symposium on fruit flies of economic importance (Callvaro, R. ed). Athens, Greece.353-365.

Hill, D, S. (1983).Agricultural insect pest of tropics and their control. 2nd. Cambridge University Preess .cambridge .UK.

Hooper, G. H. S. (1989). The effect of ionizing radiation on reproduction in: World crop pests: Fruit flies (Robinson, A. S. and Hopper, G. ed.) Vol. 3A:153-164.

Hooper, G. H. S. (1991). Fruit flies control strategies and their implementation in the Tropics. Proceeding of the first International Symposium on the fruit flies in the tropics (Vijaysegaran, S. and Ibrahim, A. G. ed). Kuala Lumpur, Malaysia: 30-43.

IAEA(International Atomic energy Agency) (1996). Standardization of medfly trapping for use in sterile insect technique programmes. Final report of coordinated research program.IAEA-TECDOC-883.

IAEA (International Atomic energy Agency) (1998). Development of female medfly attractant system for trapping and sterility assessment .Final report of coordinated research programme international Atomic Energy Agency(IAEA) TECDOC-1099.228pp.

Iwashi,O.(1977). Eradication of melon fly, *Dacus cucurbitae*, from Kume Island, Okinawa, with sterile insect method. Res Popul. Ecol. 19: 87 :98.

Kawasaki , K. (1991). Eradication of fruit flies in Japan. Proceeding of the International Symposium on the Biology and Control Fruit flies (Kawasaki, K Lwahashi, O. and Kaneshiro, K. Y. ed.): 22-43. Okinawa, Japan.

Knipling, E. F. (1992). Principles of insect parasitism analyzed from new perspectives. United States Department of Agriculture Research Service. Agricultural hand book 693: 1-335.

Linares, F. and R. Valenzuela. 1993. Medfly program in Guatemala and Mexico: current situation. pp. 425-438In M. Aluja, and P. Liedo [eds.], Fruit Flies: Biology and Management. Springer-Verlag, NY.

Lindegren, J. E. and Vail, P. V.(1986) Susceptibility of Mediterranean fruit fly, melon fly and oriental fruit fly (Diptera:Tephritidae) to the

entomologenous nematode,sterinernema feltiae in laboratory tests. Environmental Entomology,15:465-468.

Lindegren, J. E. and Wong ,T. T and Mclnni, D. (1990) Response of Mediterranean fruit fly (Diptera:Tephritidae) to the entomophagous nematode,sterinernema feltiae field-test in Hawaii .environmental Entomology,19:383-386.

L. Jose, D. Cugala , L. Santos (2013). Assessment of invasive fruit fly, fruit infestation and damage in Cabo Delgado province northern mozambiqu.

Lux, S.A. and Kimani, S. (1998). The African fruit fly Initiative development, testing and dissemination of technologies for the control fruit flies. KIPE. Annual Scientific Report 1998- 1999, 7: 78-80.

Lux, S.A.; Copeland, R.S.; White, I.M.; Manrakhan, A. and Billah, M.K. (2003). A new invasive fruit fly species from the *Bactrocera dorsalis* (Hendel) group detected in East Africa. Insect Science and its Application, 23(4), 355-361.

Malio, E. (1979). Observation on the mango fruit fly, Ceratitis capitata, in the Coast Province Kenya. Kenya Entomologist Newsletter 19: 7-10.

Manoto, E.C.(1991).Status of the fruit fly control programme in the Philippines. Proceeding of the International Symposium on the Biology and Control of fruit flies (Kawasaki,K,Iwahashi,O,and Kaneshiro,K.Y.ed) Okinawa, Japan. 98-104.

Martinez, A. J. Robacker, D.C. and Garcia, J. A. (1997).Toxicity of an isolate of *Bacillus thuringensis* sub –species, darmstadiensis to adult of Mexican fruit fly (Diptera:Tephritidae) in the laboratory .J. Econ Entomol .90:130-134).

Mcphail, M .(1939). Protein lures for fruit flies .J.Econ .Entomol.32:758-761.

Michael, F. (2007). Organic fruit fly control .green harvest. com.au.

Mohamed A.S.(2003).Biology ,host and Host plant Relationship of two *psyttalia* species (Hymenoptera:Braconidae):parasitoids for fruit flies (Diptera:Tephritidae) in Kenya .ph.D.thesis, University of Gezira.

