US Open Food Science & Technology Journal
Vol. 1, No. 3, July 2014, pp. 1 - 11
Available online at http://www.arepub.com/Journals.php

Review article

Fruit Insect Pests of Guava (*Psidium guajava* L.) and Mango (*Mangifera indica* L.) and their Management in Sudan: A Historic Review

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Abstract

A number of insect pests are known to infest fruits of mango and guava in Sudan. The first report was in 1960s of the Medfly (*Ceratitis, Ceratalaspis, capitata* Wiedemann) followed by the next report of the *Ceratitis, Pardalaspis, quinaria* Bezz. (the Rhodesian fruit fly) and then *Ceratitis cosyra* Walker (the mango fruit fly) in 1980s, all of them from guava. However, the first report of a mango fruit pest was in 1996 reflecting a heavy infestation of these fruits by *C. cosyra*. This latter report drew the attention clearly to the tangible need of a control program due to the destructive infestation and/ or the mango value. The FAO intervene by a program, jointly with the Plant Protection Directorate (PPD), of vigilance for the peach fruit fly (PFF) [*Bactrocera zonata* (Saunders)] which concluded to an incidence of another species (*Bactrocera novus*) in 2003 from South Kordofan that was not really so but (*Bactorcera invadens* Drew – Trusta and White). In 2004 two other scientists reported this species from mango in different areas and separate reports. This followed by a report of this species from guava in Kadaro orchards (30 Km North Khartoum center) in 2007. The FF *Dacus longistylus* (Wiedemann) was reported from mango in Sinnar State in 2008. The dried fruit beetle (*Carpophilus hemipterus* L.), in addition to an unidentified maggot (20 – 30 mm) used to lodge at the distal end of the guava fruit with a reddish rear part. This fold of insects pushed all the in charge of crop protection to list them with the national pests in 2005. However, an unidentified coleopteran was also reported from mango fruits in orchards and cold

stores as well in 2010. In 2012 the peach FF [*Bactrocera zonata* (Saunders)] was reported from a number of states in Sudan. All these studies were accompanied by other studies for the host range which include banana (*Musa sapientum* L.), exotic and local sidir [*Ziziphus spina – christi* (L.) Desf.], Osher [*Calotropis procera* (Aiton) W. T. Aiton]. However, a report in 1990 mentioned no incidence of *C. capitata* from citruses in Shambat, Khartoum North. In addition, two FF predators were reported from Kadaro in 2010 which include a spider and an earwig (Dermaptera). Moreover, the great most of the attempts of control couldn't succeed in disinfesting mango and guava from FF pests. These include use of pheromone traps, cultural practices (such as dumping the infested fruits in pits, cleaning, weeding and pruning), spraying with natural and synthetic insecticides, use of maturity indexes and fruit morphology, cropping pattern etc…. However, more reliance must be on the postharvest control methods to ascertain a complete disinfestation including the egg stage. Other attempts include hot water treatment, storage period, hot dry air treatment, hot humid air treatment, laser beam, ultrasound and gamma irradiation. Part of these techniques revealed 100% ridding of the mentioned pests. However, the integrated management approach (IMA) of these pests may be highly recommended together with the organic production of mango and guava as been done in Elshaab Scheme at Elfaki Hashim, Khartoum North that is registered internationally. Any success of this IMA panorama may upgrade the fruit quality for local and international markets.

Keywords: Control, Disinfestation, Guava, Insect pests, IMA, Mango and Sudan.

