Diversity and Host Plants of Tephritidae From Two Islands of the Comoro Archipelago (Grande-Comore and Moheli).

KASSIM Bakar (karibu5051@gmail.com)
Institut National de Recherche pour l'Agriculture, la Pêche et l'Environnement.

Turgay ÜSTÜNER
Selçuk University

Research Article

Keywords: Comoros, Biodiversity, Tephritidae, Host-plants, Infestation rate

DOI: https://doi.org/10.21203/rs.3.rs-571533/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License. Read Full License
DIVERSITY AND HOST PLANTS OF TEPHRITIDAE FROM TWO ISLANDS OF THE COMORO ARCHIPELAGO (GRANDE-COMORE AND MOHELI).

KASSIM Bakar*1,2, Turgay ÜSTÜNER1

1Selçuk Üniversitesi, Fen Fakültesi, Biyoloji Bölümü Selçuklu, Konya- Türkiye.
2Institut National de Recherche pour l’Agriculture, la Pêche et l’Environnement (INRAPE),BP 1406, Moroni, Union des Comores.

Corresponding author*: E-mail: karibu5051@gmail.com
Tel: 00905377901531- 002693313190

ABSTRACT

This paper summarizes the different host plants and fruit flies present in two islands (Grande-Comore and Mohéli) of the Comoros Archipelago. Different exotic and wild fruit plants were sampled. Eighty plant species, potential hosts, belonging to thirty-four families were collected and incubated for the emergence of fruit flies from December 2019 to September 2020. Twenty-five plant hosts from ten families comprising cultivated and wild fruits have been identified. Fruit fly infestation rates per kilogram of fruit (T.Kg⁻¹) varied from plant to plant. Exotic fruit plants, which accounted for more than half of infested plants, including Cucumis melo, Cucurbita pepo, Prunus persica, Coffea arabica and Capsicum frutescens had high infestation rates. For wild plants, the highest infestation rates have been observed in some families including Combretaceae, Cucurbitaceae, Solanaceae and Vitaceae. The highest infestation rate per kilogram of fruit was observed in a wild plant: Cyphostemma lageniflorum. Thirteen new host plants infested by Tephritidae are reported and/or listed for the first time in Comoros. In total, eight species of fruit flies identified. However, the species Bactrocera dorsalis Hendel, 1912 (47.5%) and Dacus bivittatus (Bigot, 1858) (37.6%) were the most representative of the Tephritidae that emerged.

KEY WORDS: Comoros, Biodiversity, Tephritidae, Host-plants, Infestation rate.
INTRODUCTION

Comoros archipelago is a group of islands in the Indian Ocean, located in the north of the Mozambique Channel, in the south-east of Africa, between the northern Mozambican coast and at the northern tip of Madagascar (11° 23’- 13° 00’S 43° 13’-45° 18’E). It includes a group of four main islands: Grande-Comore, Mohéli, Anjouan and Mayotte (Emerick & Duncan, 1982). These four volcanic islands cover from north to south an area of 2,236 km². However, the emerged lands are distinguished as follows: Grande-Comore (1025 km²), Mohéli (211 km²), Anjouan (424 km²) and Mayotte (374 km²).

The climate of the Comoros is tropical humid under the influence of the sea. The average temperature varies between 25 °C and 28 °C at low altitude (Anllaouddine, 2009). This climate is also characterized by two seasons: from December to April, the weather is hot and rainy (hot and humid season); and between May and November, the weather is cool and dry (dry season) (Adjanohoun et al., 1982; Hassani-El-Barwane, 2010). Due to these climatic variations, different types of microclimates develop in the different islands. Due to these climatic parameters, this has allowed the establishment of different fleshy fruits and vegetables, mainly intended for subsistence agriculture, which is a reservoir for fruit flies (De Meyer et al., 2012). However, there is a multitude of other fleshy fruits and vegetables known as wild and not consumed by the population. The latter is an important reservoir for fruit flies because they represent the major part of the fruits and vegetables present in the Comoros Islands.

Although fruit flies are a major problem in Comoros, their range of host plants is poorly understood (Issa, 2017). In all cases, De Meyer et al., (2012) described around ten species of Tephritidae in Comoros. These tephritites were collected by trapping (McPhail trap) containing para-pheromones (Methyl-eugenol, Cuelure, Trimedlure) and/or food additives (Torula)( De Meyer et al., 2012). But also, Hassani and al., (2016) studied fruits fly from Comoros. They only identified five species of Tephritidae in 42 plant species sampled in the study.

However, we believe that the methods applied by these researchers are selective and have had many limitations to determine the biodiversity of the host plants of the different species of Tephritidae likely to colonize Comoros. For our part, this study is characterized by the sampling of several ranges of fleshy (or not) fruits and vegetables, wild or cultivated, over large areas, at random periods and in different areas. This study provided a complementary list of host plants and associated Tephritidae found in Comoros (Grande-Comore and Mohéli).
RESULTS

Host plants infestation

A total of 6178 fruit samples were collected in the islands of Grande-Comore and Mohéli from December 2019 to September 2020. They have been identified as 80 species of fruits from 34 families of plant species. However, a few batches of fruit samples were infested with fruit flies. These lots contained 4,669 fruits weighing 69,925 kg in total. Among the fruit species sampled, 25 plant species from 10 families were infested. The main families of infested plants were Cucurbitaceae, Annonaceae, Myrtaceae, Rutaceae and Solanaceae (Table 1). The results also showed that 55 fruit species out of 80 were not infested with tephritids.

Table 1. Plant species sampled during the study in Comoros (Grande-Comore and Moheli) to determine fruit fly host plants (December 2019 to September 2020).

