

Effect of Parapheromones on the Capture of Fruit Flies (Diptera: Tephritidae) in Burundi

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Abstract: This study aimed to make an inventory of fruit fly species in Burundi, by use of parapheromones. The trapping by parapheromones is a method used to capture fruit fly species. Four types of parapheromones were used, namely, methyl eugenol, cuelure, terpinyl acetate and trimedlure. In total, 70,115 individuals were captured, of which, 68,728 individuals (or 98.02%) were fruit flies, while 1,387 individuals (1.98%) were non-fruit flies. The majority of Tephritidae has been captured by methyl eugenol with 62,538 individuals (90.97%), followed by cuelure with 3,621 individuals (5.27%). Terpinyl acetate and trimedlure have captured 1,900 and 669 individuals, respectively. The effectiveness of parapheromones has varied from one locality to another. In fact, methyl eugenol showed efficiency in the city of Bujumbura, Rumonge, Kigwena and Cibitoke located at an altitude between 780 m and 887 m; cuelure in Bubanza and Kayanza at an altitude between 1,101 m and 2,219 m; trimedlure and terpinyl acetate at Mwaro at an altitude of 1,640 m. From the point of view of abundance of species caught, *Bactrocera dorsalis* dominates with 62,349 individuals (90.72%), and it is in the Bujumbura city that this species has been captured in abundance.

Key words: Abundance, distribution, effectiveness of parapheromones, localities, species.

1. Introduction

Fruit production provides a source of income and employment to many farmers [1]. Unfortunately, infestation by fruit flies is a major constraint to fruit production [2]. Tephritid fruit flies (Diptera: Tephritidae) cause devastating direct losses to many fresh fruits and vegetables [3].

Due to some species of Tephritidae, quarantine restrictions are imposed to prevent the transfer of foreign species from one region to another [4, 5]. Without control, direct damage has been reported from 30% to 80%, depending on the fruit variety, location and fruit season [6]. The damage caused by fruit flies is a major impediment in African countries. For example, in Kenya [7], as well as in Tanzania [8, 9], the fruit flies cause heavy losses to producers of mangoes.

In Burundi, the fruit production industry has grown markedly since 2005 with an increase in export. Many local businesses of transformation have been implanted. The produced fruits of economic significance are mandarins, oranges, mangoes, bananas, avocados, passion fruit, etc., which are sold on the local markets and exported to neighboring countries [10, 11]. The agricultural industry has been experiencing losses due to spoilage and fruits which fall extensively prior to maturity as well as deformed fruits which are not appreciated on the market. Little information is available on the fruit flies of Burundi. Seeing the magnitude of damage, the identification of the major pests is required to develop an effective control strategy [12]. The identification of species is possible with parapheromones [13, 14] and for identifying adults that emerge from fruits [15]. In Burundi, research into the fruit fly diversity started in 2009, in the framework of a research project on the fruit flies of natural and agricultural areas of Burundi.

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Thus, from 2009 up to 2014, studies using trapping by parapheromones, namely, methyl eugenol, cuelure, trimedlure and terpinyl acetate, have been carried out for the purpose of making an inventory of fruit flies of Burundi and testing the effectiveness of parapheromones in the capture of species in natural environments, agricultural and urban areas.

This paper presented a current state on the prevalence of fruit flies in Burundi, their abundance in

the localities inspected, as well as the efficacy of parapheromones used.

2. Methodology

2.1 Field Sites

Research was conducted in 12 sampling sites across seven localities: three in Bujumbura, two in Bubanza, one in Rumonge, one in Kigwena, one in Cibitoke, one in Mwaro and three in Kayanza (Fig. 1). Field sites in a range of altitude from 780 m to 2,219 m (Table 1) were grouped into high (1,900-2,600 m), medium (1,400-1,700 m) and low altitude (750-1,300 m).

