Chapter 14
Chronological Review of Fruit Fly Research and Management Practices in Sudan

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Abstract Fruit flies are the main constraints that limit horticultural production in Sudan. More than 39 fruit fly species have been sampled by the Insect Museum of the Agricultural Research Corporation since the early nineteenth century. Studies from 2008 to 2017 have reported 19 species of economic importance. The situation regarding fruit flies worsened after the invasion of Sudan by the alien invasive species, *Bactrocera dorsalis*, in 2005 and by *B. zonata* in 2012. A competitive displacement was noticed between *B. dorsalis* and the species of the genus *Ceratitis* MacLeay, later also reported between *B. zonata* and *B. dorsalis* on mango and guava, mainly. Several host plants were reported to attract various species of fruit flies. Species of genera *Bactrocera* Macquart, *Ceratitis* MacLeay, and *Dacus* Fabricius responded positively to food bait attractants, mainly Torula and Mazoferm. More than ten local attractants are comparable with standard attractants and are capable of attracting both sexes of different fruit flies species. Male annihilation was the only governmental control option applied, countrywide, to control *B. dorsalis* for 12 years, and lately *B. zonata*, although resistance of the latter species to Malathion (an insecticide applied with Methyl eugenol) has been recently reported. The integration of different control measures, including cultural practices, the use of food-based attractants, the utilisation of biocontrol agents, and the application of post-harvest techniques, are suggested for application in an eco-friendly management approach.

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14.1 Introduction

14.1.1 Importance of Horticultural Sector in Sudan

Sudan is a large country, measuring an estimated 1,765,048 Km^2, with a population of 41,511,526 in 2018 (World Bank 2018). Its arable land is estimated to amount to 83,333.3 million hectares (only 20% of total area) (Mahgoub 2014) . The areas utilised in agriculture are distributed over nine states and are divided into five distinct ecological zones: desert, semi-desert, woodland savannah, flood region, and montane vegetation. Fertile soils, with diverse sources of water – rivers, springs and rains – allow the country to produce various crops. The agricultural sector in Sudan is the most important source of income and livelihoods for 60–80% of the population, and represents 31% of the national income (Elgali 2010; Abdelkareem 2003). The areas used in horticultural production, ca 104,166 hectares, provide 12% of the national agricultural income (Idris 2006; Mahgoub 2014).

Mango, *Mangifera indica* (family Anacardiaceae), is the main fruit in Sudan, and is produced along the banks of the rivers and tributaries in South Kordofan, Khartoum, Kassala, River Nile and Western Darfur States. The area cultivated for mango in Sudan was estimated to be about 2,814,000 ha in 2004, with more than 57 cultivars. The most important exported cultivars are Zibda, Alphons, Malgoba, Hindi, Sinaria, Shendi, Taimoor, Nailam, Mabroka, Dibsha Abu Samaka, and lately, Tommy Atkins. Generally, 60% of grape fruit (*Citrus* × *paradisi*) and 40% of orange (*C. sinensis*), both belonging to the family Rutaceae, are produced mainly in the Kassala, River Nile and Northern States. Orange is also produced in Western Darfur, while banana, *Musa* sp., family *Musaceae*, is produced in Kassala and Blue Nile States, in percentages of 35 and 25%, respectively (Elbashir and Imam 2010).

Guava (*Psidium guajava*, family Myrtaceae), is produced all around the country, in gardens and houses, and in Sudan institutions, all year round (Ali et al. 2014).

Date fruits (*Phoenix dactylifera*, family Arecaceae), are produced in the Northern and River Nile States, of which 75% are dry and 25% are soft dates. The production of vegetables has been estimated to amount to 1.9 million tons, on 186,000 ha (Elbashir and Imam 2010).

The estimated productions of main crops, during the period from 2006 to 2009, are shown in Fig. 14.1, and the average amounts of exported fruits are presented in Fig. 14.2.

The main areas of mango production in Sudan extend along the banks of the River Nile in the Khartoum, River Nile and Northern States. Mango is also grown on a small scale along the banks of the Blue Nile and White Nile Rivers in central Sudan. In Kassala State, fruit trees are grown on the banks of the Gash River and in some parts of South Kordofan, on the banks of the Khor Abuhabil, while another cultivated species of mango is found in Darfur State (UNEP 2005).