| Host families | Scientific name | Common name | Types of plants | Fruit flies | Parasitoids |
|---------------|----------------|-------------|-----------------|-------------|-------------|
| Aphloiaceae   | Aphloisia theafourmis | ----- | Wild | - | - |
| Anacardiaceae | Mangifera indica | Mango | Cultivated | + | - |
| Spondias dulcis | Jambolan plum | Wild | + | - |
| Cananga odorata | ilang-ilang | Cultivated | - | - |
| Annonaceae | Annona squamosa* | Custard apple | Cultivated | + | - |
| Annona muricata | Custard-apple | Cultivated | - | - |
| Apocynaceae | Thevetia peruviana | Yellow oleander | Wild | - | - |
| Saba comorensis | ----- | Wild | - | - |
| Araceae | Pothos scandens | ----- | Wild | - | - |
| Borraginaceae | Ebretia sp | ----- | Wild | - | - |
| Bromeliaceae | Ananas comosus | Pineapple | Cultivated | - | - |
| Caricaceae | Carica papaya | Papaya | Cultivated | - | - |
| Combretaceae | Terminalia catappa | Tropical almond | Wild | + | + |
| Cucurbitaceae | Citrullus lanatus* | Watermelon | Cultivated | + | - |
| Cucumis melo* | Muskmelon | Cultivated | + | - |
| Cucumis melo spp. | ----- | Cultivated | - | - |
| Cucurbita pepo* | Field pumpkin | cultivated | + | + |
| Cucumis sativus | Cucumber | Cultivated | - | + |
| Luffa cylindrica | Sponge gourd | Wild/ Cultivated | - | - |
| Momordica charantia | Bitter melon | Wild | + | + |
| Sechium edule | Chayote | Cultivated | + | + |
| Cycadaceae | Cycas thouarsii | Sago | Cultivated | - | - |
| Euphorbiaceae | Jatropha curcas | Purgung nut | Wild/ Cultivated | - | - |
| Lauraceae | Persea americana | Avocado | Cultivated | - | - |
| Malvaceae | Abelmoschus esculentus | Okra | Wild | - | - |
| Melastomataceae | Clidemia hirta | Soapbush | Wild | - | - |
| Tristemma mauritianum | ----- | Wild | - | - |
| Moraceae | Artocarpus altis | Breadfruit | Cultivated | - | - |
| Artocarpus heterophyllus | Jackfruit | Wild | - | - |

(*) Host fruits detected and / or listed for the first time in Comoros., (+): infested ; (−) not infested.
| Host families | Scientific name | Common name | Types of plants | Fruit flies | Parasitoids |
|---------------|----------------|-------------|----------------|-------------|-------------|
| Musaceae      | Musa acuminata  | Banana      | Cultivated     | -           | -           |
| Myristicaceae | Myristica fragrans | Nutmeg    | Cultivated     | -           | -           |
| Myrtaceae     | Psidium cattleyanum | Strawberry guava | Wild        | +           | +           |
|               | Psidium guajava  | Guava       | Wild           | +           | +           |
| Syzygium      | Syzygium aromaticum | Clove / Cengkih | Cultivated     | +           | -           |
|               | Syzygium jambos  | Rose-apple  | Wild           | +           | -           |
|               | Syzygium malaccense | Malay apple | Cultivated     | -           | -           |
| Montiniaceae  | Tambourissa comorensis | ...... | Wild          | -           | -           |
| Oxalidaceae   | Averrhoa bilimbi | Cucumber tree | Cultivated     | -           | -           |
|               | Averrhoa carambola | Star fruit | Cultivated     | -           | -           |
| Passifloraceae | Passiflora edulis | Passion fruit | Cultivated     | -           | -           |
|               | Passiflora foetida | Passion flowers | Cultivated     | -           | -           |
|               | Passiflora quadrangularis | Barbudine/Giant granadilla | Cultivated | -           | -           |
| Piperaceae    | Piper nigrum    | Black pepper | Cultivated     | -           | -           |
| Punicaceae    | Punica granatum | Pomegranate | Wild          | -           | -           |
| Rosaceae      | Rubus idaeus   | Wild raspberry | Wild         | -           | -           |
|               | Prunus persica  | Peach tree  | Cultivated     | +           | -           |
|               | Eriobotrya japonica | Japanese plum | Cultivated | -           | -           |
| Rubiaceae     | Coffea arabica* | Coffee      | Cultivated     | +           | +           |
|               | Morinda citrifolia | Noni      | Wild           | -           | -           |
| Rutaceae      | Citrus aurantifolia* | Key lime | Cultivated     | +           | -           |
|               | Citrus clémentina* | Clementine | Cultivated     | +           | +           |
|               | Citrus limon    | Lemon       | Cultivated     | +           | -           |
|               | Citrus maxima   | Pomelo/Pummelo | Cultivated     | -           | -           |
|               | Citrus reticulata | Mandarin tree | Cultivated  | +           | -           |
|               | Citrus sinensis | Sweet orange | Cultivated    | -           | -           |
| Salicaceae    | Flacourtia indica | Governor's plum | Wild       | -           | -           |
| Sapindaceae   | Litchi chinensis | Litchi     | Cultivated     | -           | -           |
| Sapotaceae    | Manilkara comorensis | ...... | Wild          | -           | -           |
| Solanaceae    | Capsicum annum  | Black nightshade | Cultivated     | -           | -           |
|               | Solanum americanum | Black nightshade | Wild/ Cultivated | -           | -           |
|               | Capsicum chinense | Chilli | Cultivated     | +           | -           |
|               | Capsicum frutescens* | Cayenne pepper | Cultivated     | +           | -           |
|               | Solanum incanum* | Bitter tomato | Wild          | +           | -           |
|               | Solanum lycopersicum | Tomato       | Cultivated     | -           | -           |
|               | Solanum mauritianum | Bugweed | Wild          | -           | -           |
|               | Solanum melongena | Egg plant    | Cultivated     | -           | -           |
|               | Solanum seaforthianum* | Brazilian nightshade | Wild | +           | -           |
|               | Solanum torvum  | Turkey berry | Wild          | +           | -           |
|               | Solanum tuberosum* | Potato       | Cultivated     | +           | -           |
|               | Solanum sp.     | ......       | Wild           | -           | -           |
| Sterculiaceae | Theobroma cacao | Cocoa tree   | Cultivated     | -           | -           |
| Verbenaceae   | Duranta erecta | Golden dewdrop | Wild          | -           | -           |
| Vitaceae      | Cyphostemma lageniflorum* | ...... | Wild          | -           | -           |

(*) Host fruits detected and / or listed for the first time in Comoros, (+): infested ;(−) not infested.
Diversity of Tephritidae and host plants.

During a 10-month sampling period, 2671 fruit flies emerged from the pupae of the incubated fruits. Eight species from two tribes (Ceratitidini and Dacini) of Tephritidae have been identified. Twenty-five plant species are identified as host plants for Tephritidae. *Bactrocera dorsalis* was the species infesting a wide range of host plants (13 plants from 6 families). *Ceratitis capitata* was the second species to infest the most plants (7 plants) of Rubiaceae, Rutaceae and Solanaceae. The species *Neoceratitis cyanescens*, *Trirhithrum nigerrimum*, *Dacus bivittatus* and *Dacus ciliatus* have infested more than one plant species. On the other hand, *Dacus vertebratus* and *Dacus etiennellus* respectively infested only *Citrullus lanatus* and *Cucurbita pepo* (Table 2).