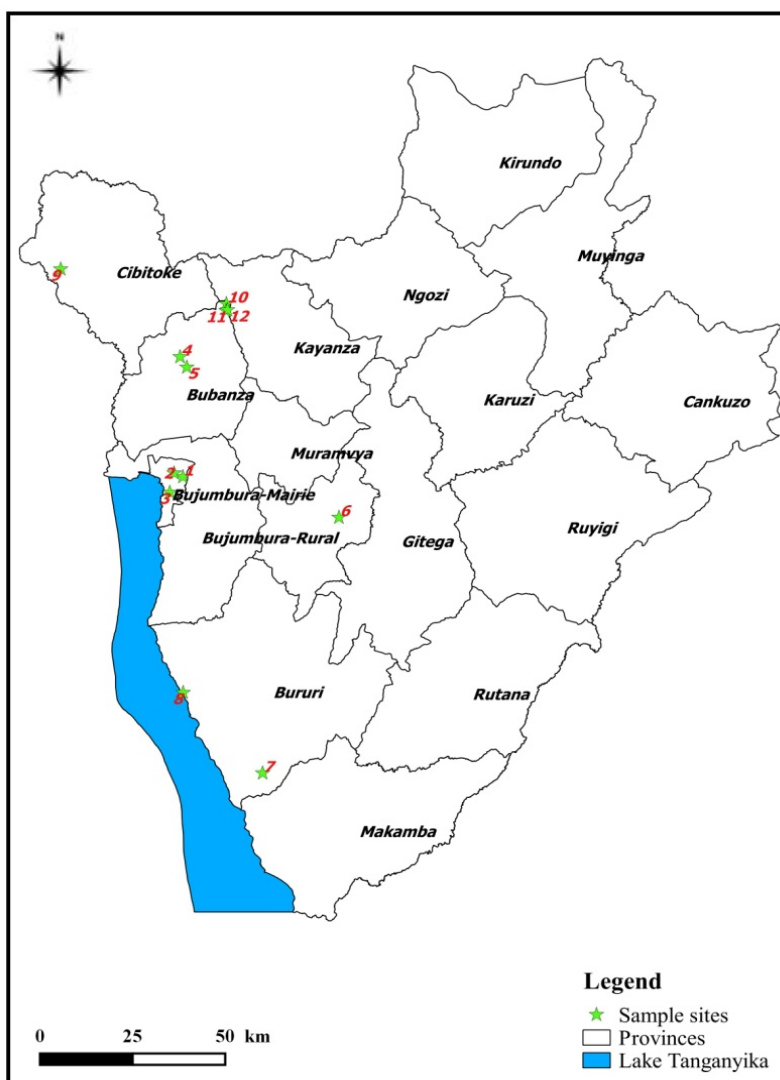


Fig. 1 Map representing different study sites across Burundi where various baited fruit fly traps were deployed for the period from November 2009 up to April 2014.

High altitudes: sites 10, 11 and 12; medium altitude: site 6; low altitudes: sites 1, 2, 3, 4, 5, 7, 8 and 9.

Table 1 Study sites in Burundi where Tephritidae-specific parapheromone traps were deployed (2009-2014).

Level of altitudes	Localities	Sites	Coordinates	Altitudes	Habitats
Low altitude	Bujumbura	Site 1	3°21'16" S and 29°23'48" E	887 m	Green spaces, orchard
		Site 2	3°20'46" S and 29°22'27" E	819 m	Farmfield
		Site 3	3°23'40" S and 29°21'49" E	820 m	Orchard
	Kigwena	Site 7	4°5'51" S and 29°35'20" E	790 m	Forest, farmfield
	Rumonge	Site 8	3°53'46" S and 29°23'46" E	780 m	Farmfield
	Cibitoke	Site 9	2°50'6" S and 29°5'56" E	790 m	Orchard
	Bubanza	Site 4	3°3'17" S and 29°23'19" E	1,248 m	Orchard
		Site 5	3°4'51" S and 29°24'18" E	1,101 m	Farmfield
	Medium altitude	Mwaro	Site 6	3°27'25" S and 29°46'26" E	1,640 m
High altitude	Kayanza	Site 10	2°55'18" S and 29°30'4" E	2,219 m	Forest
		Site 11	2°56'21" S and 29°30'1" E	2,212 m	Farmfield
		Site 12	2°56'14" S and 29°30'13" E	2,172 m	Farmfield

The sites 1, 2, 3, 4, 5, 7, 8 and 9 were low altitudes, the site 6 was medium altitude, and the sites 10, 11 and 12 were high altitudes. Field sites in Kayanza and Kigwena consisted of natural vegetation and agricultural ecosystems, while the remaining field sites were dominated by agricultural ecosystem. The field sites were sampled over a period of six months from November 2009 to April 2014.

2.2 Collection of Fruit Flies

Four types of parapheromones were used, namely, methyl eugenol, cuelure, terpinyl acetate and trimedlure from International Pheromone Systems (IPS), Wallasey, Wirral, UK. Lures were placed in Tephri-traps (Sorygar, Madrid, Espagne) with an insecticidal pad (dichlorvos 20%) (IPS, Wallasey, Wirral, UK). The numbers of trees varied from 500 up to 2,200 for the orchards inspected. The distance between trees was roughly 6 m and the traps were suspended on branches at 1.30 m from the ground. The traps were suspended with the aid of a twine coated with strong grease to prevent predatory action of ants. Traps were emptied every two weeks and flies collected were placed in sample jars containing 70% ethyl alcohol and labeled according to sample site and date. The type of tree and lure were also recorded for each sample. Lures and insecticide were replaced every six weeks based on efficacy periods according to Ekesi and Billah [16]. Fruit fly collection was done

from November 2009 to April 2014. The co-ordinates of each field site were taken at the position of each Tephri-trap.

2.3 Identification of Species of Fruit Flies

Samples were first sorted on the basis of morphospecies, and then identification was done using published keys of Ekesi and Billah [16]. A voucher specimen was sent to the RMCA in Tervuren, Belgium to confirm the identification and preservation. The identification and confirmation of identified samples were done by Dr. Marc De Meyer.

2.4 Data Analysis

The index of Sorensen was used to compare the surveyed localities according to their faunistic richness. The index of Sorensen reveals the localities where species can fit well. Apart from this, it can show which species are particular to a given locality or area. Most of the time, these species are found in one locality abundantly.