Elyas (2008) reported that the fragmentation of lands, lack of financing, low-yield varieties, absence of quality control measures, high cost of transportation, and the incidence of pests and diseases, are the main constraints that hinder horticultural production in Sudan.

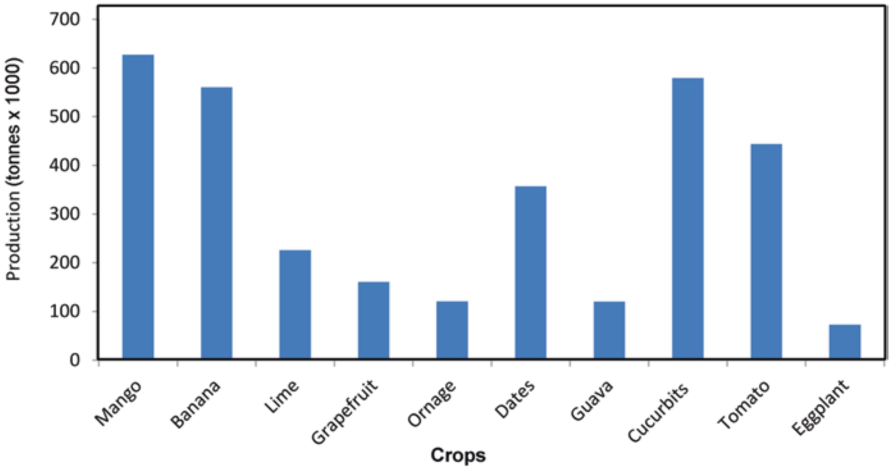

Fig. 14.1 Mean production/ton of certain horticultural crops in Sudan, 2006–2009. (Source: Ministry of Agriculture, Department of Horticulture, Sudan)

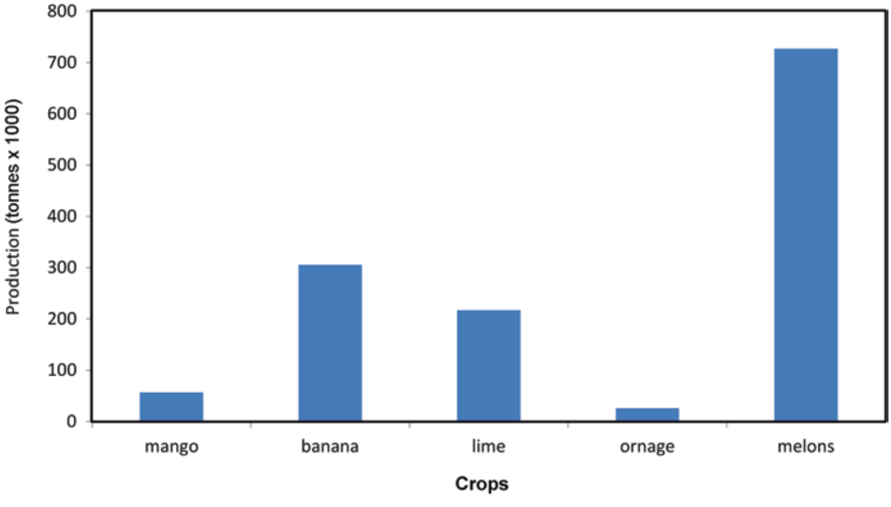

Fig. 14.2 Average amount of Sudan exported fruits (2009). (Source: Ministry of Agriculture, Department of Horticulture, Sudan)

Among pests and diseases, fruit flies are reported as the main threat, causing severe losses to fruit production, which exceed 80% of guava and 30–50% of the Abu Samaka mango variety, from 2005 to 2008 (PPD 2008; Gesmallah et al. 2014). According to El Tahir and Taha Yousif (2004), in addition to the problems already faced by the indigenous fly species in Sudan (*Ceratitis capitata*, *C. cosyra*, *Dacus vertebratus* and *D. ciliatus*), the country is threatened by invasions of exotic species from across its borders with several neighbouring countries, and by its weak interception and quarantine procedures.

14.1.2 Fruit Fly Species Compositions in Sudan

Fruit flies have been reported in Sudan since the early nineteenth century. Specimens of more than 39 Tephritid fruit flies have been preserved and documented at the Insect Taxonomy Unit of the Agricultural Research Corporation, Wad Medani, Sudan. Of this number, the information for 19 species has been well documented, including their place of collection and host plants.