**Table 2.** List of fruit flies species identified with their localities and inter-altitudes.

| Fruit flies species | Host plants | Family | Scientific name | Locality | Inter-altitudes (m) |
|---------------------|-------------|--------|-----------------|----------|---------------------|
| *Bactrocera dorsalis* | *Mangifera indica* | Anacardiaceae | Moroni, Lac-Hantsongoma | 35-520 |
|                     | *Spondias dulcis* | Annonaceae | Inrape | 45-55 |
| *Annona squamosa*   | *Terminalia catappa* | Combretaceae | Moroni | 10-35 |
| *Psidium cattleanum* | *Psidium guajava* | Myrtaceae | Lac-Hantsosima, Boboni, Boeni | 415-520 |
|                     | *Syzygium aromaticum* | Myrtaceae | Boboni | 400-520 |
|                     | *Syzygium jambos* | Myrtaceae | Boboni, Chongo-dunda | 350-520 |
| *Prunus persica*    | *Citrullus lanatus* | Rosaceae | Ivembeni | 750-840 |
| *Citrus aurantifolia* | *Citrus clemantina* | Rutaceae | Ivembeni, Bandamadji | 465-800 |
|                     | *Citrus reticulata* | Rutaceae | Kangani, Hamavouna | 100-250 |
| *Solanum incanum*   | *Citrullus lanatus* | Solanaceae | Bandamadj | 300-375 |
| *Dacus bivittatus*  | *Cucumis melo* | Cucurbitaceae | Boboni, Ivembeni | 450-800 |
|                     | *Citrullus lanatus* | Cucurbitaceae | Ivembeni | 5-25 |
|                     | *Cucurbita pepo* | Cucurbitaceae | Ivembeni, Bandamadji | 750-840 |
| *Solanum tuberosum* | *Momordica charantia* | Solanaceae | Moroni | 5-800 |
| *Momordica charantia* | *Sechium edule* | Solanaceae | Ivembeni | 25-50 |
| *Dacus ciliatus*    | *Cucurbita pepo* | Cucurbitaceae | Moroni, Ivembeni, Bandamadji | 750-840 |
|                     | *Momordica charantia* | Solanaceae | Moroni | 5-800 |
| *Sechium edule*     | *Solanum tuberosum* | Solanaceae | Ivembeni | 25-50 |
| *Dacus etiennellus* | *Cucurbita pepo* | Cucurbitaceae | Ivembeni | 750-800 |
| *Ceratitis capitata* | *Coffee arabica* | Rubiaceae | Ivembeni | 750-840 |
|                     | *Citrus clemantina* | Rutaceae | Mdjoyez | 240-275 |
| *Capsicum chinense* | *Capsicum frutescens* | Solanaceae | Mdjoyez | 225-265 |
|                     | *Solanum incanum* | Solanaceae | Bandamadj | 300-375 |
|                     | *Solanum seaforthianum* | Solanaceae | Inrape, Douniani | 50-265 |
|                     | *Solanum torvum* | Solanaceae | Moroni | 15-50 |
| *Neoceratitis cyanescens* | *Coffee arabica* | Rubiaceae | Ivembeni | 750-840 |
|                     | *Solanum incanum* | Solanaceae | Bandamadj | 300-375 |
|                     | *Solanum tuberosum* | Solanaceae | Ivembeni | 750-840 |
| *Trirhithrum nigerrimum* | *Psidium cattleanum* | Myrtaceae | Mdjoyez, Djouadju, Nioumamilima, kourani | 173-735 |
| *Rubia intermedia* | *Coffee arabica* | Rubiaceae | Ivembeni | 750-840 |
| *Vitaceae* | *Cyphostemma lageniflorum* | Vitaceae | Iconi, Nvouni | 35-400 |
Incubation of 4439 pupae resulted in 2671 fruit flies of different species. The Tephritidae obtained belonged to eight different species with different percentages of occurrence (Figure 2). The species *Bactrocera dorsalis* and *Dacus bivittatus* were largely the most dominant with the respective percentages of 47.5 % and 37.7 %. *Dacus ciliatus* was the third species with 5.6%; followed by *Ceratitis capitata* with 4.2% and *Trirhithrum nigerrimum* with 2.8 %. *Neoceratitis cyanescens* was estimated at 1.6 % of the sample. On the other hand, *Dacus etiennellus* (0.3%) and *Dacus vertebratus* (0.4 %) were the species with low emergence rates.

The abundance of Tephritidae in fruits was influenced by fruit species (*Kruskal-Wallis*, p<0.001), Tephritidae species (*Kruskal-Wallis*, p<0.001) and the interaction between these two factors. A very significant difference was observed in the level of infestation of fruit flies between the host plants (*Kruskal-Wallis*, p <0.001). So there is at least more than one different species of tephritid that has infested the host plants. But also that more than one host plant has been infected with at least two species of fruit flies (Figure 3).
Bactrocera dorsalis infested 13 host plants alone. On the other hand, it shared with Ceratitis capitata with the host plant Citrus clementina and Trirhithrum nigerrimum with the host plant Psidium cattleyanum; but dominated over 90% infestation. And finally with Neoceratitis cyanescens and Ceratitis capitata on the host plant Solanum incanum.

Ceratitis capitata infested 7 host plants, 4 of which alone were from the Solanaceae family. Another hand, he shared the infestation of host plants including Coffea arabica with more than 50% infestation; Citrus clemantina with less than 5% and Solanum incanum with a little more than 10% infestation. Only Dacus bivittatus infested Cucumis melo and shared the infestation respectively of Cucurbita pepo and Solanum tuberosum with Dacus ciliatus, Dacus etiennellus and Neoceratitis cyanescens.

Dacus ciliatus infected only 3 species of cucurbits. It alone infected Momordica charantia and Sechium edule. Two species each infected a single host plant. Dacus etiennellus infested Cucurbita pepo, which it shared in the infestation, and Dacus vertebratus which alone infested Citrullus lanatus. Trirhithrum nigerrimum alone infested Cyphostemma lageniflorum. However, it shared the infestation with other species on Psidium cattleyanum and Coffea arabica.