The value of Sorensen similarity index (K) [17] is obtained by the following Eq. (1):

$$K = \frac{2a}{2a + b + c} \times 100 \quad (1)$$

where, a is the number of species common to the two ecosystems, b and c are the numbers of species absent in one of the two ecosystems, but present in the other.

3. Results

3.1 Numbers of Flies Captured

During the research period (November 2009-March 2014), total 70,115 individuals were collected, of which 68,728 (98.02%) were Tephritidae fruit flies and 1,387 (1.98%) were non-tephritid fruit flies and Hymenoptera. The majority of Tephritidae were captured by methyl eugenol (90.97%), followed by cuelure (5.27%). Terpinyl acetate and trimedlure accounted for 1,900 and 669 individuals, respectively (Table 2). Methyl eugenol has shown an attractive power of 99.39%, followed by terpinyl acetate with 94.81%. Trimedlure and cuelure have an attractive power of 85.66% and 82.09%, respectively.

Non-tephritids (Diptera) and Hymenoptera represented 1.96% (1,373) and 0.02% (14) of trap captures, respectively. Diptera were found in the traps containing the four parapheromones, whereas the Hymenoptera have been found in the traps containing cuelure and methyl eugenol only. It should be noted that a lot of non-fruit flies were found in the traps containing cuelure, followed by methyl eugenol.

3.2 Tephritidae Captured by Parapheromone in Different Sites

There was a difference in response to parapheromones at the site level.

3.2.1 Capture by Methyl Eugenol

Bactrocera dorsalis Hendel was highly captured at low altitude sites (sites 1, 2, 3, 4, 5, 7 and 9). By comparison, *B. dorsalis* showed lower captures at middle and high altitude sites (sites 6, 10, 11 and 12).

The species of *Ptiloniola edwardsi* was captured extensively at site 10, but not in sites 11 and 12. This species could be weakly attracted to methyl eugenol. There was no dominant species captured at the medium altitude (site 6) (Table 3).

3.2.2 Capture by Cuelure

For cuelure, species *Dacus punctatifrons* Karsh, *D. bivittatus* Bigot, *Zeugodacus cucurbitae* Coquillett and *Ptiloniola edwardsi* were captured. *D. punctatifrons* was most abundant in sites 4 and 6, and lower prevalence at sites 2, 3, 7 and 8. *D. bivittatus* was most abundant at site 5, with lower prevalence at sites 1, 2, 3, 5 and 8. *Z. cucurbitae* was most abundant at site 2 and lower prevalence at sites 7, 8 and 9. *P. edwardsi* has been captured at low numbers only at site 10. This species has also been captured by methyl eugenol.

3.2.3 Capture by Terpinyl Acetate

Considering terpinyl acetate, *Ceratitis cosyra* Walker and *C. fasciventris* Bezzi were most abundant. *C. cosyra* was abundant at site 1, moderately abundant at site 2 and less abundant at site 3. Also, it was abundant at site 6 (medium altitude), but absent at sites 4 and 5 (low altitude), sites 10, 11 and 12 (high altitude).

3.2.4 Capture by Trimedlure

Trimedlure captured *C. fasciventris* and *C. capitata* Wiedemann. *C. capitata* was present at site 4 and absent at site 5. *C. capitata* was most abundant at site 9. *C. fasciventris* was only detected at site 6.

In total, 24 species of fruit flies were captured. Methyl eugenol captured 14 different species with *B. dorsalis* the most dominant (99.60%). Thirteen species

Table 2 Individuals captured by parapheromones across seven localities in Burundi.

Parapheromones	Cuelure	Methyl eugenol	Terpinyl acetate	Trimedlure	Total	%
Tephritidae	3,621	62,538	1,900	669	68,728	98.02
Non-tephritidae						
Diptera	788	369	104	112	1,373	1.96
Hymenoptera	2	12	0	0	14	0.02
Subtotal	790	381	104	112	1,387	1.98
Total	4,411	62,919	2,004	781	70,115	100
Attractive power in %	82.09	99.39	94.81	85.66	98.02	

Table 3 Variation of catches by parapheromones in different sites.