Venkatarman and El Khidir (1965) and Ali (1967) were the first to report the presence of the Mediterranean fruit fly, *C. capitata*, in Sudan. Schmutterer (1969) reported *C. quinaria* as major pest of grapefruit and *Dacus vertebratus* as a pest of watermelon. *Ceratitis cosyra* has been considered as the predominant species from 1990 to 2008 in mango production areas (Arop 1990; Ahmed 2001; Elhewairs 2003; Mohamed 2003; Abdellah and Mohammed 2010).

Beije et al. (1996) reported that *Zeugodacus cucurbitae*, *D. ciliatus*, *D. vertebratus*, *D. longistylus* on watermelon and melon from Kassala and Gash, with 92% relative abundance for *D. ciliatus*. They also reported Baluchistan fruit fly *Carpomya (Myiopardalis) pardalina* that was reared on musk melon. In addition to the species that attack watermelon, *C. capitata*, *C. quinaria* and *C. cosyra* were the main fruit flies infesting guava and mango in the same study area, causing 11–33% infestation levels during the study period (Beiji 1997).

In 2005, the country witnessed the invasion of numbers of *B. dorsalis*, which were captured in McPhail traps by Abdellah at Shendi, River Nile State, in a collaborative study between the Agricultural Research Corporation (ARC), the Sudan and the International Centre for Insect Physiology and Ecology (ICIPE). This pest changed the situation regarding fruit flies in Sudan and led to an upgrade regarding fruit flies being added to the list of notorious national pests in Sudan in 2008. The same species, except the *Carpomya* (*Myiopardalis) pardalina* Baluchistan fruit fly, were recently reported by Mahmoud et al. (2012a, c) in Kassala, Khartoum, South Kordofan and Gedarif States. They have also been recorded by Fadlelmula et al. (2014) in Blue Nile State, by Gesmallah and Abdellah (2011) in Sennar state, and by Abdel Magid et al. (2012) and Suliman et al. (2014) in River Nile State. Surveys carried out in 2008 in Kassala and South Kordofan, using male attractants, revealed that *C. cosyra* was not in the group of fruit flies found in Kassala State, and that *C. capitata* was not present in South Kordofan State (Mahmoud et al. 2012b, c; Mahmoud 2017).

In 2011, Gesmallah and Abdellah reported the occurrence of *D. punctatifrons* in Sennar State, and recently, the same species was reported from River Nile State (Mahmoud et al. 2015, unpublished).

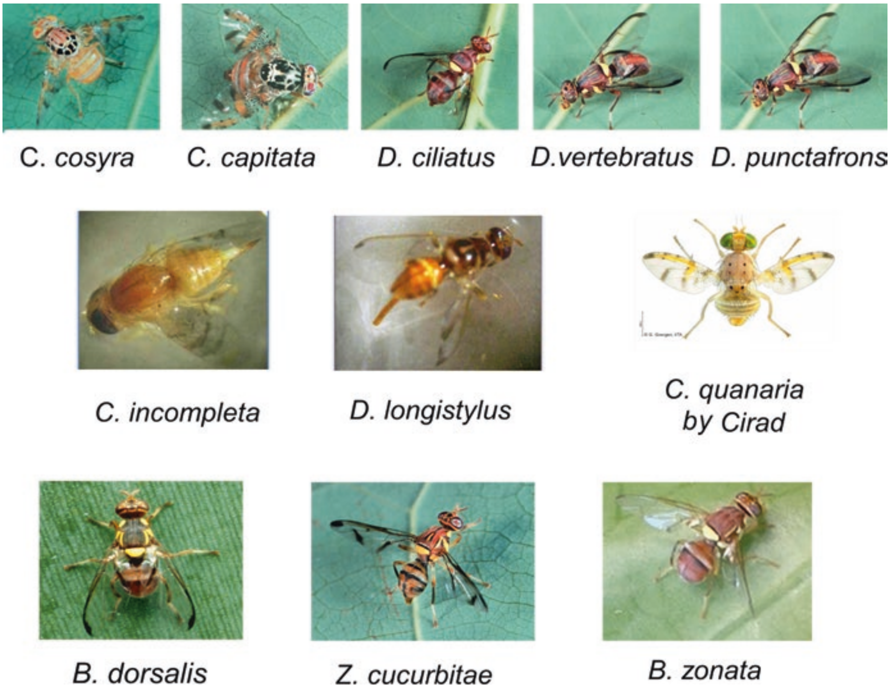

Fig. 14.3 Fruit flies of Sudan

Peach fruit fly, *B. zonata*, was first reported in Gezira and Sennar States by Salah et al. (2012), and later it was recorded in the Northern, River Nile, Khartoum, Gedarif, White Nile, North Kordofan and South Kordofan States (Mahmoud et al. 2015, unpublished). The occurrence of the peach fruit fly in the south and east of Sudan is threatening both Ethiopia and Kenya, as well as other African countries. Figure 14.3 and Table 14.1 show the most important fruit flies found in Sudan.