**Figure 3.** The relative abundances of Tephritidae species in host fruits.
The number of fruit flies per kg of fruit was not significantly affected by either fruit flies or host plants (Kruskal-Wallis, \( p < 0.001 \)). Several species had very high values for the number of flies per kilogram of fruit (Figure 4). *Cyphostemma lageniflorum*, infested only by *Trirhithrum nigerrimum*, was the reference species with 1162 flies / Kg of fruit. *Capsicum frutescens* (500 flies / Kg), infested only by *Ceratitis capitata*, was the second species to have a high value. Some host plants infested only by Bactrocera dorsalis had high values for the number of flies per kilogram: *Prunus persica* (430 flies /Kg), *Syzygium jambos* (444 flies /Kg), *Syzygium aromaticum* (250 flies /Kg) and *Terminalia catappa* (288 flies /Kg). *Momordica charantia*, infested by *Dacus ciliatus*, 186 flies / Kg of fruit was observed. *Cucurbita pepo* was the only host plant infested by more species including *Dacus bivittatus*, *Dacus ciliatus* and *Dacus etiennellus* showing a high value of 217 flies / Kg of fruit. In addition, other host plants show moderately high values: *Solanum seafortianum* (96 flies /Kg), *Solanum incanum* (74 flies /Kg) and *Psidium cattleyanum* (40 flies /Kg). The smallest values were observed almost in cultivated plants including *Solanum tuberosum* (3 flies / Kg), *Sechium edule* (6 flies / Kg), *Citrus aurantifolia* (6 flies / Kg), *Citrullus lanatus* (13.74 flies / Kg) and *Cucumis melo* (14 flies / Kg).

![Figure 4](image-url)
**Parasitoids emergence**

A very significant difference was observed between the number of parasitoid obtained and the different species of fruit plants. (*Kruskal-Wallis, p < 0.001*) (Table 3). So there were at least two different species of parasitoids in our samples. The number of parasitoids was not negligible because it represented 3.74 % of the insects that emerged in our samples.

The percentages of samples infested with the parasitoids of *Cucumis sativus* (66.66 %) and *Terminalia catappa* (61.53 %) were the highest. However, small values were observed on two wild plants: *Psidium guajava* (8.8%) and *Psidium cattleyanum* (7.2 %). Indeed, cultivated plants had high percentages compared to wild plants. The wild plants *Terminalia catappa* (35 %) and *Psidium cattleyanum* (22.95 %) had the highest number of parasitoids per kilogram of fruit infestation. On the other hand, the infestation rate observed in the wild plant *Psidium guajava* remained the lowest. Despite the infestation of host plants by parasitoids, fruit flies emerged in our samples. The only exceptions were *Cucumis sativus* and *Sechium edule*.

**Table 3.** Presence of parasitoids in the sampled fruits (December 2019-September 2020).

| Host plants                  | Number of P | % Samples | P / Kg of fruits | Species in the same samples               |
|------------------------------|-------------|-----------|------------------|-------------------------------------------|
| *Cucumis sativus*            | 4           | 66.66     | 18.18            |                                            |
| *Psidium guajava*            | 4           | 8.8       | 4.44             | *B. dorsalis*                             |
| *Cucumaria pepo*             | 20          | 25        | 14.28            | *D. bivittatus*                           |
| *Citrus clementina*          | 14          | 29.62     | 11.66            | *B. dorsalis*/*T. nigerrimum*             |
| *Psidium cattleyanum*        | 14          | 7.2       | 22.95            | *B. dorsalis*/*T. nigerrimum*             |
| *Sechium edule*              | 3           | 10        | 5.35             |                                           |
| *Terminalia catappa*         | 29          | 61.53     | 35               | *B. dorsalis*                             |
| *Coffea arabica*             | 16          | 32.45     | 16.5             | *B. dorsalis*/*T. nigerrimum*/*N. Cyanescens*/*C. capitata* |

*P* : parasitoids, Kg : kilogramme

**The latest literature review of fruit flies in Comoros**

Hassani *et al.*, (2016) conducted a similar study of fruit flies from Comoros. Sampling was done on 42 host ranges from 22 families. The results showed that 22 fruit species from 11 families were infested with fruit flies. Six species of fruit flies were detected in the fruits sampled. Unlike this study, the sampling was carried out on three islands of the Comoros. For this study, more species of tephritites were found (Table 4).
Table 4: List of fruit flies species in Comoros Islands in the article of Hassani et al., 2016a and this study.

| Genus  | Species                | Hassani et al., 2016a | This study |
|--------|------------------------|-----------------------|------------|
| Dacini | Bactrocera *dorsalis*   | *                     | *          |
|        | Dacus *bivittatus*      | *                     | *          |
|        | ciliatus                | *                     | *          |
|        | vertebratus             |                       |            |
|        | punctatifrons           |                       |            |
|        | etiennellus             |                       |            |
| Ceratitisidini | Ceratitis *capitata* | *                     | *          |
|        | Ceratitis *malgassa*    |                       |            |
| Neoceratitis | cyanescens            | *                     | *          |
| Trirhithrum | nigerrimum             |                       | *          |

* Present

Discussion

Among the 80 plant species sampled, 25 species of cultivated and wild plants from 10 families were infested by fruit flies. The relative abundance and seasonal phenology of fruit flies are highly dependent on the availability of host plants. And or the absence of natural enemies that limit the growth of pest populations (Hassani et al., 2016a; Rwomushana et al., 2008; Mwatavala et al., 2009; Mohamed et al., 2010; Geurts et al., 2012; Badii et al., 2015; Vayssières et al., 2015; Gnanvossou et al., 2017). According to Geurts et al. (2012), the diversity of fruit fly species in a biotope depends on the diversity of the host fruit. Previous studies have shown that the dynamics and abundance of fruit fly populations are primarily influenced by host fruit availability and climatic factors (rainfall, temperature, and relative humidity) (Rwomushana et al., 2008; Mwatavala et al., 2009; Mze Hassan et al., 2016a; Gnanvossou et al., 2017).

Bactrocera dorsalis Hendel, 1912

*Bactrocera dorsalis*, oriental fruit fly, is a large species complex containing almost 100 morphologically similar taxa (Drew and Hancock, 1994). It was first detected on the island of Taiwan in 1912 (De Hardy, 1973). *Bactrocera dorsalis* is home to a number of important pest species such as *B. invadens*, *B. carambolae*, *B. papayae* and *B. kandiensis* (Drew and Hancock, 1994). In Africa, this species was detected in Kenya in 2003 (Lux et al., 2003) and has spread rapidly to several countries in Africa (De Meyer et al., 2010). In West and Central Africa, Bactrocera dorsalis is polyphagous and infests more than 40 plant species (Goergen et al., 2011; Clarke et al., 2005). In Comoros, it was identified at Grande-Comore in 2005 and Mayotte in 2007 (De Meyer et al., 2012). Indeed, *Bactrocera dorsalis* infested more than half of the samples taken in this study. It colonized almost all the different niches from which the samples were taken. *Bactrocera dorsalis* infested different families of host plants:
Anacardiaceae, Annonaceae, Combretaceae, Myrtaceae, Rosaceae, Rutaceae. Also, it was the type species of our samples with almost 50% of the flies that emerged. It shared the infestation of some host plants with Ceratitis capitata, Trirhithrum nigerrimum and weakly with Dacus bivittatus. Bactrocera dorsalis has been able to acclimatize in different areas at different altitudes. In addition to the thirteen species infested in this study, Hassani et al., (2016a) identified three other host plants of Bactrocera dorsalis in Comoros: Passiflora edulis, Momordica charantia and Annona senegalensis. So, the species Bactrocera dorsalis is associated with sixteen host plants from eight families in Comoros.