Parapheromones	Species captured	Low altitude									Medium altitude	High altitude				Total	
		Bujumbura				Bubanza			Kigwena	Cibitoke	Rumonge	Mwaro	Kayanza				
		Site 1	Site 2	Site 3	Total	Site 4	Site 5	Total	Site 7	Site 9	Site 8	Site 6	Site 10	Site 11	Site 12		Total
Methyl eugenol	<i>Bactrocera dorsalis</i>	13,684	16,810	25,311	55,805	314	394	708	3,581	412	1,718	62	1	2	0	3	62,289
	<i>Bactrocera mesomelas</i>	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1
	<i>Ceratitis capitata</i>	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
	<i>Ceratitis cosyra</i>	3	0	0	3	0	0	0	0	0	0	10	0	0	0	0	13
	<i>Ceratitis ditissima</i>	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
	<i>Ceratitis fasciventris</i>	0	0	0	0	0	0	0	0	0	0	28	0	0	0	0	28
	<i>Ceratitis lineata</i>	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
	<i>Dacus bivittatus</i>	0	2	2	4	0	0	1	0	0	0	63	1	2	0	3	71
	<i>Dacus humeralis</i>	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
	<i>Dacus punctatifrons</i>	0	0	1	1	0	1	1	0	0	0	17	0	0	0	0	19
	<i>Perilampus pulchella</i>	2	4	0	6	0	0	0	0	0	0	53	14	1	1	16	75
	<i>Ptiloniola edwardsi</i>	0	0	0	0	0	0	0	0	0	0	0	10	0	2	12	12
	<i>Trirhithrum nigerrimum</i>	1	0	0	1	14	0	14	0	2	0	5	0	0	0	0	22
	<i>Zeugodacus cucurbitae</i>	0	0	3	3	0	1	1	0	0	0	0	0	0	0	0	4
	Subtotal	13,690	16,816	25,317	55,823	328	398	726	3,582	416	1,719	238	26	5	3	34	62,538
Cuelure	<i>Bactrocera dorsalis</i>	0	2	4	6	0	1	1	0	0	0	0	0	0	0	0	7
	<i>Bactrocera mesomelas</i>	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
	<i>Ceratitis anonae</i>	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
	<i>Ceratitis cosyra</i>	0	0	0	0	0	0	0	0	6	0	23	0	0	0	0	29
	<i>Ceratitis ditissima</i>	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
	<i>Ceratitis fasciventris</i>	0	0	0	0	0	0	0	0	2	0	21	0	0	0	0	23
	<i>Ceratitis rubivora</i>	0	0	0	0	0	0	0	0	0	0	0	0	4	0	4	4
	<i>Dacus masaicus</i>	0	0	0	0	0	0	0	0	0	0	0	0	7	3	10	10
	<i>Dacus bivittatus</i>	54	40	102	196	32	1,042	1,074	17	30	60	434	0	26	0	26	1,820
	<i>Dacus cf. minus</i>	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1
	<i>Dacus humeralis</i>	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	2
	<i>Dacus punctatifrons</i>	16	2	1	19	66	12	78	4	60	4	95	0	0	0	0	256
	<i>Dacus telfaireae</i>	0	0	0	0	0	0	0	0	0	0	26	0	4	0	4	30
	<i>Perilampus pulchella</i>	1	0	0	1	0	0	0	0	0	0	1	0	0	0	0	2
	<i>Ptiloniola edwardsi</i>	0	0	0	0	0	0	0	0	0	0	0	24	0	0	24	24
<i>Trirhithrum nigerrimum</i>	0	0	0	0	5	0	5	0	1	0	3	0	0	0	0	9	
<i>Zeugodacus cucurbitae</i>	165	757	171	1,093	0	275	275	21	9	3	0	0	0	0	0	1,401	
Subtotal	236	801	278	1,315	103	1,331	1,434	43	109	67	604	24	43	3	70	3,621	

(Table 3 continued)

Parapheromones	Species captured	Low altitude										Medium altitude	High altitude			Total	
		Bujumbura				Bubanza			Kigwena	Cibitoke	Rumonge	Mwaro	Kayanza				
		Site 1	Site 2	Site 3	Total	Site 4	Site 5	Total	Site 7	Site 9	Site 8	Site 6	Site 10	Site 11	Site 12		Total
Terpinyl acetate	<i>Bactrocera dorsalis</i>	31	5	2	38	0	0	0	6	1	1	2	0	0	0	0	48
	<i>Bistrispinaria magniceps</i>	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1
	<i>Ceratitis pallidula</i>	0	0	0	0	0	0	0	0	0	17	0	0	0	0	0	17
	<i>Ceratitis anonae</i>	0	0	0	0	0	1	1	0	0	1	6	0	0	0	1	8
	<i>Ceratitis capitata</i>	0	0	1	1	4	0	4	0	9	0	0	0	0	0	0	14
	<i>Ceratitis cosyra</i>	608	195	48	851	0	0	0	29	23	29	135	0	0	0	0	1,038
	<i>Ceratitis fasciventris</i>	0	0	1	1	10	3	13	0	1	0	632	0	0	0	0	647
	<i>Dacus bivittatus</i>	0	0	0	0	0	0	0	0	33	0	39	0	2	0	2	74
	<i>Dacus punctatifrons</i>	0	0	0	0	0	0	0	0	11	0	1	0	0	0	0	12
	<i>Dacus telfaireae</i>	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	5
	<i>Ptiloniola edwardsi</i>	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1
	<i>Trirhithrum nigerrimum</i>	0	0	0	0	3	0	3	0	0	0	12	0	0	0	0	16
	<i>Zeugodacus cucurbitae</i>	0	0	0	0	0	1	1	0	18	0	0	0	0	0	0	19
Subtotal		639	200	52	891	18	5	23	35	96	48	832	0	3	0	4	1,900
Trimedlure	<i>Bactrocera dorsalis</i>	5	0	0	5	0	0	0	0	0	0	0	0	0	0	0	5
	<i>Bactrocera mesomelas</i>	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
	<i>Ceratitis anonae</i>	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1
	<i>Ceratitis capitata</i>	14	0	2	16	42	1	43	0	53	4	0	0	0	2	2	118
	<i>Ceratitis cosyra</i>	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	9
	<i>Ceratitis fasciventris</i>	0	0	3	3	0	0	0	0	1	0	515	0	0	0	0	519
	<i>Ceratitis punctata</i>	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	2
	<i>Ceratitis rubivora</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	6	6	6
	<i>Dacus bivittatus</i>	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	2
	<i>Ptiloniola edwardsi</i>	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1
	<i>Trirhithrum coffeae</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2
	<i>Trirhithrum nigerrimum</i>	0	0	0	0	3	0	3	0	0	0	1	0	0	0	0	3
	Subtotal		19	0	6	25	45	1	46	1	55	5	526	1	1	10	12