Introduction

Fruit flies are, as their name implies, true flies that attack fruits usually. They belong to the Diptera order and the family Tephritidae (Trypetidae). This family includes about 4000 species fall into 500 genera. The distribution of these insects was observed in all the continents of the world except the Antarctica. However, it was reported that about 140 genera are known from the Afrotropical region, about 160 genera from tropical Asia, about 130 genera from Australia and the Oceanic regions, 140 genera from Europe, the Middle East and North Africa (the Palaearctic Region), about 60 genera from the Nearctic region that includes Canada and USA and about 90 genera from Neotropical Region of the America [1]. The economic importance of these flies can be well illustrated by a total 910 million $US annual loss in California with 290 million $US for their control and the corresponding figure for Australia was estimated at 100 million Aus. $. However, in the developing countries the situation may be the worst i.e. in Egypt they spend millions of dollars in the control programs of fruit flies such as *Dacus* spp. in citruses; *Ceratitis* spp. in guava and mango and *B. zonata* (the peach FF) which are very destructive to a wide spectrum of fruit production. Moreover the FAO pose more care on this issue by holding the conferences and auspicing the scientific cooperation between whom of concern such as the 2012 Hammamet symposium for fruit flies in Near East held in Tunisia. However, some international centers also give much care in their research for fruit flies e.g. the big FF biocontrol program of ICIPE in Nairobi, Kenya [2]. In Sudan the first report of fruit flies was in the 1960's of the Medfly (*C. capitata*) from guava [3]. A number of records of new species followed that which include report of *C. quinaria* Bez. (the Rhodesian fruit fly) [3] and the mango FF (*C. cosyra*) from guava in Shambat [4]. However, the first report of the mango FF from mango was in 1996 and from the great most of Sudanese states including Juba (the capital of the newly announced

Southern Sudan Republic) [5]. In 2004 the invader fly was reported from mango in Hantoub orchards at Wad Medani which was capable of replacing *C. cosyra* in most places there (Mohamed personal communication) [6] this insect pest was also included simultaneously in another report from mango in South Kordofan State [7]. Kabbashi reported the invader FF (*Bactrocera invadens* Drew, Trusta & White) from guava fruits in Khartoum in 2007 [8]. An earlier survey in 2003 was taken by the FAO supported effort executed by the Federal Plant Protection Directorate in Khartoum. This work included a thorough trans-state survey ended with no record for the *B. zonata* and reported *Bactrocera novus* which was nothing else but the *B. invadens* and by so doing this may be considered the right first report in Sudan of this pest from mango [9]. However, this joint work included some surveys in a number of big cold fruit stores in Khartoum Central Market for the peach FF but faced with a lot of doubts from the owners. Another newly reported mango fruit pest was recorded in 2012 which was identified as the peach FF *Bactrocera zonata* Saunders [10].

The IMA of fruit flies of fruit trees constitute an array of methods that includes cultural, biological, chemical, mass trapping and bait stations, MAT (male annihilation technique) & SIT (sterile insect technique), quarantine and postharvest methods. The cultural methods such as hoeing, flooding, orchard cleaning and early harvest of fruits before ripening reduced the fly infestation in a range of 29 – 83% in Shendi, Sudan [11]. The biological control include using of *Fobius arisansus* in the control of *B. invadens* and other five tephritid flies in Kenya [12] where they also used *Diachasmimiphora longiqudata* parasitoid in the control of these pests.

The chemical control of FF in Sudan includes the attempts of spraying methidathion for the control of guava fruit flies in Khartoum North [4]. Methyl eugenol was used to trap *B. invadens* males [13] this followed by its registration for commercial use in Sudan [14]. However, the MAT (Male Annihilation Technique) technique was used in some countries of Africa such as Senegal for the control of mango fruit flies [15]. SIT, has also a successful track record for eradication or routine suppression of FF populations to establish pest – free areas and areas of low pest prevalence, providing better options to address International Plant Protection Convention (IPPC) Standards and to overcome barriers to international agricultural trade [16]. It is also reported that SIT and the MAT are being successfully applied to prevent, contain, or eliminate outbreaks of tephritid FF pests as a component of an area – wide integrated pest management (IPM) [16]. However, a number of postharvest treatments were applied in tests for control of fruit flies of mango and guava in Sudan these include hot water dip [17], [8]; use of gamma rays [8]; use of ultrasound [18], use of laser beam [19] and use of maturity indexes [20].

This review focuses on displaying and discussing the findings of the IMA of fruit flies in fruit crops in Sudan.