**Dacus bivittatus (Bigot, 1858)**

Dacus bivittatus, commonly known as the pumpkin fly, is one of the most common species of the genus Dacus. It has been reported in Africa in 28 countries spread across the continent (White, 2006). It mainly attacks cucurbits such as cucumber and melon (Cucumis melo L.). But it is also reported in hosts other than cucurbits such as tomato (Lycopersicon esculentum) (Mwatawala et al., 2016). In the Indian Ocean, in addition to its occurrence in Comoros, Dacus bivittatus reported at Madagascar and Seychelles (Mansell, 2006, White et al., 2000); but it’s presence in Seychelles not confirmed (De Meyer et al., 2010; Hassani et al., 2016a). In our study, Dacus bivittatus generally infested Cucurbitaceae family plants (Cucumis melo, Cucurbita pepo et Citrullus lanatus). Indeed, this species is capable to infest the Solanaceae group because in this study it infested Solanum tuberosum. It is the second species that has emerged the most with nearly 38%. Dacus bivittatus acclimatized well in altitudes between 450 m to 800 m. Indeed at these altitudes, the infestation of host plants was very interesting with more than a hundred nymphs appearing after incubation. Neither the weight nor the quantity of the samples played a role. Its presence at low altitude has just been observed in watermelon (Citrullus lanatus) at an inter-altitude of 5-25 m with a minimal appearance of a few individuals.

The presence of Dacus bivittatus is confirmed in Grande-Comore, Anjouan and Mohéli (Hassani et al., 2016a); but it is just associated with the host plant Cucumis sativus in Grande-Comore (Hassani et al., 2016b). However in our study Dacus bivittatus did not infest Cucumis sativus; but it infested Cucurbita pepo, Citrullus lanatus and Cucumis melo. However, there was just an appearance of parasitoids in Cucumis sativus without any fruit flies or nymphs.
**Dacus ciliatus Loew, 1862**

Commonly referred to as the "Ethiopian fruit fly" or "little pumpkin fly"; *Dacus ciliatus* is a widespread African species. Generally, this species attacks a wide variety of Cucurbitaceae (Mwatawala et al., 2006). It seems to thrive in drier areas like the Sahel, Namibia and the Karoo. *Dacus ciliatus* has been observed in several regions of the world including the Near and Middle East and South Asia (De Meyer et al., 2012). In the Indian Ocean, it's identified in Mauritius and Reunion (White, 2006) and at Madagascar (White, 2006; Mansell, 2006; White, 1992). In the Comoros Archipelago, adults were seen in a cucumber patch in M'Rereni, Mayotte. (Quilici, 1996; De Meyer et al., 2012). In the study of Hassani et al., (2016b), *D. ciliatus* is detected in Anjouan in traps containing torula yeast. The author hypothesizes that the presence of *D. ciliatus* in Anjouan can probably be explained by the presence near the study sites of many hosts of cucurbits such as chayote (*Sechium edule*), cucumber (*Cucumis sativus*) and pumpkin (*Cucurbita maxima*). However in Grande-Comore it is obtained in traps containing Cuelure (De Meyer et al., 2012); and isolated from *Momordica charantia* (Hassani et al., 2016a). In our study, *Dacus ciliatus* represented 5.6% of the adults that emerged in the total samples. This species only infested plants of the Cucurbitaceae family: *Cucurbita pepo*, *Sechium edule* et *Momordica charantia*. *Dacus ciliatus* shared the infestation of a single host plant, *Cucurbita pepo*, with *Dacus bivittatus* and *Dacus etiennellus*.

**Dacus vertebratus Bezzi, 1908**

Commonly known as the melon fly or the jointed pumpkin fly, *Dacus vertebratus* is a known pest of cucurbits, particularly watermelon (*Citrullus lanatus*) and several *Cucumis* spp. (White, 2006). This species is widespread and present in most Afro-tropical countries, the Arabian Peninsula and Madagascar (De Meyer et al., 2012). In Comoros Archipelago, Dacus vertebratus was first recorded in Mayotte by Bordat and Arvanitakis (2004). De Meyer et al., (2012) identified a few species in Grande-Comore and Anjouan. But these specimens were captured in traps containing Cuelure and Torula. However, these studies have not associated with well-defined host plants. In our study, Dacus vertebratus infested only *Citrullus lanatus*. He shared the infestation in this host plant with Dacus bivittatus with a low infestation rate.

**Dacus etiennellus Munro, 1984**

Close relative of *D. bivittatus*, *Dacus etiennellus* is an endemic species of the Comoros Archipelago (De Meyer et al., 2012). It was identified for the first time in 1974 in Mayotte or
Grande Comore (White, 2006). It is closely related to *D. demmerezi* (Bezzi) (present in Madagascar, Mauritius and Reunion), but differs in the shape of the coastal strip of the wing. (De Meyer *et al.*, 2012). In these studies, no plant host was associated with *D. etiennellus*. However, De Meyer *et al.*, (2012) identified some specimens captured in a Cuelure trap. In this study, *Dacus etiennellus* infested Cucurbita pepo at inter-altitudes of 750-800 m. This infestation is shared with *D. bivittatus*.