Mohamed, A.H. and Ali E. A. (2008). Evaluation of para –pheromones and a three component food bait for mass trapping of fruit flies in fruit trees. The 78th Meeting of the National Pests and Diseases Committee. 17pp.

Mwatawala, M.W.; White, I.M.; Maerere, A.P.; Senkondo, F.J. and Meyer, M. (2004). A new invasive *Bactrocera* species (Diptera: Tephritidae) in Tanzania. African Entomology, 12(1): 154-156.

Narayanan ,E.S and Bartra ,H.N.(1960).Fruit flies and their control .published by Indian council of Agricultural Research ,New Delhi.56-60pp.

Nelson, W. F. A. (1946). Some effects of relative humidity on development of over wintering pupae of apple maggot *Rhagoletis pomonella* .J.Econ.Entomol,96:810-811.

Newel, I.M. and Harmoto mfmh.(1968) .Biotic factors influencing population of *Dacus dorsalis* in Hawaii .proceeding of Hawaii Entomological society ,20:81-139.

Norrbom, A. L. Carrel, Thompson, F,C. White, I. M. F freidberg, A.(1999) systematic database of names. in:Fruit fly export identification system and systematic information database (Thompson, F.C.ed.) 9:65-252.

P.P.D, 2007 (Plant Protection Department, Sudan),The 78th Meeting of

National pests and diseases committee.

Poffley M. and Owens G. (2006). Mango pruning in the top end. www.nt.gov.au/dpifm

Prokpy, R.J. (1978). Visual responses of apple maggot flies *Rhagoletis pomonella*: orchard studies. Entomol. Exp. App. 11: 403- 422.

Pruitt, J.H. (1953). Identification of Fruit Fly Larvae Frequently Intercepted at Ports of Entry of the United States. University of Florida (Gainesville), M.S. thesis. 69 pp.

Qureshi, Z. Hussain, T. Carey J. R. & Dowell R.V (1993) Effects of temperature on development of *Bactrocera zonata*. Pan-Pacific Entomologist. 69, 71–76.

Robacker, D. C; Martinez, A. J; Garcia, J. A; Diaz ,M. and Romero ,C (1996). Toxicity of *Bacillus thuringiensis* to the Mexican fruit fly (Diptera:Tephritidae). J.; Econ Entomol ,89:104:110.

Ronald F.L. (2007). Bactrocera cucurbitae (coquillett) the melon fruit fly .www.extento.hawaii.edu .

Schmutterer, H. (1969). Pests of crops in northeast and central Africa. Gustav Fischer Verlag, stuttgard and Portland. USA

Severin ,H.H.P.(1913) The life history of medfly *Ceratitis capitata* with with alist of fruits attacked in Hawaiian island J.Econ Entomol,6:399-403.

Shoukry, A. and Hafiz, M. (1969). Studies on the biology of Medfly *Ceratitis capitata*. Entomol. Exp. And Appl. 26:33-39.

Sivinski, J.M.; Calkins, C.O.; Baranowki, R.; Harris, D. Barmila, J.; Burns, E.; Holler, T. and Dodson, G. (1996). Suppression of Caribbian fruit fly,

Anastrepha suspense through augmented release of the parasitoid, *Diachasmimorpha longicaudata* (Ashmead) (Hymenoptera: Braconidae). *Biological control* 6: 177- 185.

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

Sparks,T.C.,Thompson,G.D.,Kirst,H.A.,Hertlein,MB.,Larson,L.L.,T.V.,and Thibault, S.T. (1998). Biological activity of the spinosyns newfermentation derived insect control agents ,on tobacco budworm (Lepidoptera:Noctuidae) larvae .J.Econ. Entomol. 91,1277-1283.

Steiner, L. F; Mitchel, W. C; Harris, E. Kozuma, T. T. and Fujimotom, M. S. (1965). Oriental fruit fly eradication by male annihilation .J.Econ Entomol ,58:961-964.

Steiner, L. F; Miyashita, D. H and Christenson, l. d. (1957). Angelica oils as Mediterranean fruit fly lures. J. Econ. Entomol, 50 (4):505.

Steiner, L. F; Hart, W .G., Harris, E. J. Cunningham, R. T. Ohinata, K. and kamakahi ,D. C (1970). Eradication of Oriental fruit fly from Mariana Island by method of annihilation and sterile insect release. J. Econ Entomol, 63:131-135.