14.1.3 Fingerprints of Fruit Flies from Sudan

Sequences of genomic DNA of *B. dorsalis*, *C. cosyra*, *C. capitata*, *C. quinaria*, *Zeugodacus cucurbitae*, *D. ciliatus*, *D. vertebratus* and *D. longistylus* were determined using Cytochrome Oxidase (COI) 1, applying 2 sets of primers. The sequences of certain species of fruit flies from Sudan were compared with those for *B. dorsalis* and *C. capitata* deposited in the International Gene bank database (Mahmoud et al. 2012a).

Table 14.1 Tephritids deposited and documented at the Insect Museum Unit of the Agricultural Research Corporation, Wad Medani, Sudan

Genus	Species and authority
Carpomyia	*incompleta* Beck.
Ceratitis	*capitata* Wied.
Pardalaspis	*melanaspis* Bezzi
Elaphromyia	*adatha* Walker
Acanthiophilus	*helianthi* Rossi
Paroxyna	*sororcula* Wied.
Paroxyna	*ignobilis* Loew.
Paroxyna	*praetexta* Lw.
Craspedoxantha	*marginalis* Wd.
Dacus	*vertebratus* Bezzi
Dacus	*ciliatus* Lw. = *brevistylus* Bezzi
Coelotrypes	*vittatus* Bezzi
Dacus	*longistylus* Wied.
Dacus	*marginalis* Bezzi
Dacus	*vertebratus* Bezzi *var. marginalis* Bezzi
Dacus	*frontalis* Becker
Myiopardalis	*pardalina* big.
Platensia	*diaphasis* big.
Pterandrus	*anonae* Grah.
Spheniscomyia	*sexmaculata* Macq.
Bactrocera (*Dacus*)	*zonata* Saunders
Bactrocera (*Dacus*).	*oleae* Rossi
Carpomyia (*Pardalaspis*)	*quinaria* Bezzi
Carpophthoromyia	*superba* Bezzi
Celidodacus	*obnubilus* Ksm.
Cheliyophora	*magnicps* Bezzi
Ceratitis (Pardalaspis)	*bipustulata* Bezzi
Euribia.	*tristrigata* Bezzi
Rhacoclaena.	*pulchella* Bezzi
Rhabdochae.	*taneavei* Bezzi
Tephrella.	*cyclopica* Bezzi
Trypanea	*amoena* Frauenfeld
Trypanea	*auger* Frauenfeld
Trypanea	*kingi* Bezzi
Trypanea.	*eluta* Meigen
Leptoxyda	*longistylus* Wd.

CO1F and CO1R (first set of primers) gave around 1300 bps length and 425 kDa of DNA weight, and the lengths of DNA of each species were as follows: 1328, 1334, 1303, 1336, 1328, 1323, and 1332 bp for *C. quinaria*, *C. capitata*, *C. incompleta*, *C. cosyra D. longistylus*, *B. invadens* 1, *B. invadens* 2, *B. invadens* 3, and

D. vertebratus, respectively, while the kDa weights were 428.5; 430.4; 420.1; 430.5; 428.6; 426.7; and 429.4; respectively.

Samples of *B. dorsalis* (1-2-3-4-5), *Z. cucurbitae* and *D. ciliatus* were successfully sequenced using UEA7 and UEA10 primers (2nd set). These species gave around 222.7, 223.1, 223.2, 222.4, 223.5, 222.8, and 221.2 kDa of DNA weight, and 696, 697, 697, 695, 698, 695, and 692 bp length, respectively (Mahmoud et al. 2012c).