**Ceratitis capitata (Wiedemann, 1824)**

The Mediterranean fruit fly is the most common fruit fly in the world. Some researchers characterize it as the most harmful fruit fly (Mwatawala *et al.*, 2006; De Meyer *et al.*, 2012). Probably from eastern or southern Africa (De Meyer *et al.*, 2002), it has spread throughout the world and colonizing nearly 400 host plants thus acquiring the term polyphages (Clarke *et al.*, 2005; Liquido *et al.*, 1998; De Meyer *et al.*, 2002b). In Africa, *Ceratitis capitata* is extremely polyphagous with more than a one hundred different host plants from about thirty families (De Meyer *et al.*, 2002b; De Meyer *et al.*, 2012). In the Ocean Indian Islands, *Ceratitis capitata* was probably introduced because it has been observed in several islands (De Meyer 2000; De Meyer *et al.*, 2008; White *et al.* 2000). In Comoros, male specimens are captured in traps containing trimedlure; and females and males in traps containing torula (De Meyer *et al.*, 2012). After *B. dorsalis*, *Ceratitis capitata* remains the second species that infested several host plants at the same time (*Solanum torvum, Solanum seaforthianum, Solanum incanum, Capsicum frutescens, Capsicum chinense, Citrus clemantina* and *Coffea arabica*). It infested plants of the Solanaceae, Rutaceae and Rubiaceae families at different altitudes (15 m to 850 m). *Ceratitis capitata* shared the infestation of some host plants with *Neoceratitis cyanescens*, *Trirhithrum nigerrimum* and *Bactrocera dorsalis*.

**Neoceratitis cyanescens (Bezzi, 1923)**

The genus *Neoceratitis* Hendel is a predominantly afrotropical group (Yun *et al.*, 2017). *Neoceratitis cyanescens* is considered endemic to Madagascar (De Meyer *et al.*, 2012). Their populations have the potential to grow rapidly in several different habitats where both wild and cultivated fruiting hosts are present throughout the year (Brévault *et al.*, 2008). The main host plants of *Neoceratitis cyanescens* are plants of the Solanaceae family and rarely *Passiflora edulis* (Hassani *et al.*, 2016a; Brévault *et al.*, 2008). *Neoceratitis cyanescens* is a serious pest of tomato on the islands of the Indian Ocean (Madagascar and Réunion) (Brévault *et al.*, 2008).
In Comoros, this species was observed for the first time in a tomato plot in Mayotte (Quilici, 1996). In the other islands, the tomato fly was reported by Kassim et al., (2000); but the report lacked more details. Hassani et al., (2016a) reported that the main wild fruits infested with *N. cyanescens* were *Solanum mauritianum* and *Solanum torvum*, while the commercial fruits were chili (*Capsicum chinense*) and tomato (*Solanum lycopersicum*). In our study, *N. cyanescens* infested *Solanum incanum* and *Solanum tuberosum* (Solanaceae) et *Coffea arabica* a plant of the Rubiaceae family. *N. cyanescens* shared the infestation in *C. arabica* with *T. nigerrimum* and *C. capitata*; in *S. incanum* with *B. dorsalis* and *C. capitata* and in *S. tuberosum* with *D. bivittatus*.

**Trirhithrum nigerrimum** (Bezzi, 1913)

*Trirhithrum* Bezzi, 1918, is an Afrotropical genus of 40 species belonging to the Ceratitidini tribe (subfamily Dacinae) (White et al., 2003). In the Indian Ocean islands exist some endemic species, but none of these has been recorded in Comoros. Only *Trihithrum nigerrimum*, widespread throughout Africa, has been identified in Comoros (De Meyer et al., 2012). Indeed, it has been identified in the islands of the Comoros archipelago except in Grande-Comore. Characterized as the pest of coffee (Rubiaceae) (White et Elson-Harris, 1994), *T. nigerrimum* attacks a variety of host plants (polyphagous) (White et al., 2003). In this study, *T. nigerrimum* showed a strong infestation preference for *Cyphostemma lageniflorum* (Vitaceae). For this plant, the infestation per kilogram of fruit far exceeded other host plants of Tephritidae. It infested *Coffea arabica* (Rubiaceae), which is shared with *C. capitata* and *N. cyanescens*. And finally, *T. nigerrimum* infested *Psidium cattleanum* (Myrtaceae) with *B. dorsalis*.

Finally, eight species of fruit flies have identified from twenty-five infested host plants in this study. In the report by Hassani et al., (2016a), several host plants different from ours were reported: *Annona senegalensis*, *Passiflora edulis*, *Citrus sinensis*, *Cucumis sativus* and *Solanum lycopersicum*. In the same report, *Dacus punctatifrons* was identified in some cucurbits. Thus, the number of Tephritidae in Comoros amounts to nine (9) fruit flies associated with thirty (30) host plants.

**Parasitoïdes**

Hassani et al., (2016a) identified four species of tephritid parasitoids in Comoros: *Fopius arisanus, Diachasmimorpha fullawayi, Psyttalia insignipennis* et *Psyttalia phaeostigma*. They belonged to the *Braconidae* family and the *Opiinae* subfamily. In this study, an identification
of the different species of parasitoids was not made. However, a very significant difference was observed between parasitoids and infested host plants (Kruskal-Wallis, $p < 0.001$). So, there were at least two different species of parasitoids that emerged in our samples. In total, around one hundred parasitoids have emerged in eight host plants from five plant families (Cucurbitaceae, Rutaceae, Myrtaceae, Rubiaceae et Combretaceae). Unlike the study by Hassani et al., (2016 a) of 2013-2016, we observed a significant emergence in the number of parasitoids. Several plants have been infested with both parasitoids and fruit flies. Only Cucumis sativus and Sechium edule were the exceptions. It should be noted that not all sample lots of Cucumis sativus were infested by any fruit flies (Tephritidae).

**Materials and Methods**

**Study sites**

This research work was carried out in Comoros (Grande-Comore and Mohéli). For ten months (December 2019 to September 2020), we made field trips on both sides of the two islands. Grande-Comore remains the largest island, with different microclimates, with an area of 1025 km$^2$. It is approximately 40 km$^2$ from Mohéli, which is its neighbouring island. Mohéli island is the smallest of the four islands, with an area of 211 km$^2$. Despite its small size, this island contains significant microclimates. Indeed, although these islands are of the same nature and close to each other, very diverse and varied climatic ecosystems exist there. The localities in which the samples were taken are indicated by dots followed by the name of the locality in Figure 1. The variation in the altitude at which the samples were taken was significant in the range of 5 m to 877 m.
Sampling was carried out on two islands of the Comoros archipelago. The fruits were collected in 30 locality in the islands between December 2019 and September 2020. The fruits were collected at random according to their availability on each of the sites. Priority has been given particularly to sites with a large diversity of fruits to maximize the diversity of the plant species sampled. The sampling areas included coastal forests, mid-latitude forests, areas of intense agricultural activity, mangroves, cultivated fields, backyard gardens and roadsides. Ripe and sometimes unripe fruits were harvested by hand and sometimes with a knife. At each location, approximate latitude, longitude and altitude were taken using a global positioning system (GPS). These GPS data were recorded at the site of each collection or the nearest opening, if the fruits are collected in a dense area. Collections do not represent an equal sampling effort as some fruits were much easier to find and harvest than others at a given time and place. The fruit collections were placed in individual plastic bags and closed directly to avoid contamination (Copeland et al., 2002). Also, photos are taken regularly before each harvest of the fruit or

Figure 1. Sampling sites in both islands.
vegetable and of the entire plant for the identification or verification of plant species at the Comoros herbarium (University of Comoros). The harvested fruits were transported to a breeding unit at the National Research Institute for Agriculture, Fisheries and the Environment (INRAPE-Comoros).