Results and Discussion

The invader fruit fly *B. invadens* was reported from mango by a number of scientists and practitioners in different locations in Sudan [6], [7] &] [9]. This may reflect a lack of coordination between the scientists and the PPD which may represent the general trend in the other research programs too, so a neat and well planned projects must be set by the different departments and institutions of concern. In addition, the pheromones used by some scientists were brought and passed by the technical committee(s) in charge before been registered, so it may be better to engage the registration process to the ongoing research by the authorized candidates and there may be no need to begin another research to do that which may take a couple of years particularly if the chemical bears a different brand. However, the expectation of the invasion of *B. zonata* to Sudan was announced

by the PPD and FAO since the adoption of the survey program in the beginning of this millennium and inspite of gaining some positive results in reporting other important fruit insect pests it should have been succeeded in reporting that noxious pest had it been continuous upto 2012 or even before. That is, the monitoring of the noxious pests must has a fixed body represented by the needed personnel to take care and have a continuous vigilance and not a discrete one or rely on the individual scientists' efforts as before. However, the invasion of *B. zonata* to Sudan was also expected with some other alien pests from other countries in another report in 2011 [21]. Siddig mentioned *P. quinaria* as a major pest on *Citrus* and guava and *C. capitata* as a minor pest on them [22]. However, the collection of fruit flies from guava in 2007 identified as *B. invadens, C. cosyra and C. capitata*. This may reflect the competitiveness of these species and the absence of *C. quinaria* which may deny the earlier report of *C. quinaria* as a major pest compared to *C. capitata*. Nevertheless another justification may be due to the ability of *B. invadens* in replacing the C. *quinaria* as it succeeded earlier in Gezira [13] in replacing the *C. cocyra* both accounts may reflect the least survival ability of this species, *C. quinaria*, as compared to the other studied. In addition, [23] it was reported that, *B. invadens*, *C. cosyra* and *C. cucurbitae* were the three species trapped (by yellow sticky traps) on mango and guava trees in Sinnar. In addition the former was trapped on mango in Singa all the year round. It is the highest population caught compared to the other two mentioned fruit flies. *C. capitata* was reported as a pest of mango fruit [24] in Sudan as it was already listed with the fruit pest of mango in other countries [1]. That is, the percentage reported was 8%, 19.8% and 0.2% for *B. invadens*, *C. cosyra* and *D. longistylus*, respectively. It is worth to report that about 15 insect pest of mango fruit tree were reported in Sudan besides two natural enemies (Table 1). The heavy FF infestation of mango since its first report in 1996 pushed the leaders of crop protection in Sudan to include them in the national pests list and consequently allotted an annual fund of about two million US$ for its control. That is, this decree followed a rapid and sharp drop in the quantities of mangoes exported due to FF infestation [25]. Another report stated a different date of the listing of the fruit flies as national pest "In 2007 the problem of FFs was aggravated to the extent that these pests were listed among major national pests receiving considerable attention in control by the Plant Protection Directorate (PPD) of the Ministry of Agriculture" [23]. However, one of the elements of the management of the fruit flies by the PPD is the higher steering committee that include a lot and diverse specialties but it did not has a unique and gradual plan to contain this escalating problem. This despite some individual efforts of some scientists with regional and international institutions of concern such as ICIPE. However, the IMA efforts for the control of fruit flies in mango and guava may include the following categories

A. Preharvest Methods

1. Cultural methods: Test in Shendi area [24] include use of plastic bags for collection of infested and exposed and to direct sun light, burying of damaged fruits, pruning of trees etc…… The maturity indexes were also used to reduce the fly infestation which include the harvest of ripe green smaller fruits and the avoidance of big and yellow fruits [20]. The late maturing cultivars of mangoes (e.g. abusamaka and galbeltour) may escape FF infestation [26]. The mixed cropping of guava and mango results in heavy infestation of fruit flies in mango that is, guava acts as a reservoir for fruit flies. This may be better illustrated by the absence of FF infestation in mango in Elbagair 50 Km south Khartoum which was