Sutanta-wong, M. (1991). problems of fruit flies and its control by the sterile insect technique in Thailand. proceeding of the international Symposium on the biology and control of fruit flies (Kawasaki, K., I wahashi, O. and Kanishiro, K. Y. ed.): 98-104. Okinwa, Japan.

Temerak, SA. Bahgat, IM, El Kady G A, and Lysandrou, M. (2007): The natural bio-insecticide spinosad and its toxicity to combat some mosquito species in Ismailia Governorate, Egypt. World J Agric

Sci , 3:396-400.

Thomas, M. C.; Hopper, J. B.; Woodruff, R. E; Weems, H. V. and Steek, G. J. (2001). The Mediteranean fruit fly. *Ceratitis capitata* (wiedmann). Entomolog Circular 4, 230. Department of Agriculture- University of Florida.

Vargus, R.I. (1983). Distribution and seasonal occurrence of medfly on Island of Kauai in Hawaiian Island. *Env. Ento*. 15: 507- 512.

Venkatraman, T.V, El Khidir, E.I. (1965). Outbreak and new records (Sudan). FAO Plant Protection Bull., p. 22.

Waterhouse, D. F. (1993)Biological control :pacific prospeets supplement Canberra, Australia; ACIAR,Vol.11.188pp.

Wharton .R.H. (1989). clasical control of fruit –infesting tephritids in:Fruit flies ;their Biology ,Natural enemies and control (Robinson ,A.S.,Hooper G.,eds.)World crop pests .3(B).Amsterdam,Neyherland :Elsevier,303-313.

White, I. M, Elson-Harris, M .M. (1992). Fruit flies of economic significance: their Identification and bionomics. Wallingford, UK:CAB International.

White, I. M., and Tsuruta, K. (2001) Eleven new species of the genus Bactrocera (Diptera:Tephritidae) from Sri lanka. *Entomological Science*, 4:69-87.

Wong, T. Y. Y. and Ramadan, M. M . (1992) Mass rearing and biology of larval parasitoids (Hymenoptera: Braconidae: Opiinae) of tephritid flies (Diptera:Tephritidae) in Hawaii in :Advances in insect for Research and pest management (T.E.Anderson, and N. C. Leppla

,eds).Westview, Boulder, co.405-426.

Yokoyama V. Y. (2007). Biological and cultural control of olive fruit fly in California. 9th Annual Exotic F.Fly Symposium April 25-26, 2007, Fresno, California. P.72.

Zavala, J. L Gutierrez, J. S. ,Reyes, J. F., Villasenor, A. C. and Enkerlin ,W. H. (1991). Proceeding of the international Symposium on the Biology and control of fruit flies (Kawasaki, K., I wahashi,O.and Kanishiro, K. Y. ed.) :98-104.Okinwa,Japan.

http://www.maphill.com/india/maharashtra/ahmadnagar/shendi/detailed-maps/road-map

*SMS (Shendi Meteorological Station).

Appendixes

Appendix. (1) Temperature, relative humidity and Rainfall at Shendi area 2012 -2013.* (source**:** SMS).

Month	temperature (°C)	R.H. (%)	Total rainfall (mm)
April	30.0	34	0.0
May	34.5	34	Trace
June	35.2	20	3.0
July	33.7	17	44.2
August	32.3	19	27.0
September	33.5	24	0.0
October	33.4	34	6.8
November	32.5	54	0.0
December	28	31	0.0
January	23.6	31	0.0
February	23.5	28	0.0
March	26.5	26	0.0
April	28.2	36	0.0

Appendix. (2)Temperature, relative humidity and Rainfall at Shendi area 2013-2014*(source**:** SMS).

Month	temperature (°C)	R.H. (%)	Total rainfall (mm)
April	28.2	36.0	0.0
May	33.0	34.0	0.0
June	34.3	19.0	0.0
July	34.0	23.0	Trace
August	31.0	24.0	5.2
September	33.0	32.0	113.0
October	27.0	37.0	2.1
November	23.0	64.0	1.9
December	23.0	45.0	0.0
January	26.0	32.0	0.0
February	28.0	40.0	0.0
March	27.0	46.0	0.0
April	27.0	45.0	0.0