14.1.4 Biology of Fruit Flies

In laboratory conditions, at 25 °C and 60% relative humidity, the rearing of *B. zonata* on fruits of guava and mango and an artificial diet resulted in 18.6, 18.7, and 23.6 days, respectively (Mahmoud et al. 2016), while the life cycles of *B. dorsalis*, *C. capitata* and *C. cosyra* were 18.4, 22.3, and 23.3 days, respectively, when reared only on mango fruits (Abdel Magid et al. 2012).

14.1.5 Host Range of Fruit Flies in Sudan

Mango and guava are the main host plants for *C. capitata*, *C. cosyra* and *C. quinaria*, *B. dorsalis*, and *B. zonata*. Grape fruit, orange, mandarin, banana, lemon, annona, papaya, cantaloupe, Brazilia (*Terminalia braziliensis*), and wild strawberry (*Fragaria vesca*) were reported as hosts for *B. dorsalis* (Fadlelmula et al. 2014). Cucumber, water melon, musk melon and wild strawberry were found infested by *D. ciliatus*, *D. vertebratus* and *Z. Cucurbitae*, while Sidir (*Ziziphus spina-christi*) is infested by *Carpomya incompleta*. Indian date, *Z. jujube*, is infested by *B. dorsalis* and *Z. cucurbitae*. Usher, (*Calotropis procera*), is attacked by *D. longistylus* (Abdellah 2010; Mahmoud 2011).

Since its detection in Sudan, *B. zonata* has been reported to attack fruits of mango, guava, grape fruit and orange, while it also lives on ivy fruit (*Coccina grandis*) and the Indian date (Mahmoud et al. 2016). On other hand, *B. zonata* is capable of attacking sweet lemon, banana, cucumber, date palm, tomato, eggplant and sweet pepper, as indicated in ‘choice’ and ‘no choice’ tests (Mahmoud et al. 2016; Mahmoud 2017).

14.1.6 Seasonal Abundance

B. dorsalis has become the most abundant species in Sudan since 2005, and has displaced *C. cosyra*, *C. capitata* from mango and guava fruits all around the country (Fadlelmula et al. 2014; Abdel Magid et al. 2012; Abdalla et al. 2014; Gesmallah and Abdellah 2011; Mahmoud et al. 2012a; Mahmoud et al. 2015).

In 2008, *B. dorsalis* was reported as the dominant species, during all the year, and all over the country. Its highest populations were reported during September to December in Khartoum, and from October to November in Kassala, while in South Kordofan, it crested two times, June and August in autumn, and November and December in winter, due to high production of fruits at low temperatures and high relative humidity (Mahmoud et al. 2015).

The highest population of *C. cosyra* was recorded in May, September, October and November in Khartoum State, while the population of *C. capitata* flared up from August to November. In South Kordofan, the population of *Z. cucurbitae* peaked during the period from January to March, which represents the period of maturity of cucurbits.

According to Mahmoud et al. (2015), *B. dorsalis* was the most dominant species all around the country, where it had displaced *C. cosyra* and *C. capitata* in the Kassala, Gezira, White Nile, Blue Nile, South Kordofan, and Sennar States.

In South Kordofan, only *C. quinaria* (0.1%) was found to coexist with *B. dorsalis* (99.9%) on mango and guava (Mahmoud et al. 2012a).

In Khartoum State, few numbers of *C. capitata*, *C. cosyra* and *C. quinaria* (0.01%) were reared from fruits of guava. In the upper parts of Northern State, only *C. cosyra* (0.001%), together with numerous numbers of *B. zonata,* was reared from mango and orange.

Bactrocera zonata peaked two times in Gezira States during 2014 and 2015, coinciding with the fruiting season for mango trees, which bear fruit twice a year in Sudan (Mahmoud et al. 2016).

14.1.7 Competitive Displacement Between Fruit Fly Species in Sudan

During the invasion of *B. dorsalis* in 2005, the populations of *C. capitata*, *C. cosyra* and *C. quinaria* decreased drastically to very low levels, and *B. dorsalis* became dominant in various states. In 2010, the populations of *C. capitata* and *C. cosyra* started to increase again because the heavy mass-trapping operations of the invasive species conducted by Plant Protection Directorate had resulted in reducing the numbers of *B. dorsalis*. In 2012, *B. zonata* invaded some states and started to displace *B. dorsalis* and other *Ceratitis* species from guava and mango trees in several orchards in Khartoum and Gezira States, and has become the main insect pest.