Table 1: Fruit Insect Pests of Mango and Guava and Some Natural Enemies in Sudan

Serial	Common Name	Binomial Name	Host of Report/ Host range	Year of	Reference
1	Mediterranean FF	*Ceratitis capitata* (Wied.)	Guava/ ziziphus, citruses etc….	196?	Venkatraman & Elkhidir (965)
2	– Do –	– Do –	Mango	Unknown	Abbas (2013)
3	Rhodesian FF	*Ceratitis quinaria* (Bez.)	Guava/ peach, apricot etc….	196?	Schmutterer (1969)
4	Mango FF	*Ceratitis cosyra* (Walker)	Guava/ marula plum, mango, orange etc……	1989	Deng (1990)
5	Mango FF	*Ceratitus cosyra* (Walker)	Mango/ marula plum, guava etc….	1996	Kabbashi (2004)
6	The invasive fly	*Bactrocera novus*	Mango	2003	Ali (2004)
7	The invasive fly	*Bactrocera invadens* (Drew – Trusta and	Mango/ guava, ziziphus, etc…..	2004	Mohamed (2004) & Bashir (2007)
8	The invasive fly	*B. invadens*	Guava/ mango, ziziphus etc……..	2007	Kabbashi (2012)
9	The mango FF	*Dacus longistylus* (Wiedemann)	Mango/ sadom apple	2008	Gassmalla (2008)
10	Mango white scale	*Parlatoria crypta* Mc Kenzie	Mango and neem	?	Schmutterer (1969)
11	California red scale	*Aonidiella* aurantii (Maskell)	Guava and citruses	?	Schmutterer (1969), Venkaterman
12	Mango gall midge	*Procontarinia matteiana* Kieffer and	Mango	2004	ARC (2004) & Mardi (2010)
13	Mango bronze	*Chrysobothris dorsata* (F.)	Broad – leaved forest trees	?	FAO (2007)
14	Dried fruit beetle	*Carpophillus hemipterus* L.	Guava	2009	Kabbashi (2012)
15	The peach FF	*Bactrocera zonata* (Saunders)	Mango	2012	Salah *et al.* (2012)
16	Mango fruit beetle	Unidentified	Mango	2010	Kabbashi (2012)
17	Mango maggot	Unidentified	Guava	2009	Kabbashi (2012)
18	Dermapteran	Unidentified earwig	Mango fruit flies	2010	– Do –
19	Acarid	Unidentified spider	Mango fruit flies	2010	– Do –

attributed to the absence of guava trees in the proximity [27]. This may need more elaboration and indepth research in the future.

2. Tolerance, some studies were done to assess the tolerance of mango cultivars to FF infestation, that is, a test of more than 10 mango cultivars for FF infestation from a collection from different states in Sudan revealed that none of them is resistant to these pests but the baladi (local) one reflected the least infestation [5]. Another study of the tolerance of mango cultivars to fruit flies wad conducted at Wad Medani and concluded that Alphonso cultivar is the most tolerant. In addition a third similar study dealt with only two varieties in Singa orchards showed that Kitchener cultivar is superior to Abusamaka with respect to FF infestation. That is, the former reflected FF infestation of 10% in March, 15% in April and 20% in May and the latter showed an infestation by 30% in June and 50% in July [23]. However, a comprehensive study is needed to valuate the tolerance of each grown variety in Sudan considering a number of parameter the main of which may be the geography – FF species, the tolerance genetics, the tolerance biochemistry, tolerance/ tree morphology etc…… It is reported that trap catches of FFs were significantly among locations in Khartoum North and the catches were significantly correlated with both temperature and humidity [4]. This is also found in another study in guava fruits from different locations in Khartoum through two years [8].
3. Chemical control, some farmers used to spray their orchards with recommended insecticides for other crops a practice also done by some protectionists. However, three insecticides were sprayed in 1980s on guava to control FFs in Khartoum North namely methidathion (Supercide®), carbaryl (Sevin®) and cypermethrin (Polytrin®) all of which gave significant reduction in FF infestation in that crop [4]. Cypermethrin (Aim®) and Brigade® (three entomopathogenic fungi) were sprayed once on mango after fruit setting stageduring stage during a course of two years. Both insecticides reflected significant control of FFs. This experiment studied the residue of cypermethrin where the detected levels were all below the allowed maximum limit of the Code Alimentarius [27]. Brigade® and neem were also used in guava to control fruit flies and any synthetic insecticide was excluded from guava to avoid residue complications because of no enough safety period in guava due to the rather daily collection of guava. [4]. The first experiment lacking both residue analysis of the used insecticides besides any hint to the safety period and it was mentioned that the guava was sprayed in an interval of 7 and 14 days. However, the spraying of mango with synthetic soft insecticides was recommended in mango trees for FF control once and a couple of months before harvest [27]. Experiments on chemical control with synthetic soft insecticides in mango are highly needed to avail alternatives for those who rely more on that control option.
4. Trapping and lures, were used extensively in FF control and monitoring in Sudan where a lot of types used (Table 2). The field response of FF to nulure, torula yeast, AFFI and G – 120 and male attractants was studied in Khartoum and Kassala in two years 2007 – 2009.