were captured by terpinyl acetate with two dominant species, namely, *C. cosyra* (54.63%) and *C. fasciventris* (34.05%). Cuelure captured 17 species, including two dominant species: *D. bivittatus* (50.26%) and *Z. cucurbitae* (38.69%). Trimedlure has captured 12 species dominated by *C. fasciventris* at 77.58%. The remaining species were present in minor amounts (Table 4).

Generally speaking, for all species caught by parapheromones, *B. dorsalis* was the dominant species at a rate of 90.72%.

3.3 Distribution of Species by Localities

Of 24 species captured, the localities of Bubanza and Cibitoke had the highest diversity of species (11

species), followed by Kayanza and the city of Bujumbura with 10 species. The locality of Rumonge had the lowest diversity with six species. Of all species identified, *B. dorsalis* was present at all the localities. It can be qualified as a widespread species. Nevertheless, its presence was the minimal at Mwaro with 2.91% and Kayanza with 2.52%. An average rate of presence was also seen in Bubanza with a rate of 31.79%. *B. dorsalis* was most abundant in Cibitoke, Kigwena, Rumonge and the city of Bujumbura. The highest rate of presence was at Kigwena with 98.38% and Cibitoke with 61.09% (Table 5).

D. bivittatus was moderately abundant at Bubanza (48.21%), Kayanza (26.89%) and Mwaro (24.41%). These three localities are located in high altitude,

Table 4 Abundance of species by parapheromones.

Species	Abundance of species								Total	%
	CUE	%	ME	%	TA	%	TRI	%		
<i>Bactrocera mesomelas</i> (Bezzi, 1908)	1	0.03	1	0.00	0	0.00	1	0.15	3	0.00
<i>Zeugodacus cucurbitae</i> (Coquillet, 1899)	1,401	38.69	4	0.01	19	1.00	0	0.00	1,424	2.07
<i>Bactrocera dorsalis</i> (Hendel, 1912)	7	0.19	62,289	99.60	48	2.53	5	0.75	62,349	90.72
<i>Ceratitis anonae</i> (Graham, 1908)	1	0.03	0	0.00	8	0.42	1	0.15	10	0.01
<i>Ceratitis cosyra</i> (Walker, 1849)	29	0.80	13	0.02	1,038	54.63	9	1.35	1,089	1.58
<i>Ceratitis ditissima</i> (Munro, 1938)	1	0.03	1	0.00	0	0.00	0	0.00	2	0.00
<i>Ceratitis fasciventris</i> (Bezzi, 1920)	23	0.64	28	0.04	647	34.05	519	77.58	1,217	1.77
<i>Ceratitis rubivora</i> (Coquillet, 1901)	4	0.11	0	0.00	0	0.00	6	0.90	10	0.01
<i>Dacus bivittatus</i> (Bigot, 1858)	1,820	50.26	71	0.11	74	3.89	2	0.30	1,967	2.86
<i>Dacus cf. eminus</i> (Munro, 1939)	1	0.03	0	0.00	0	0.00	0	0.00	1	0.00
<i>Dacus humeralis</i> (Bezzi, 1915)	2	0.06	1	0.00	0	0.00	0	0.00	3	0.00
<i>Dacus masaicus</i> (Munro, 1937)	10	0.28	0	0.00	0	0.00	0	0.00	10	0.01
<i>Dacus punctatifrons</i> (Karsh, 1887)	256	7.07	19	0.03	12	0.63	0	0.00	287	0.42
<i>Dacus telfaireae</i> (Bezzi, 1924)	30	0.83	0	0.00	5	0.26	0	0.00	35	0.05
<i>Perilampus pulchella</i> (Austen, 1910)	2	0.06	75	0.12	0	0.00	0	0.00	77	0.11
<i>Ptiloniola edwardsi</i> (Munro, 1967)	24	0.66	12	0.02	1	0.05	1	0.15	38	0.06
<i>Trirhithrum nigerrimum</i> (Bezzi, 1913)	9	0.25	22	0.04	16	0.84	4	0.60	51	0.07
<i>Ceratitis lineata</i> (Hering, 1938)	0	0.00	1	0.00	0	0.00	0	0.00	1	0.00
<i>Ceratitis capitata</i> (Wiedemann, 1824)	0	0.00	1	0.00	14	0.74	118	17.64	133	0.19
<i>Bistrispinaria magniceps</i> (Bezzi, 1824)	0	0.00	0	0.00	1	0.05	0	0.00	1	0.00
<i>Ceratitis pallidula</i> (De Meyer, Mwatawala & Virgilio, 2016)	0	0.00	0	0.00	17	0.89	0	0.00	17	0.02
<i>Ceratitis punctata</i> (Wiedemann, 1824)	0	0.00	0	0.00	0	0.00	1	0.15	1	0.00
<i>Trirhithrum coffeae</i> (Bezzi, 1918)	0	0.00	0	0.00	0	0.00	2	0.30	2	0.00
Total	3,621	100	62,538	100	1,900	100	669	100	68,728	100
%		5.27		90.99		2.76		0.97		100
Number of species	17		14		13		12			