The dominance of *B. zonata* is attributed to the high reproductive characteristics of the species, its ability to infest more than 50% of plant species, and its ability to develop resistance to the extermination action of several insecticides, as reported in Asia, and especially to malathion (Nadeem et al. 2014; Radwan 2012).

14.1.8 Response of Fruit Flies to Food Bait Attractants

Ceratitis capitata, B. dorsalis, C. cosyra, C. quinaria, and *Z. cucurbitae* have responded positively to Nulure, *Torula* yeast, AFFI, GF-120, and Mazoferm (Mahmoud et al. 2012a). The highest number (fruit flies/trap/day) was attained by *Torula* yeast, while the least was attained by AFFI.

Despite the potency of Nulure and Mazoferm for trapping fruit flies, it was found that they also serve as good media for the growth of a layer of fungi that hindered the emission of volatiles and thus reduced their efficiency as baits. Both males and females of the above-mentioned species were attracted to human urine (Mahmoud et al. 2012b), urea, and water extracts of guava, mango, cucumber and apple. Tests with ready-made juice solutions proved the effectiveness of the solutions in attracting the five most important species: *B. zonata* responded to *Torula* yeast, Mazoferm and GF-120, and also positively to water extracts of sorghum, millet and maize (Basher et al. 2017).

The use of Mazoferm in combination with Tracer in traps reduced the population and infestation levels of *B. zonata* in guava orchards to very low levels (2 flies/trap/day), when compared with untreated traps (25 flies/trap/day) (Mahmoud 2017).

14.2 Control Practices in Sudan

14.2.1 Cultural Control

Abdel Magid et al. (2014) have reported that cultural practices carried out at mango orchards, including hoeing, flooding, cleaning and early harvesting before fruit ripening, reduced the infestation levels of fruit flies by more than 70% on mango fruits. In another study, (Mahmoud 2011) it was proved that the removal of infested, fallen fruits reduces the infestation percentages from 92.3% to 7.3%.

Figure 14.4 shows the efforts taken by the Plant Protection Directorate in controlling fruit flies in Sudan, especially *B. dorsalis*, over three consecutive years (2012, to 2014).

Control operations of fruit flies conducted by Plant Protection Directorate incorporated pheromone traps and local food baits (yeast + sugar + pesticides) since 2008, the year of recommendation of using methyl eugenol on mass trapping of fruit flies. Data for years 2012, 2013 and 2014 revealed that the treated area was 14,900.9, 13,000, 9796.7 ha respectively. The distributed traps were 68,514, 35,550 and 36,064 for methyl eugenol and the number of distributed food attractant traps were 13,336, 8800 and 32,370, for the above-mentioned years, respectively (Fig. 14.4).

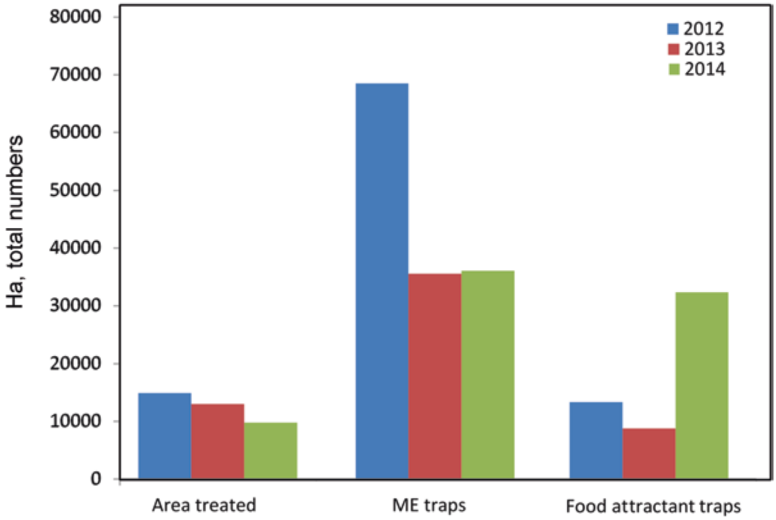

Fig. 14.4 Number of distributed pheromone and local food traps and area/ha in 2012, 2013 and 2014

14.3 Aspects of Biological Control

14.3.1 Parasitoids

Three parasitoids have been reported to attack *B. zonata* reared from guava and mango fruits: *Tetrastichus giffardianus* (Hymenoptera: Eulophidae), *Aganaspis* sp. (Figitidae: Eucoilinae) and *Psyttalia* sp. (Braconidae: Opiinae). *Tetrastichus giffardianus* has been reported as the most efficient parasitoid that naturally controls *B. zonata*, where it is found all year round, with parasitism percentages ranging from 10 to 60% (Mahmoud 2017) (Fig. 14.5).