**Incubation of fruit samples**

The fruit samples were weighed and placed in transparent boxes containing previously sand (one or more fruits of the same species per box) of dimensions 12x7x9 cm, 11x9.5x8 cm and/or 7x7x4 cm, depending on the size of the fruits (Hassani, 2016a). The lids were perforated and covered with muslin to allow ventilation. After a week to ten days of incubation of the fruit, pupae appear. These are collected by filtering the sand through a sieve. All pupae collected from an individual fruit are placed in a transparent box with a perforated lid covered with muslin. After the emergence of adults, the fruit flies were placed in Eppendorf (1.5ml) containing 95% alcohol before being identified (sexes, groups).

**Fruit fly identification**

Fruit flies that emerged from pupae from laboratory rearing were grouped into morphotypes. This first sorting was based on the key to identifying Tephritidae of electronic economic importance. (key_to_African_Tephritids_v1) (Virgilio et al., 2014). Confirmation of these species identifications was carried out at the Entomology section of the Royal Museum for Central Africa (Tervuren, Belgium).

**Statistical analysis**

Differences between the levels of infestation by host plants, fruit flies and emerged parasitoids were analyzed using Kruskal-Wallis tests with $p < 0.001$ in R v. 4.0.3 under the "Rcmdr" library. The tests are considered significant at the 5% level. This test is a nonparametric alternative to first-order ANOVA (intergroup).
Acknowledgements

We thank the National Research Institute for Agriculture, Fisheries and the Environment (INRAPE-Comoros) for the availability of their laboratories. But also the Comoros herbarium team at the University of Comoros. We also thank the Royal Museum for Central Africa (Tervuren, Belgium), more particularly Pr Marc De Meyer, Annelies Kayenbergh and Dr Kurt Jordaens for the confirmation of the identification of certain fruit flies. We do not forget Dr Issa Mze Hassani for the technical support of the sampling and breeding of fruit flies. And finally our undergraduate students at the University of Comoros for their participation in the fruit sampling in the field.

REFERENCES :

ADJANOHOUN, E. J. 1982. Contribution aux études ethnobotaniques et floristiques aux Comores. Paris: L'Agence de Coopération Culturelle et Technique.

ANLLAOUDINE, A. H. 2009. Caractérisation écologique des espèces végétales les plus utilisées et de leurs habitats sur la partie Nord du massif de la grille (Grande-Comore), inventaire ethnobotanique, écologie et cartographie. Mémoire pour l'obtention du Diplôme d'Etudes Approfondies de biologie et écologie végétales, Option: Ecologie végétale appliquée. Faculté des Sciences, Université d'Antananarivo. 147 pages.

BORDAT, D. AND ARVANITAKIS, L. 2004. Arthropodes des cultures légumières d'Afrique de l'Ouest, centrale, Mayotte et Réunion. Montpellier, France: CIRAD.

BRVAULT, THIERRY, PIERRE-FRANCOIS DUYCK, and SERGE QUILICI. 2008. "Life-history strategy in an oligophagous tephritid: the tomato fruit fly, Neoceratitis cyanescens". Ecological Entomology. 33 (4): 529-536.

CLARKE, A.R., ARMSTRONG, K.F., CARMICHAEL, A.E., MILNE, J.R., RAGHU, S., RODERICK, G.K., & YEATES, D.K. 2005. Invasive phytophagous pests arising through a recent tropical evolutionary radiation: the Bactrocera dorsalis complex of fruit flies. Annu. Rev. Entomol., 50, 293-319.

COPELAND, R.S., WHARTON, R.A., LUKE, Q., & DE MEYER, M. 2002. Indigenous hosts of Ceratitis capitata (Diptera : Tephritidae) in Kenya. Annals of the Entomological Society of America, 95, 672-694.

DE MEYER, M., M. P. ROBERTSON, A. T. PETERSON, and MANSELL. M. W. 2008. "Ecological Niches and Potential Geographical Distributions of Mediterranean Fruit Fly (Ceratitis capitata) and Natal Fruit Fly (Ceratitis rosa)". Journal of Biogeography. 35 (2): 270-281.
DE MEYER, M., QUILICI, S., FRANCK, A., CHADHOULIATI, A., ISSIMAILA, M., YOSSOUFA, M., ABDOU-ΕΑΡΙΜΕ, A.-L., BARBET, A., ATTIÉ, M., & WHITE, I. 2012. Records of frugivorous fruit flies (Diptera: Tephritidae: Dacini) from the Comoro archipelago. *African Invertebrates*, 53, p10.

DE MEYER, M. 2000. Systematic revision of the subgenus *Ceratitis* MacLeay s.s. (Diptera, Tephritidae). *Zoological Journal of the Linnean Society* 128: 439–467.

DE MEYER, M., M. P. ROBERTSON, A. T. PETERSON, AND M. W. MANSELL. 2008. "Ecological Niches and Potential Geographical Distributions of Mediterranean Fruit Fly (Ceratitis capitata) and Natal Fruit Fly (Ceratitis rosa)". *Journal of Biogeography*. 35 (2): 270-281.

DE MEYER, M., COPELAND, R.S., WHARTON, R.A. & MCPHERON, B.A. 2002. On the geographical origin of the medfly, *Ceratitis capitata* (Wiedemann) (Diptera: Tephritidae), in: Barnes B. (Ed.), Proc. 6th Int. Symp. Fruit Flies Econ. Importance, Isteg Sci. Publ., Stellenbosch, S. Afr., 45–53.

DE MEYER, M., COPELAND, R., LUX, S., MANSELL, M., QUILICI, S., WHARTON, R., WHITE, I. & ZENZ, N. 2002. Annotated check list of host plants for afrotropical fruit flies (Diptera: Tephritidae) of the genus *Ceratitis*. Tervuren, Belgique: Musée Royal de l’Afrique Centrale. 91 p.