ME: methyl eugenol; CUE: cuelure; TA: terpinyl acetate; TRI: trimedlure.

Table 5 Distribution of species according to localities.

Species	Distribution of species in localities														Average of %
	Cibitoke	%	Bubanza	%	Kigwena	%	Kayanza	%	Mwaro	%	Rumonge	%	Bujumbura	%	
<i>Bactrocera mesomelas</i> (Bezzi, 1908)	2	0.30	1	0.04	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0.05
<i>Zeugodacus cucurbitae</i> (Coquillet, 1899)	27	3.99	277	12.42	3	0.08	0	0.00	0	0.00	21	1.16	1,096	1.89	2.79
<i>Bactrocera dorsalis</i> (Hendel, 1912)	413	61.09	709	31.79	3,582	98.38	3	2.52	64	2.91	1,724	95.35	55,854	96.21	55.46
<i>Bistrispinaria magniceps</i> (Bezzi, 1918)	0	0.00	1	0.04	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0.01
<i>Ceratitis anonae</i> (Graham, 1908)	0	0.00	1	0.04	1	0.03	0	0.00	7	0.32	0	0.00	1	0.00	0.06
<i>Ceratitis capitata</i> (Wiedemann, 1824)	62	9.17	47	2.11	5	0.14	2	1.68	0	0.00	0	0.00	17	0.03	1.88
<i>Ceratitis fasciventris</i> (Bezzi, 1920)	4	0.59	13	0.58	0	0.00	0	0.00	1,196	54.36	0	0.00	4	0.01	7.93
<i>Dacus bivittatus</i> (Bigot, 1858)	63	9.32	1,075	48.21	0	0.00	32	26.89	537	24.41	60	3.32	200	0.34	16.07
<i>Dacus cf. eminus</i> (Munro, 1939)	0	0.00	1	0.04	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0.01
<i>Dacus punctatifrons</i> (Karsh, 1887)	71	10.50	79	3.54	4	0.11	0	0.00	113	5.14	0	0.00	20	0.03	2.76
<i>Trirhithrum nigerrimum</i> (Bezzi, 1913)	3	0.44	26	1.17	0	0.00	0	0.00	21	0.95	0	0.00	1	0.00	0.37
<i>Ceratitis pallidula</i> (De Meyer, Mwatawala & Virgilio, 2016)	0	0.00	0	0.00	17	0.47	0	0.00	0	0.00	0	0.00	0	0.00	0.07
<i>Ceratitis cosyra</i> (Walker, 1849)	29	4.29	0	0.00	29	0.80	0	0.00	177	8.05	0	0.00	854	1.47	2.09
<i>Ceratitis ditissima</i> (Munro, 1938)	1	0.15	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0.02
<i>Dacus humeralis</i> (Bezzi, 1915)	1	0.15	0	0.00	0	0.00	2	1.68	0	0.00	0	0.00	0	0.00	0.26
<i>Ceratitis rubivora</i> (Coquillet, 1901)	0	0.00	0	0.00	0	0.00	10	8.40	0	0.00	0	0.00	0	0.00	1.20
<i>Dacus masaicus</i> (Munro, 1937)	0	0.00	0	0.00	0	0.00	10	8.40	0	0.00	0	0.00	0	0.00	1.20
<i>Dacus telfaireae</i> (Bezzi, 1924)	0	0.00	0	0.00	0	0.00	4	3.36	31	1.41	0	0.00	0	0.00	0.68
<i>Perilampus pulchella</i> (Austen, 1910)	0	0.00	0	0.00	0	0.00	16	13.45	54	2.45	0	0.00	7	0.01	2.27
<i>Ptiloniola edwardsi</i> (Munro, 1967)	0	0.00	0	0.00	0	0.00	38	31.93	0	0.00	0	0.00	0	0.00	4.56
<i>Trirhithrum coffeae</i> (Bezzi, 1918)	0	0.00	0	0.00	0	0.00	2	1.68	0	0.00	0	0.00	0	0.00	0.24
<i>Ceratitis ditissima</i> (Munro, 1938)	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.06	0	0.00	0.01
<i>Ceratitis lineata</i> (Hering, 1938)	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.06	0	0.00	0.01
<i>Ceratitis punctata</i> (Wiedemann, 1824)	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.06	0	0.00	0.01
Total	676	100	2,230	100	3,641	100	119	100	2,200	100	1,808	100	58,054	100	100
Number of species	11		11		7		10		9		6		10		

Table 6 Similarity indices of Sorensen (%) between the different localities.