14.3.2 Entomopathogens

Applications of insect parasitic fungi *Beauveria bassiana* (at 6.5×10^{10} conidia/ml) and *Metarhizium anisopliae* (at 4.3×10^{10} conidia/ml) caused 62.6 and 72.8% mortality to the larval stages of *Z. cucurbitae* and *D. vertebratus*, respectively. They also caused 65.7 and 51.9% mortality to the pupal stage of both species, respectively Musa (2014). Abdellah et al. (2017) stated that adult emergence from the pupae of *B. dorsalis* was inhibited by the tested concentrations of *M. anisopliae*. The inhibition increased with increases in concentration. The LC_{50} and LC_{90} values for *M. anisopliae* were 10×10^6 and 18×10^6 conidia/ml, respectively. The mentioned fungus can be incorporated in fruit fly management strategies.

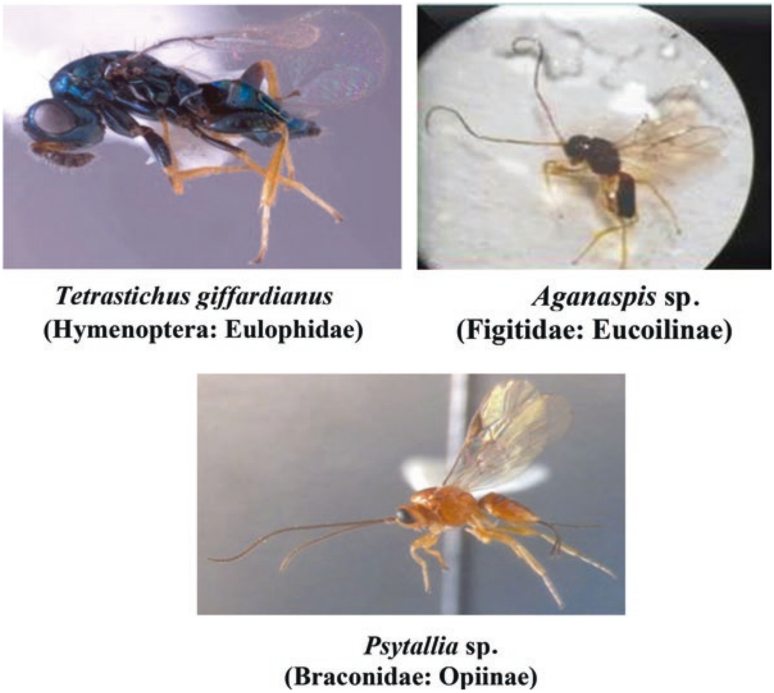

Fig. 14.5 Parasitoids of *Bactrocera zonata*

14.3.3 Botanical Extracts

Neem Azal 15 ppm was found very effective against *Z. cucurbitae* and *D. vertebratus*. Various concentrations of ethanolic extracts of neem and basil caused high mortality to adult flies of *B. dorsalis*, when applied topically and as a food bait (Hussein 2015).

14.4 Chemical Control

Chemical control is practiced by farmers in all states, with different groups of insecticides used, including malathion, cypermethrin and deltamethrin. Suliman et al. (2014) reported that three doses of deltamethrin – 1, 1.5 and 0.25 L/feddan – gave high reductions in populations of *B. dorsalis* when applied using fogging machines.

Gesmallah et al. (2014) reported that chlorpyrifos, imidacloprid and neem seed powder extracts are very effective when applied against the third larval stage of *B. dorsalis* by inhibiting the emergence of adults, when applied on sand under laboratory condition.

14.4.1 Post-Harvest Treatment

Various studies have been conducted to assess the role of heat treatment in controlling the immature stages of fruit flies on fruits (Bashir 2008). The results were promising, and according to that finding, the private sector initiated the Sudanese Centre for Sterilization of Horticultural Exports in 2013. The Centre uses advanced technology that applies vapour heat treatments, according to international standards and regulations.