   More than 10 species belong to 3 genera were recorded; *Ceratitis capitata, C. cosyra, C. quinaria, B. invadens, Dacus ciliatus, B. cucurbitae, Dacus sp, Paradalopsis incompleta and B. longistylus* and two other not identified species. Mango and guava were found attacked by *C. capitata, B. invadens, C. cosyra and C. quinaria*. Grape fruit, orange, mandarin and banana were found

infested by *B. invadens*. Lemon and anonna were recorded as new hosts of *B. invadens* at Kassala [28]. It was found that Torula yeast significantly attracted the highest number of FF at Elfaki Hashim (North Khartoum) and Abugebieha (Southeastern Kordofan) during 2007 and 2008 compared to Nulure, GF – 120 and AFFI bait [29]. Nonetheless, in 2007 a joint control program of FF was launched by the University of Shendi and the State Ministry of Agriculture. That is, Shendi area is one of the major fruit production zones in Sudan (773 ha) 80% of it occupied by mango, 18% with citruses and only 2% with guava. This program includes trapping, food baits and mass trapping in addition to extension services to adopt GAP (good agricultural practices) to check FF infestation [30]. Human urine (5%) was proved as a good and cheap lure or FFs and as effective as Torula yeast. It reflected appositive a positive response of 7 tephritids [31]. The peaks of a number of fruit flies were determined with about 42% efficacy of the total attracted by Torula yeast in 8 consecutive weeks [31].

Table 2: Lures of Fruit Flies in Sudan

Serial	Chemical	Nature	Target FF Species
1	AFFI	Lure	*Ceratitius spp.* & *B. invadens*
2	Ciproflaxocine	Lure synergizer	*Ceratitus* spp.; *B. invadens*; *Dacus* spp.
3	Culure	Lure	– Do –
4	Fermented guava juice etc……	Lure	– Do –
5	G – 120	– Do –	*Ceratitius spp.* & *B. invadens*
6	Human urine 5%	– Do –	– Do –
7	Masoferm	Lure	– Do –
8	Methyl eugenol	– Do –	*B. invadens* Male
9	Molasses	– Do –	– Do –
10	Molasses + Malathion	Toxic lure	– Do –
11	Terpinyl acetate	Lure	*Ceratitis* spp. Male
12	Torula yeast	– Do –	General and potent
13	Trimedlure	– Do –	*C. capitata* Male alone

These studies and other not mentioned may ascertain the essential role of lures in monitoring and studies of FFs but yet they may ignore a major information about the impact of these IMA element and the FF infestation and consequently their efficiency in reducing such infestation.

5. Population dynamics, a number of studies investigated the dynamics of a number of FF species. That is, it is reported that the FF infestation in Kitchener mango (10% in March, 15% in April and 20% in May) whereas it was 30% in June and 50% in July in Abusamaka cultivar in Singa (Sennar State). The FF infestation in guava was 90, 80 and 90% in October, November, and December, respectively [23]. However, another study reported no infestation of FF in mango in Elbagair (South Khartoum) and Elsaggay (North Khartoum) orchards in different mango cultivars [27]. In addition late maturing mango varieties such as Abusamaka and Galbeltour found to escape FF infestation [26]. The peaks of three FF species was determined to specify the right time for their management. That is, *B. invadens* has two peaks in August and November whereas *C. capitata* and *C. cosyra* have one peak each in August and November, respectively. The peak of FF infestation of guava was found to have association with high relative humidity that is two peaks for FF infestation in guava were reported in autumn and winter [8]. However, a fluctuation in the population of FF species was reported in guava orchards in Elfaki Hashim where the most dominant species

reflected 74% (*C. capitata*), 22% (*B. invadens*) and 4% (*C. cosyra*) and only 0.1% (*B. cucuritae*) in 2008. In 2009 the relative abundance was 39%, 32% and 18% for the first three species, respectively. However, the population of *C. quinaria* flared up from 0.5% in 2008 to 74% in 2009 [29]. Therefore these results may stimulate the need for further studies to specify the peak time for each species in specific fruit crop geared to specific location as well.