Localities	Bubanza	Mwaro	Rumonge	Kigwena	Bujumbura	Cibitoke
Bubanza						
Mwaro	60					
Rumonge	37.5	26.666				
Kigwena	55.555	50	30.769			
Bujumbura	76.190	84.210	37.5	66.666		
Cibitoke	76.190	60	35.294	55.555	76.190	
Kayanza	28.571	44.444	25	23.529	40	30.095

showing that the distribution of *D. bivittatus* was limited to sites above an altitude of 1,640 m. *C. fasciventris* was the most abundant species at Mwaro (54.36%). Species present at Mwaro (1,640 m) showed higher abundance in the other localities.

The average percentage of the seven localities shows that *B. dorsalis* was most abundant in Burundi with an average of 55.46%, followed by *D. bivittatus* at 16.07% and *C. fasciventris* (7.93%). The species *P. edwardsi* made up 4.56% of trap captures in Burundi and was concentrated at only one locality (Kayanza). Other species are poorly represented at this site. This could be due to altitude or ecosystem.

3.4 Similarity between Localities

The index of Sorensen found is more than 50% for some localities, whereas for others it is less than 50% (Table 6).

The index of Sorensen indicated the highest similarity between localities Mwaro and Bujumbura (84.120%), Cibitoke and Bujumbura (76.190%), Cibitoke and Bubanza (76.190%), Bubanza and Bujumbura (76.190%).

A medial similarity existed between Bujumbura and Kigwena (66.666%), Mwaro and Bubanza (60%), Mwaro and Cibitoke (60%), Kigwena and Bubanza and Cibitoke and Kigwena (55.555%).

The lowest similarity was between localities Kigwena and Kayanza (23.529%), Rumonge and Kayanza (25%), Kayanza and Bubanza (28.571%).

According to these values abovementioned, it can be concluded that the similarity between localities doesn't depend on altitude.

4. Discussion

4.1 Fruit Flies and Non-fruit Flies Captured

The number of fruit flies captured are far superior to those of non-fruit flies. This would be due to the fact that parapheromones are products intended to attract species of fruit flies [18]. Nevertheless, species of non-fruit flies captured can not be considered as improvised species, given that they have been caught in research done elsewhere. It could also be said that the presence of non-fruit flies in the traps may be due to accidental introductions.

The results show that the parapheromone products used in this study attract Tephritidae species at far greater strength than other insects. Nevertheless, the capture of non-target species could not be considered as negligible, given that they have been recorded in other studies. In Hawaii, flower-visiting insects, such as bees [19], *Anthidium* sp. [20] and syrphid flies *Melanostoma mellinum*, *Meliscaeva cincetella*, *Blera scitula*, *Hadromyia pulcha* [21] have been recorded in small quantities by methyl eugenol containing traps. Drosophilidae was also found in the traps in this study; this may be due to dead flies in the traps [19]. Uchida et al. [22] found that there was a relationship between the parapheromone used and the non-target species captured. In this study it was found that methyl eugenol had a high incidence of non-target species. This supports results found by Leblanc et al. [23] with regards to Diptera and Hymenoptera. In Ghana, Foba et al. [24] found that methyl eugenol and trimedlure captured non-target species from eight different insect orders and one arachnid (Arachnida). Due to the low

numbers of non-target species in the traps, it can be concluded that these captures are coincidental. The non-fruit flies are also either attracted to moisture in the traps or the yellow color of the trap.

4.2 Species Caught by Parapheromones

In this study, 24 species of fruit flies were recorded in Burundi. However, this list is only representative of a selected area, where genera *Bactrocera*, *Dacus*, *Bistrispinaria*, *Trirhithrum*, *Perilampus*, *Ceratitis* and *Zeugodacus* were recorded. The research has highlighted the presence of two exotic species, *B. dorsalis* and *Z. cucurbitae*. These species have a wide geographical distribution, as recorded by French [25], Drew et al. [26] and Virgilio et al. [27]. These two species are severe threat to the agricultural sector of Burundi.

Five species recorded from this study, including the two exotic invasive species, have been recorded in neighboring countries, such as Democratic Republic of Congo [28, 29], Rwanda [30] and Tanzania [31]. These species are *B. dorsalis*, *D. bivittatus*, *D. punctatifrons*, *D. humeralis* Bezzi and *C. fasciventris*. *B. dorsalis* has greatly effect on the agricultural sector of the Great Lakes region (Burundi, Democratic Republic of Congo, Rwanda and Uganda). Effective control methods for this species are needed throughout this region, such as those initiated in Tanzania. Without an area wide control, neighboring populations will continuously re-infest these countries.