14.4.2 Role of Extension Services in Dissemination of Knowledge on Fruit Fly Control

Sidahmed et al. (2014), in his assessment of farmers' knowledge of fruit flies and their management, reported that only 12% of interviewed farmers had high experience of fruit flies, 52% had received extension services and information from plant protection officials, and 43% used methyl eugenol to control fruit flies. However, only 17% of respondents applied the correct dose.

14.4.3 Capacity Buildings, Trainings and Public Awareness

Several Training of Trainers programmes (TOT), for staff of Plant Protection Directorate, universities teaching staff, and extension and plant quarantine officers, have been instituted under the auspices of the Plant Protection Directorate and Agricultural Research Corporation. In 2006, the International Centre of Insect Physiology and Ecology held one TOT at the Agricultural Research Corporation, Wad Medani. More than 15 PhD and 25 MSc degree holders from several Sudanese universities discussed various topics that dealt with basic studies and applied control.

Public awareness has been raised through various radio and television programmes, at national and state levels, that give information about the pest and the prospects for the integrated management of fruit flies, as well as the safe use of insecticides.

The awareness of fruit flies and their management reached a peak after the invasion of the alien exotic species had significantly affected the produce and exports, and these species had been placed in the list of phytosanitary dangerous organisms. Awareness was also raised through the proceedings of a national conference on the situation concerning fruit flies and their management, that was held in 2008 in Khartoum.

14.5 Future Studies

To enhance knowledge on fruit flies and promote ecologically sound management options, further studies are most especially required in the:

- Evaluation of the effectiveness of local plant materials as food-based attractants for the mass trapping of fruit flies.
- Evaluation of local diet for mass rearing.
- Evaluation of various materials as repellents to oviposition.
- Determination of the host marking pheromones and assessment of their roles as deterrents to oviposition.
- Evaluation of the phenomenon of competitive displacement between species, the factors governing this phenomenon, and the fate of displaced species.
- Examination of the effects of cross-mating between *B. zonata* and *B. dorsalis* which occurred under laboratory condition, the determination of its side effects on the aggressiveness of the progenies, and the determination of the genetic makeup of the progenies.
- Breaking down of the resistance of *B. zonata* to the malathion used in male annihilation technique.
- Incorporation of indigenous entomopathogens in control programmes.
- Evaluation of the efficacy of indigenous and exotic parasitoids in controlling Tephritid fruit flies.

14.6 Conclusion

The main problem in controlling fruit flies is given by the reliance on one control option, neglecting the role of other options. This dependence is attributed to many factors, such as economic costs, technical difficulties, availability, and certain impracticalities, for various reasons.

The use of one control option might lead to the resurgence of neglected insect pests and promoted them to the class of primary pests, which has actually happened in Sudan. Before the invasion of the country by *B. dorsalis*, the main fruit flies that infested mango and guava were *C. cosyra*, *C. capitata* and *C. quinaria*. Because of the high fecundity and rapid invasion of *B. dorsalis* into different crops and territories, encouraged by the attraction of different host plants, suitable temperature and relative humidity, the alien invasive pest in Sudan has displaced species of genus *Ceratitis* from mango and guava. The population of *Ceratitis* species started diminishing to very few numbers in 2008–2009 (Mahmoud et al. 2015). During that time, fruit flies were declared as national pests and a control campaign was instituted by the Plant Protection Directorate, that recommended the adoption of a lure and kill system using methyl eugenol with malathion in cotton wicks, to control *B. dorsalis*.

The campaign continued for 12 years, and resulted in excellent mass trapping of the species, but also gave the opportunity to the population of *Ceratitis* spp. to build up again. This occurred because it had been left without control, while the Plant Protection Directorate had been concentrated completely on using one method to control only one targeted species. In 2012, *B. zonata* invaded Sudan and started to displace all other species. By 2017 it had displaced *B. dorsalis*, *C. capitata* and *C. cosyra* from fruits of guava in two states. Then, a huge concern developed when it was noted that *B. zonata* generates resistance to malathion, not being killed by this pesticide any more.

As an agricultural country needs to export its production to other countries, it is imperative that measures be taken in Sudan to (i) adopt good practices that reduce reliance on pesticides, thereby achieving the goals of Good Agricultural Practices (GAP), and (ii) reduce the risk of safety hazards in food, as required by the Hazard Analysis and Critical Control Point (*HACCP*) regulations. Moreover, there is a need to adopt effective integrated pest management plans, including cultural, physical, biological options to meet the growing demands of global markets.

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