6. Host range, is a mandatory element for the knowledge of the IMA planners. That is, the alternative host may act as a backup home for the FF. That is, the infestation free mangoes were reported in guava free areas [27]. That is, guava represents a FF reservoir. However, some studies mentioned that *C. capitata* and *C. quinaria* (known guava pests) infest mango [30] other studies ascertain that *C. capitata* is not a pest of citruses in Shambat, Khartoum North [4], whereas a report of its pest status was in citruses in the formerly Southern Sudan (Now the Republic of South Sudan) [3]. These controversial facts may need to be fixed by thorough studies.

A. Postharvest Fruit Fly Management

The preharvest management tools may never ensure a complete disinfestation of the fruits from FFs. This may lead consequently to the need for further postharvest treatments. Internationally there are a lot of treatments for the disinfestation of fruits from insect pests and diseases as well. Moreover, in Sudan some experiments were conducted for this purpose. These can be divided into two main sections

1. Treatments not succeeded in complete disinfestation of fruits from fruit flies include
   - 1.1. Hot humid air treatment (HHAT) [8].
   - 1.2. High Temperature Short Time Treatment (HTST) (65° C and 5 minutes and 70°C and 5 minutes yielded 68% and 96% disinfestation of guava, respectively) [17]. However, 35°C, 40°C, 45°C, and 50°C and one hour were capable of reducing FFs in guava but only the three later produced a significant control [8].
   - 1.3. Use of laser beam [a complex waves (660, 870, 880 and 950 nm) and 24 Jule for 15 and 30 minutes gave 67% control] [19].
   - 1.4. Use of ultrasound, an experiment of ultrasound (60 Hz) gave 30% control of FF when used for 30 minutes [18].
   - 1.5. Use of gamma rays, irradiation of guava with different doses starting form 100 Gy to 1.9 KGy resulted in a significant control as compared to untreated specimens [32].
2. Treatments succeeded in disinfesting fruits from FF completely
   - 2.1. Hot water dip, a study in Kordofan used a regime of 55°C and 5 minutes to disinfest mango from fruit flies [7]. Nonetheless, 55°C and 15 minutes disinfested guava and mango from FF in Khartoum [8]. The populations tested in these experiments may differ in genetics, adaptability and species. That is, South Kordofan mango production areas are known by their high humidity and lower temperature compared to the dry hot climate in Khartoum.
   - 2.2. Ultrasound, use of 60 Hz for one hour was capable of disinfesting guava fruits from FFs in Khartoum [8].
   - 2.3. Use of γ irradiation, a dose of 2 KGy γ rays was enough to disinfest mango and guava fruits from fruit flies and other fruit pests such as *C. hemipterus* in Khartoum [8, 32].

The postharvest control of FFs is considered the most mandatory element of IMA of these pests. That is, it insures a better quality and better marketing chances locally and internationally as well. More efforts and attention must be offered to this part of IMA of FFs in Sudan.

Conclusion

A lot of work on fruit flies was done in Sudan. However, more SMART (specific, measurable, achievable, realistic and time bound) plans must be available with a high degree of coordination, precision and inclusion of all of concern in this respect, locally, regionally and internationally. In addition, postharvest treatments of IMA must be updated and intensified for they represent the climax of the IMA and the only possible means of disinfestation. The governmental intervention targeting the PPD with the finance which must be directed to the research institutes that is intuitive in finding recommendations to apply by the PPD and to adopt by the farmers as well.

Acknowledgements

I am really grateful to Dr. Hassan Ali Farrag who has encouraged us to write reviews of research in general and in the Sudanese findings in particular.

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