It was shown in this study that *C. anonae* Graham, *C. capitata*, *C. cosyra* and *C. punctata* Wiedemann are present in Burundi, and they are also present in Democratic Republic of Congo [29]. *C. capitata*, *C. cosyra*, *C. punctata* and *C. rubivora* are present in Burundi and Tanzania. *C. fasciventris* is present in Rwanda.

The species *Z. cucurbitae* is present in Burundi and Tanzania [32]. This species is absent in Rwanda and the Democratic Republic of Congo. The species *Trirhithrum nigerrimum* Bezzi detected in this study is

also present in the Democratic Republic of Congo [28], while the species *T. coffeae* Bezzi is also present in Tanzania [31]. It is noted that the species *D. masaicus* Munro, *C. ditissima* Munro, *Bistrispinaria magniceps* Bezzi, *B. mesomelas* Bezzi, *Ptioniola edwardsi* and *D. cf. minus* Munro are present in Burundi, but not in the neighboring countries [29-31].

4.3 Effect of Parapheromones

Bactrocera, *Perilampus* and *Trirhithrum* were extensively captured by methyl eugenol. Other species of the genera *Ceratitis*, *Dacus*, *Zeugodacus* and *Ptioniola* were attracted to a lesser extent by methyl eugenol. However, *C. rubivora*, *C. anonae*, *C. punctata*, *D. masaicus*, *D. telfaireae* Bezzi, *D. cf. minus* and *T. coffeae* were not attracted. These results coincide with those of Mwatawala et al. [31] and Alvin et al. [33], showing the sensitivity of *B. dorsalis* to methyl eugenol.

Cuelure captured *Z. cucurbitae*, *D. bivittatus* and *D. punctatifrons* extensively. In addition to these three species, cuelure captured other species of the genera *Ceratitis*, *Trirhithrum* and *Bactrocera* to a lesser extent. Vayssières et al. [34], De Meyer et al. [35] and Dhillon et al. [36] have found the same results for *Z. cucurbitae*, *D. bivittatus* and *D. punctatifrons*. The capture of *B. dorsalis* by cuelure is an abnormal event, as males of economically important Tephritidae may be attracted to either cuelure or methyl eugenol, but never to both [37]. This recording may be due to possible contamination or coincidental attraction to the yellow trap.

Terpinyl acetate captured *C. fasciventris* and *C. cosyra* in abundance and *C. anonae* to a lesser extent. These results are in accordance with those found by Vayssières et al. [34]. Terpinyl acetate is known to attract the species of the genus *Ceratitis* [3], but in this study, attraction of species from the genera *Dacus*, *Trirhithrum*, *Ptioniola* and *Bactrocera* was recorded. The same phenomenon is observed in trimedlure, which was developed as a lure for *C. capitata* [16].

4.4 Distribution of Species by Localities

Taking into account all species captured, *B. dorsalis* was the most abundant and present in all the localities inspected. However, its abundance differed from one locality to another, confirming its invasive nature [26]. Its abundance was the highest in the localities of low altitude, especially in Bujumbura. The abundance decreased with an increase in altitude with the lowest abundance at Kayanza located at high altitude.

C. fasciventris seems to be a species of high altitude, as it was most abundant at an altitude of 1,640 m (Mwaro) than at an altitude of 1,101 m (Bubanza). *C. anonae* was found throughout low altitude, on average elevation and high altitude. These two species are present throughout East Africa [38, 39].

C. cosyra was abundant at low altitude at Bujumbura. Although it was abundant in Bujumbura, it was dominated by *B. dorsalis* in terms of numbers. Mwatawala et al. [8] and Ekesi et al. [40] found that the presence of *B. dorsalis* lead to a decrease in the abundance of *C. cosyra*. *D. bivittatus* was abundant at medium altitude, while *D. punctatifrons* was abundant at medium and high altitudes. The other species caught were present at low numbers throughout and had no correlation to altitude.

4.5 Similarity between Localities

The index of Sorensen shows in general that some localities had the same species, but the altitudinal configuration was not confirmed. The localities of Mwaro and Bujumbura with a high similarity (84.120%) were a low altitude and high altitude sight, respectively. On the contrary, the localities of Cibitoke and Kigwena had a low similarity (55.555%) and both were located at low altitude. The similarity is not linked to the altitude rather to the presence of a particular species at a given locality. This presence or absence of a species is due to biotic or abiotic factors [41-43]. The great similarity observed between Bujumbura and Mwaro would be due in large part to

biotic factors. Indeed, some fruit plants in the city of Bujumbura are also found at Mwaro. Biotic factors contribute in the sustainability of the populations of fruit flies in these two localities.

5. Conclusions

Burundi is a country rich in species of Tephritid fruit flies. In addition to the species specific to the African continent, there are other exotic species. *B. dorsalis* and *Z. cucurbitae* are a great threat to the horticultural sector of Burundi. These results demonstrated the need for an effective control strategy to lessen the damage caused by these dreaded pests. Results showed that methyl eugenol was a highly effective lure for *B. dorsalis* and further research efforts should focus on using this in control programs.

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