DREW, R. A. I., AND D. L. HANCOCK. 1994. *The Bactrocera dorsalis complex of fruit flies (Diptera: Tephritidae: Dacinae) in Asia*. Wallingford, Oxon, UK: CAB International.

DREW, R. A. I. 2005. *A new species of pest fruit fly (Diptera: Tephritidae: Dacinae) from Sri Lanka and Africa*. Entomological Society of Southern Africa, http://journals.sabinet.co.za/essa.

EMERICK C M, AND DUNCAN R A. 1982. "Age progressive volcanism in the Comores Archipelago, western Indian Ocean and implications for Somali plate tectonics". *Earth and Planetary Science Letters*. 60 (3): 415-428.

Geurts, K., Mwatawala, M., & De Meyer, M. 2012. Indigenous and invasive fruit fly diversity along an altitudinal transect in Eastern Central Tanzania. *Journal of Insect Science*, 12.

GOERGEN, G., VAYSSIERES, J. F., GNANVOSSOU, D. & TINDO, M. 2011. *Bactrocera invadens* (Diptera: Tephritidae), a new invasive fruit fly pest for the afrotropical region: host plant range and distribution in West and Central Africa. *Environmental Entomology*, 40, 844-854.

HARDY, D. E. 1973. *The fruit flies (Tephritidae-Diptera) of Thailand and bordering countries*. Honolulu: Entomology Department, Bernice P. Bishop museum.
HASSANI-EL-BARWANE, M. 2010. Le système foncier comorien de 1841 à 1975. Thèse de doctorat : Histoire contemporaine. Université de La Réunion, 340 p. La Réunion : 2010.

LIQUIDO, N.J., BARR, P.G., CUNNINGHAM, R.T. 1998. An encyclopedic bibliography of the host plants of the Mediterranean fruit fly, Ceratitis capitata (Wiedemann), version 1, in: Thompson F.C. (Ed.), Fruit fly expert identification system and systematic information database, Diptera dissemination disk 1, Washington DC, USA.

LUX, S. A., COPELAND, R. S., WHITE, I. M., MANRAKHAN, A., & 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. https://doi.org/10.1017/S174275840001242X.

MANSELL, M. 2006. Preliminary report on a visit to Madagascar to evaluate trap-catches from a survey of fruit flies (Diptera: Tephritidae) possibly associated with litchis. Unpublished USDA-APHIS Report. 3.

MOHAMED, S. A. & MICHELINE, D. 1993. Diagnostic de l'état de l'environnement aux Comores [Online]. S.l., Direction Générale de l'Environnement, KM. Available: https://portals.iucn.org/library/node/6808 [Accessed].

MWATAWALA, M.W., DE MEYER, M., MAKUNDI, R.H., & MAERERE, A.P. 2006a. Biodiversity of fruit flies (Diptera, Tephritidae) in orchards in different agroecological zones of the Morogoro region, Tanzania. Fruits, 61, 321-332.

MWATAWALA, M., DE MEYER, M., MAKUNDI, R. & MAERERE, A. 2006b. Seasonality and host utilization of the invasive fruit fly, Bactrocera invadens (Dipt., Tephritidae) in central Tanzania. Journal of Applied Entomology, 130, 530-537.

ISSA, M. H., DUYCK, P.-F., RAVELOSON RAVAOMANARIVO, L. H., REYNAUD, B., MANRAKHAN, A., DE MEYER, M., & JEANNODA, V. L. R. 2017. Études écologiques des mouches des fruits (diptera tephritidae) nuisibles aux cultures fruitières aux Comores. Thèse de doctorat : Biologie animale, spécialité Entomologie agricole : La Réunion : 2017.

MZE HASSANI, I., RAVELOSON-RAVAOMANARIVO, L.H., NOUHOU, S., QUILICI, S. & DUYCK, P.F. 2016a. Dominance of the invasive Bactrocera dorsalis among tephritids in host fruits in Comoros. Bulletin of Entomological Research.

MZE HASSANI, I., RAVELOSON-RAVAOMANARIVO, L.H., DELATTE, H., CHIROLEU, F., ALLIBERT, A., NOUHOU, S., QUILICI, S. AND DUYCK, P.F. 2016b. Invasion by Bactrocera dorsalis and niche partitioning among tephritid species in Comoros. Bulletin of Entomological Research : 106, 749–758.
QUILICI, S. 1996. Rapport de Mission à Mayotte du 22 au 26/07/1996. Unpublished CIRAD- FLHOR Réunion report. 25 p.

TIAGO L.T. and al. 2013. Fruit flies (Diptera, Tephritidae) and their parasitoids on cultivated and wild hosts in the Cerrado-Pantanal ecotone in Mato Grosso do Sul, Brazil. Revista Brasileira de Entomologia. 57(3): 300–308.

VIRGILIO, M., WHITE, I.M. AND DE MEYER, M. 2014. A set of multi-entry identification keys to African frugivorous flies (Diptera, Tephritidae). ZooKeys 428, 97–108.

WHITE, I. M. 2006. Taxonomy of the Dacina (Diptera: Tephritidae) of Africa and the Middle East. Hatfield, South Africa: Entomological Soc. of Southern Africa.

WHITE, I. M., COPELAND, R.S. & HANCOCK, D.L. 2003. Revision of the Afrotropical genus Trirhithrum Bezzi (Diptera: Tephritidae). Cimbebasia 18: 71–137.

WHITE, I. M. & ELSON-HARRIS, M. M. 1994. Fruit flies of economic significance: their identification and bionomics. Fruit flies of economic significance: their identification and bionomics. Wallingford: CAB International.

WHITE, I. M. 1992. Fruit flies of economic significance: their identification and bionomics. Wallingford: CAB.

WHITE, I. M., DE MEYER, M. & STONEHOUSE, J. 2000. A review of the native and introduced fruit flies (Diptera, Tephritidae) in the Indian Ocean islands of Mauritius, Réunion, Rodrigues and Seychelles. In: Price, N.S. & Seewooruthum, I., eds, Proceedings of the Indian Ocean commission, regional fruit fly symposium. Mauritius: Indian Ocean Commission. 15-21.

YUN, S., YUE, Z., SHIQIAN F., JIA, H., ZIHUA Z., ZHENZHEN, B., LIJUN, L., RONG, Z. AND ZHIHONG L. 2017. The mitochondrial genome of the wolfberry fruit fly, Neoceratitis asiatica (Becker) (Diptera: Tephritidae) and the phylogeny of Neoceratitis Hendel genus. Scientifik Reports. 7: 16612.